OPERATIONAL CHARACTERISTICS OF AN INTERNAL COMBUSTION ENGINE USING MIXTURES OF GASOLINE AND PROPANE AS THE FUEL

by

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VITA

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NOMENCLATURE

Symbol	Significance	Units
AF	Air-fuel ratio	lbm air/lbm fuel
AMG	Actual gasoline scale differential	lbm
AMP	Actual propane scale differential	lbm
BMEP	Brake mean effective pressure	psi
BSFC	Brake specific fuel consumption	lbm fuel/hp hr
CAMG	Consumed mass of gasoline	lbm
CAMP	Consumed mass of propane	lbm
CFM	Cubic feet per minute of air into the engine	cu ft/min
DENSA	Density of atmospheric air	lbm/cu ft
FMMG	Final measured gasoline scale differential	lbm
FMMP	Final measured propane scale differential	lbm
HHV	Higher heating valve	Btu/lbm
HP	Horsepower	hp
IMMG	Initial measured gasoline scale differential	lbm
IMMP	Initial measured propane scale differential	lbm
LHV	Lower heating valve	Btu/lbm
MMG	Measured gasoline scale differential	lbm
MMP	Measured propane scale differential	lbm
PATM	Atmospheric pressure	in Hg
PIM	Intake manifold vacuum	in Hg
PMN	Measured pressure drop across the flow nozzle	in H_2O
PNSD	Standard density pressure drop across the flow nozzle	in H_2O
PW	Vapor pressure of water in the air	psi
S	Sensitivity factor in uncertainty equations	dimensionless

T	Torque	ft lbf
TDB	Atmospheric dry bulb temperature	^oF
TE	Exhaust gas temperature	^oF
TIMEG	Measured time for gasoline flow	sec
TIMEP	Measured time for propane flow	sec
TWB	Atmospheric wet bulb temperature	^oF
TWHA	Theoretic maximum mass of air intake by the engine per hour	lbm/hr
TWHF	Total mass of fuel consumed per hour	lbm/hr
WHA	Actual mass of air of air intake by the engine per hour	lbm/hr
WHG	Mass of gasoline consumed per hour	lbm/hr
WHP	Mass of propane consumed per hour	lbm/hr
λ	Uncertainty	dimensionless
η_{th}	Thermal efficiency	dimensionless
η_v	Volumetric efficiency	dimensionless

CHAPTER I

Introduction

In recent years, there has arisen a great furor over the lack of availability of the fuels that we have taken for granted for decades. Besides this, there has been a growing concern over the possible impact upon man's environment of dumping toxic exhaust gases into the atmosphere. These concerns have prompted the renewed search for more and new sources of energy for our vast number of combustion processes.

The automobile is generally regarded as one of the most serious contributors to both problems stated above (1). For this reason, there continues to be vigorous research in the areas of automotive engine design, and automotive fuels and lubricants.

In the present study, the research on what is felt to be an original fuel for spark ignition, internal combustion engines is discussed. This fuel consists of mixtures of gasoline and propane.

Propane was first introduced as a possible fuel for internal combustion (I.C.) engines in 1930 (2). Since this time, propane has not been widely used by the general public due to the difficulty and potential danger in its handling.

Today, propane is used as an engine fuel mostly by industry and agriculture. In industry, propane is a valuable source of fuel for fork-lifts and other vehicles operated in enclosed spaces because the exhaust is lower in unburned hydrocarbon and carbon monoxide content - 80 and 50 per cent reductions respectively over gasoline (3) - although somewhat higher in NO_x emissions. Some agriculturists have, in the past, turned to propane as a motor fuel for use in their farm equipment as a means of reducing operating costs or increasing power output. Today, however, the price of propane approaches that of gasoline and fuel oil, thus losing its economic advantage.

Propane can be used to boast the output of diesel engines to some extent. By aspirating propane in substitution of as much as 40 per cent of the fuel oil, it is possible to improve the delivered power by up to 25 per cent (3). According to one source (4) however, this is not sanctioned by the agriculture equipment manufacturers because it narrows the tolerance limits of the engine. In other words, the engines are not designed to put out this additional power and consequently may be damaged by the practice.

One of the advantages of propane over gasoline as an engine fuel has already been mentioned. In addition to cleaner exhaust, the absence of fuel additives in propane also leaves fewer deposits on the combustion chamber walls. Because of this cleaner burning characteristic of propane over gasoline, the spark plugs do not foul and misfire as readily. The fourth advantage of propane is the longer interval between required oil changes. This is accomplished, of course, through supplimenting the base oil with the necessary additives (3).

As with any engine fuel, however, propane has some disadvantages too. In the case of propane, the largest disadvantage is with handling and distribution. Very few propane filling stations exist. Besides this, it takes qualified personnel to refill the pressurized storage tank. While competent station attendants can be easily trained, propane simply cannot be handled safely by the general public without rigorous education and training in its proper handling.

The danger with propane (other than its obvious combustibility), is that at atmospheric pressure, the vaporization temperature is $-44^{o}F$ ($-42^{o}C$). Since propane is stored as a liquid, any that escapes a storage tank or transfer line, which immediately comes into contact with one's skin, can cause severe "freeze burns."

To this point, the advantages and disadvantages of propane as an engine fuel have been outlined. As gasoline becomes more and more scarce, it occurs to this author and his advisor that it may become advantageous to stretch the gasoline supply by supplimenting it with an optimum proportion of propane which is yet unknown. On the other hand, it is realized that the known base petroleum resources from which propane is derived are also in short supply. This in itself negates the possibility of converting all engines to burn propane exclusively. For these reasons the use of propane-gasoline mixtures may help solve both the problems of gasoline supply and air pollution from vehicle exhaust.

It must be pointed out, however, that as the cost of gasoline and propane rise, the supplies of these fuels essentially increase also. This is because it is the expense of secondary recovery which is currently limiting supplies. As the prices of the fuels increase, it becomes economically more attractive to recover more and more of the original reserve. Also, there are vast areas of the world which have not yet been closely studied to determine their potential for petroleum production, e.g. South America (1).

As one can easily see, higher prices or new petroleum reserves may alter the nation's need to stretch the gasoline or propane supplies.

At this point in time, only a few fuels have been extensively researched for mixing with gasoline. These include alcohol (5), hydrogen (6), and methanol (7). It is hoped that the present study may spark further interest and research into the mixing of propane and gasoline.

CHAPTER II

Literature Review

Literature on the subject of propane-gasoline mixtures is very sparse. After many, many hours of searching, the author has been unable to find any material written on the topic at hand. This, then, leads one to the conclusion that very little, if any, work has been done in the area. That deduction is reinforced by the response of a number of companies and individuals across the nation to inquiries about references or research results from investigations into the idea of these mixtures.

Correspondence with Caterpillar, International Harvester, J. I. Case Co., Deere and Co., Pacific Gas & Electric, Century Propane Equipment Co., engineers at the Amoco Oil Research Center, professors of engineering at Kansas State University and professors of mechanical engineering at the University of Michigan resulted in no information being made available. Professor Bolt of the Mechanical Engineering Department of the University of Michigan stated that to his knowledge, no work had been done on the subject within the last ten years.

The situation is quite different however, if one looks for information on operating engines on propane only. From this literature, clues as to recommended engine alterations were obtained. The suggestions in the literature included raising the compression ratio of the engine, advancing the ignition timing, installation of "colder" spark plugs, and hardening of valve seats (2, 3, and 8). These changes will be discussed further in the next chapter.

Adams et al. (8) performed research on three engines at various compression ratios to discover how engine performance varied when propane was used as the fuel. Their work showed that when compared to gasoline, engines operating on propane developed slightly less power. This has been attributed by some to the lower volumetric efficiencies which result from air being displaced by propane. Also, it was shown that at compression ratios of 7.3 and 7.5, propane exhibited anti-knock values far higher than those associated with gasoline. Thirdly, they showed that the brake specific fuel consumption was lower for propane than for operation on gasoline; the decrease was approximately 12 per cent at low speeds and 0-9 per cent at high speeds. Another of their results which has a bearing on this study is that as the compression ratio of one engine was increased from 7.5 to 11.5, the power increased by 12 per cent with propane. The same approximate increase was observed with gasoline. The compression ratio of the other two engines was not altered.

The last of their conclusions which should be noted here is that one of their engines showed essentially no difference in minimum spark advance for best torque between propane and gasoline. The other two engines showed some difference between the fuels. Where a difference existed, the engines required less spark advance on propane at high speeds.

CHAPTER III

Equipment and Testing Procedures

In this chapter the equipment and experimental layout will first be discussed. Next, the engine revisions will be pointed out, followed by the data taking procedures.

A reproduction of the equipment and instrumentation layout used in this study is shown in Plates I, II, and III. Because of the physical size of the apparatus and space limitations, a single photograph could not be taken which would clearly display all the devices. Therefore, the area is pictured and identified in three parts.

The major piece of equipment used for the experimentation was a 1968 model, 96.6 cu in (1.58 l) displacement, four cylinder, horizontally opposed, electronically fuel injected, air cooled, spark ignition, internal combustion, Volkswagen engine. Table 1 lists several important facts about the engine as it was assembled.

TABLE 1*

Valve Clearance	.006 in (.15 mm) intake & exhaust
Ignition Timing	0^{o} (TDC) @ 850 rpm[1]
Spark Plug Type	Bosch W 145 T 1
Spark Plug Gap	.028 in (.7 mm)
Breaker Point Gap	.016 in (.4 mm)
Engine Oil	between 40^{o}F & 86^{o}F SAE 30 (MS)
Bore	3.36 in (85.5 mm)
Stroke	2.72 in (69 mm)
Displacement	96.6 cu in (1.584 l)
Compression Ratio	7.7:1
Torque (SAE)	86.8 ft lb @ 2800 rpm
Output (SAE)	65 bhp @ 4600 rpm

[1] Vacuum hose(s) disconnected

* Data taken from reference 9

EXPLANATION OF PLATE I

Left End of Experimental Layout

Item	Description
1.	Vertical Mercury Manometer
2.	Oscilloscope
3.	Cooling Water Supply
4.	Hydraulic Oil Filter
5.	Hydraulic Oil Reservoir
6.	Power Supply
7.	Function Generator
8.	Daytronic Modular Instrument System
9.	Counter
10.	Manual Pressure Regulating Valve
11.	Stop Watches
12.	Auxiliary Fuel Injection Control Unit
13.	Strain Gauge Transducer
14.	Electronic Control Unit
15.	Hydraulic Pump Dynamometer

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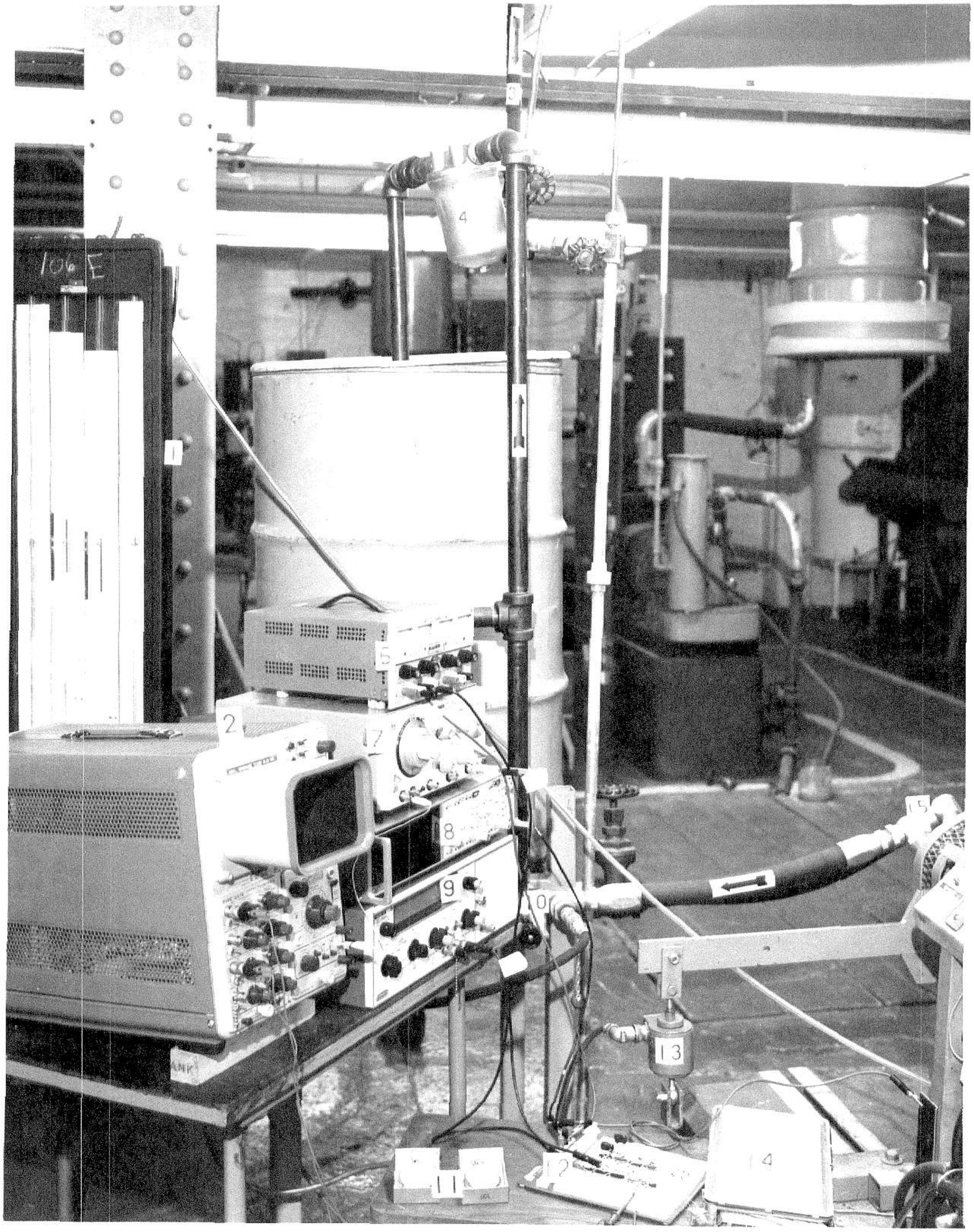

Plate I

EXPLANATION OF PLATE II

Center Section of Experimental Layout

Item	Description
1.	Throttle
2.	Magnetic Speed Pick-Up
3.	Propane Line from Converter
4.	Propane Volume Flow Indicators
5.	Propane Throttle Valves
6.	Throttle Position Switch
7.	Location of Propane Entry into Engine
8.	Location of Tee in Manifold Vacuum Line
9.	Fuel Pump
10.	Manifold Pressure Sensor
11.	Gasoline Supply and Return Lines
12.	Combustion Air Intake
13.	Shut-Off Valve in Auxiliary Air Line

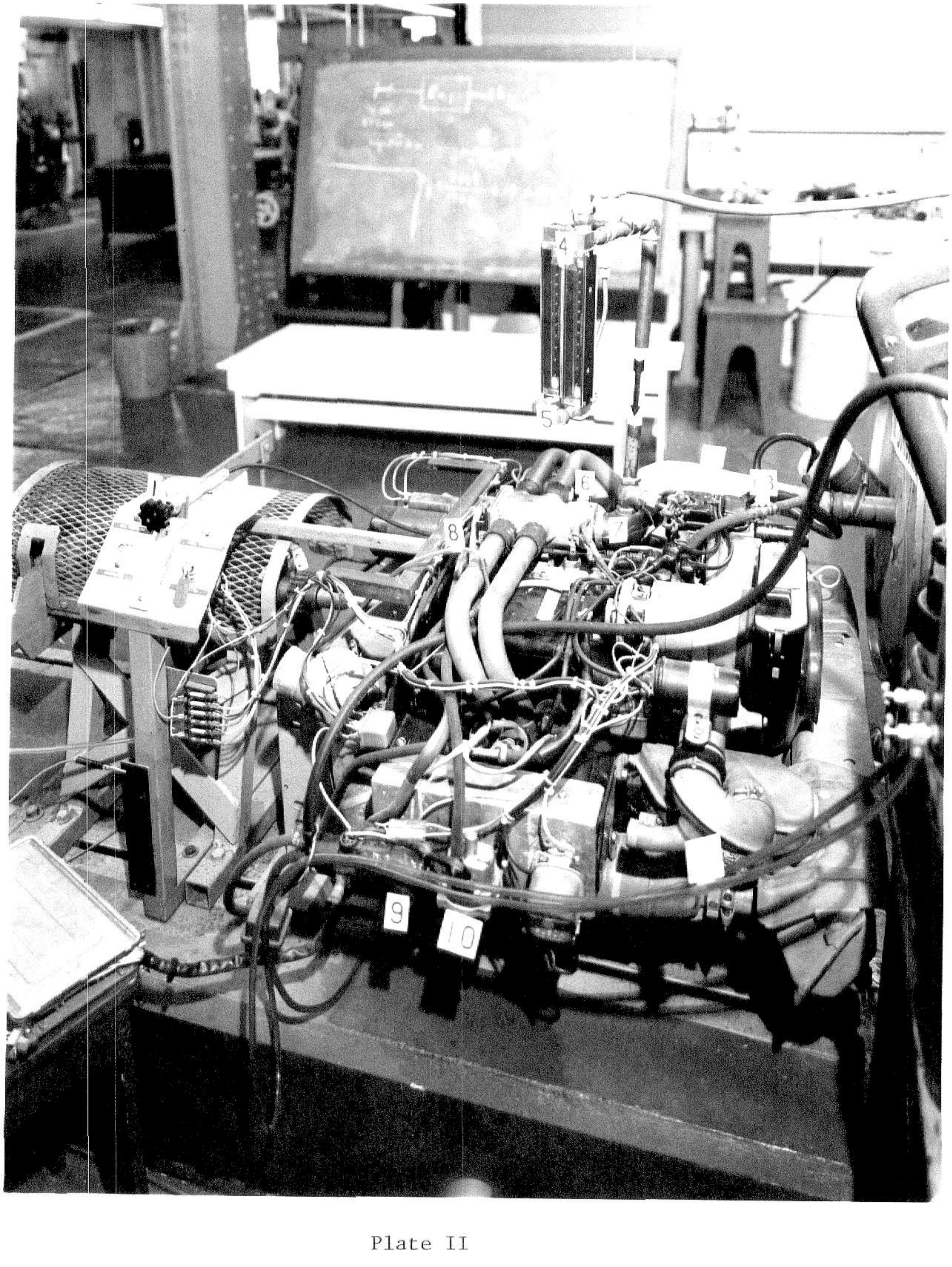

Plate II

EXPLANATION OF PLATE III

Right End of Experimental Layout

Item	Description
1.	Location of Thermocouple in Exhaust
2.	Propane Supply to Engine
3.	Gasoline Container and Scale
4.	Water Supply to Propane Converter
5.	Weights to Obtain Positive Guage Pressure in Propane Supply Line
6.	Propane Converter
7.	Water Return from Propane Converter
8.	Propane Container and Scale
9.	Micro Manometer
10.	Sling Psychrometer
11.	Flow Nozzle Location
12.	Propane Supply Line to Converter
13.	Millivolt Potentiometer
14.	Vacuum Bottle

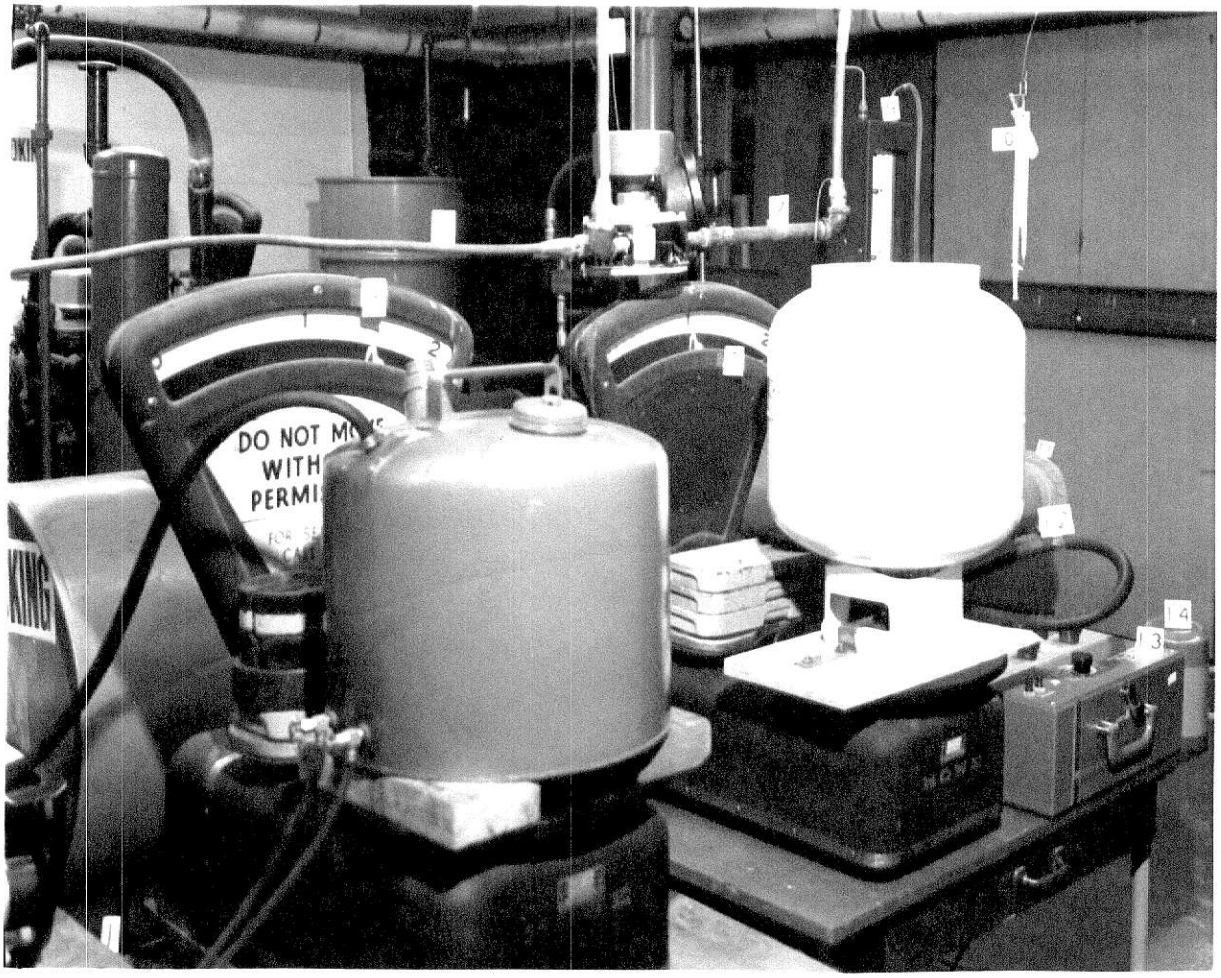

Plate III

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The electronically controlled fuel injection system on this engine was manufactured by the Robert Bosch Gmbh. of Stuttgart, Germany. The system uses an electronic control unit to calculate the length of the timed manifold injection.

The parameters used to determine the injection time are engine speed, intake manifold vacuum, oil and cylinder head temperatures, and throttle position. See Figure 1.

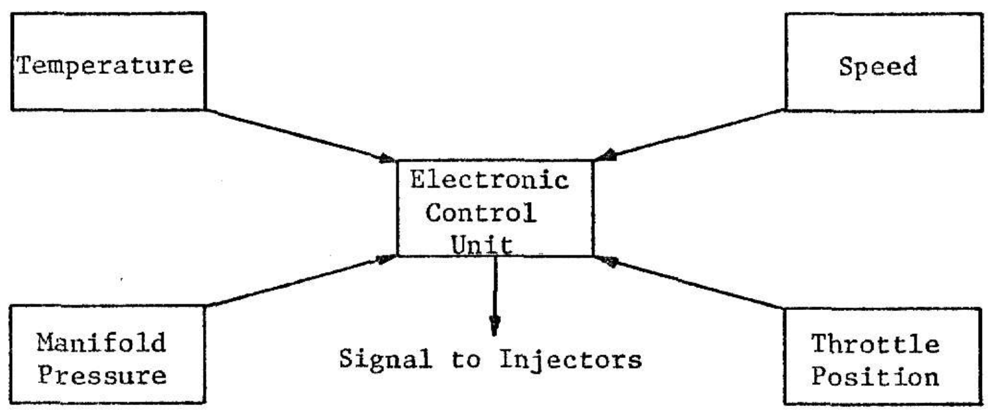

Figure 1. Electronic Fuel Injection Component Diagram

The engine speed was fed in by way of two trigger contacts which were activated by a cam on the distributor shaft. Each contact initiated the injection for two cylinders in order to simplify the system and keep it as inexpensive as possible. Therefore, only one injector in each set delivered fuel while the intake valve was open. The other two injectors - again, one in each set - deposited fuel onto the closed intake valve. Figure 2 shows the timing graphically.

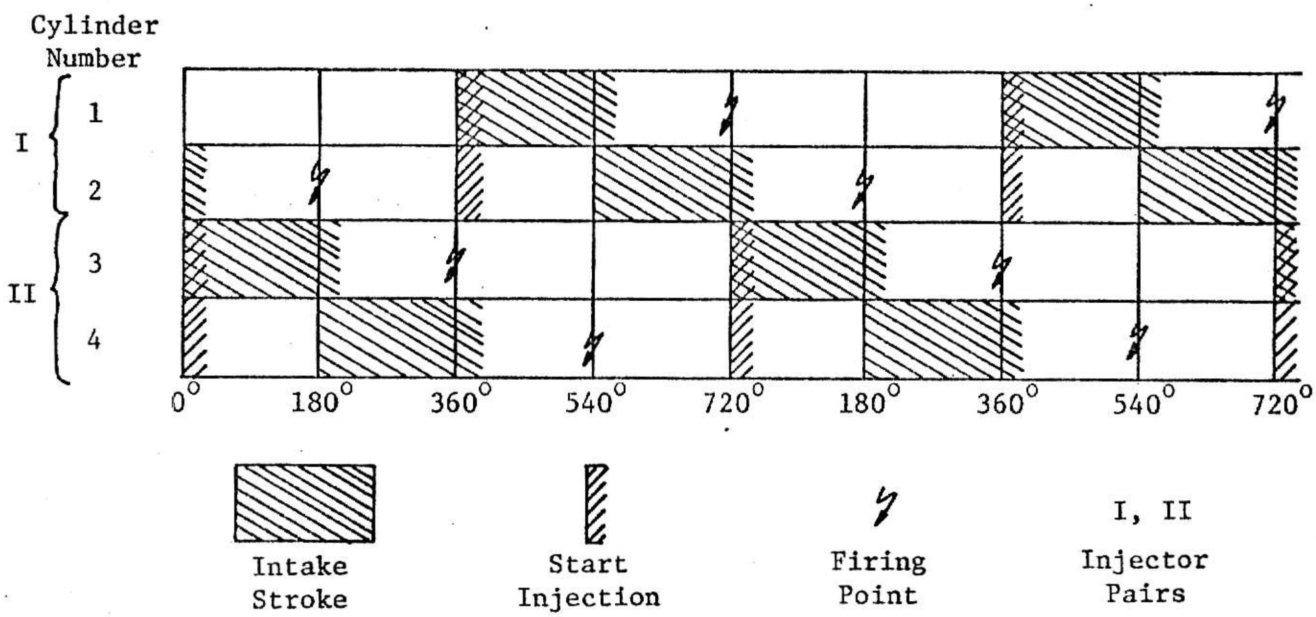

Figure 2. Fuel Injection Timing

The intake manifold pressure sensor contains an inductive data transmitter. As the manifold pressure changes, the evacuated aneroids in the sensor position the plunger in the magnetic circuit and thus change its inductance. When the load is small, the throttle is closed, the manifold pressure is low, the inductance is low and injection time is short. Naturally, when the load is large, the injection time is long.

The oil and cylinder head temperatures were received by the control unit from temperature sensors in appropriate locations.

Timed injection of gasoline into the intake manifold was realized by briefly opening the injectors to which gasoline was continuously supplied at constant pressure. The injectors consisted of an electric coil around a spring loaded plunger (see Figure 3) which closed the injector orifice until an electrical pulse was received from the control unit. When a pulse arrived, the plunger lifted off its seat and the pressurized fuel was atomized as it was sprayed into the manifold.

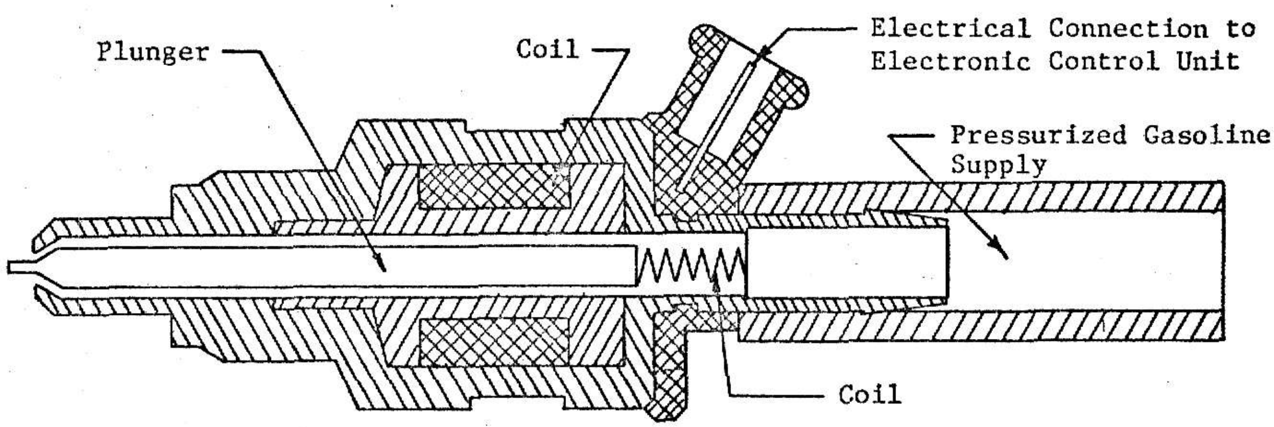

Figure 3. Fuel Injector Cross-Section

The pulse duration was equal to the injector open time. Therefore, manipulation of the pulse length was the way the control unit adjusted the fuel flow to match the engine requirements.

The gasoline was supplied to the injectors by a low-pressure, common rail system. See Figure 4. The positive displacement electric pump drew gasoline from the storage tank and delivered it to the injectors at a constant pressure of 28 psig (2 kg/cm^2). The constant pressure was maintained by the pressure regulating valve located, of course, at the end of the system. The excess gasoline was then returned to the storage tank.

The throttle position was a parameter for the injection process only during deceleration from engine speeds in excess of 1800 rpm. If the throttle valve closed to 5° or less while the engine was at a speed greater than 1800 rpm, then all fuel was shut off from the engine by the injectors until 1200 rpm was reached.

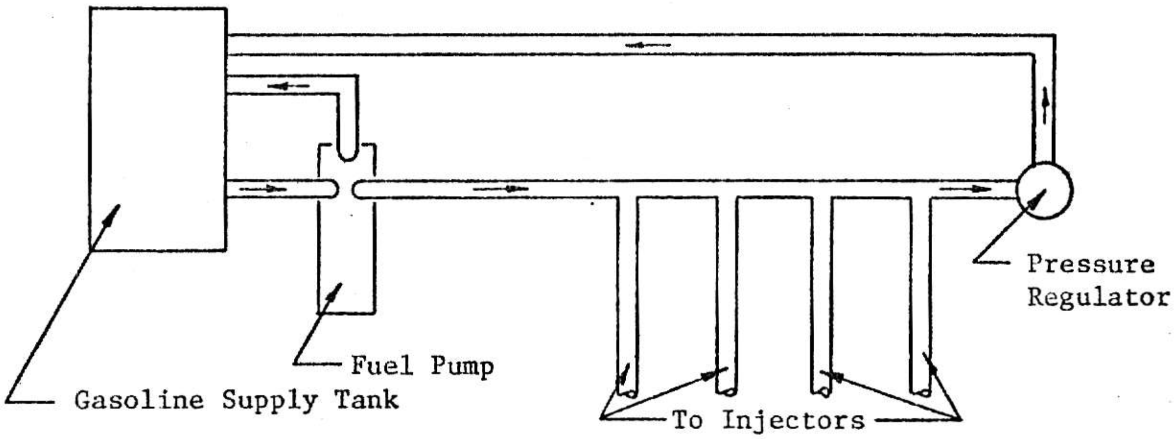

Figure 4. Common Rail Fuel Supply Diagram

There are two conditions of engine operation which demand richer mixtures than "normal" - warm-up and full load, wide-open-throttle. The first of these was perceived by the oil and cylinder head temperature sensors. If they were reading low temperature values, then the fuel mixture was enriched for warm-up. In conjunction with this, an auxiliary air valve opened at low temperatures to allow more air into the intake manifold, thus decreasing the manifold vacuum which caused the control unit to lengthen the injector pulse.

Wide open throttle enrichment was attained by more, rather than longer, injection pulses. When the throttle was opened completely, then the pressure in the intake manifold was very nearly atmospheric which closed contacts in the pressure switch, allowing additional injections to take place.

Reference 10 states that the minimum required quantities to record during any engine testing are torque, engine speed, horsepower, mass flow of air into the engine, fuel consumption, time duration of test, room wet and dry bulb temperatures, and atmospheric pressure. In addition to these, exhaust temperature, manifold vacuum, and when running at other than 100 per cent gasoline, the time of injector opening were also recorded. A brief description of the instrumentation used in measuring these values will be presented next.

The engine speed was obtained by using a fixed magnetic pick-up and a 60 tooth metallic gear mounted on the drive shaft between the clutch and the dynamometer. The pulses from the pick-up and an electrical signal from a strain guage transducer were both fed into a Daytronic Modular Instrument System which not only gave a digital display of the speed and torque, but also the horsepower that the engine delivered to the dynamometer.

As mentioned above, the torque against the engine was measured by a strain guage transducer. The torque was applied to the engine by way of an aviation hydraulic pump. See figure 5. Low pressure oil was drawn from a 55 gal (208.2 l) reservoir and pumped back again through a manual pressure regulating valve and strainer.

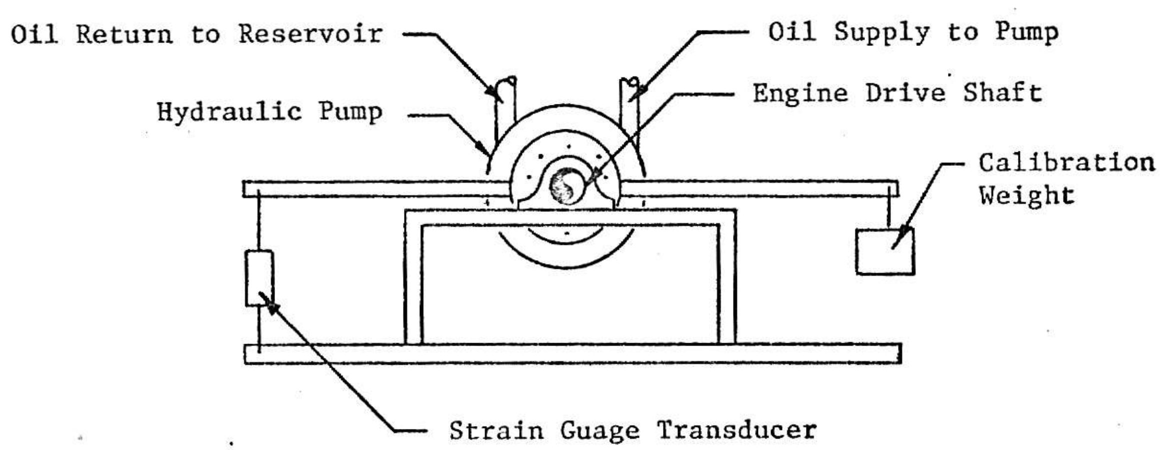

Figure 5. Dynamometer and Strain Guage Transducer Configuration

As the pressure against which the pump had to do work was increased, the torque against the engine also increased. The pressure was controlled (as the name implies) with the pressure regulating valve.

Since the oil was absorbing most of the energy output from the engine, it would become quite hot after extended periods of operation. A coil of copper tubing was immersed in the oil and water from a near-by supply line flowed through the coil to cool the oil. This heat exchanger worked very well for the intended purpose.

The air mass flow rate was calculated from the pressure drop across first a 2 in (5.08 cm) then later a 1.59 in (4.04 cm), A.S.M.E. long radius flow nozzle as measured with a 10 in (25.4 cm) water micro-manometer. The nozzle was placed in one end of a surge tank and from the opposite end, the air was drawn by the engine. See Figure 6.

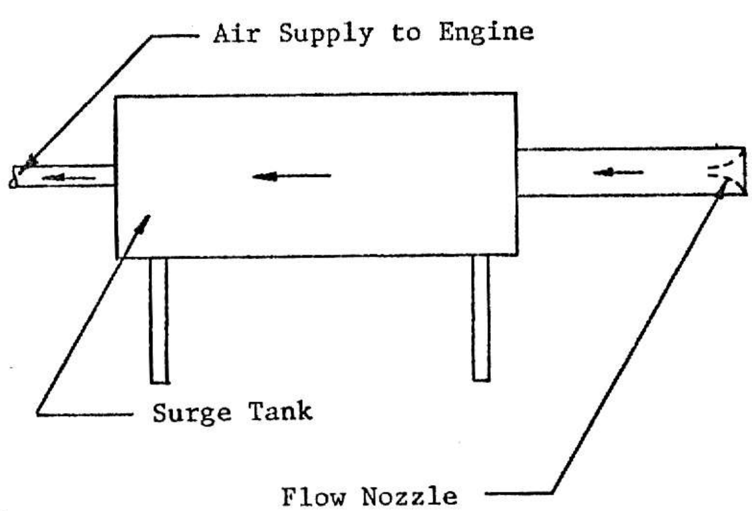

Figure 6. Air Intake System

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The 1.59 in (4.04 cm) nozzle was substituted for the original 2 in (5.08 cm) nozzle shortly after testing had begun when it was realized that the 2 in (5.08 cm) nozzle would not give pressure drops large enough to minimize the error associated with reading the micro-manometer scale.

Gasoline and propane consumptions were measured by timing how long it took for a certain mass of fuel to flow from the respective container. The scales used for this data allowed one to measure the difference between a known and an unknown mass. See Figure 7. The span of differential weight was 0-2 lbs (0-.907 kg) as indicated by a pointer which swept the full extent of the graduated scale.

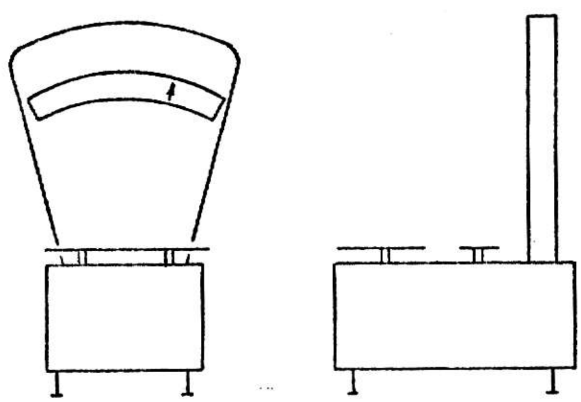

Figure 7. Fuel Scales

Two stopwatches were incorporated in the time measurements. One watch was used to measure the time for an amount of gasoline to be burned and the other was used for an identical purpose with the propane.

The atmospheric conditions were obtained in the usual manner. Barometric pressure was read from a barometer in a room near the testing area. The wet and dry bulb temperatures were obtained through the use of a sling psychrometer. As is proper, only distilled water was used on the wet bulb wick.

Exhaust temperature was found by measuring the electromotive force (emf) produced by a two-junction chromel-alumel thermocouple with one junction in the exhaust stream and the other in an ice bath. The emf was measured with a null-balance millivolt potentiometer. See Figure 8. After measuring the emf, it was used to find the temperature of the exhaust from the appropriate table.

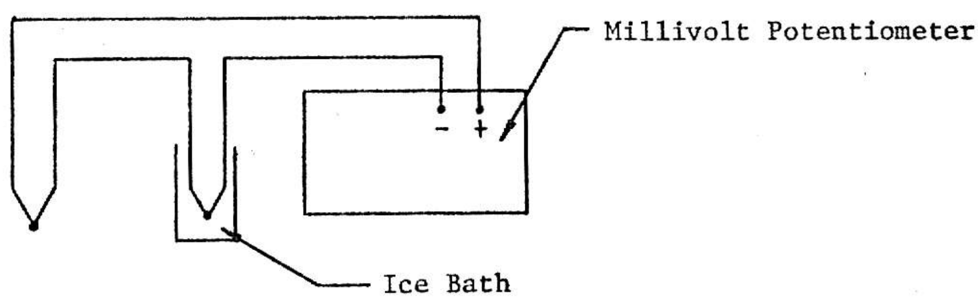

Figure 8. Millivolt Potentiometer and Thermocouple Diagram

The intake manifold pressure was measured with a vertical mercury manometer. A tee in the vacuum line from the manifold to the manifold pressure sensor (one of the components of the fuel injection system) was connected to the manometer. This location was selected because it was assumed that the manufacturer placed the manifold tap for the pressure sensor to give a fairly constant and accurate measure of the pressure.

Several changes were made on the engine; some of them very minor but others were quite major. The minor changes were performed to either allow more accurate measurement of the desired quantities or to help the engine run more smoothly. The major modifications, however, had the purpose of either conforming to the recommendations set forth in references 2, 3, and 8, or installing the propane fuel system.

In discussion with Mr. Royce Bunner (district representative for Volkswagen) the author was informed that often spark plugs one range hotter than those recommended by the manufacturer are installed in the model engine used for this testing. It was his opinion, however, that they would not be needed for operation under mild conditions such as prevailed in the testing room. For this reason and the recommendation in the literature that cooler spark plugs be used for propane fueled engines, Bosch W 145 T 1 spark plugs were used in the engine for all testing.

Along with a new set of spark plugs, other necessary maintenance was carried out before the start of testing. Ignition breaker points, condenser and oil were all changed. The breaker points and ignition timing were set to manufacturer's suggested values shown in Table 1. The oil used throughout the testing was Mobil non-detergent SAE 30.

The 1968 VW Program Provisional Workshop Manual for fuel and electrical systems gives detailed step-by-step instructions for the checking of the electronic fuel injection system. The Bosch tester obtained with the engine was used in conjunction with the check list to insure that all transmitters and their connections were operating properly before the performance testing was begun.

In preliminary observations of the engine operation, it was discovered that the air cleaner supplied with the engine did not seal well. Since the air in the engine testing area was felt to be clean enough to burn in the engine without detrimental affects, the air cleaner was removed for the duration of the testing so accurate air flow measurements could be obtained.

A small valve was placed in the auxiliary air line so that it could be tightly shut off to safeguard against erroneous air flow readings.

Early in the testing of the engine, it was discovered that under certain conditions, the engine operation was very unstable. In discussions with a Volkswagen representative and a certified repair shop foreman, the author was told that adjustment of the spring force against the slug in the manifold pressure sensor would solve the problem. It must be pointed out that this adjustment was not sanctioned by the system's manufacturer.

In any case, the adjustment did not solve the problem and attempts to readjust the spring force back to its original value were only partially successful. This will be discussed further in the chapter on results.

The instability problem was finally solved purely by accident when the throttle position switch was disconnected. The faulty switch did not reveal itself during the checking sequence of the fuel system. Since all testing was to be steady state, this switch would not be needed and therefore was detached for the remainder of the testing.

Following the running of a set of tests with only the above modifications to the engine, the single most major design alteration was made. As pointed out in the literature review, it is suggested by reference 3 that upon converting to propane fuel, the compression ratio of an engine be raised inorder to take advantage of the high octane rating of propane. This was done by milling .051 in (1.2954 mm) off the cylinder heads to elevate the compression ratio from the original 7.7:1 to 8.8:1. The ratio was not increased as much as advocated simply because the testing was not to be performed with the engine ever operating on 100 per cent propane.

Ignition timing was also adjusted during the testing. Justification for this, again, was derived from references 2 and 8. The work done by Adams et al. (8) shows that with 100 per cent propane fuel, ignition timing is a very important variable to consider.

The problem of how to get propane from the storage tank into the engine was solved in the following way. See Figure 9. First, liquid was taken from the tank and vaporized in a propane converter. The converter not only evaporated the propane, but was also a two stage pressure regulator. From the converter, the vapor was piped through a pair of volume flow indicators arranged in parallel, and dumped into the engine intake air upstream of the throttle plate. Each indicator had its own manuel throttle valve.

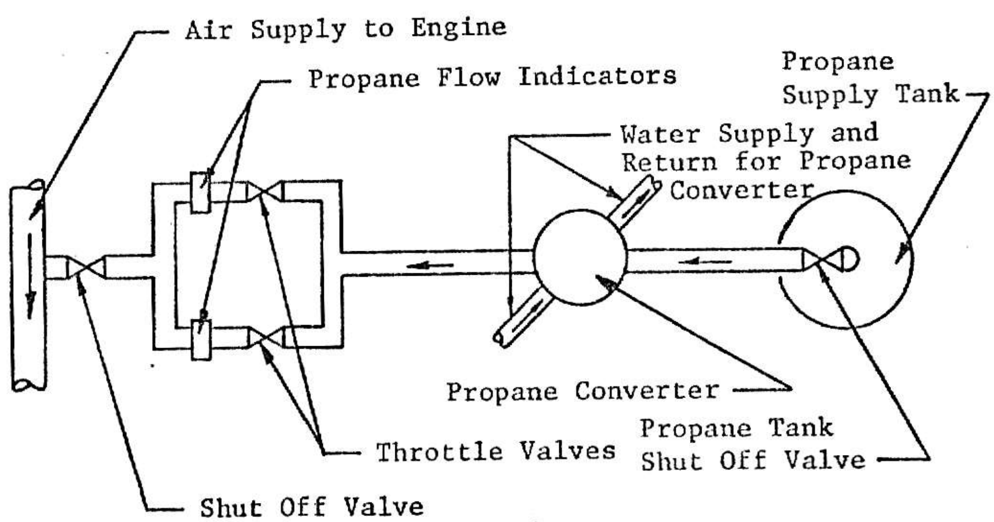

Figure 9. Propane Fuel System

These flow indicators in the propane line were made for measuring N_2 flow. However, since their function was merely to give a relative indication of propane flow, no calibration was performed on them.

A conventional propane carburetion system was not utilized during this investigation because none were available. Therefore, a positive gauge pressure had to be carried in the propane line between the engine and the converter to force the vapor into the air stream. To do this, the converter had to be modified slightly. Since it was designed without pressure adjustments, a crude system was added to allow gross changes in the outlet pressure.

The last change made on the engine concerned the control unit. As the injection system was designed, it would maintain an approximately constant air-fuel ratio based upon the parameters of manifold pressure, engine speed, engine temperature, and throttle position. The system was completely oblivious of additional fuel being taken in with the air. Therefore, if it was to be possible to maintain a constant air-fuel ratio while burning a mixture of gasoline and propane, the time of injector opening had to be proportionally controlled. Such a system for control of gasoline injection was designed, built, and installed on the engine by a graduate student at Kansas State University.

The auxiliary fuel injection control unit (see Figure 10) tied into the electronic control unit at the base of two transistors. Each transistor was part of the circuitry for one set of injectors. Signals from the base of these transistors were fed into others in the auxiliary control in order to amplify the signals to 5 volts. After passing through the transistors the signals were taken to two components. First, each signal went through a monostable multivibrator to increase its pulse width, and on to an "and gate."

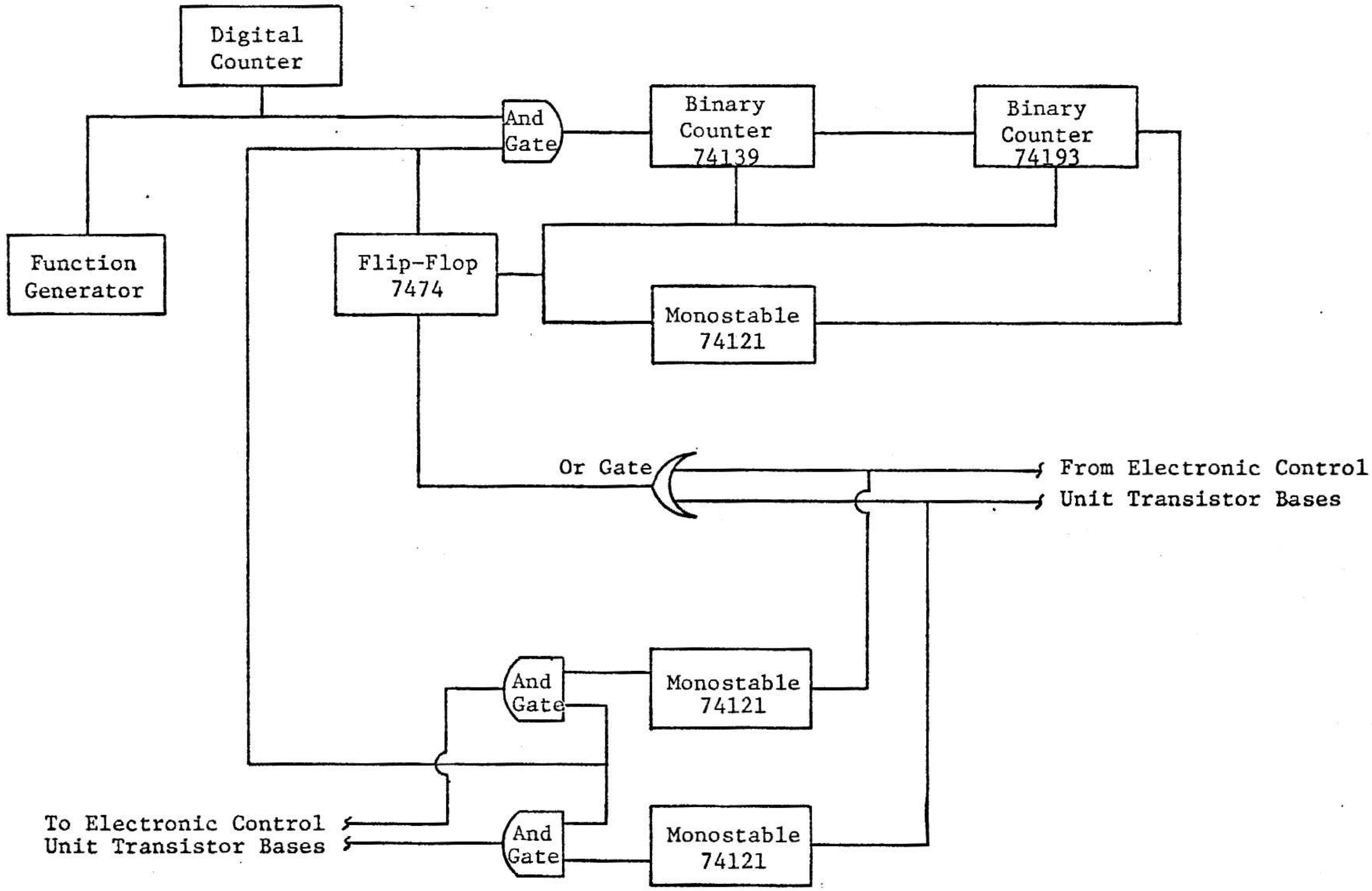

Figure 10. Auxiliary Fuel Injection Control Unit Componet Diagram

The function of these "and gates" will become evident later. The signals were secondly taken to an "or gate" which added the signals to produce a solitary output. The "or gate" was made by feeding each signal through an inverter before entering an "and gate." The signal came out of the "or gate" into a "flip-flop." When the "flip-flop" received a pulse from the "or gate" it went high. This high signal was taken to a third "and gate" which also received a signal from a function generator. The "and gate" output was a pulse identical to the function generator signal and lasted for the duration of the high condition received from the "flip-flop." The function generator signal then entered the counting circuitry which counted 256 pulses before sending a "clear" signal back to the "flip-flop" via another monostable which lengthened the "clear" pulse to insure that the "flip-flop" caught it. The pulse sent the "flip-flop" low which readied it for another pulse from the "or gate." From this monostable, a signal was also sent back to the counters to reset them to zero in preparation for the next counting sequence.

This is the point at which the first two "and gates" that were mentioned become important. Recall that each of them received a signal from the base of a transistor in the electronic control unit. They each also received the pulse signal from the "flip-flop." Finally then, the pulse leaving these two "and gates" was fed back into the electronic control unit to be used as the driving signal for the injectors.

With this design, the signals from the base of the transistors in the electronic control unit were used to start injection. The duration of injection was equal to the time for 256 pulses from the function generator to reach the counters. By this, it can be seen that as one increased the frequency of the function generator signal, the time required for 256 pulses to enter the counters decreased. The opposite was true for decreasing the function generator frequency.

The length of injection was monitored in two ways. First the signal length was fed into a digital counter and secondly it was displayed on an oscilloscope screen. These devices were used extensively to assist in accurate setting of the duration of fuel injection.

The potential required to drive the components of the auxiliary fuel injection control unit was 5 volts. This voltage was delivered by an external power source wired to each constituent.

The interested reader will find a detailed circuit diagram of the auxiliary injection control unit and interface with the electronic control unit in Appendix B.

The discussion of equipment and its alteration is now complete. The next topic will be used of this equipment and its function in the data taking process.

A dynamometer was not available which would allow full load tests to be run. Because of this, tests at zero, one-fourth, and one-half load were carried out. Curves for torque vs. speed at one-fourth and one-half loads were obtained by plotting the correct fractional values of the full load curve. See Figures 11 and 12. The full load data was taken from the 1968 VW Program Provisional Workshop Manual for fuel and electrical systems.

Generally speaking, each data point was run at a specified speed, torque, compression ratio, timing, and per cent gasoline. After running three tests at these conditions, one or more of the parameters were changed. The process continued as long as time would permit.

Enough time was not available to obtain a complete operational map of the engine under all circumstances. However, ample testing was done to draw some

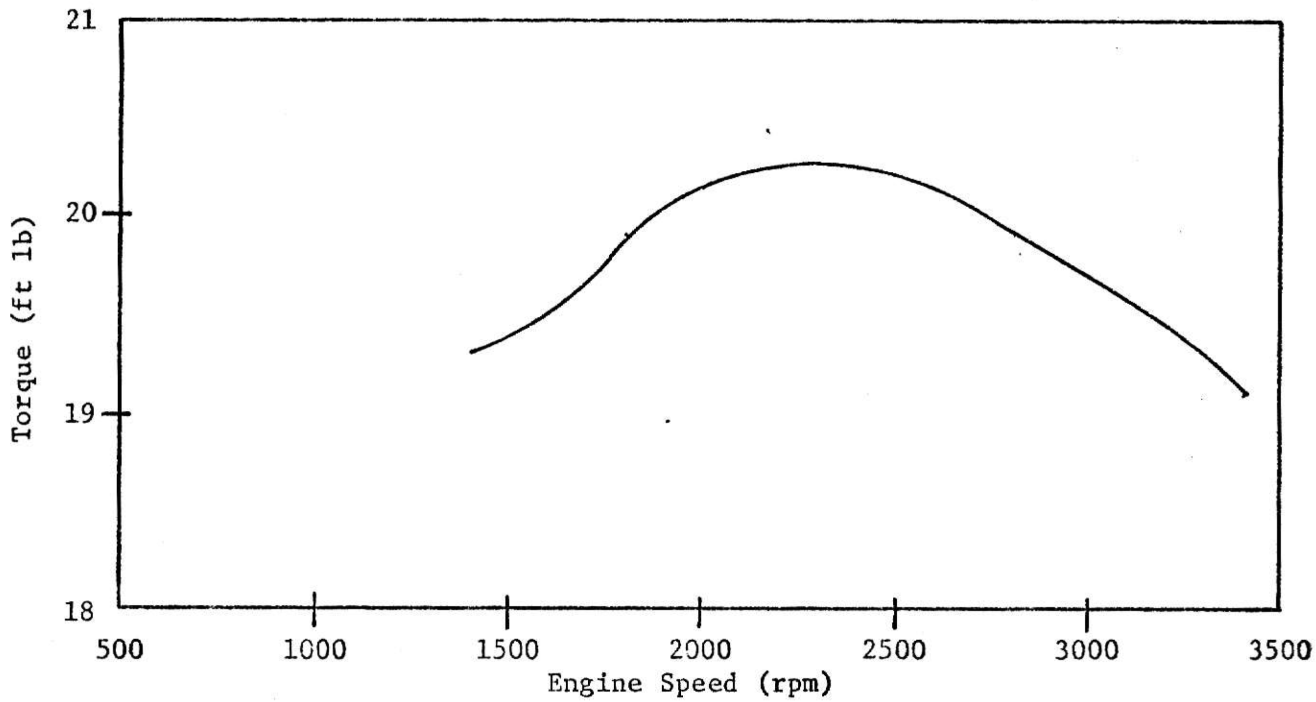

Figure 11. Torque as a Function of Engine Speed at One-Fourth Load

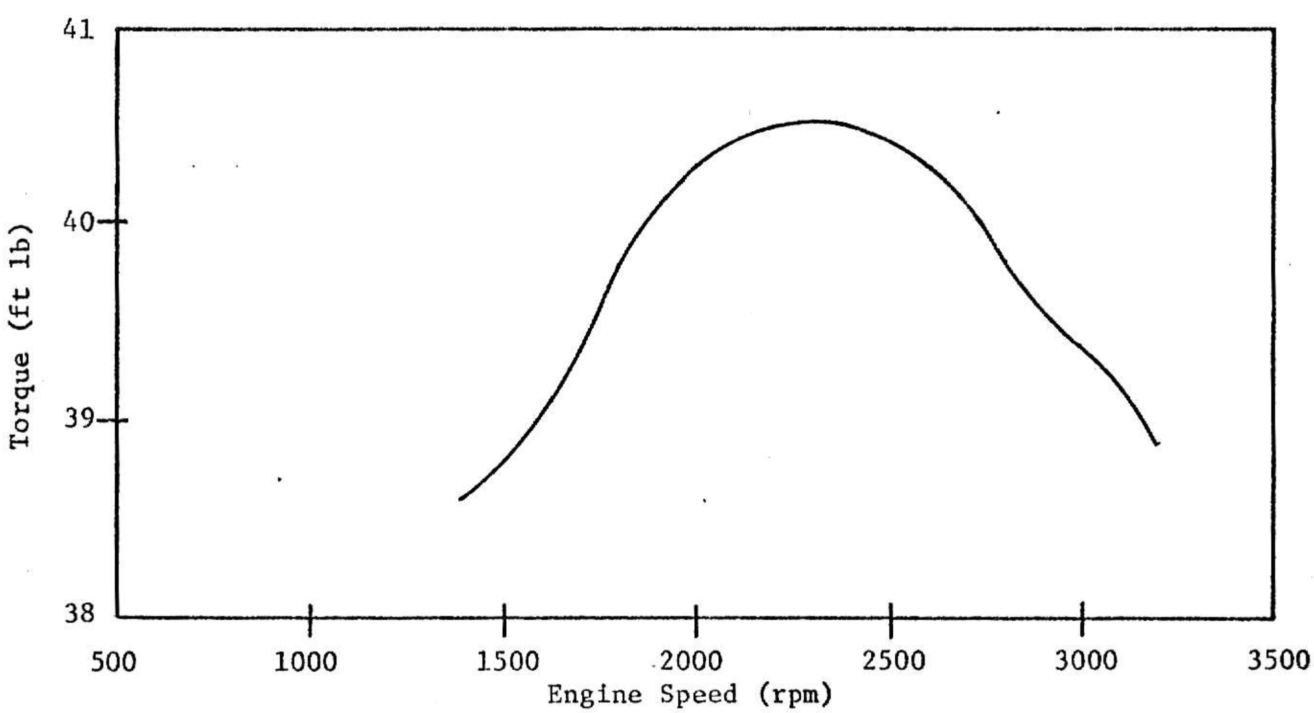

Figure 12. Torque as a Function of Engine Speed at One-Half Load

general conclusions. This will be discussed further in the results, conclusions and recommendations sections of this thesis.

After the above parameters had been set, the engine was allowed to approach stability and the test began. The stop watches were started as the scale sweep hands passed transcribed marks on the respective graduated scale. Next the differential pressure across the air flow nozzle, exhaust temperature, horsepower output, and manifold vacuum were recorded. Also noted was the per cent gasoline flow and, if any propane was being burned, the injection time.

In the testing where the period of injection was controlled, it was first set to give an air-fuel ratio of approximately 14.5:1 when burning 100 per cent gasoline. This time was then altered by the function generator, but was indicated by the counter and oscilloscope, as testing progressed toward 20 per cent gasoline. The indicator scale of the function generator was too coarse to read as accurately as necessary for sustaining a constant air-fuel ratio. The counter and oscilloscope were therefore used for this purpose.

Since testing sessions seldom lasted more than six hours, the barometric pressure was recorded at the beginning of each session and assumed constant throughout the period. Room wet and dry bulb temperatures were remeasured after each set of three data points had been run.

After letting the engine run for approximately five minutes, the watches were stopped as the scale hands swept past the nearest scale marks. Then the elapsed time and final differential masses were entered in the appropriate spaces on the data sheet.

CHAPTER IV

Development of Equations

The reduction of all data was accomplished using the Kansas State University IBM 370 digital computing system. The computer program to do this reduction was written in FORTRAN WATFIV language and is listed with the raw data and reduced results in Appendix C. In this chapter the equations used in the program will be presented and explained where necessary.

The scales used for the propane and gasoline measurement were calibrated with known differential masses to obtain the following equations. For gasoline:

$$AMG = (.9902)\ (MMG) + .0177 \tag{1}$$

and for propane:

$$AMP = (1.0234)\ (MMP) + .01366\ . \tag{2}$$

After finding the amount of fuel consumed during the test, a simple calculation was performed to find the mass of fuel burned per hour:

$$WHG = \frac{CAMG}{TIMEG} \times 3600 \tag{3}$$

$$WHP = \frac{CAMP}{TIMEP} \times 3600 \tag{4}$$

$$TWHF = WHG + WHP\ . \tag{5}$$

Next, the thermal efficiency was calculated by the equation:

$$\eta_{th} = \frac{HP \left(\frac{550}{778}\right) 3600}{(WHG)\ (19134) + (WHP)\ (19768)} \tag{6}$$

where

for propane $LHV/_{p=c}$ = 19768. Btu/lb

for gasoline $LHV/_{p=c}$ = 19134. Btu/lb .

The lower heating value for propane was taken from reference 1, but the LHV of gasoline was found by measuring its API gravity. The question of whether to use LHV or HHV for gasoline computations does not seem to yet have been settled upon by the oil industry. For this reason, while thermal efficiency results will be presented, the reader is encouraged to more closely scrutinize the brake specific fuel consumption figures to detect trends and changes.

In order to calculate the mass air flow rate, several intermediate values first had to be found. First, the density of the atmospheric air had to be found. Next, the "standard density" pressure drop across the flow nozzle had to be calculated. After obtaining this, then the air CFM and finally the WHA were computed. This process sounds very simple, but it is not actually so.

From reference 11, the equation to use for calculation of air density is:

$$\text{DENSA} = \frac{(\text{PATM})\ (.491) - .38 \left[\text{PW} - \dfrac{(\text{PATM})\ (.491)\ (\text{TDB} - \text{TWB})}{2700}\right]}{(.37)\ (\text{TDB})} \qquad (7)$$

The standard density pressure drop across the flow nozzle was acquired from:

$$\text{PNSD} = \frac{(\text{PMN})\ (.075)}{\text{DENSA}} \quad . \qquad (8)$$

In order to calculate the CFM into the engine as a function of the pressure drop across the nozzle, a calibration sequence had to be performed. The procedure incorporated an annubar meter and calibration methods as prescribed by the Air Diffusion Council. After taking the proper data in the outlined way, the data was reduced through the use of a Wang 600 Electronic Calculator and program 2029 from the Wang 600 General Library. The result of this was equations 10 and 11. Equation 10 applies to the 2 in (5.08 cm) nozzle which was first used and equation 11 is the relationship for the 1.59 in (4.04 cm) nozzle.

$$CFM = (98.3596)\ (PNSD)^{.5116} \tag{10}$$

$$CFM = (62.0524)\ (PNSD)^{.5014}\ . \tag{11}$$

After finding the CFM, the WHA was calculated by equation 12.

$$WHA = (CFM)\ (DENSA)\ (60) \tag{12}$$

Continuing through the program, the next series of calculations performed resulted in the volumetric efficiency. First, the theoretical maximum air intake by the engine was computed from equation 13

$$TWHA = \left(\frac{96.6}{2}\right) \left(\frac{RPM}{1728}\right) (DENSA)\ (60) \tag{13}$$

where engine displacement is equal to 96.6 cu in (1.58 1). Of course the volumetric efficiency was:

$$\eta_v = \frac{WHA}{TWHA}\ . \tag{14}$$

The remainder of the equations used in the computer program were all quite simple. They were, in order of appearance:

$$AF = \frac{WHA}{TWHF} \tag{15}$$

$$BMEP = 150.8 \left(\frac{T}{96.6}\right) \tag{16}$$

$$BSFC = \frac{TWHF}{HP}\ . \tag{17}$$

CHAPTER V

Presentation of Results

From the data collected, there were several quantities calculated and later plotted on graphs. These results will be discussed in the order in which the data was taken.

The first series of testing done in the engine had the purpose of establishing a base from which to begin the discussion of the effects of changing the selected parameters. The results of these tests are shown graphically in Figures 13 through 19.

Inspection of these curves shows nothing unexpected except in the case of Figure 13. This graph shows results quite contrary to the expressed capability of the electronic fuel injection system. The system was supposedly designed to maintain an air-fuel ratio of approximately 14.0:1. As pointed out in Chapter III, this could be altered somewhat for short periods of time during warm-up and deceleration as well as operation under full load. During the testing, however, none of these three conditions existed. The problem of irregular and widely varying ratios must then have been the result of either poor system design or changing the adjustment on the manifold pressure sensor, or both.

There can be no mistake that tampering with the pressure sensor may have had an ill effect upon engine performance. This was borne out in discussions with Peter Fichtner of the Bosch technical staff in Broadview, Illinois. The exact effect of this mutation upon the operation could not be obtained though.

One of the design problems with the fuel injection system on the engine was that the pressure of the gasoline supplied to the injectors was held

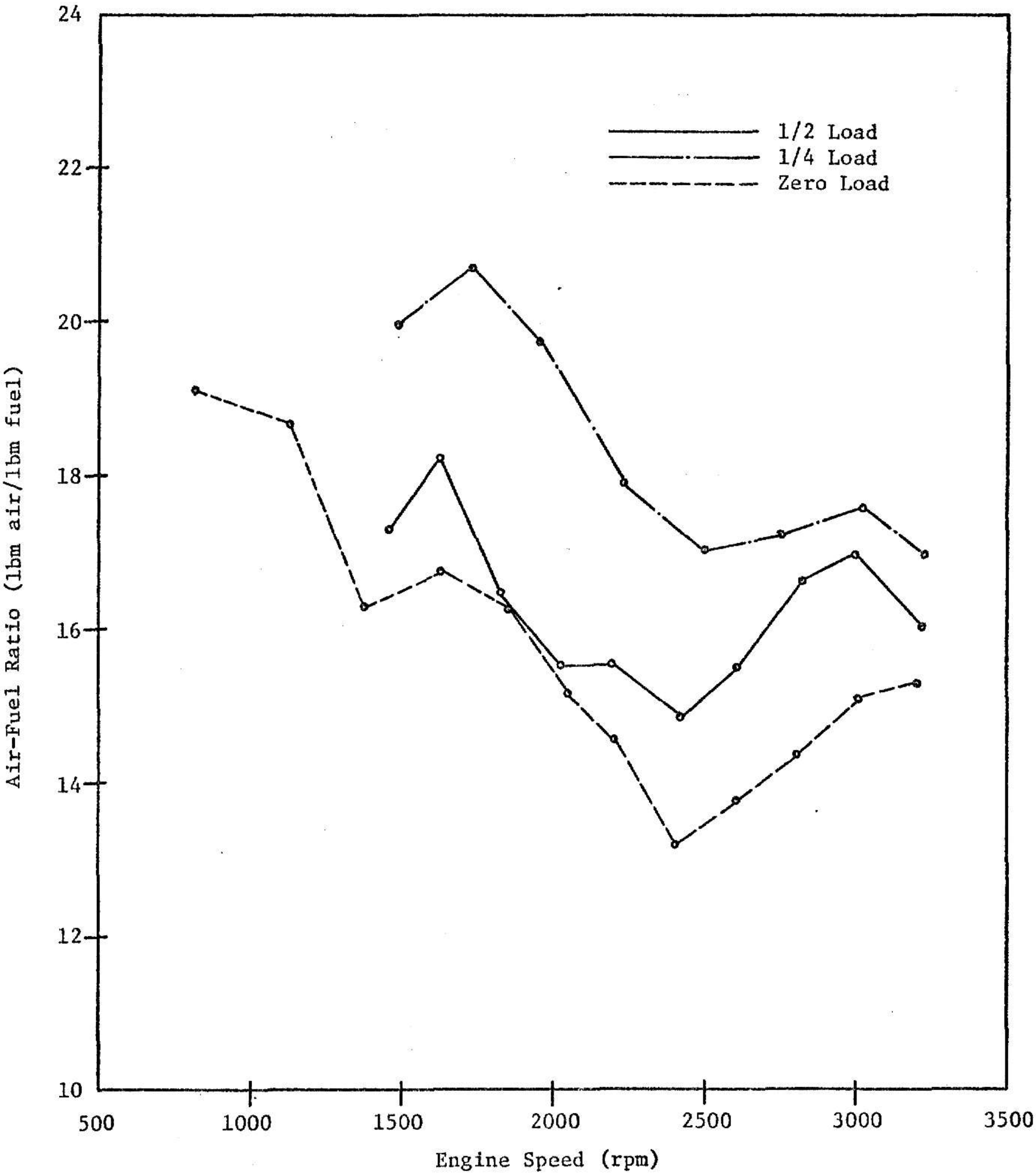

Figure 13. Air-Fuel Ratio at Zero, One-Fourth and One-Half Load as a Function of Engine Speed with a Compression Ratio of 7.7:1

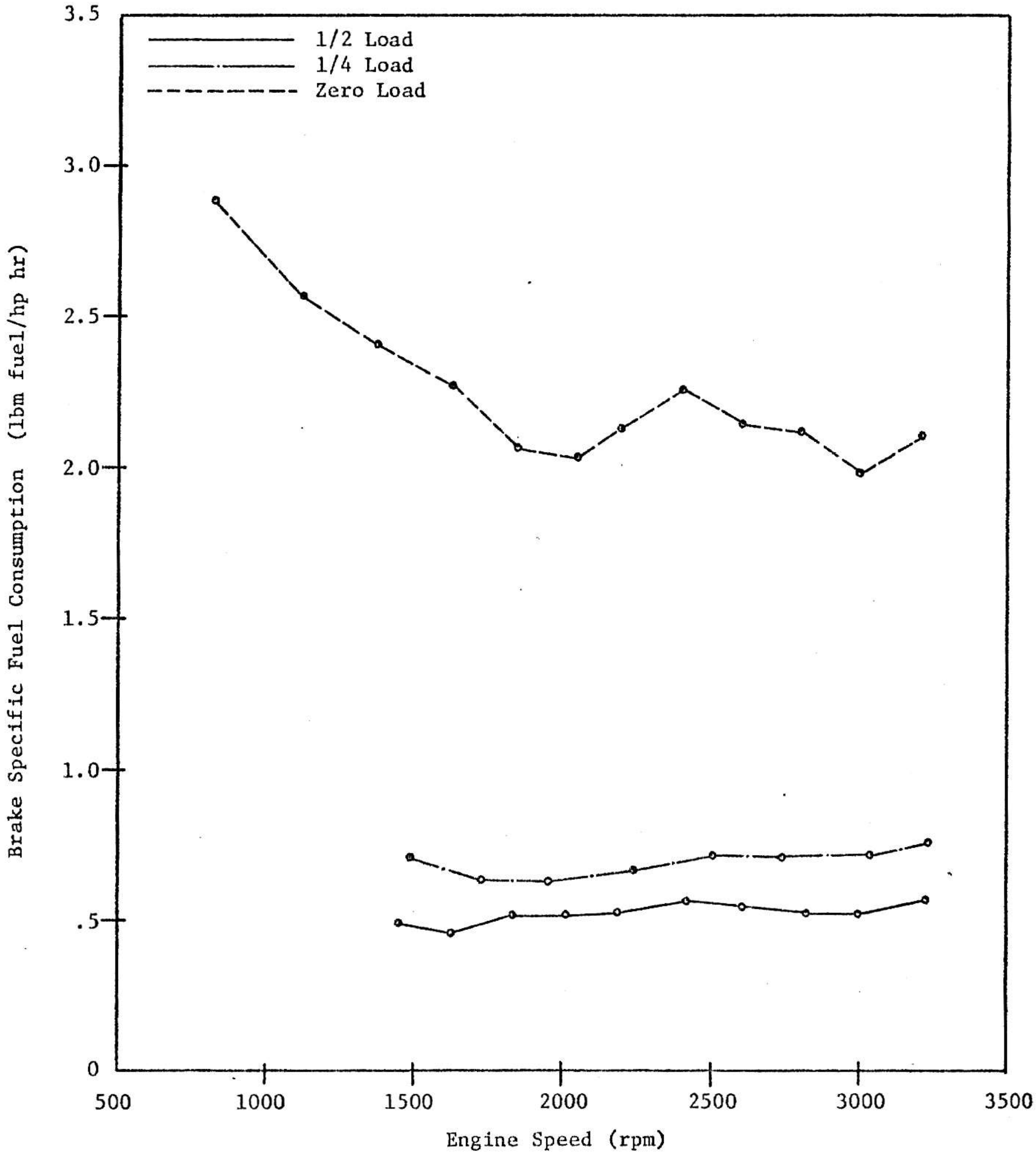

Figure 14. Brake Specific Fuel Consumption at Zero, One-Fourth and One-Half Load as a Function of Engine Speed with a Compression Ratio of 7.7:1

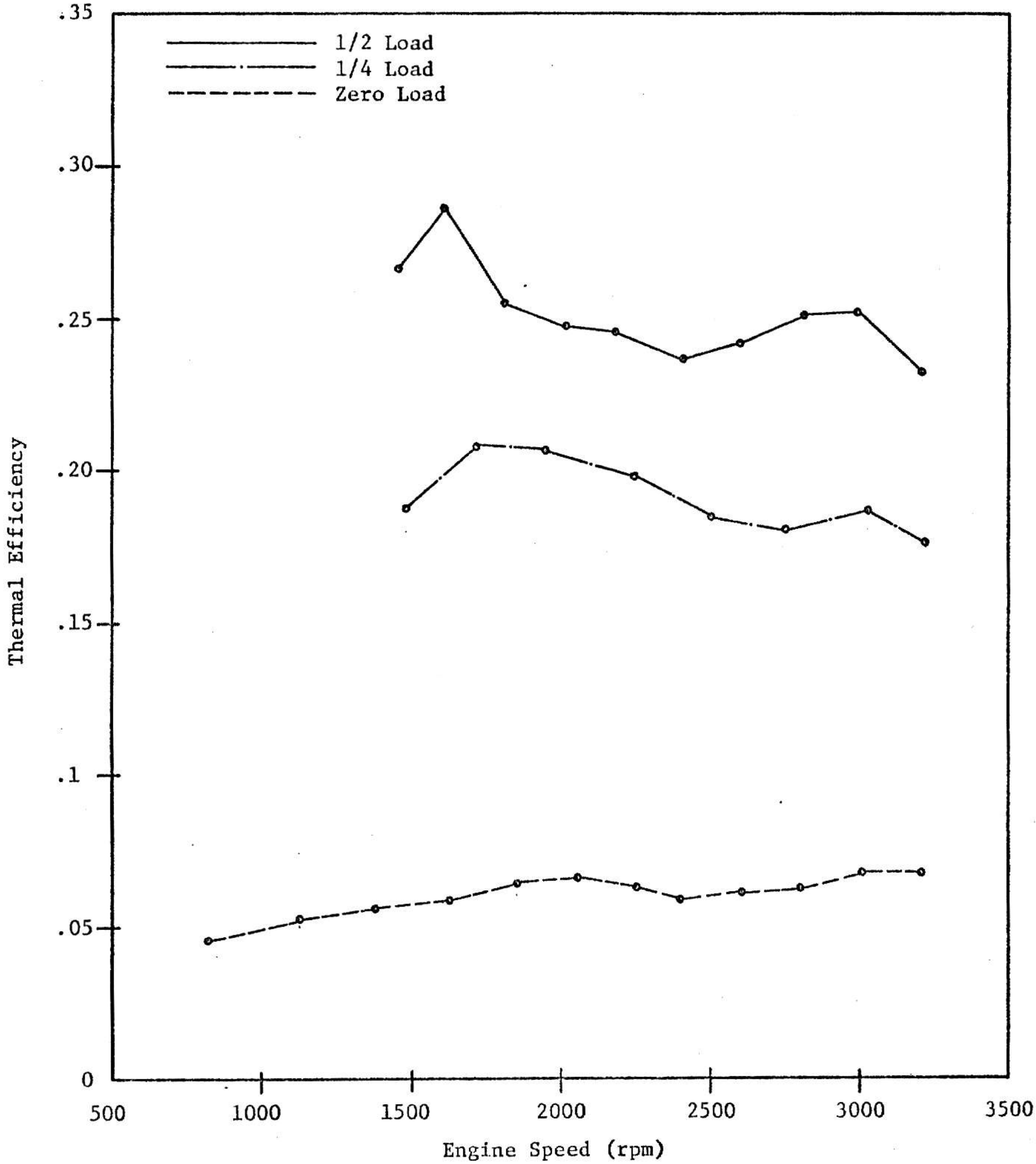

Figure 15. Thermal Efficiency at Zero, One-Fourth and One-Half Load as a Function of Engine Speed with a Compression Ratio of 7.7:1

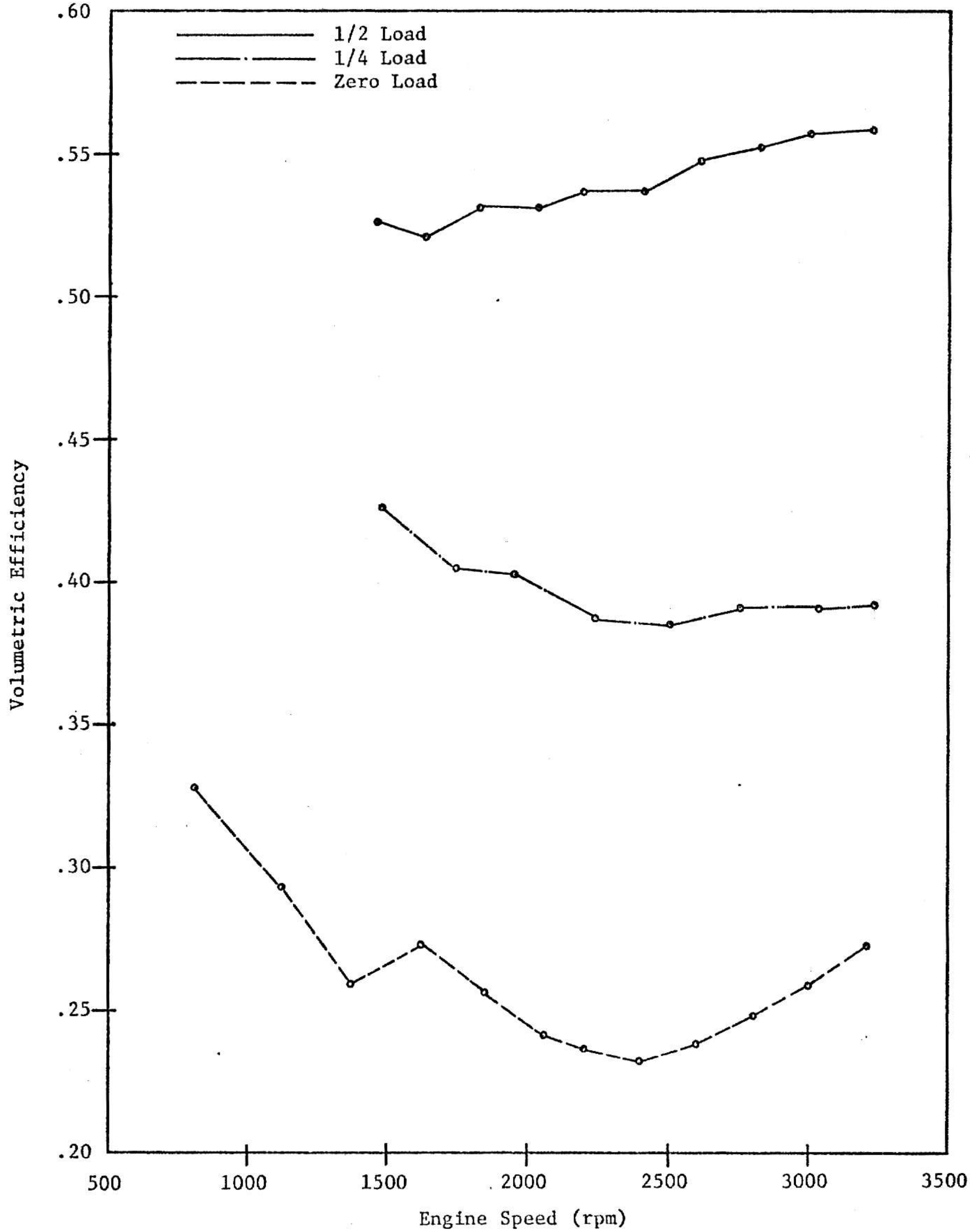

Figure 16. Volumetric Efficiency at Zero, One-Fourth and One-Half Load as a Function of Engine Speed with a Compression Ratio of 7.7:1

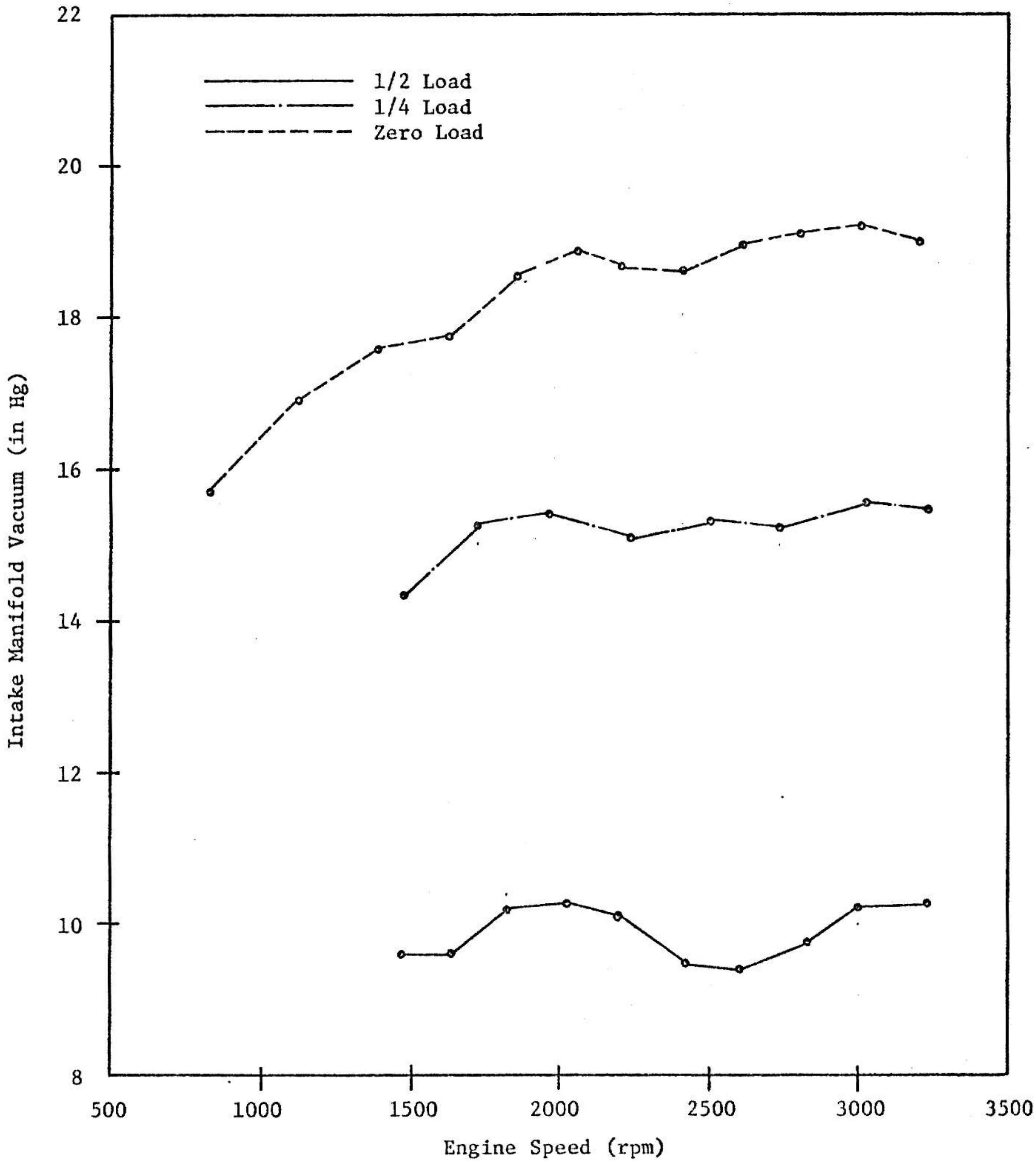

Figure 17. Intake Manifold Vacuum at Zero, One-Fourth and One-Half Load as a Function of Engine Speed with a Compression Ratio of 7.7:1

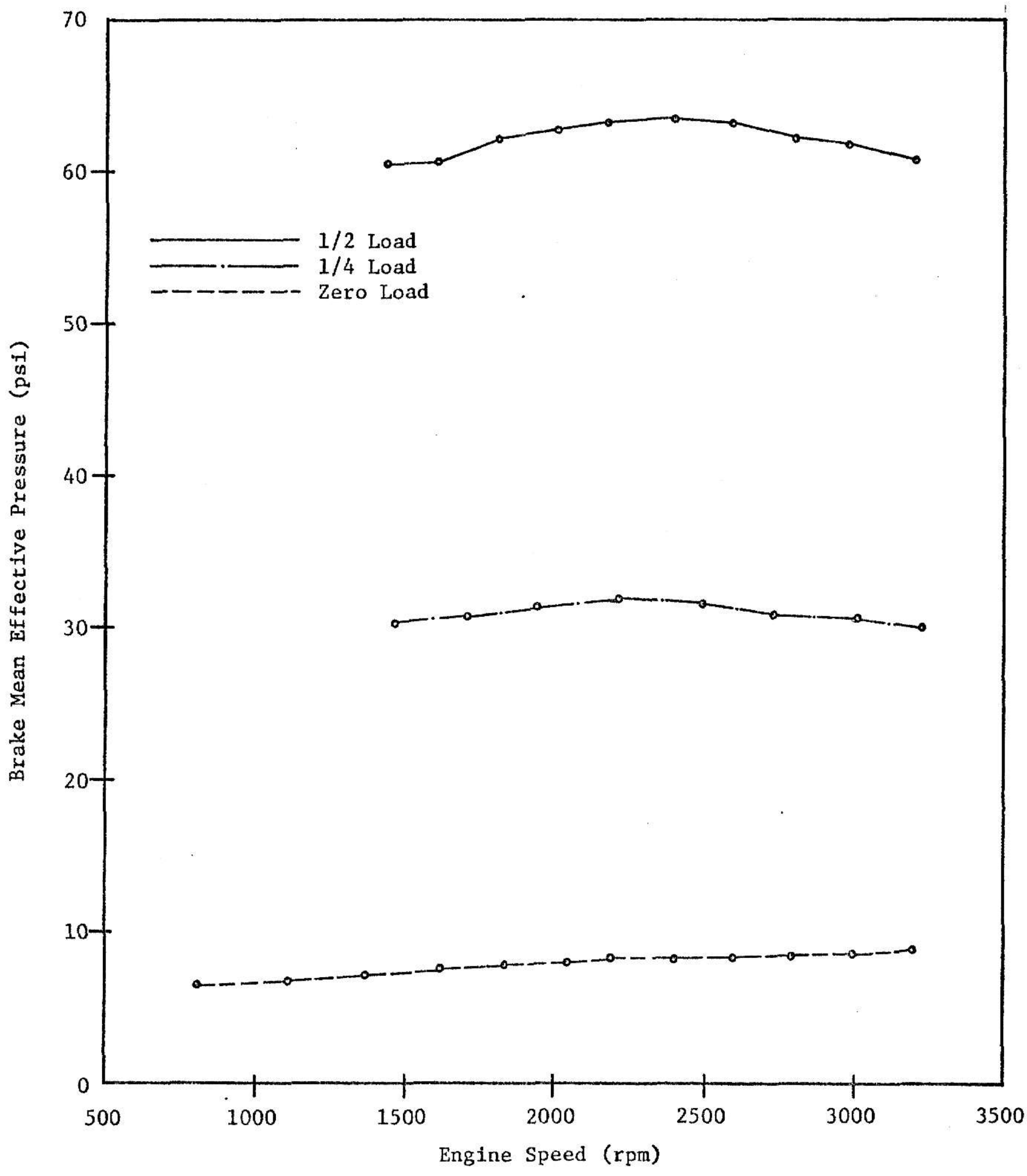

Figure 18. Brake Mean Effective Pressure at Zero, One-Fourth and One-Half Load as a Function of Engine Speed with a Compression Ratio of 7.7:1

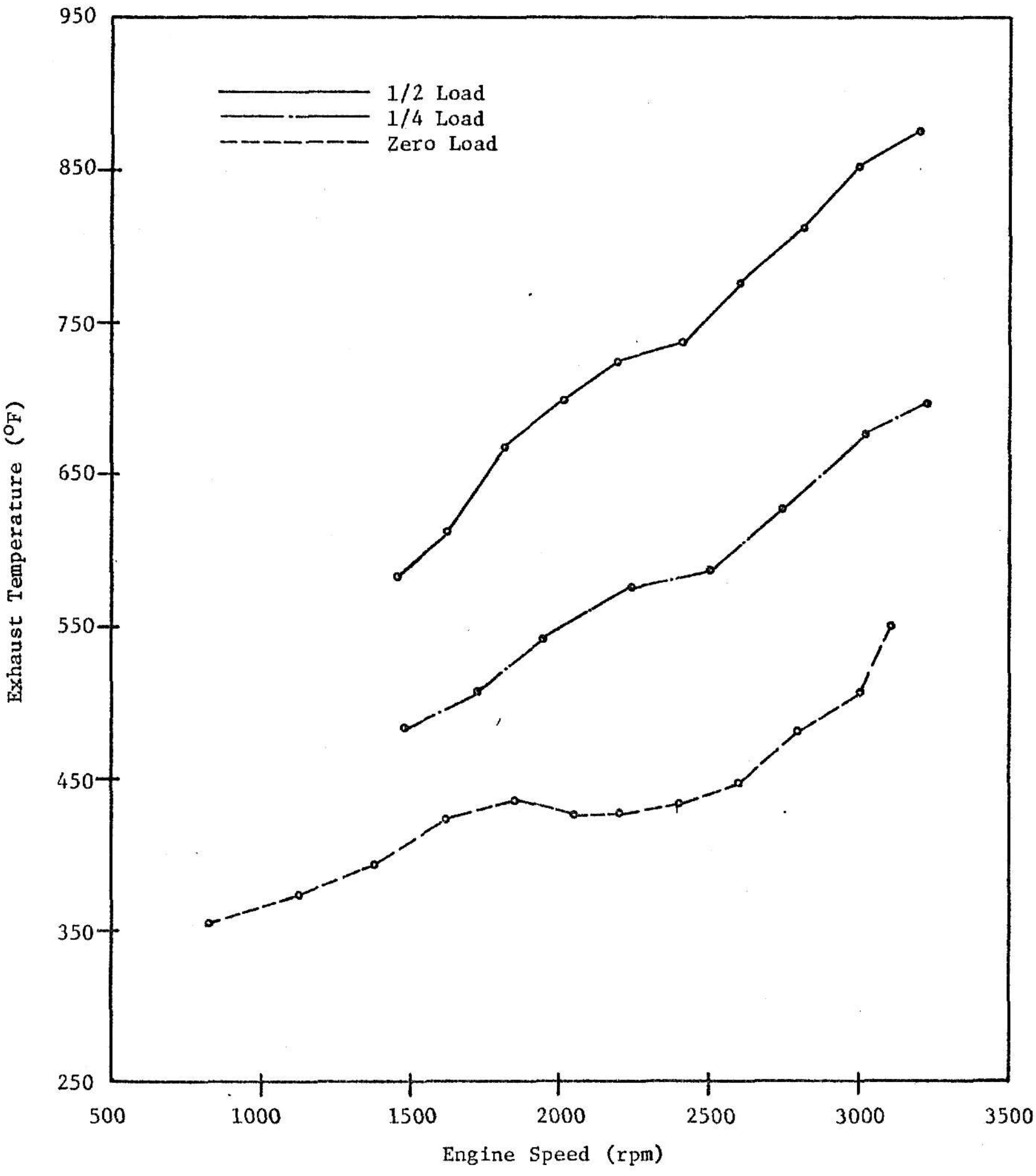

Figure 19. Exhaust Temperature at Zero, One-Fourth and One-Half Load as a Function of Engine Speed with a Compression Ratio of 7.7:1

constant with respect to atmospheric pressure. The pressure differential across the injector nozzles would have been much greater than 28 psig (2 kg cm^2) in many cases. To compensate for this, the manifold pressure sensor signal would have tended to shorten the pulse length. This concept must not have proven too successful though, as it was discarded in favor of an "air flow" system on later models.

In any event, the cause of the widely varying air-fuel ratio curves cannot be explained fully by the author.

In looking at Figure 14, one will note that there are curves of brake specific fuel consumption for all three load conditions. If what has been called the zero load test had actually been run at zero load, the brake specific fuel consumption would have been infinity, as one deduces from equation 17. It then becomes obvious that "zero load" was not truly indicitive of the actual case. Since the dynamometer could not be easily disconnected, zero load simply referred to the smallest possible load the pump would put on the engine. This turned out to be a torque in the neighborhood of 5 ft lb (.69 kg m).

The one-fourth and one-half load curves for brake specific fuel consumption behave in a manner to be expected. At the larger loads, the fuel consumption per horsepower output dropped. This is because as the dynamometer load increases, the fraction of the fuel which is burned to overcome the internal friction of the engine becomes smaller.

The thermal efficiency (Figure 15) trends are (by definition) exactly the opposite of those displayed by the brake specific fuel consumption.

Volumetric efficiency (Figure 16) naturally increased as the load and thereby the throttle opening increased. Volumetric efficiency and intake manifold vacuum are very closely related as one can see by comparing Figures 16 and 17. As the load was increased, the throttle was further open at a given speed. Therefore, the manifold pressure drifted toward atmospheric as the load increased because the pressure drop across the throttle plate diminished.

From equation 16, it can be seen that torque is the only variable in the equation for brake mean effective pressure. As the torque was increased in going from zero to one-half load, the brake mean effective pressure correspondingly increased. See Figure 18.

The rise of the exhaust temperature (Figure 19) as the load was increased can be explained through the use of Figure 20. The dashed line indicates a typical cycle at some given conditions. If then the initial pressure of the mixture is elevated from 1 to 1', the cycle would look more like that depicted

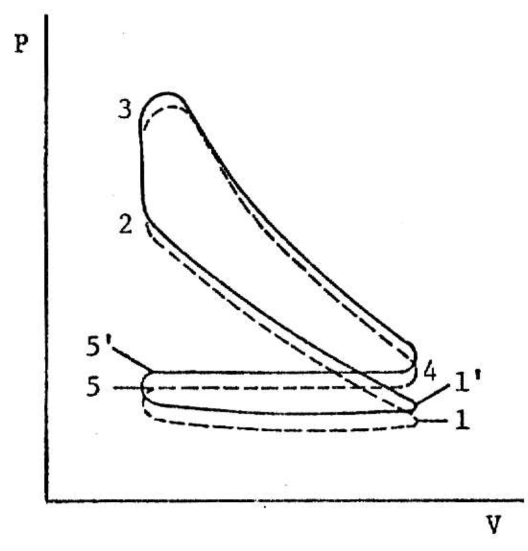

Figure 20. Pressure-Volume Diagram Showing Effect of Changing Intake Manifold Vacuum Upon Exhaust Temperature

by the solid line. The higher pressure at point 1' is, of course, the result of the throttle being further open at heavier loads for a given engine speed. Comparison of the exhaust process in the two cycles shows the high pressure cycle to have a higher exhaust gas temperature.

The rise in exhaust temperature with engine speed is the result of less time for heat trasfer with the combustion chamber walls and a decrease in the time for combustion leading to some burning still occurring in the exhaust manifold.

The second set of tests was run after the cylinder heads had been altered to give a higher compression ratio. In comparison with the first set of results, this modification generally lowered the volumetric efficiency (Figure 21), exhaust temperature (Figure 22), brake specific fuel consumption (Figure 23), and intake manifold vacuum (Figure 24). Because of the testing procedure, the revamping did not affect the brake mean effective pressure (Figure 25). As one would expect, there was also no change in the air-fuel ratio (Figure 26) as a result of this variation. The only performance indicator which changed in a positive direction was the thermal efficiency. See Figure 27.

There is no valid reason that any change in air-fuel ratio should take place. The decline in the volumetric efficiency indicates that less air flowed into the engine. The lower manifold vacuum was interpreted by the control unit as less load. Recall that removing the load decreases the fuel injected. The combination of less fuel and less air contributes to the likelihood of unchanged air-fuel ratio.

Figure 28 shows the effect upon thermal efficiency when the compression ratio of the ideal Otto cycle is increased. The spark ignition engine does not duplicate the Otto cycle, but for theoretical work it is a widely accepted approximation.

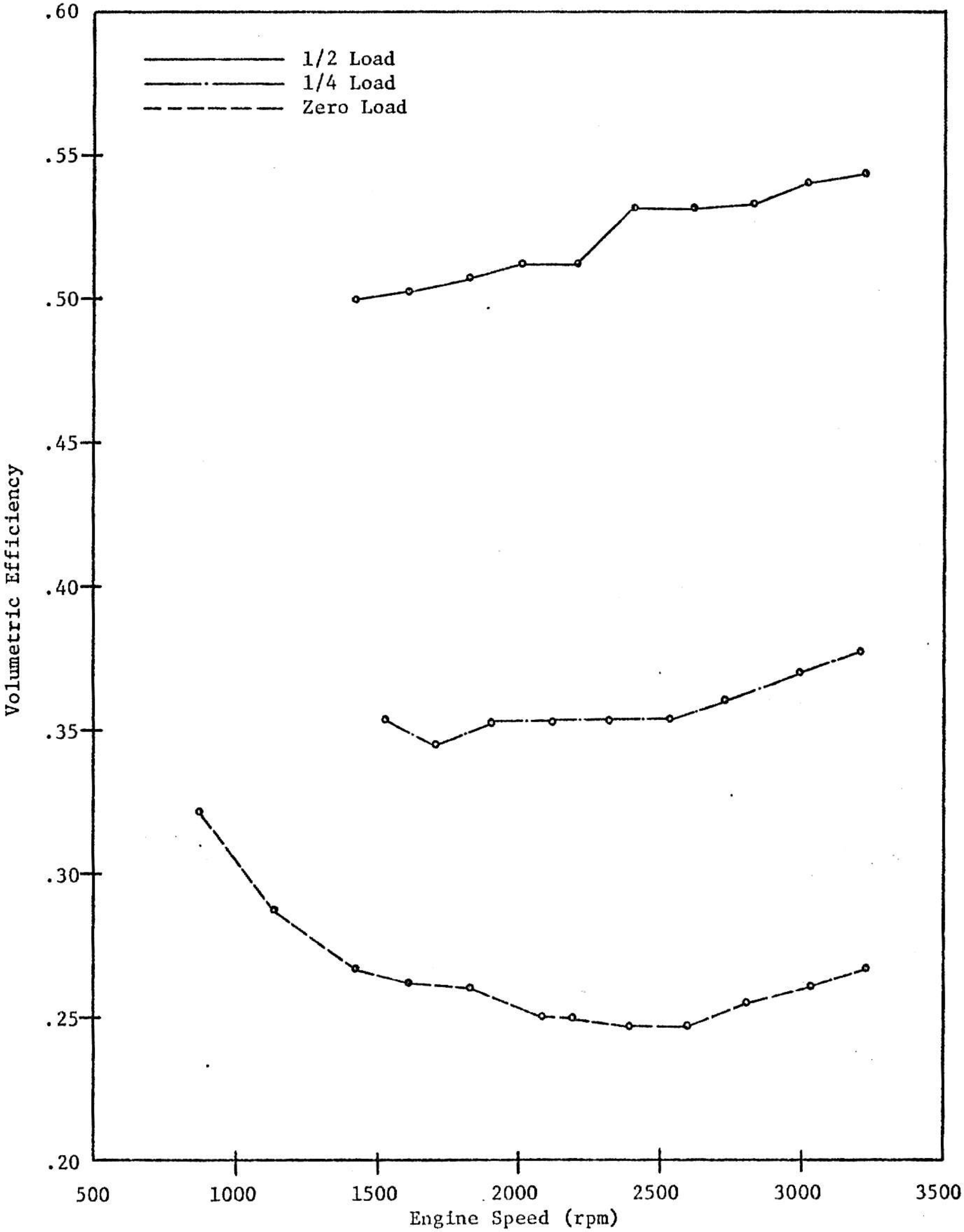

Figure 21. Volumetric Efficiency at Zero, One-Fourth and One-Half Load as a Function of Engine Speed with a Compression Ratio of 8.8:1

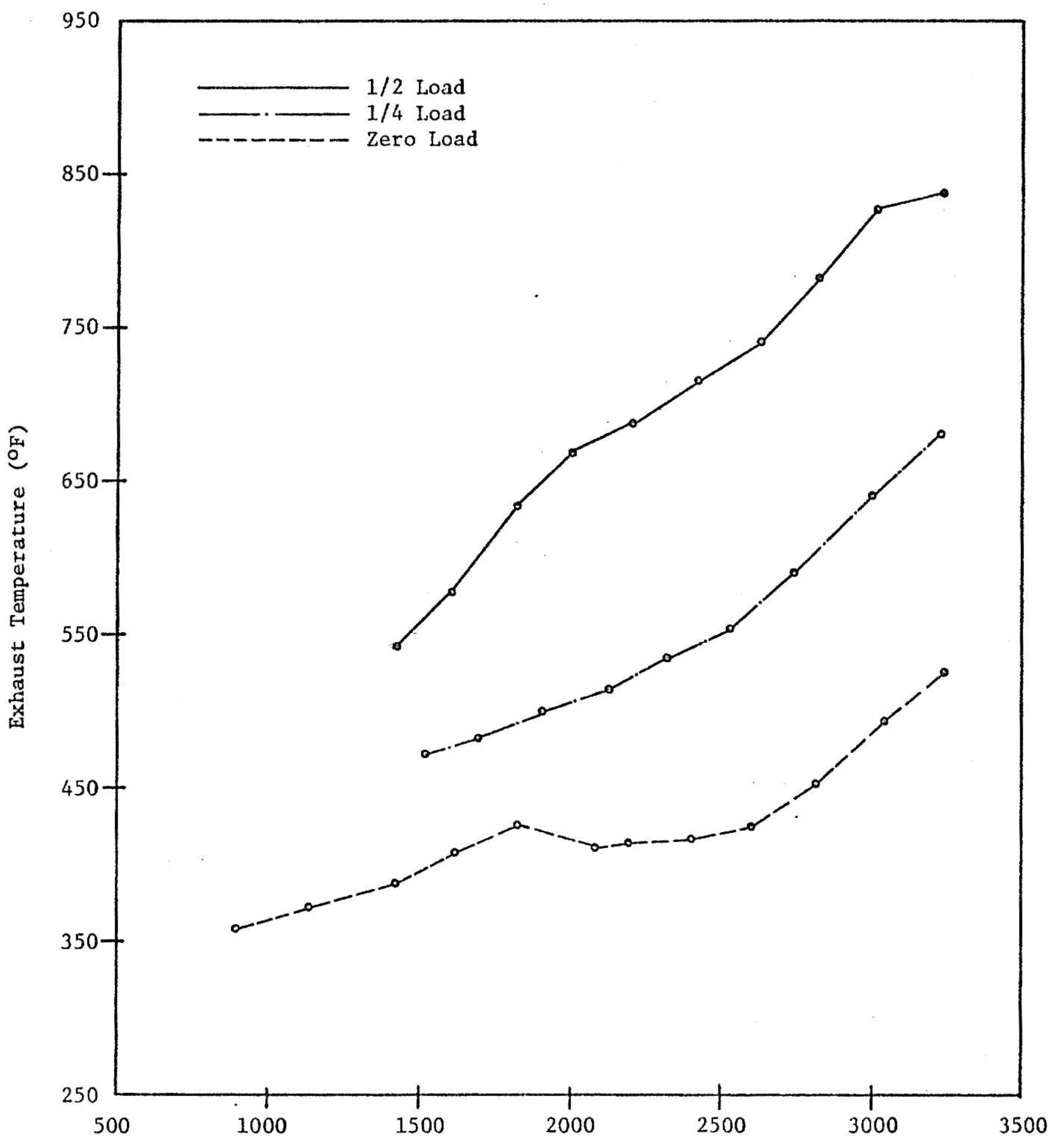

Figure 22. Exhaust Temperature at Zero, One-Fourth and One-Half Load as a Function of Engine Speed with a Compression Ratio of 8.8:1

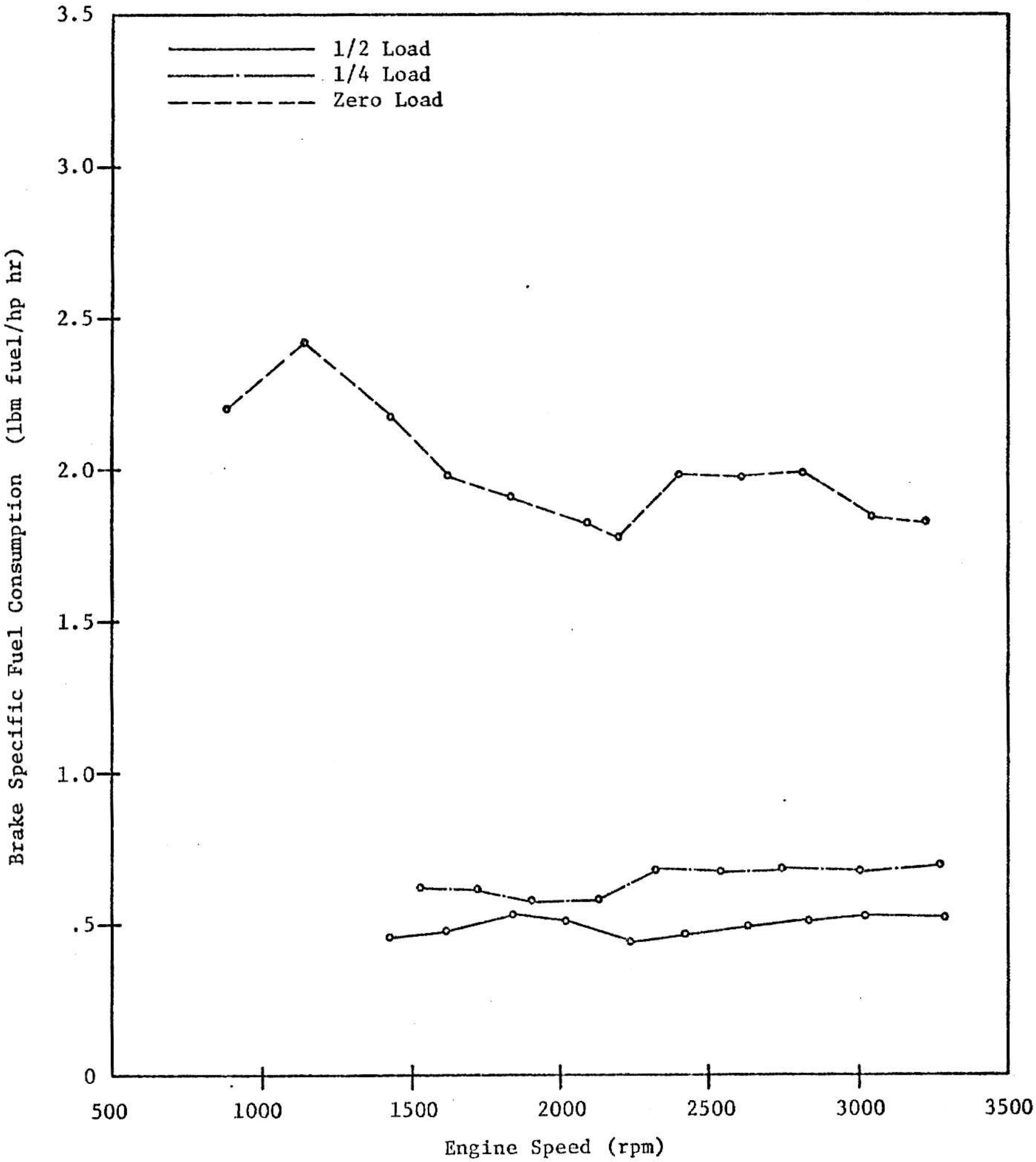

Figure 23. Brake Specific Fuel Consumption at Zero, One-Fourth and One-Half Load as a Function of Engine Speed with a Compression Ratio of 8.8:1

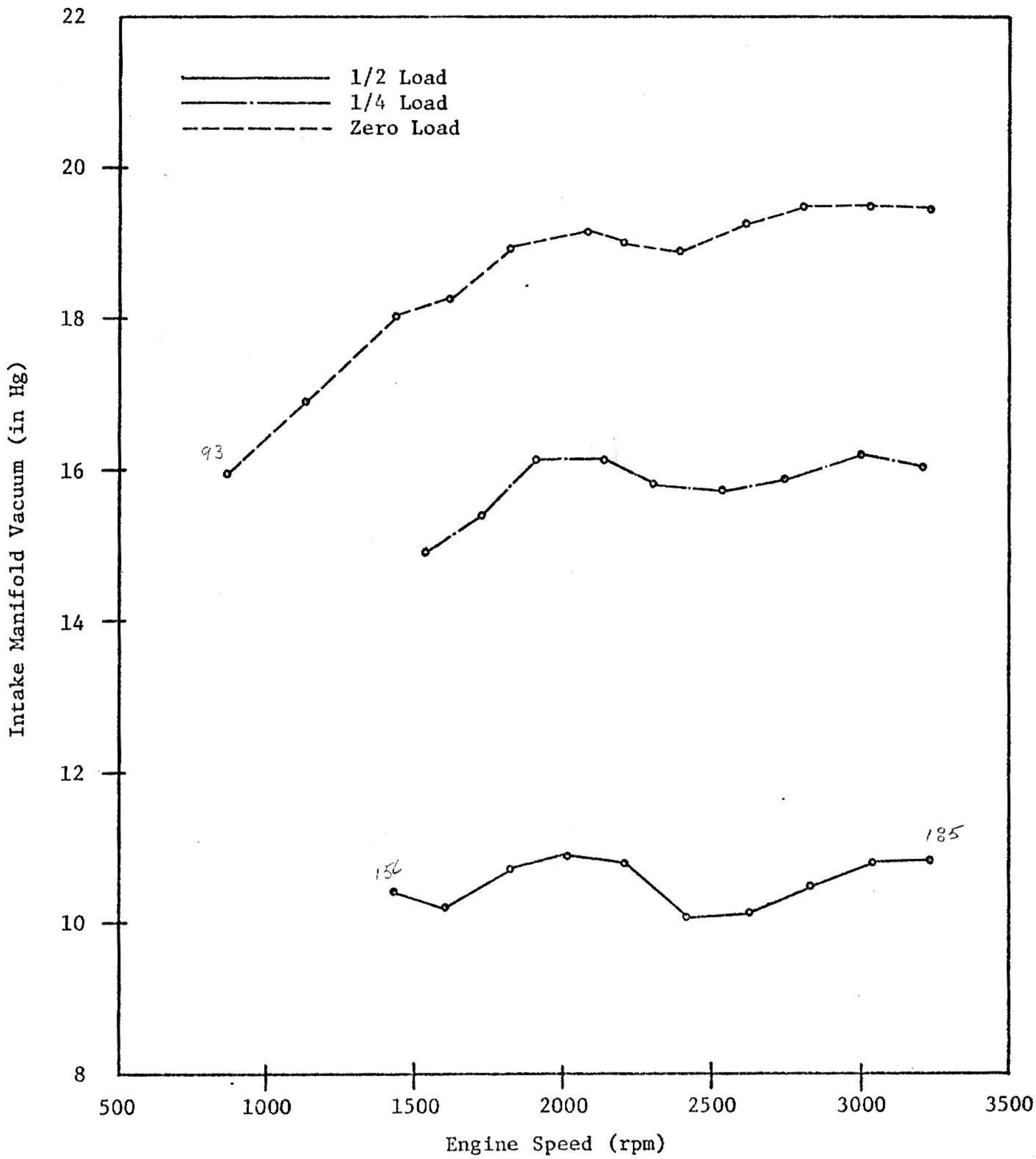

Figure 24. Intake Manifold Vacuum at Zero, One-Fourth and One-Half Load as a Function of Engine Speed with a Compression Ratio of 8.8:1

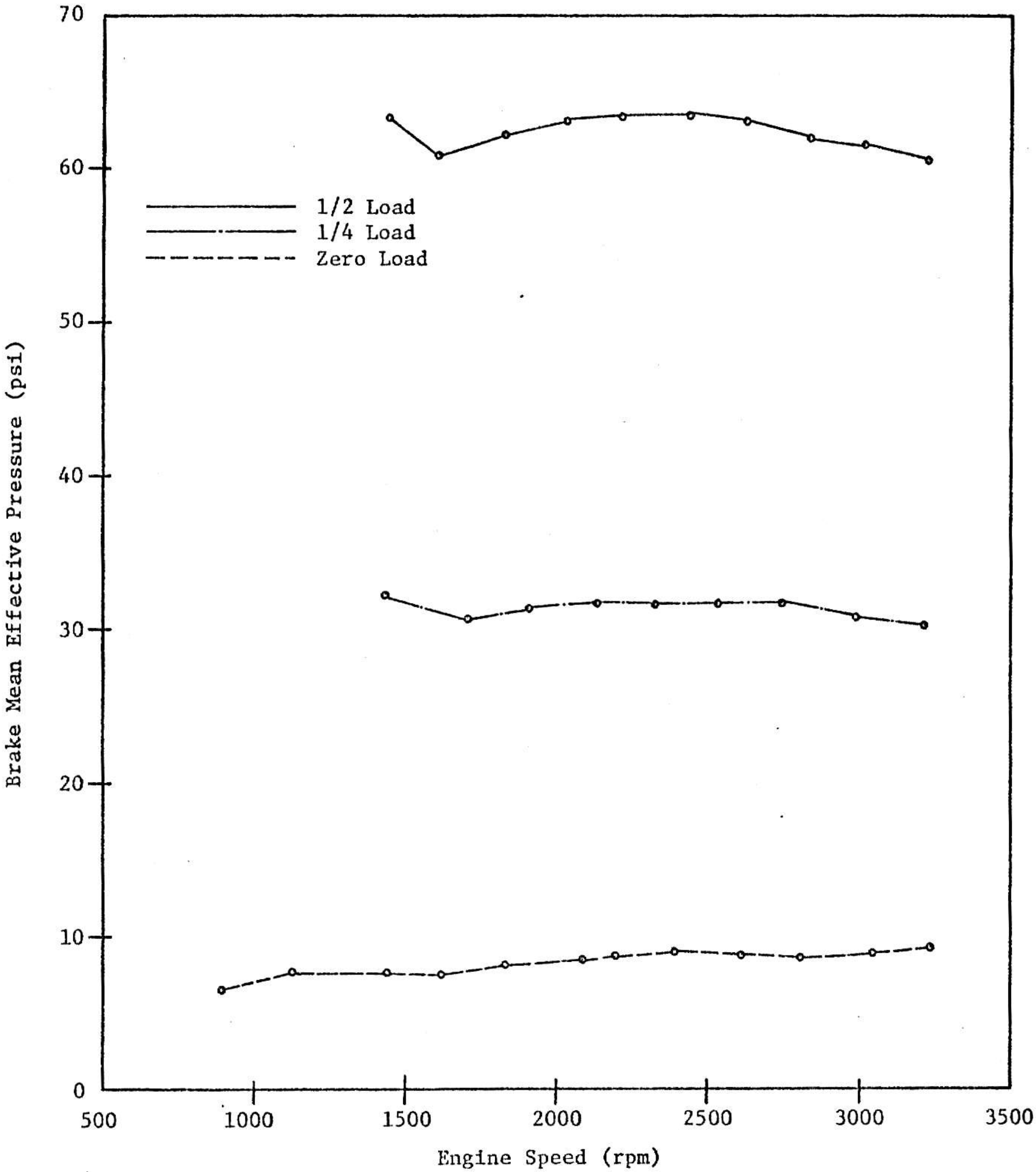

Figure 25. Brake Mean Effective Pressure at Zero, One-Fourth and One-Half Load as a Function of Engine Speed with a Compression Ratio of 8.8:1

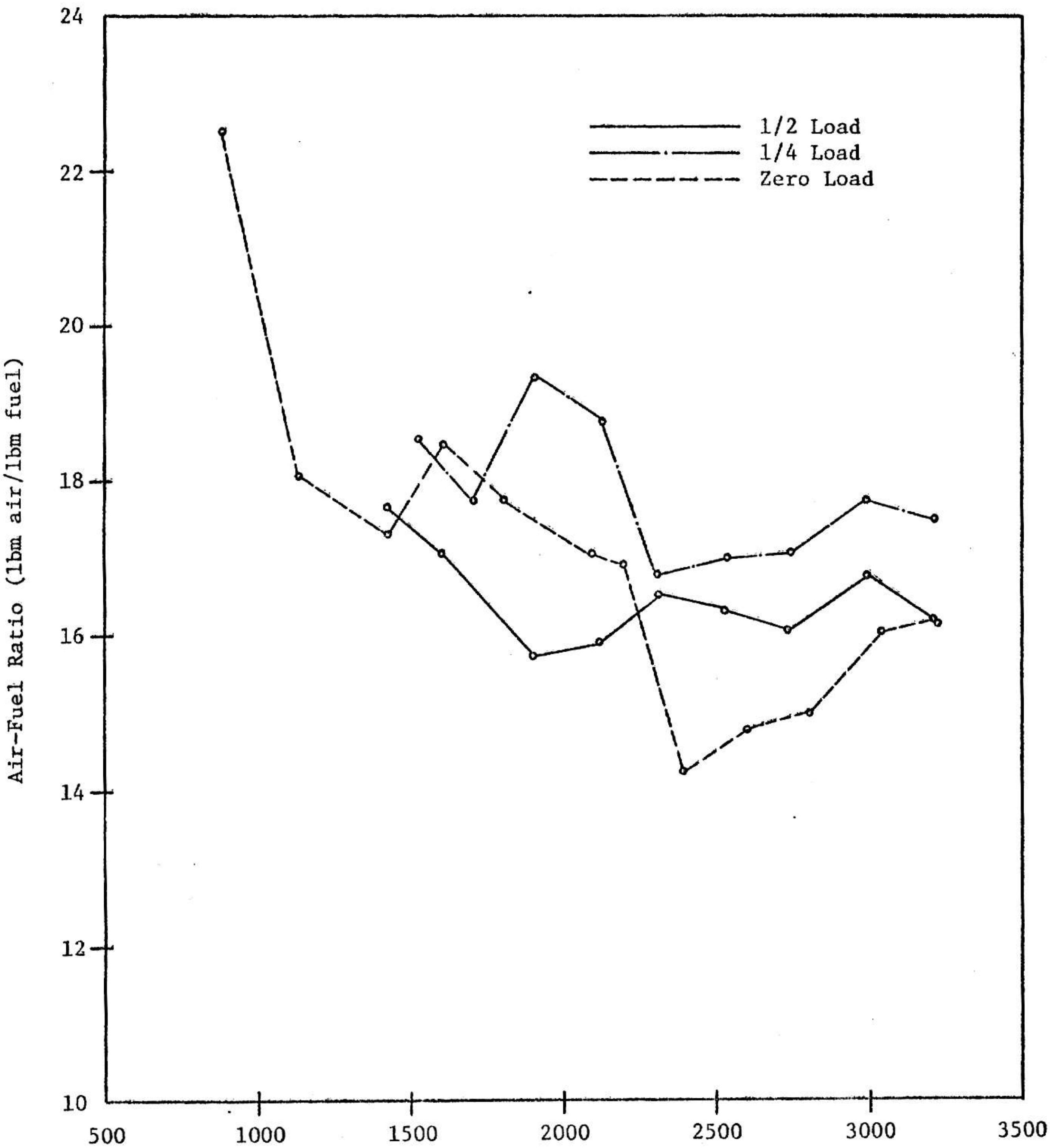

Figure 26. Air-Fuel Ratio at Zero, One-Fourth and One-Half Load as a Function of Engine Speed with a Compression Ratio of 8.8:1

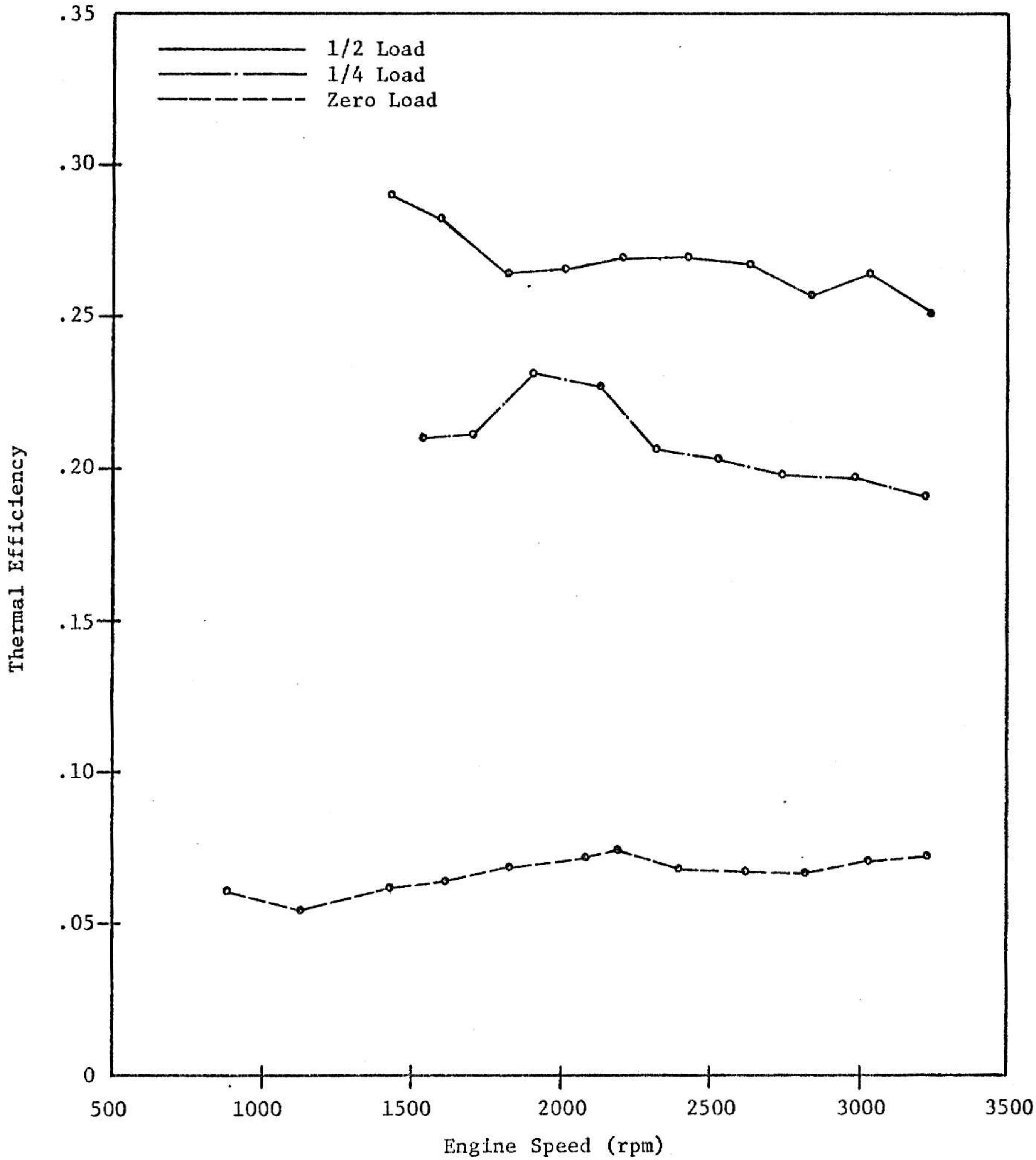

Figure 27. Thermal Efficiency at Zero, One-Fourth and One-Half Load as a Function of Engine Speed with a Compression Ratio of 8.8:1

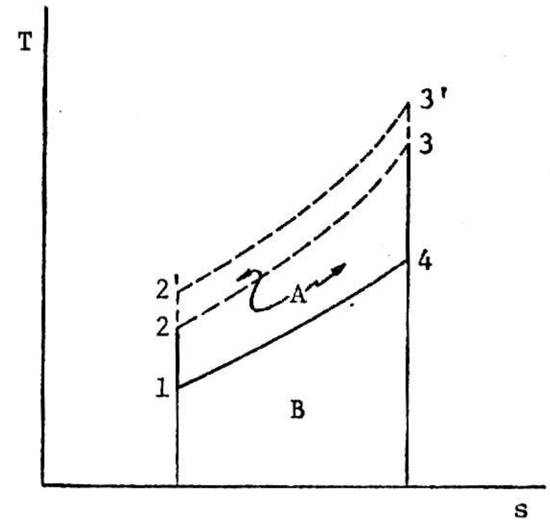

Figure 28. Temperature-Entropy Diagram to Show Increase in Thermal Efficiency with an Increase in Compression Ratio

Referring once again to Figure 28, the thermal efficiency is calculated as:

$$\eta_{th} = \frac{A}{A + B} .$$

One can see that boosting the compression ratio, which shifts point 2 to 2' and 3 to 3', increases "A" as "B" remains constant, thus the bettering of the thermal efficiency. The results of the testing therefore follow the theoretical model for increasing the compression ratio.

Once again, the trend of the brake specific fuel consumption (Figure 23) is explained by simply pointing out that it is another measure of engine efficiency which was shown above to improve with increased compression ratio.

Of course, improved values is synonymous with lower values when speaking of brake specific fuel consumption which was indeed the pattern observed in this testing.

The increase in the thermal efficiency of the engine means that there were more useful units of work output per unit of energy input after raising the compression ratio than before. This means that less of the combustion mixture needed to be fed into the engine in order to get the same amount of work out. A decrease in the demand for mixture lessened the demand for air, thereby reducing the volumetric efficiency. See Figure 21. The manifold pressure also dropped (Figure 24) since the throttle plate was held further closed at a given speed and torque.

As mentioned above, the brake mean effective pressure did not change because of the particular testing procedure used. See Figure 25. Most of the testing was designed to follow the curves in Figures 11 and 12. Thus, at any given speed and load condition (one-half or one-fourth load) the torque was set at a predetermined value. From equation 16, if the torque did not change, then the brake mean effective pressure did not change either.

The reduction in exhaust temperature is due to the general lowering of the manifold pressure. In looking at Figure 20, if point 1' is lowered to 1, the whole cycle is moved down on the graph, resulting in point 5 being at a lower temperature value than point 5' because of the change in the compression ratio.

The third set of tests run were a set of constant throttle, variable speed and torque tests. These were run in order to investigate the trend of the performance parameters as the operating conditions varied between the extremes of small load-high speed and large load-low speed.

Looking at Figures 29 through 35, one sees that the curves are, with the exception of the air-fuel ratio, smooth and regular. In comparison with the second set of tests, the curves at 1600 rpm match almost identically those for 1600 rpm and one-half load. At 3200 rpm the engine exhibited characteristics very similar to the 3200 rpm and zero load values. These are, of course, exactly the results one would expect since the torque was "zero" at 3200 rpm and about equal to the one-half load value at 1600 rpm. The tests simply substantiate the expected outcome.

The reasons for the fluctuating air-fuel ratio (Figure 29) were discussed earlier. The same explanations apply to the remainder of these results as applied to the two earlier sets of tests.

Before running any more tests, for the purpose of presentation, a great deal of time was spent to develop skills in operating the engine on mixtures of gasoline and propane. To aid in conducting these mixture tests, some curves had to be developed. The first curve was one relating the injection time to the mass of gasoline injected per opening. The other curves showed how the injection time varied with speed at one-fourth and one-half load.

These curves were used in the following way. First, the torque and speed were selected and set. Next, Figure 26 was used to find the air-fuel ratio that the electronic control unit had maintained at this speed and torque combination during the second set of tests. This value and the injection time produced by the control unit at this speed and torque were then used in linear ratios to find the injection time necessary to maintain an air-fuel ratio of 14.5:1. The auxiliary fuel injection control unit was then set to produce this injection time. The tests at 100 per cent gasoline were then run.

The curve showing the mass of gasoline flow per injector opening as a function of opening time was not linear over the full range. Therefore, to

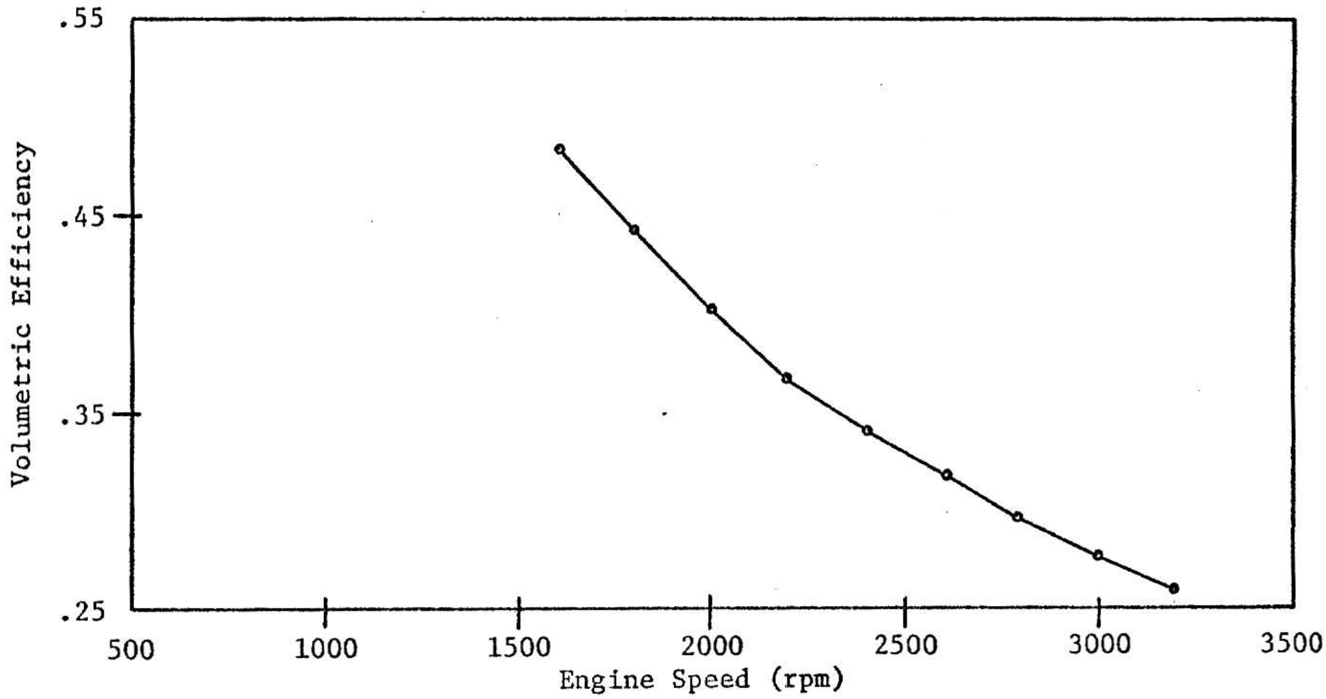

Figure 29. Volumetric Efficiency at Variable Load as a Function of Engine Speed with a Compression Ratio of 8.8:1

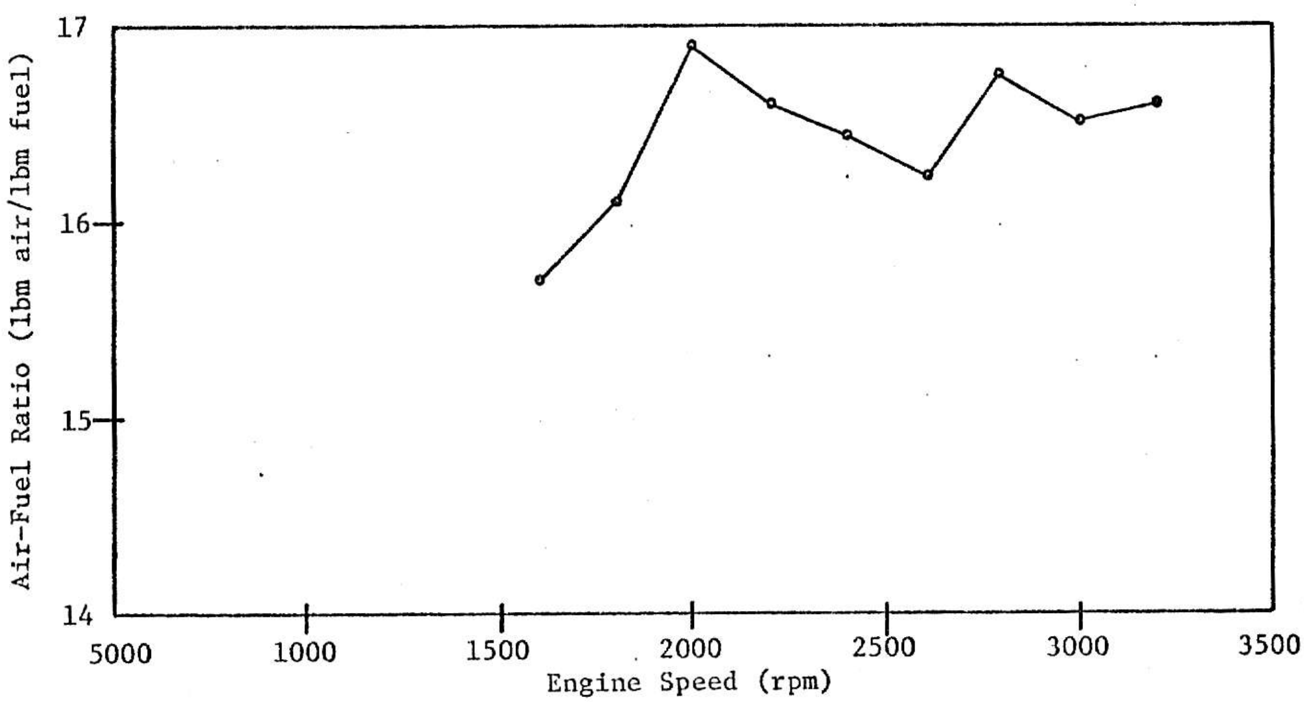

Figure 30. Air-Fuel Ratio at Variable Load as a Function of Engine Speed with a Compression Ratio of 8.8:1

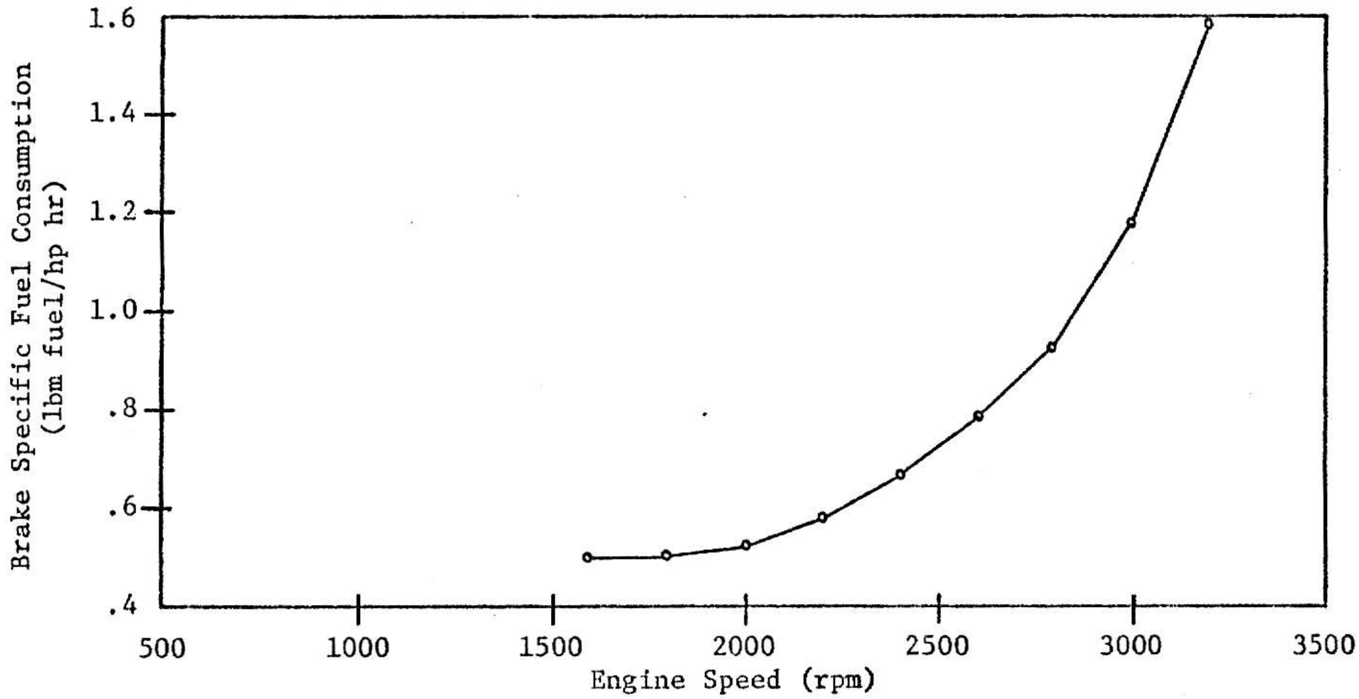

Figure 31. Brake Specific Fuel Consumption at Variable Load as a Function of Engine Speed with a Compression Ratio of 8.8:1

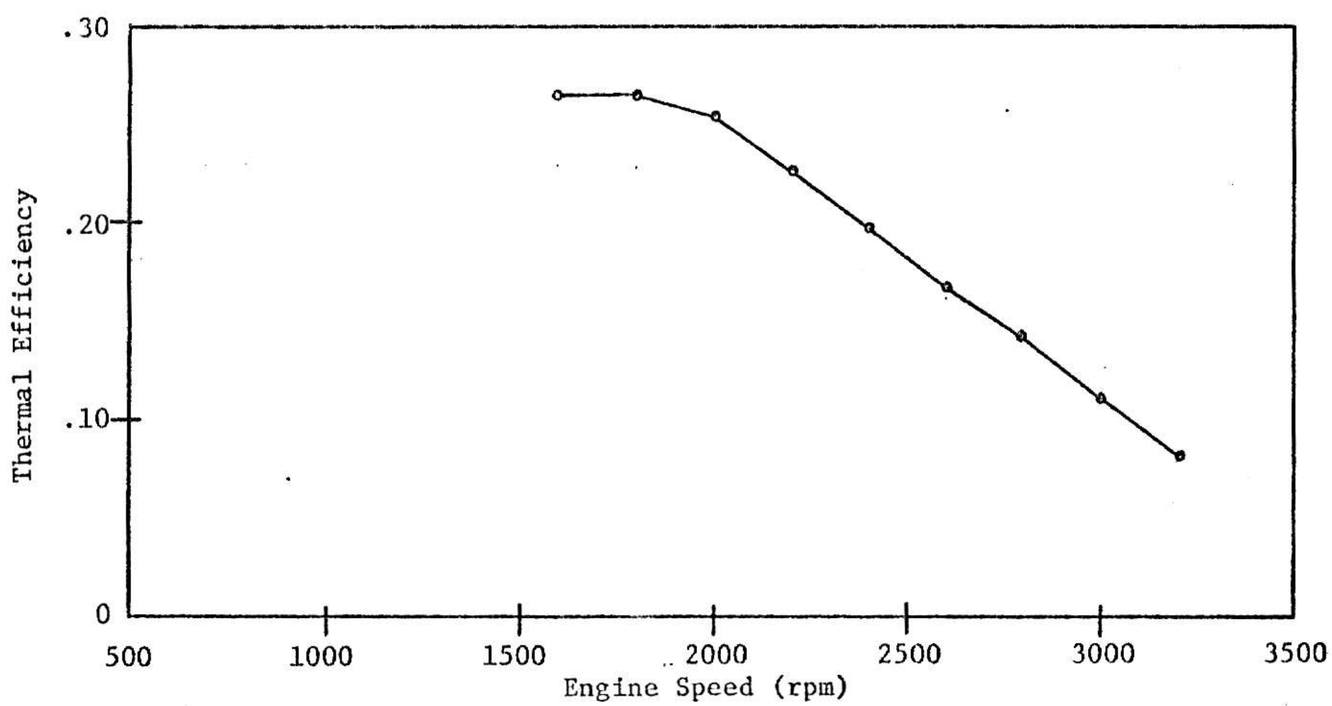

Figure 32. Thermal Efficiency at Variable Load as a Function of Engine Speed with a Compression Ratio of 8.8:1

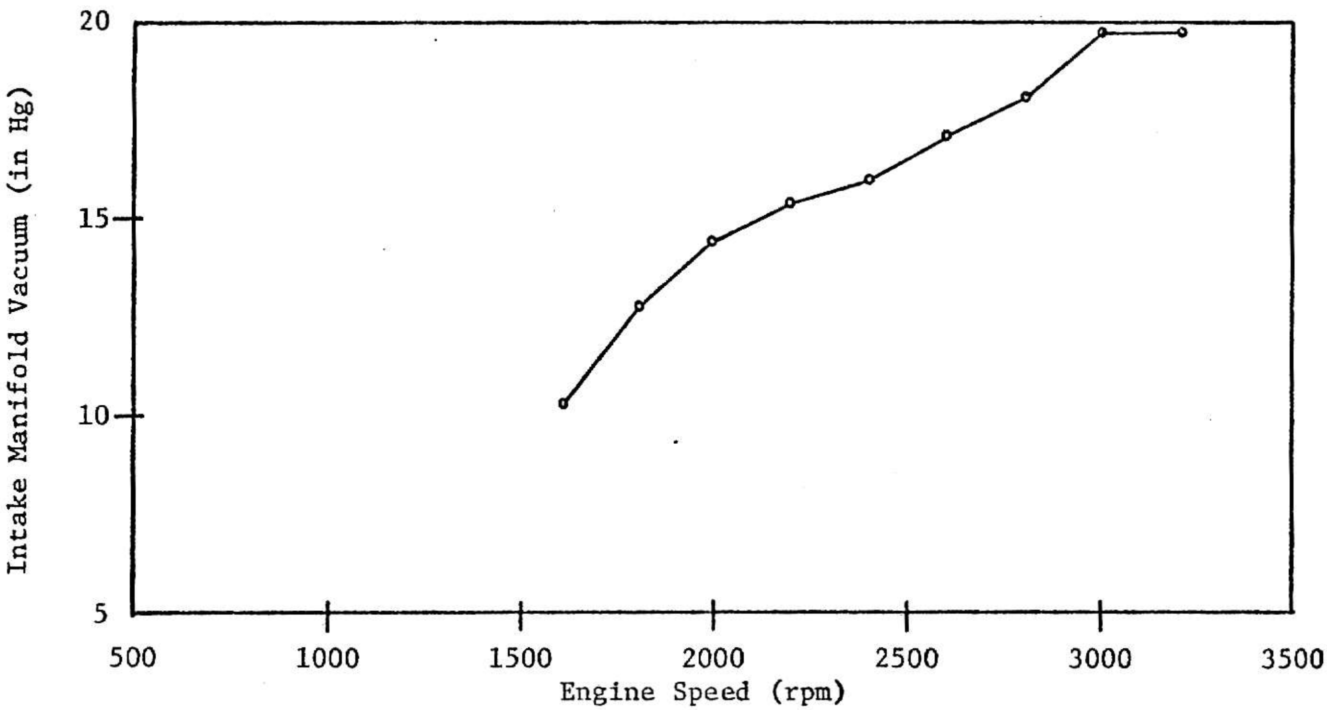

Figure 33. Intake Manifold Vacuum at Variable Load as a Function of Engine Speed with a Compression Ratio of 8.8:1

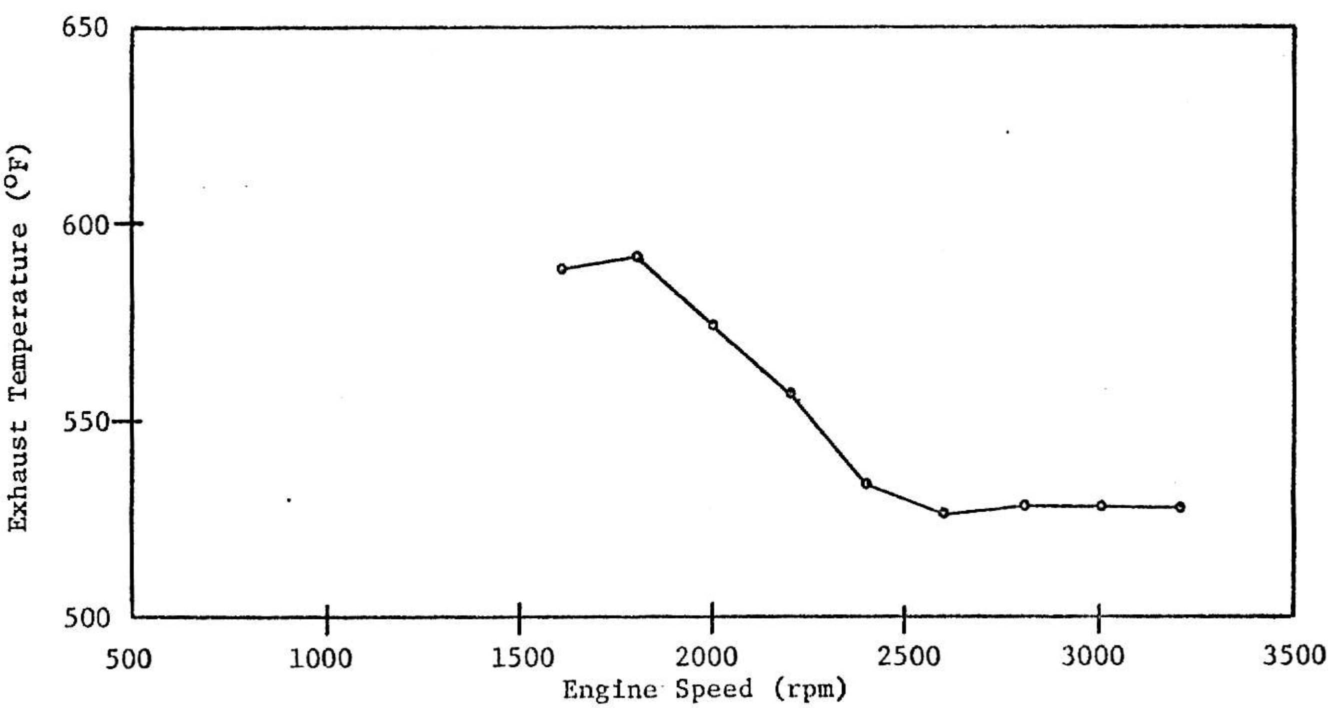

Figure 34. Exhaust Temperature at Variable Load as a Function of Engine Speed with a Compression Ratio of 8.8:1

find the injection time for burning mixtures, the 100 per cent mass flow rate was multiplied by the correct proportion to find the new mass flow rate. The corresponding injection time was then found from the curve. As the auxiliary fuel injection control unit was adjusted to give this new value for injection time, the propane flow was adjusted to give what was hoped to be an air-fuel ratio of 14.5:1.

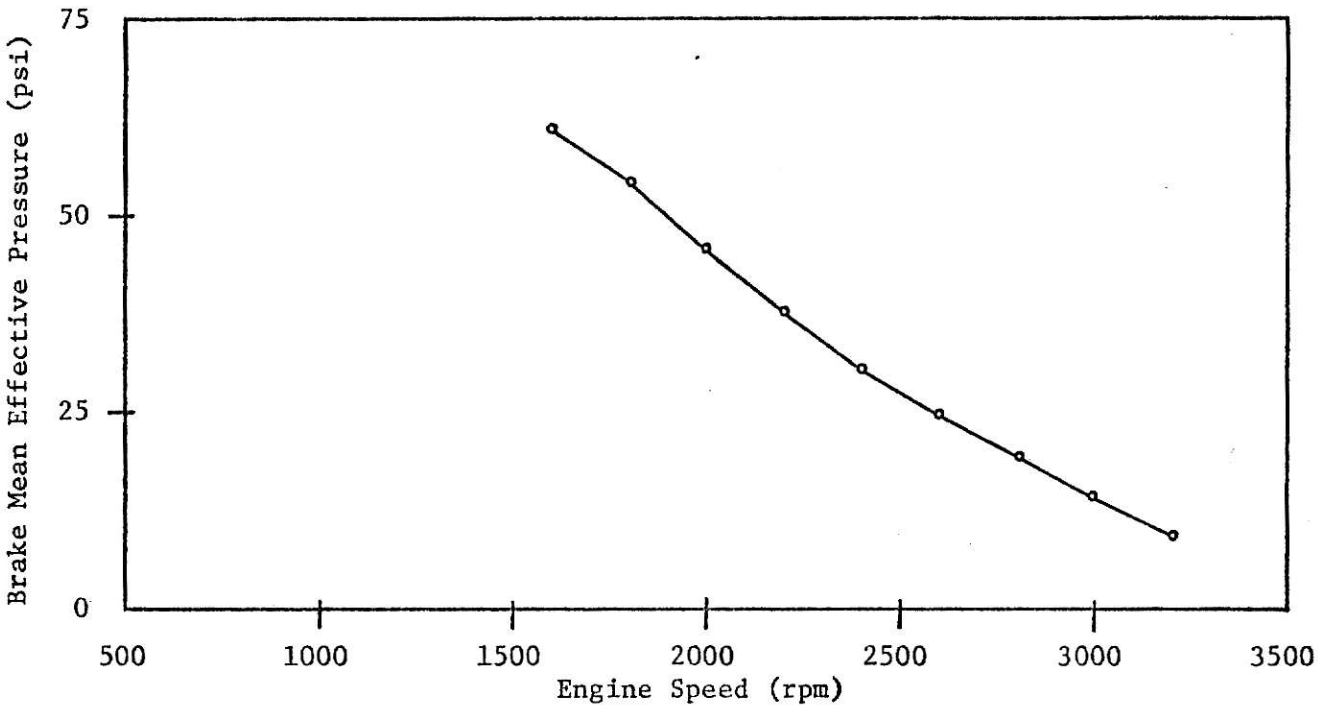

Figure 35. Brake Mean Effective Pressure at Variable Load as a Function of Engine Speed with a Compression Ratio of 8.8:1

When injection time and propane flow rate had been set as well as possible, the test was begun. After the test, some quick hand calculations were made to determine the consumption of gasoline and propane. If the proportions were not correct, the first test was discarded, adjustments in either the gasoline injection or propane flow were made and another test was run. This process continued until approximately correct usage rates for each fuel were found. The required three tests were then run.

As the testing progressed from 100 per cent gasoline to 20 per cent gasoline, the torque had to be continually decreased in order to maintain the engine speed. It was decided to run constant speed rather than constant torque tests in order to keep the changes in the propane flow rate as linear as possible. That is, the author wanted the change in propane flow rate to be the same when going from 40 to 20 per cent gasoline as in moving from 80 to 60 per cent gasoline.

Testing sequences four through seven were carried out on mixtures of fuels. The fourth and fifth sets differed only in the fact that number four was conducted at one-fourth load and number five was conducted at one-half load. These tests were run with an ignition timing of 0^{o}tdc and engine speed range of 1500 rpm to 3000 rpm in 500 rpm intervals. The per cent gasoline was also varied in 20 per cent steps from 100 to 20 per cent.

Testing group six was run at the conditions of 2000 rpm and began at a torque of 20.1 ft lb (2.79 kg m) for 100 per cent gasoline. The variables here were in ignition timing, per cent gasoline, and torque. The timing was adjusted in increments of 3^{o} from 0^{o}tdc to 15^{o}btdc. The range of gasoline percentages was again 100 per cent to 20 per cent in steps of 20 per cent. As noted earlier, the torque was regulated to maintain an engine speed of 2000 rpm.

The last set of tests were exactly like the sixth, except that the beginning torque was 40.2 ft lb (5.58 kg m) at 100 per cent gasoline.

The graphical representation of the results of test sets four and five is shown in Figures 36 through 48. These will be compared and contrasted with one another. However, before beginning the discussion of the results, it must be noted that the propane supply system would not allow enough vapor through to run the engine at 20 per cent gasoline, 2500 rpm and one-half load. This is

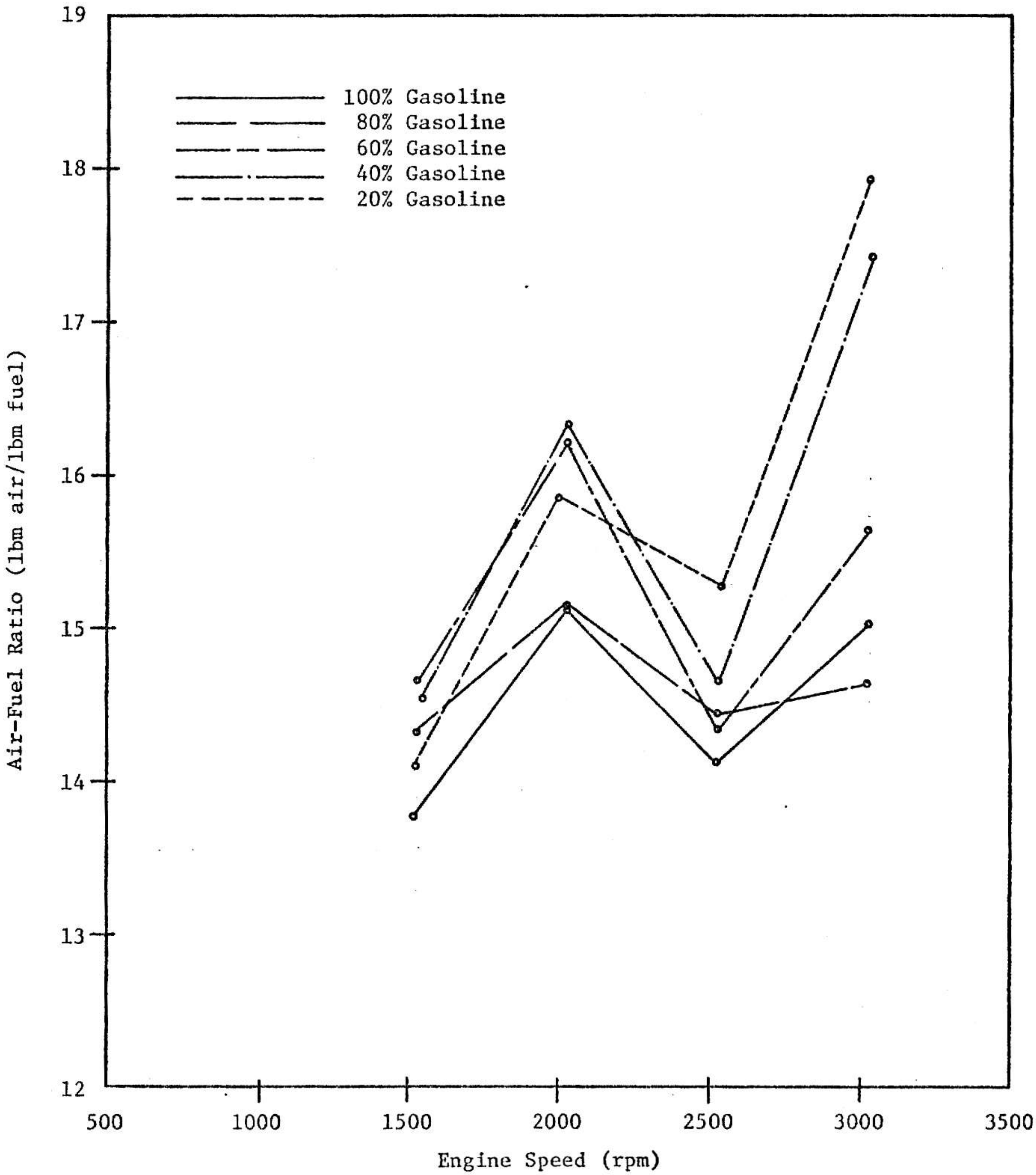

Figure 36. Air-Fuel Ratio at One-Fourth Load as a Function of Engine Speed and Per Cent Gasoline with a Compression Ratio of 8.8:1

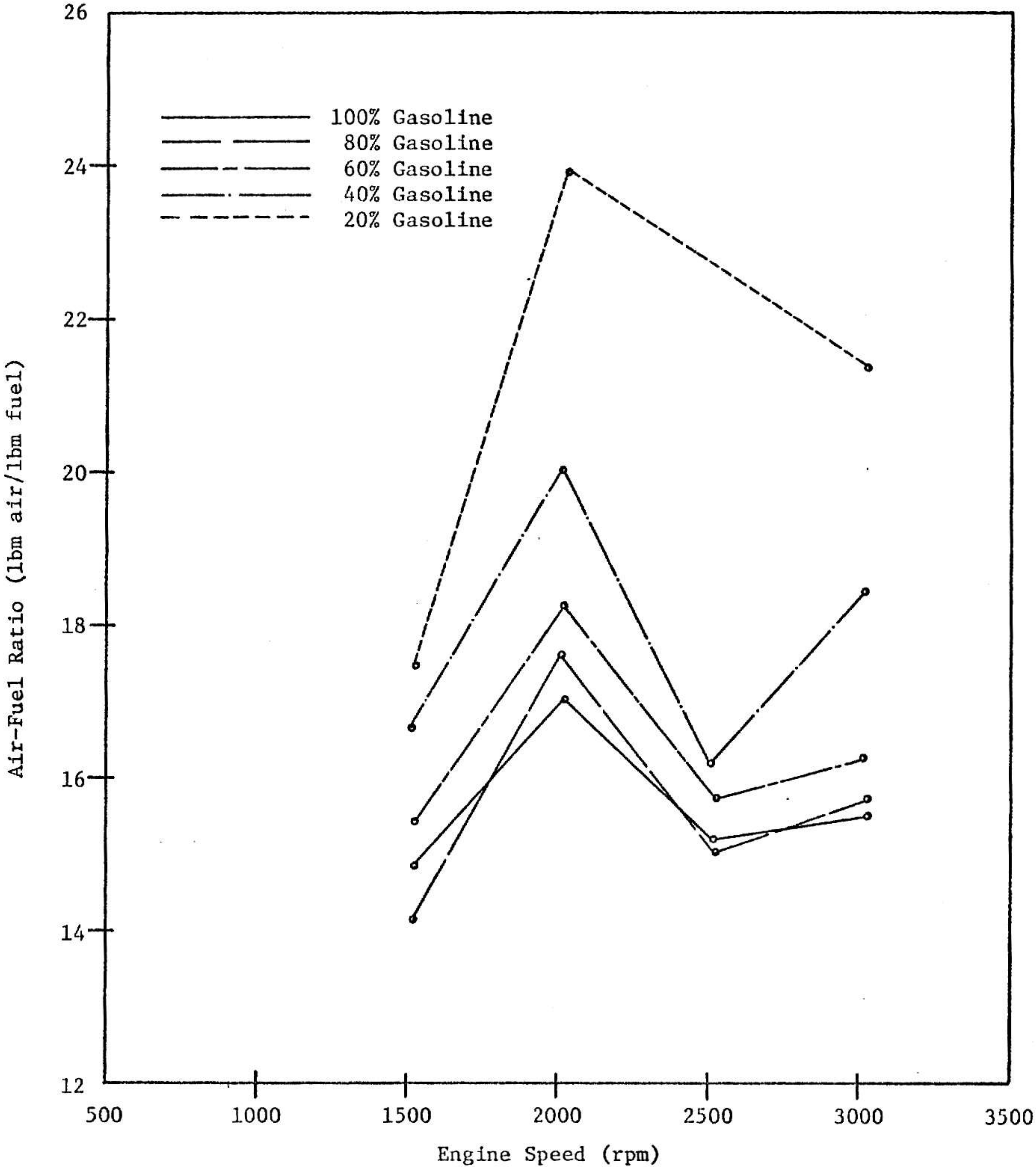

Figure 37. Air-Fuel Ratio at One-Half Load as a Function of Engine Speed and Per Cent Gasoline with a Compression Ratio of 8.8:1

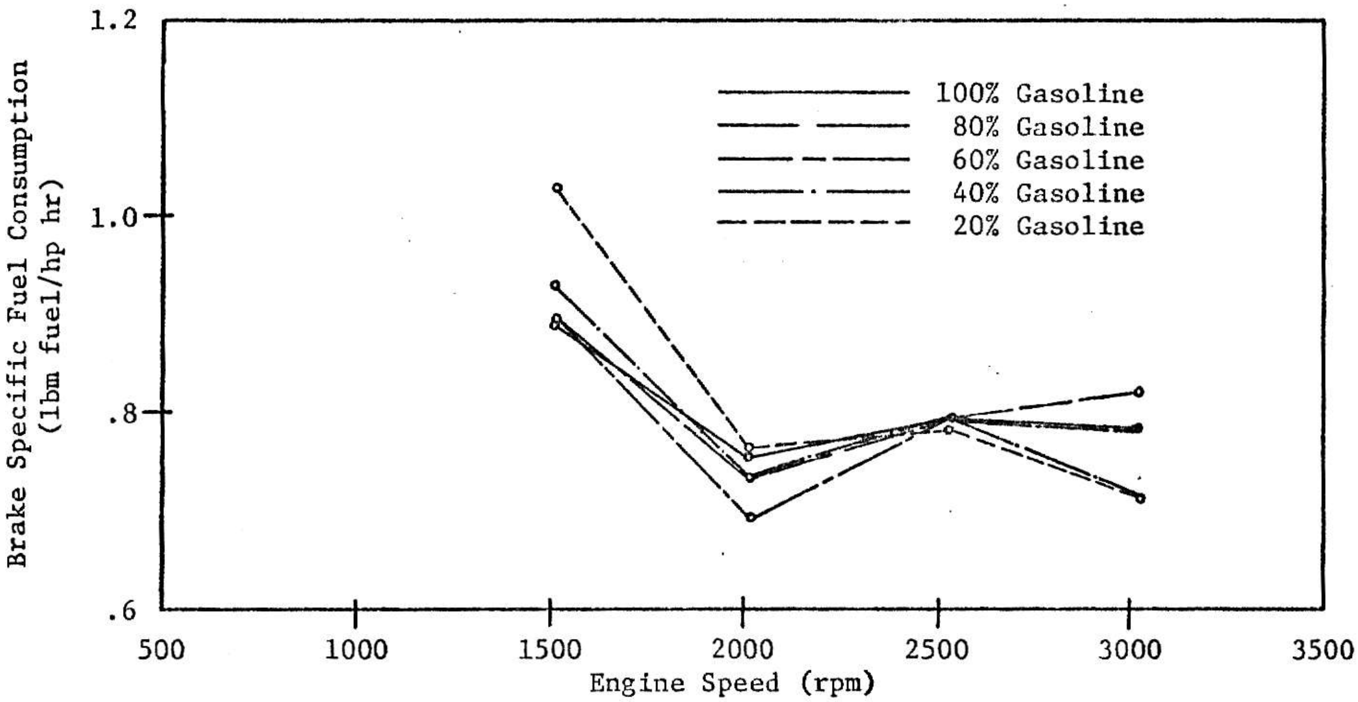

Figure 38. Brake Specific Fuel Consumption at One-Fourth Load as a Function of Engine Speed and Per Cent Gasoline with a Consumption Ratio of 8.8:1

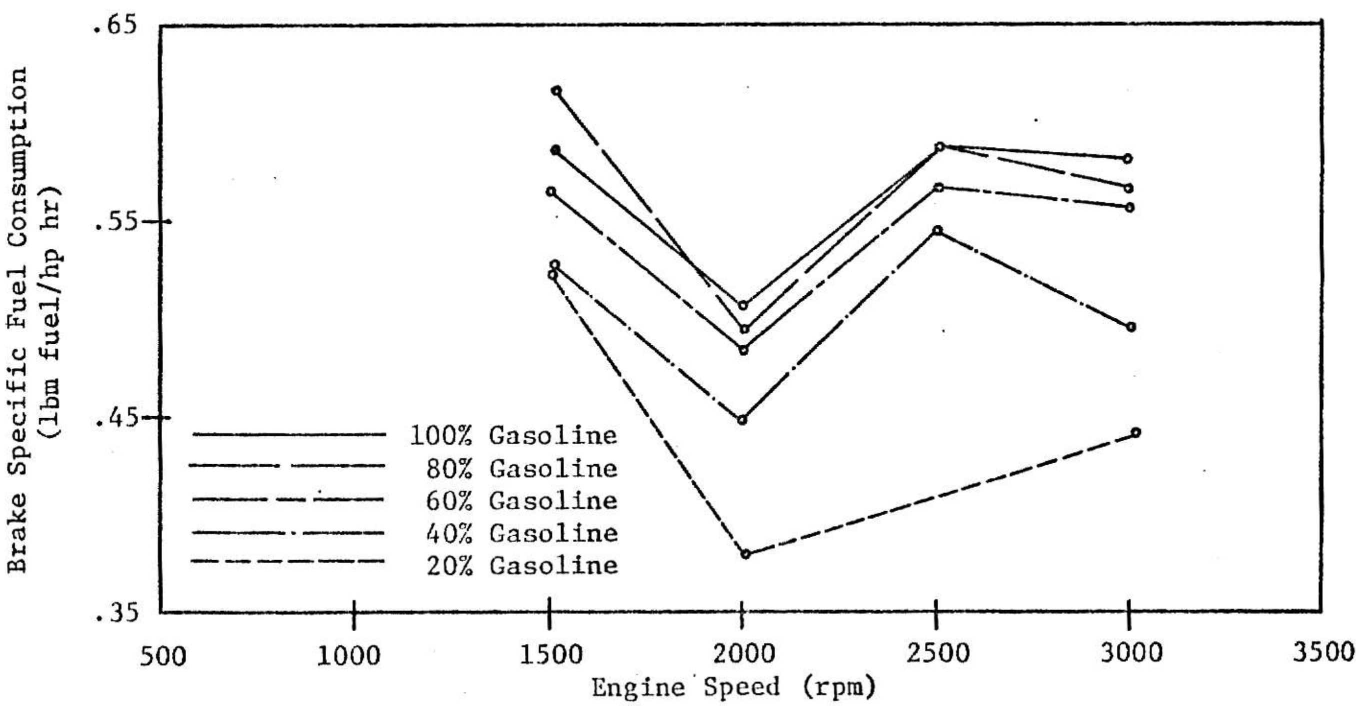

Figure 39. Brake Specific Fuel Consumption at One-Half Load as a Function of Engine Speed and Per Cent Gasoline with a Compression Ratio of 8.8:1

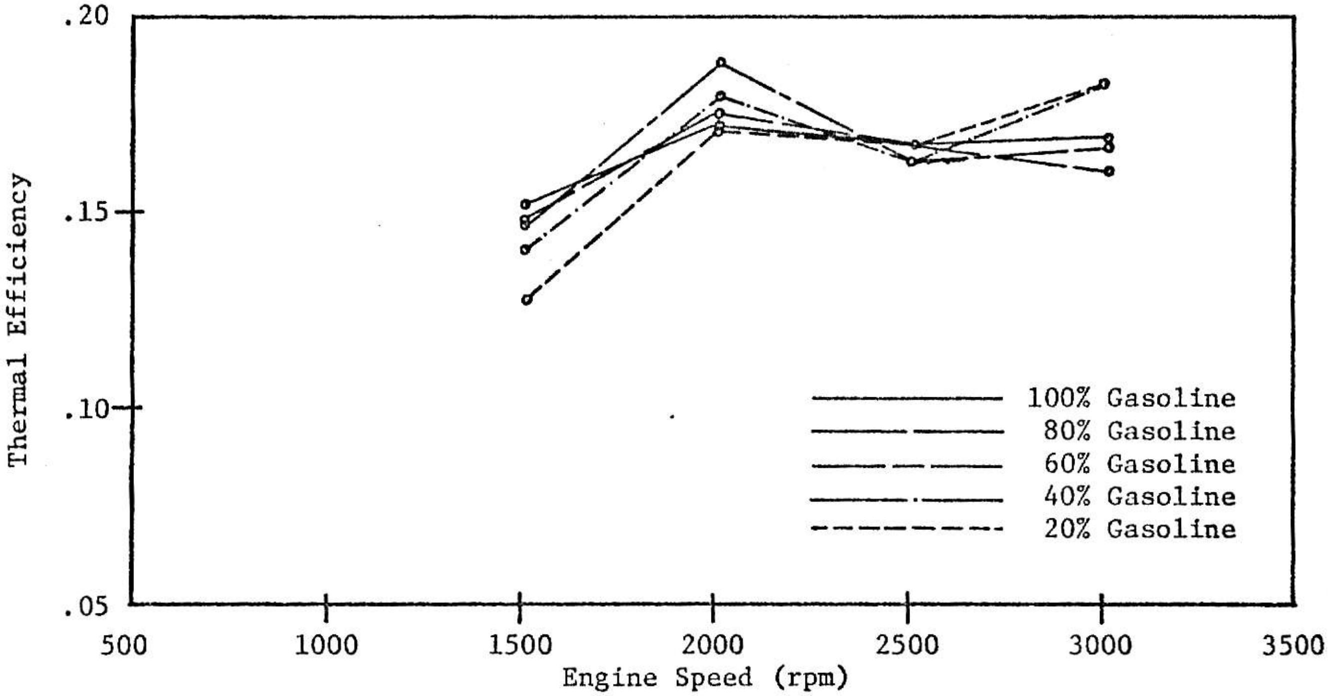

Figure 40. Thermal Efficiency at One-Fourth Load as a Function of Engine Speed and Per Cent Gasoline with a Compression Ratio of 8.8:1

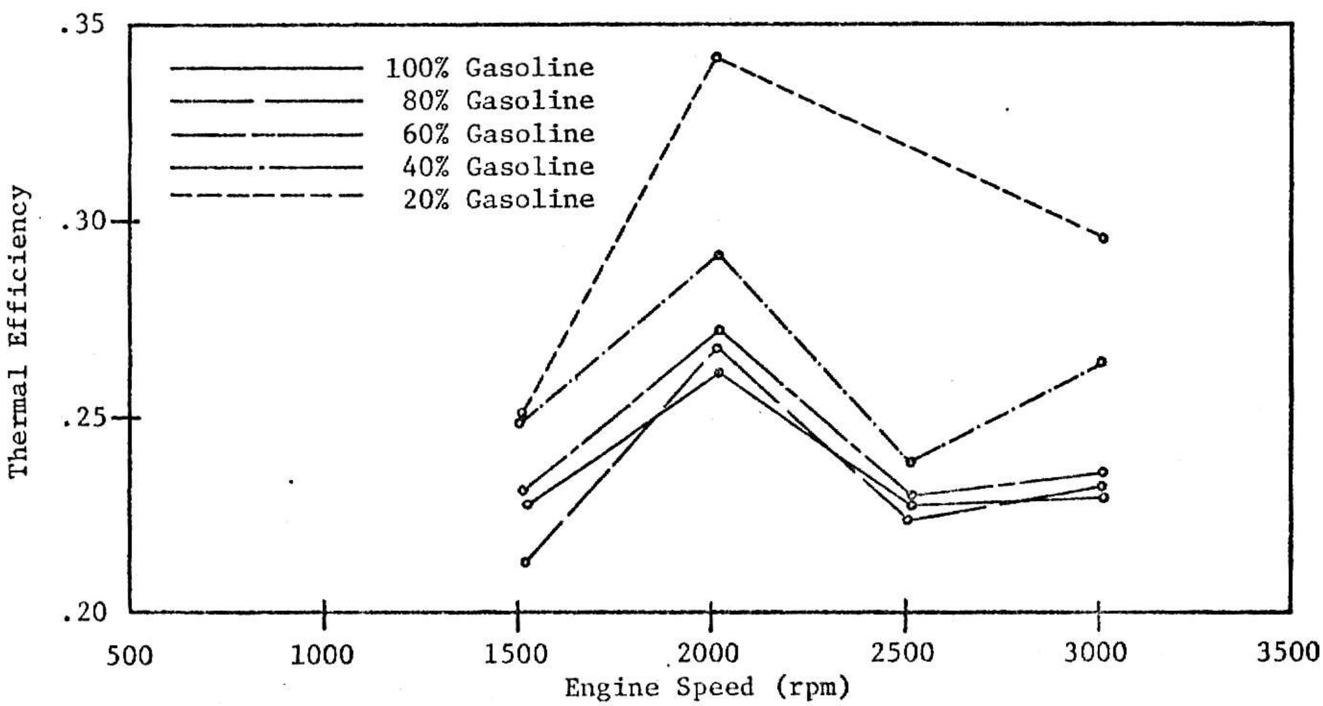

Figure 41. Thermal Efficiency at One-Half Load as a Function of Engine Speed and Per Cent Gasoline with a Compression Ratio of 8.8:1

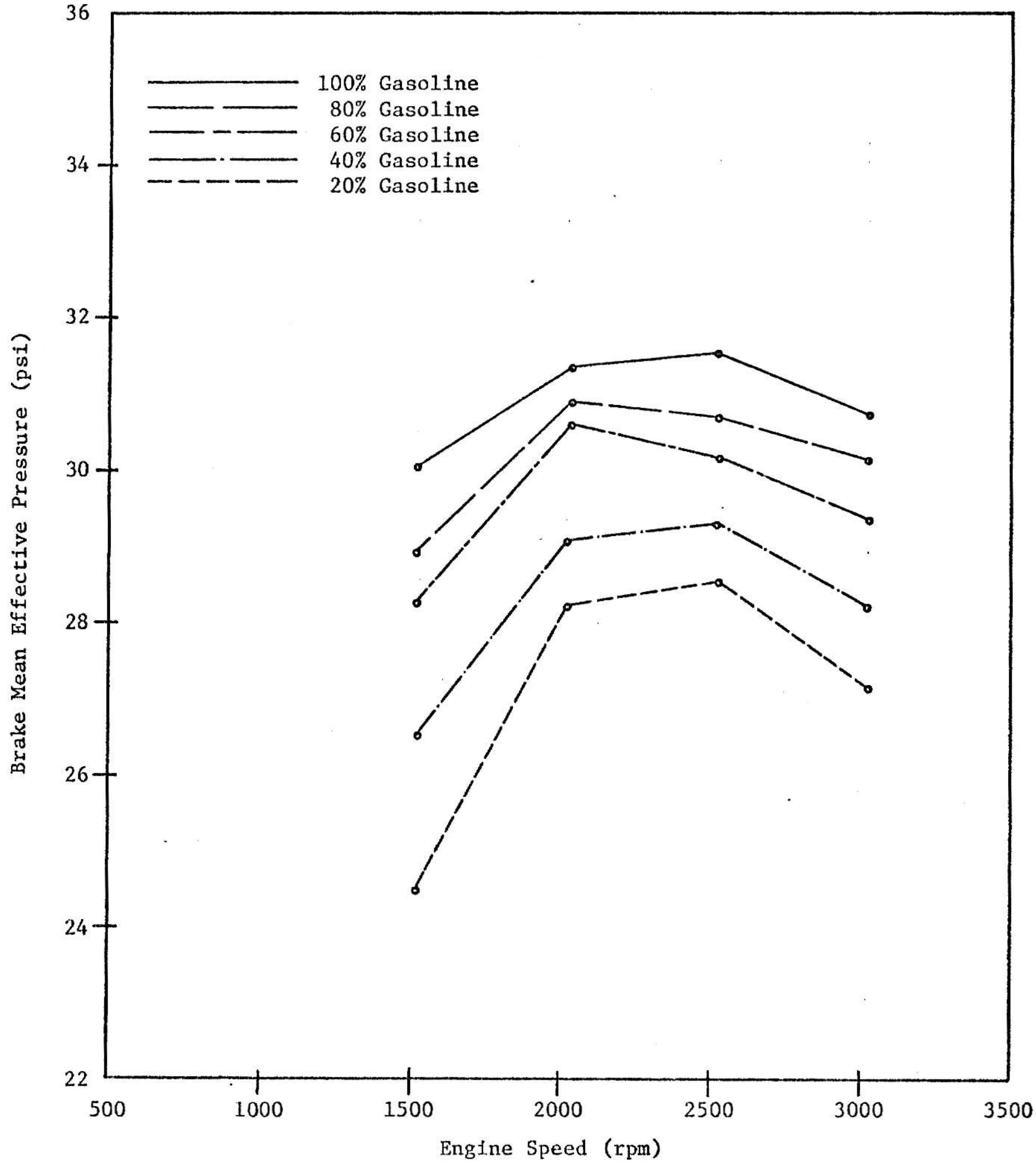

Figure 42. Brake Mean Effective Pressure at One-Fourth Load as a Function of Engine Speed and Per Cent Gasoline with a Compression Ratio of 8.8:1

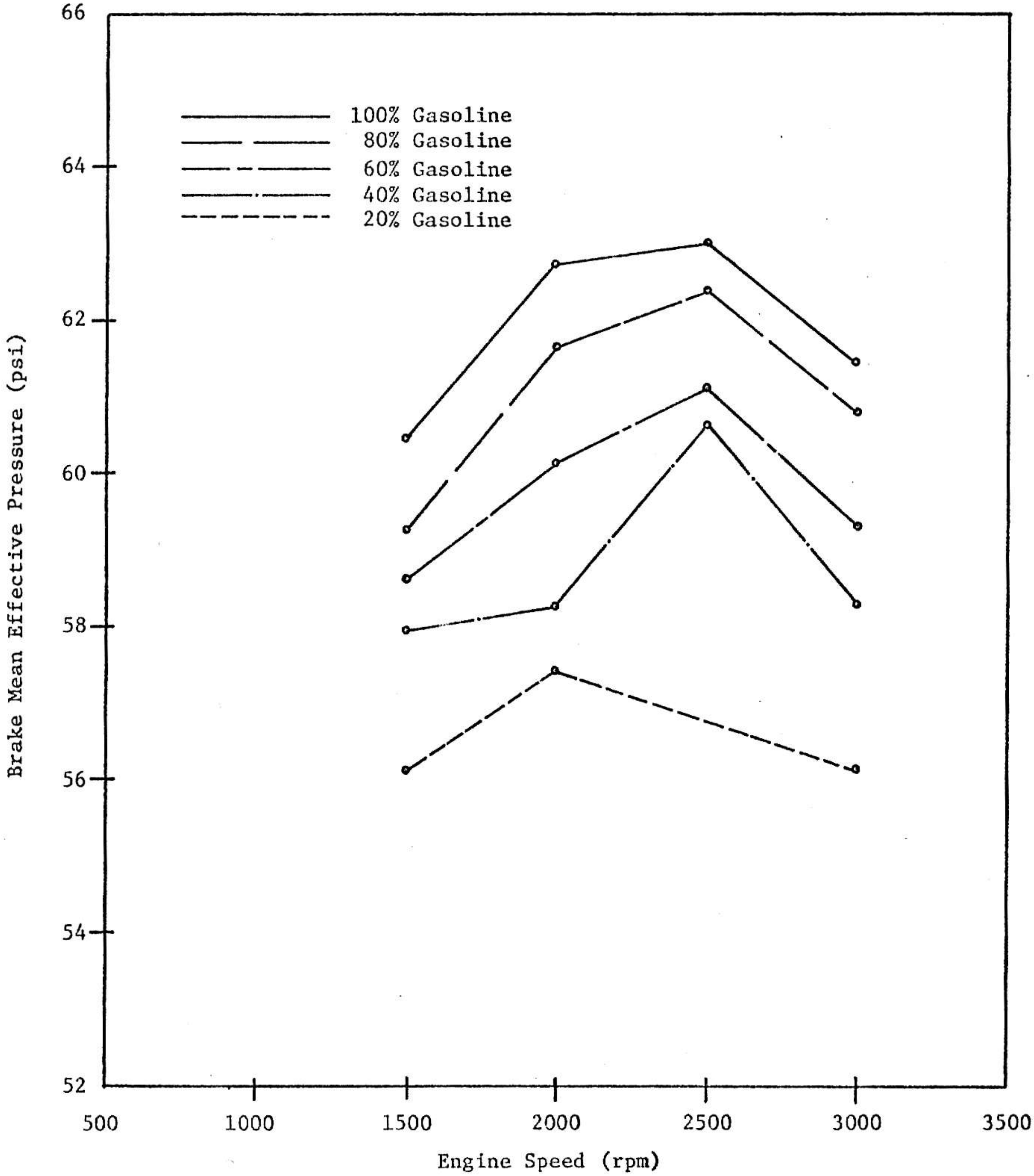

Figure 43. Brake Mean Effective Pressure at One-Half Load as a Function of Engine Speed and Per Cent Gasoline with a Compression Ratio of 8.8:1

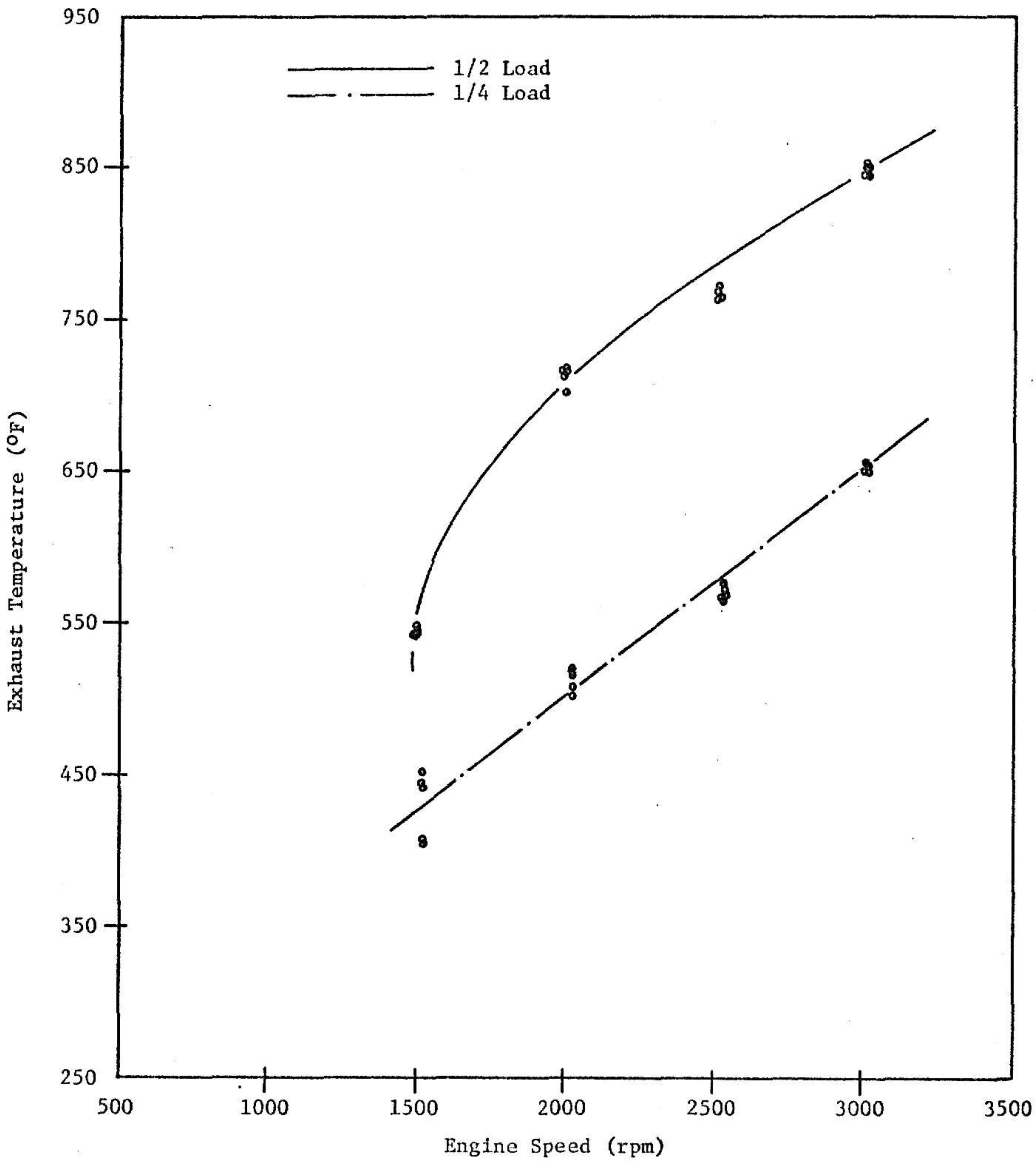

Figure 44. Exhaust Temperature at One-Fourth and One-Half Load as a Function of Engine Speed and Per Cent Gasoline with a Compression Ratio of 8.8:1

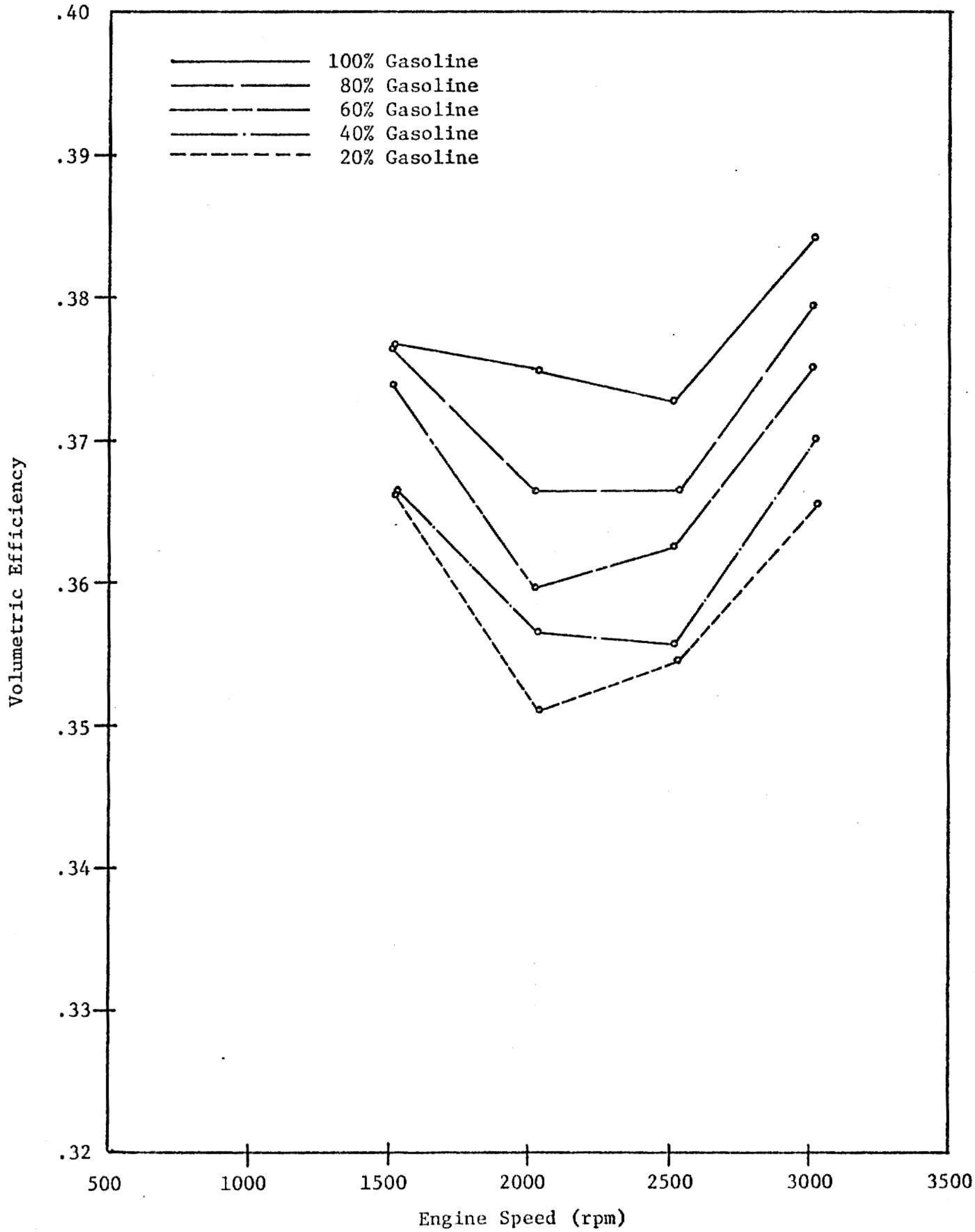

Figure 45. Volumetric Efficiency at One-Fourth Load as a Function of Engine Speed and Per Cent Gasoline with a Compression Ratio of 8.8:1

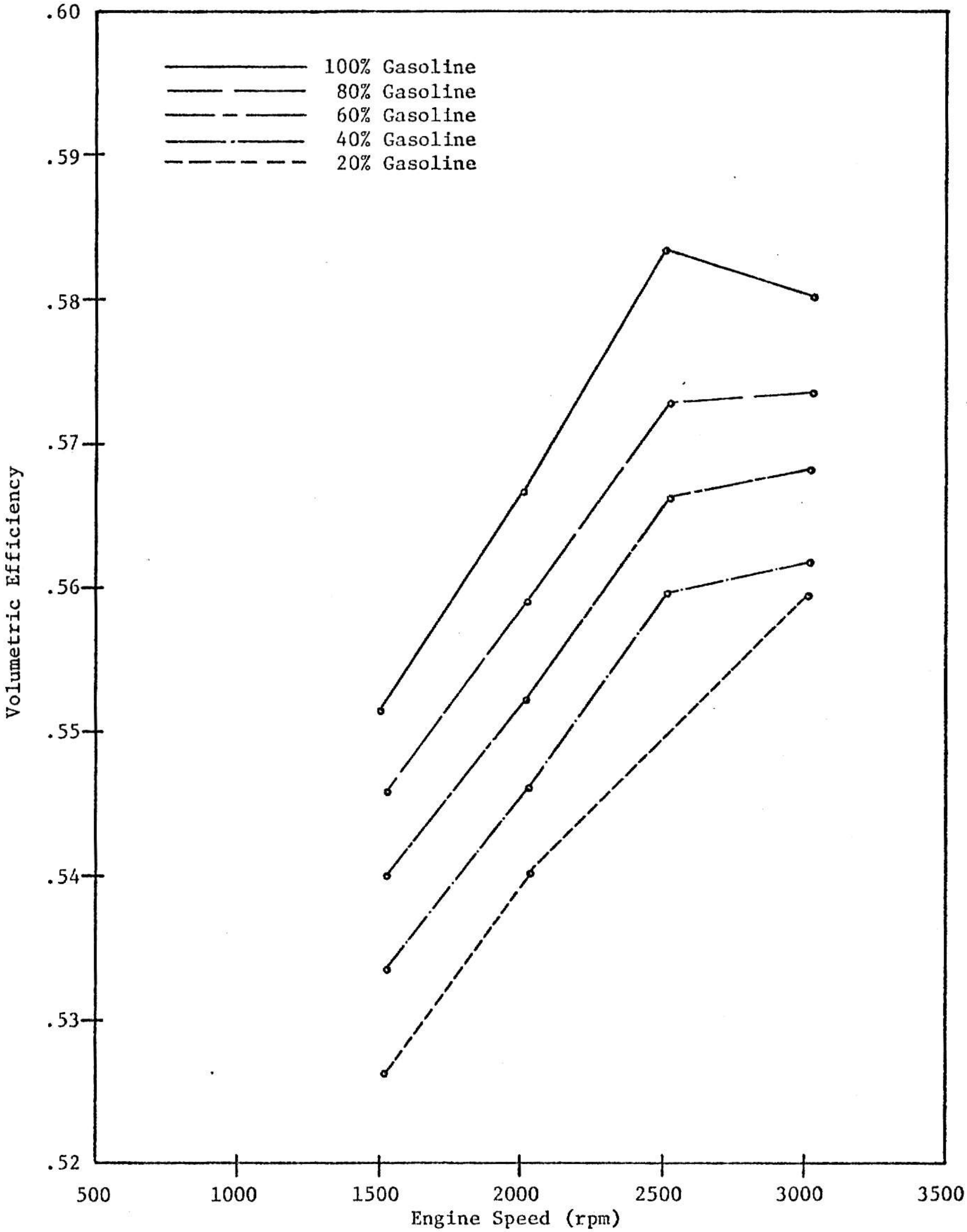

Figure 46. Volumetric Efficiency at One-Half Load as a Function of Engine Speed and Per Cent Gasoline with a Compression Ratio of 8.8:1

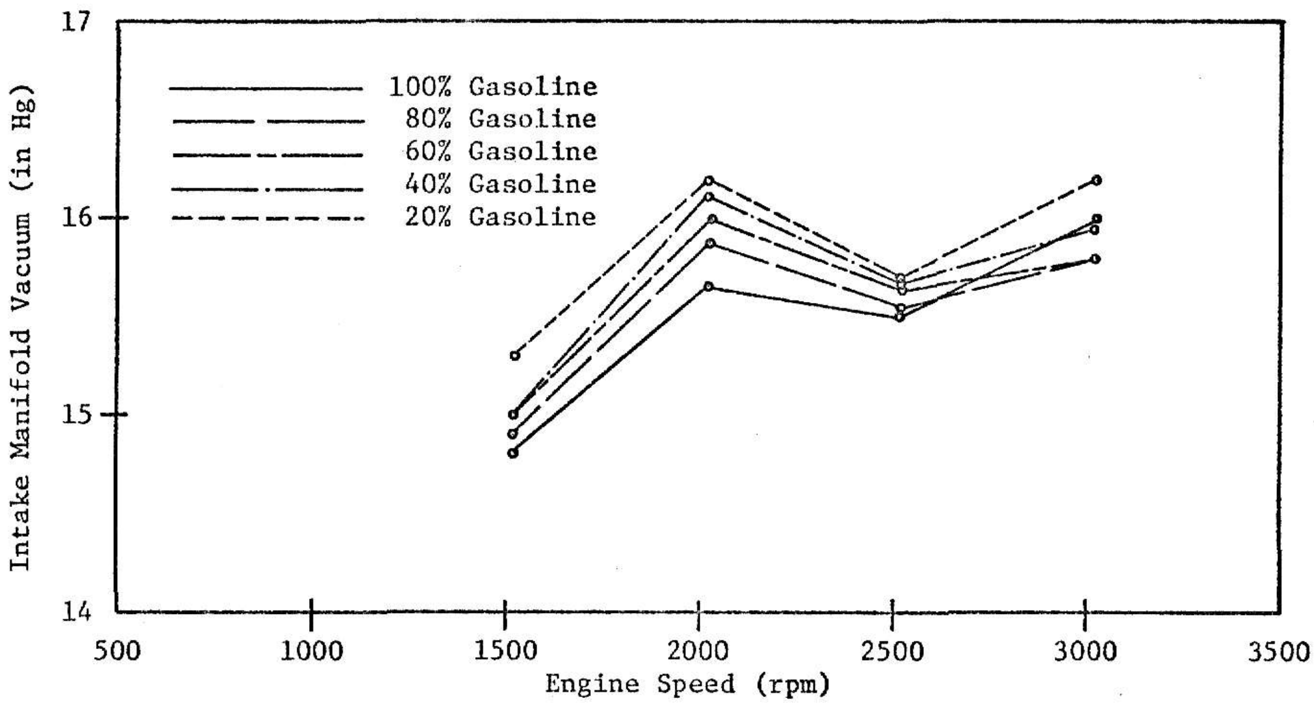

Figure 47. Intake Manifold Vacuum at One-Fourth Load as a Function of Engine Speed and Per Cent Gasoline with a Compression Ratio of 8.8:1

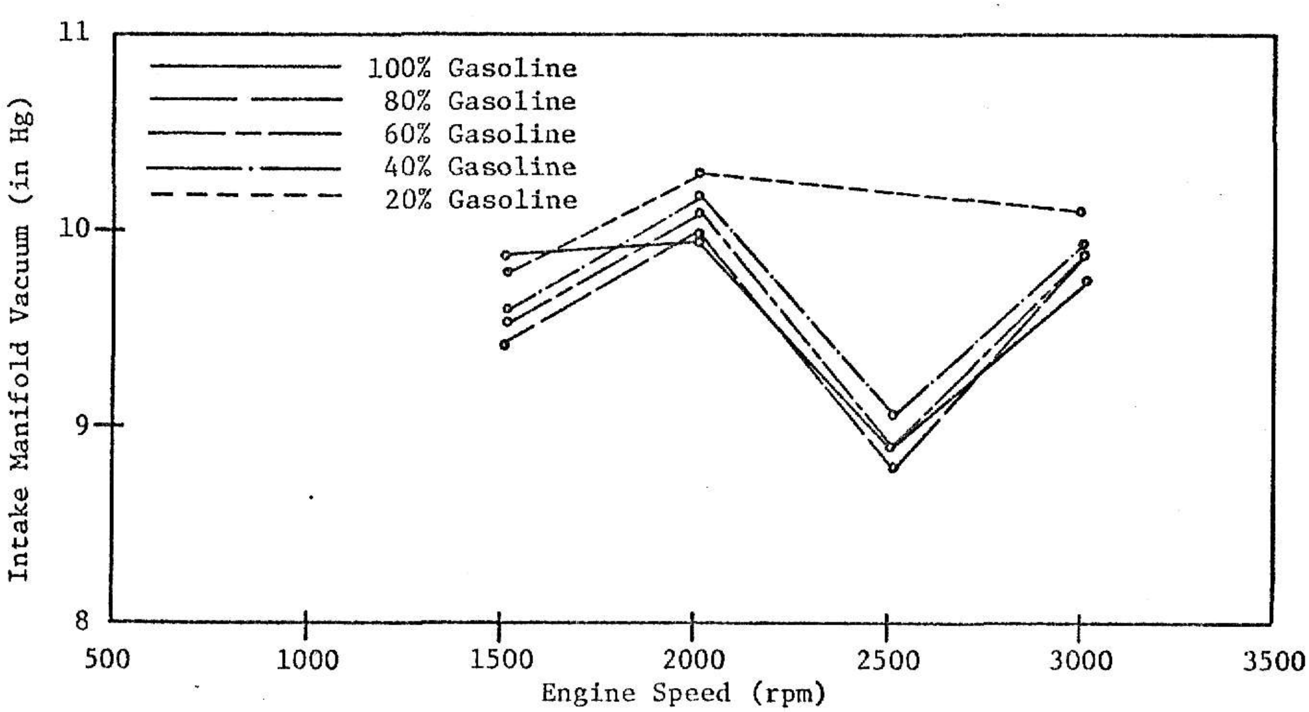

Figure 48. Intake Manifold Vacuum at One-Half Load as a Function of Engine Speed and Per Cent Gasoline with a Compression Ratio of 8.8:1

the reason that there are only three points rather than four along the one-half load curve.

Figure 36 shows the relationship between the air-fuel ratio and engine speed as the per cent gasoline varied at one-fourth load. The peculiar shape of these curves and those of the air-fuel ratio at one-half load (Figure 37) arises from the method used to find the proper injection time to maintain a fixed air-fuel ratio. Rather than assume a constant value for the injection time, the oscillating curve relating the injection time to engine speed as determined by the electronic control unit was used. Following this curve for injection time led directly to the oscillations in the air-fuel ratio as the speed varied. The rather wide range of values for the air-fuel ratio of any particular speed resulted from poor control of the propane flow.

The curves for brake specific fuel consumption (Figures 38 and 39) and thermal efficiency (Figures 40 and 41) fluctuate in opposite directions but yet it is obvious that both are related to the changes in the air-fuel ratio. As the air-fuel ratio raises, the thermal efficiency also increases and the brake specific fuel consumption falls off. The opposite case also holds true.

This can be explained by first pointing out that the horsepower was a continuously increasing function with respect to speed in the range of 1500 rpm to 3000 rpm. Therefore, as the fuel flow was reduced, as in the speed ranges of 1500 rpm to 2000 rpm and 2500 rpm to 3000 rpm, the thermal efficiency had to raise and the brake specific fuel consumption was forced to drop.

The curves for brake mean effective pressure (Figures 42 and 43) naturally follow the curves relating the torque to engine speed at one-fourth and one-half load values (Figures 11 and 12). This is because the only variable in the equation for brake mean effective pressure is torque.

Inspection of Figure 44 shows that the exhaust temperature increased with engine speed. The two probable causes of this were discussed earlier.

The fluctuations in the intake manifold vacuum (Figures 45 and 46) can be explained with the use of the air-fuel ratio (Figures 36 and 37) and thermal efficiency (Figures 40 and 41) curves. It has already been shown that thermal efficiency increased with air-fuel ratio, meaning that a greater speed was obtainable with a given fixed throttle opening. As the air-fuel ratio was leaned and the speed was increased, the manifold vacuum rose. This is not to suggest that the engine speed could be increased a full 500 rpm by leaning the combustion mixture, but the increase in speed surely was not totally accomplished by opening the throttle. The opposite case holds true for the speed range where the fuel mixture was richened.

The explanations of the changes of the volumetric efficiency curves with engine speed (Figures 45 and 46) are a bit more subtle and some speculation is necessary. The drop in the volumetric efficiency at one-fourth load (Figure 45) between the engine speeds of 1500 rpm and 2000 rpm may have been caused totally by the increase in thermal efficiency (Figure 40) associated with this speed range. If the increase in thermal efficiency was sufficient to raise the engine speed nearly the full 500 rpm and the throttle therefore only had to be opened slightly more to allow the engine to run at 2000 rpm, then the increased speed may not have induced an equally large increase in the air flow. The volumetric efficiency in the next 500 rpm interval appears to remain relatively constant indicating that because the thermal efficiency was reduced, the throttle was opened more in order to realize the desired increase in engine speed. The trend was further advanced in the highest speed range to the point that throttle position was the primary factor in setting engine speed.

Referring now to Figure 46, it is obvious that the trend in the volumetric efficiency was quite different at one-half load than at one-fourth load. The volumetric efficiency increased with speed and therefore throttle opening with the exception of one point.

The reason for this trend as opposed to the pattern noticed at one-fourth load was the large amount that the throttle had to be opened in order to speed up the engine at one-half load.

The change in the parameters with increased propane flow was generally the result of poor control of the propane flow. This was brought up earlier during the discussion of the air-fuel ratio. It has been shown that the thermal efficiency follows the air-fuel ratio and comparison of Figures 36 and 37 and Figures 40 and 41 emphasizes the point that the same characteristics existed at any mixture of gasoline and propane. The same holds true for the brake specific fuel consumption as is shown in Figures 38 and 39. The manifold vacuum (Figures 47 and 48) increased with propane content because a denser mixture was being drawn past the throttle opening. The torque and therefore the brake mean effective pressure (Figures 42 and 43) fell off with increased propane flow. Since the propane displaces air, the volumetric efficiency (Figures 45 and 46) declined with rising propane percentage. Figure 44 does not show that the exhaust temperature varied significantly with changes in the fuel composition because of the scale employed. Looking at the results as calculated by the computer shows slight decreases in exhaust temperature as the per cent gasoline dropped off. The explanation for this is that the intake manifold vacuum increased with the per cent gasoline. Earlier discussions showed the relationship between intake manifold vacuum and exhaust temperature. The same arguments apply in this case.

Now then, a discussion of test sets six and seven will be carried out with the emphasis on changes due to ignition timing alterations and per cent gasoline adjustments. The results of these tests are presented together in Figures 49 through 62. Again, it must be pointed out that the propane system would not allow sufficient flow to run the engine at 20 per cent gasoline and one-half load.

The curves for the air-fuel ratio are shown in Figures 49 and 50. At first glance it is obvious that the curves for one-fourth load did not follow regular patterns. On the other hand it appears that the one-half load ratios increased with ignition timing. In both cases, the air-fuel ratio followed quite closely the curves for volumetric efficiency shown in Figures 51 and 52. This trend of following the volumetric efficiency can be explained by recalling the testing procedure. First a timing was set and then the whole gaumet of gasoline percentages was tested. The timing was then readjusted and so on until all six specified timings had been tested. In these tests, the injection time and propane flow were manually controlled and were set identically from one ignition timing to another for similar gasoline proportions. That is to say, for example, that the injection time and propane flow were the same for all tests at 40 per cent gasoline and one-fourth load regardless of ignition timing. Similarly for every other gasoline percentage. Because of this procedure, the fuel deposited in the engine remained constant from one timing to the next, so if the volumetric efficiency, and thereby the mass of air taken into the engine, decreased, the air-fuel ratio also decreased. The opposite was naturally true for increasing the volumetric efficiency. It must be pointed out, though, that the randomness and evident lack of pattern in these curves negates the possibility of concrete arguments concerning the effect of ignition timing upon air-fuel ratio. This statement is also applicable to the

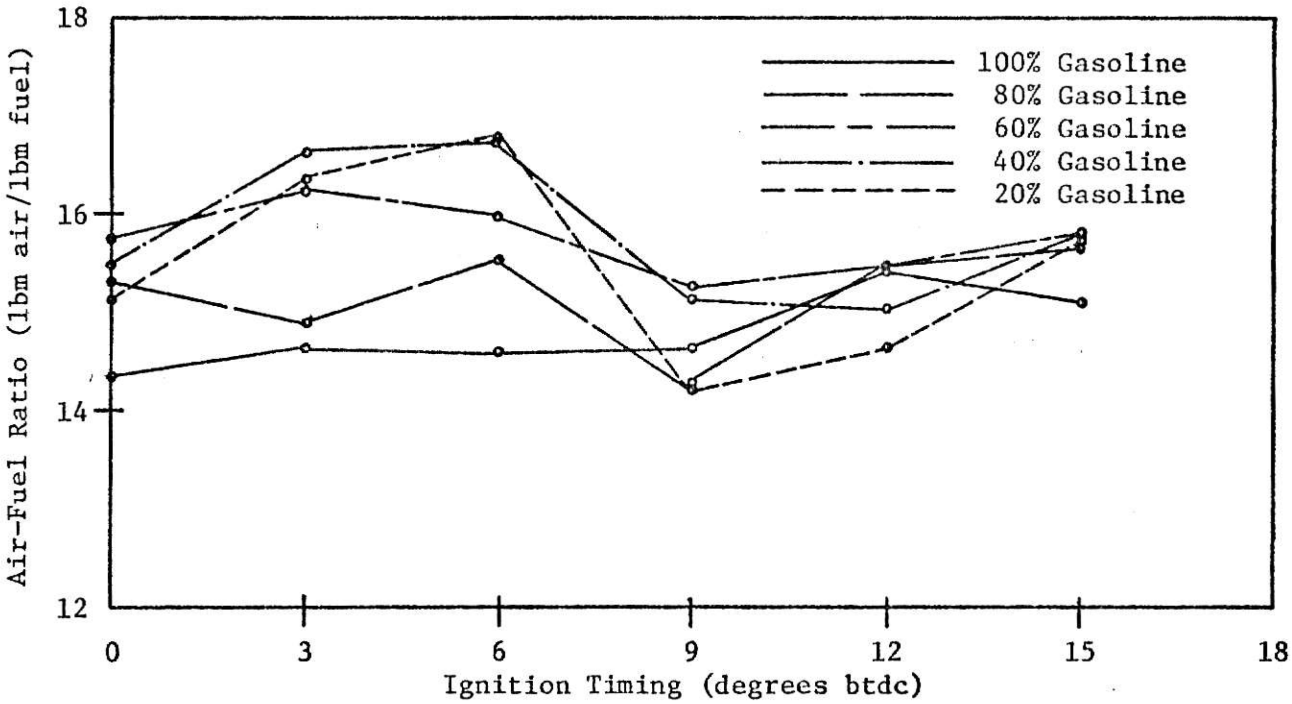

Figure 49. Air-Fuel Ratio at One-Fourth Load as a Function of Ignition Timing and Per Cent Gasoline with a Compression Ratio of 8.8:1

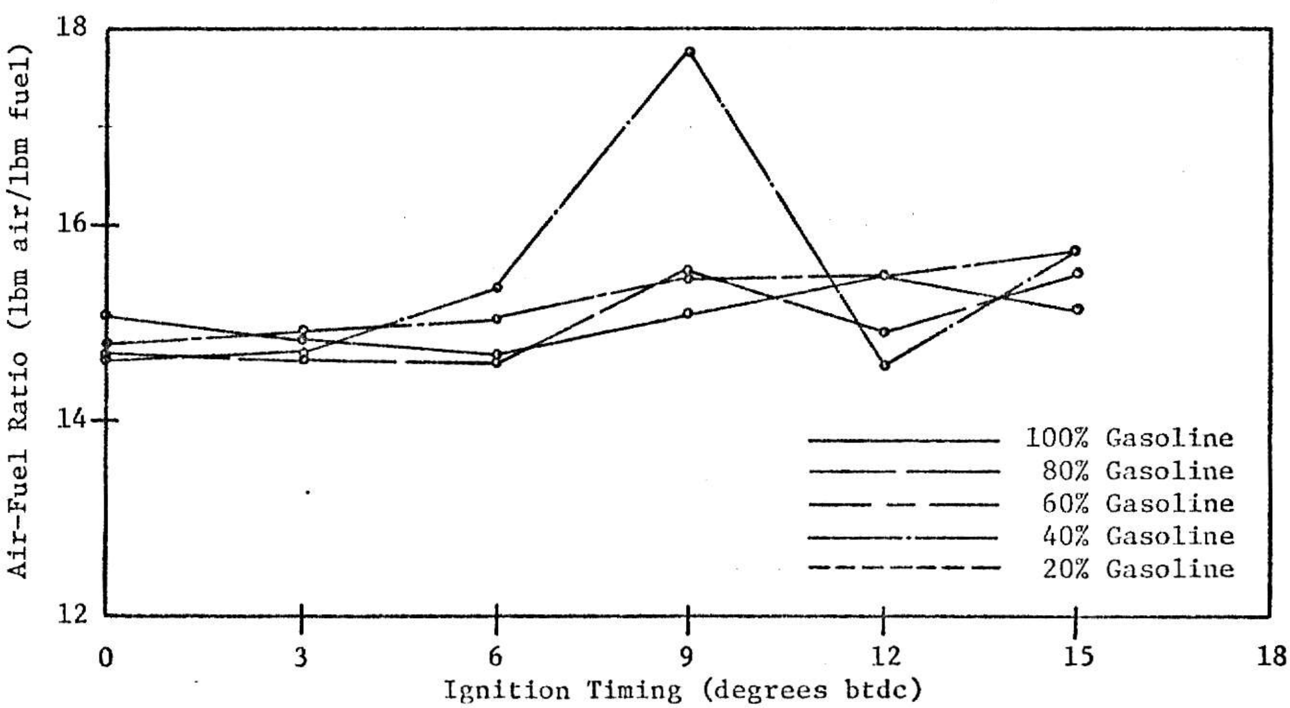

Figure 50. Air-Fuel Ratio at One-Half Load as a Function of Ignition Timing and Per Cent Gasoline with a Compression Ratio of 8.8:1

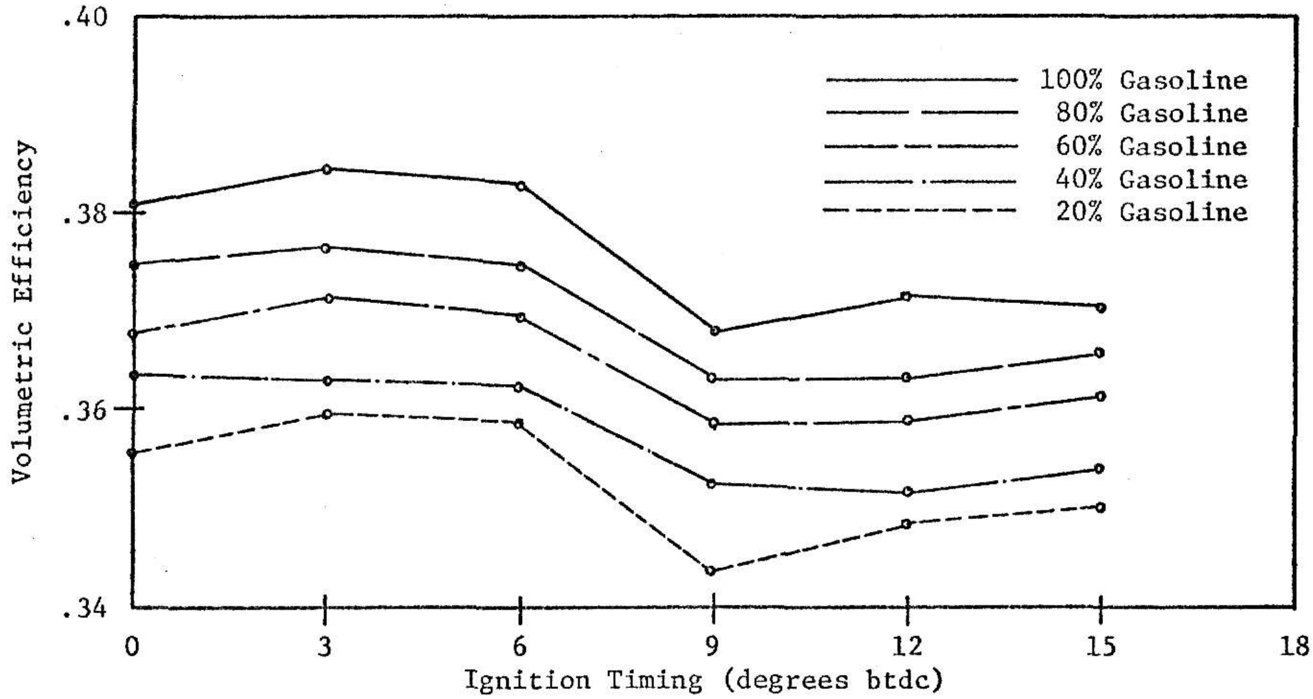

Figure 51. Volumetric Efficiency at One-Fourth Load as a Function of Ignition Timing and Per Cent Gasoline with a Compression Ratio of 8.8:1

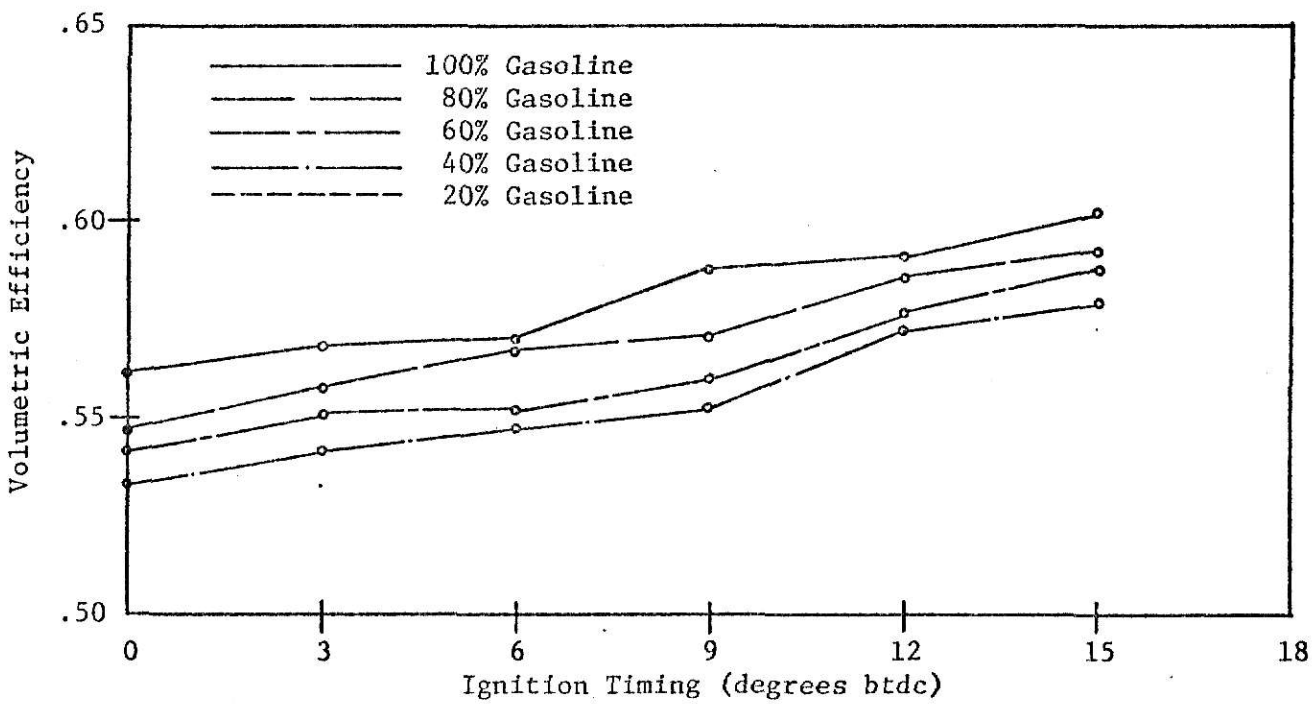

Figure 52. Volumetric Efficiency at One-Half Load as a Function of Ignition Timing and Per Cent Gasoline with a Compression Ratio of 8.8:1

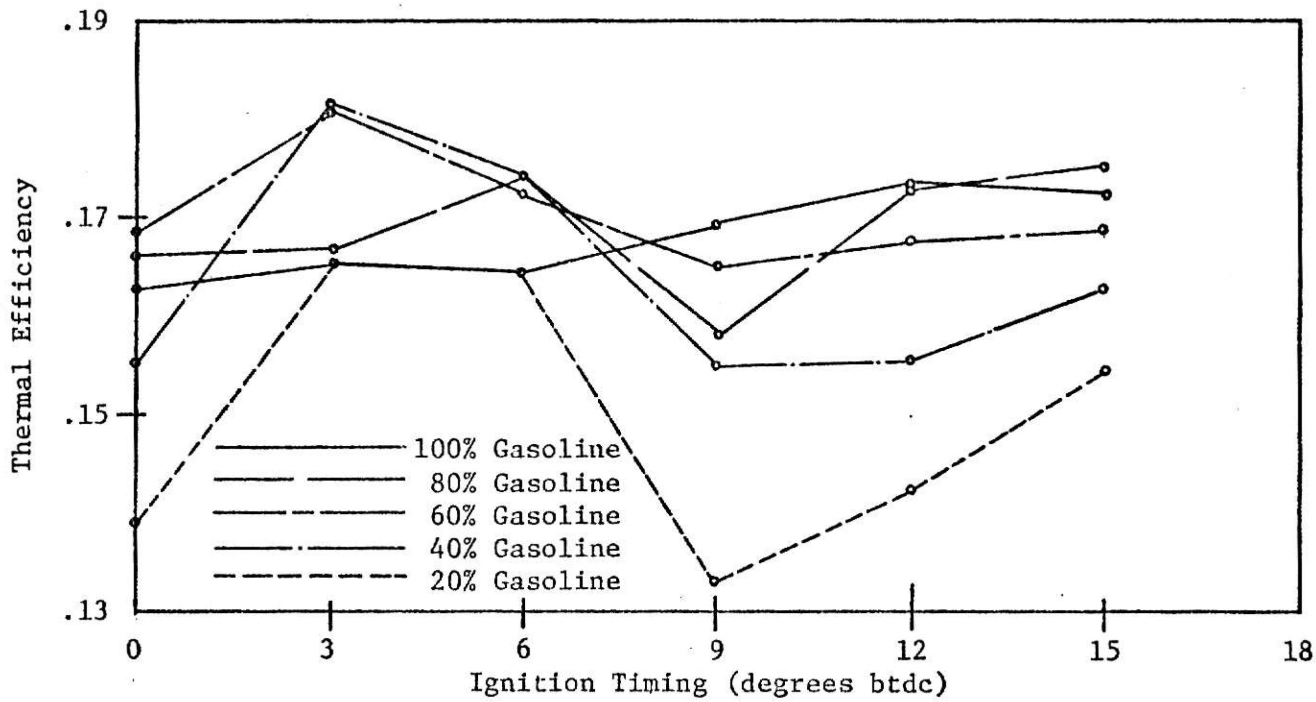

Figure 53. Thermal Efficiency at One-Fourth Load as a Function of Ignition Timing and Per Cent Gasoline with a Compression Ratio of 8.8:1

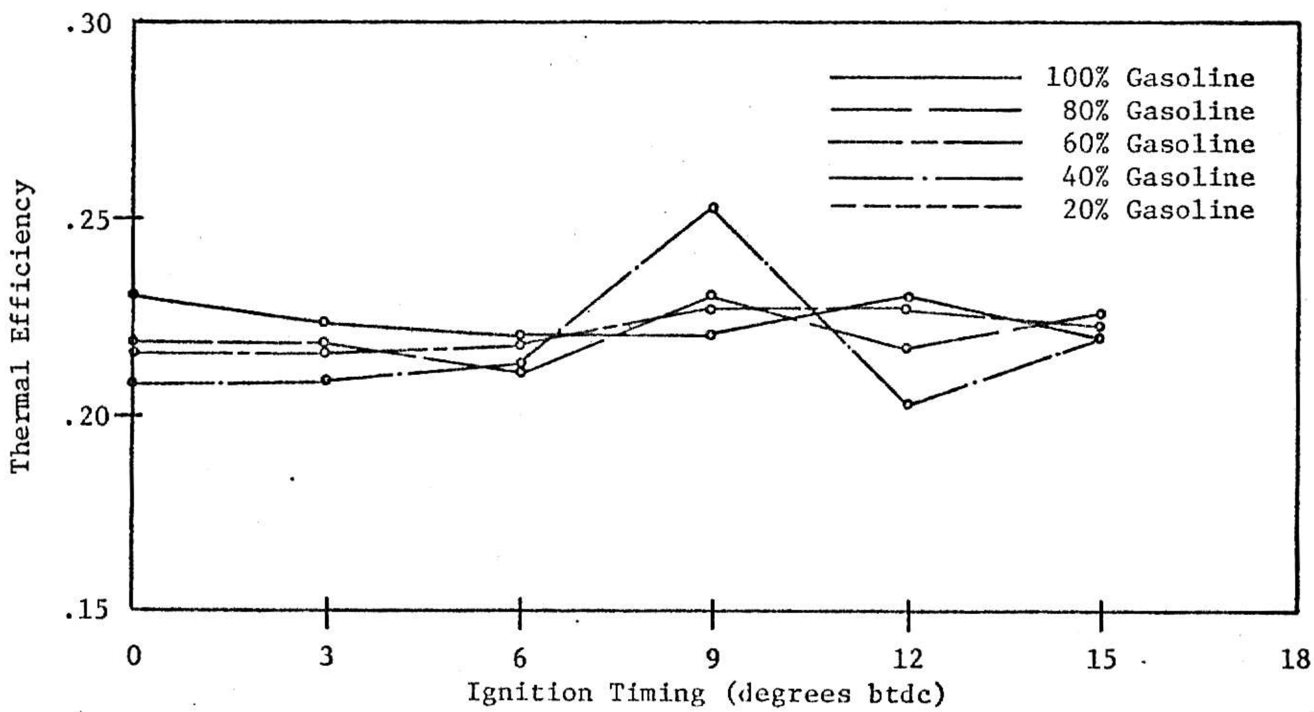

Figure 54. Thermal Efficiency at One-Half Load as a Function of Ignition Timing and Per Cent Gasoline with a Compression Ratio of 8.8:1

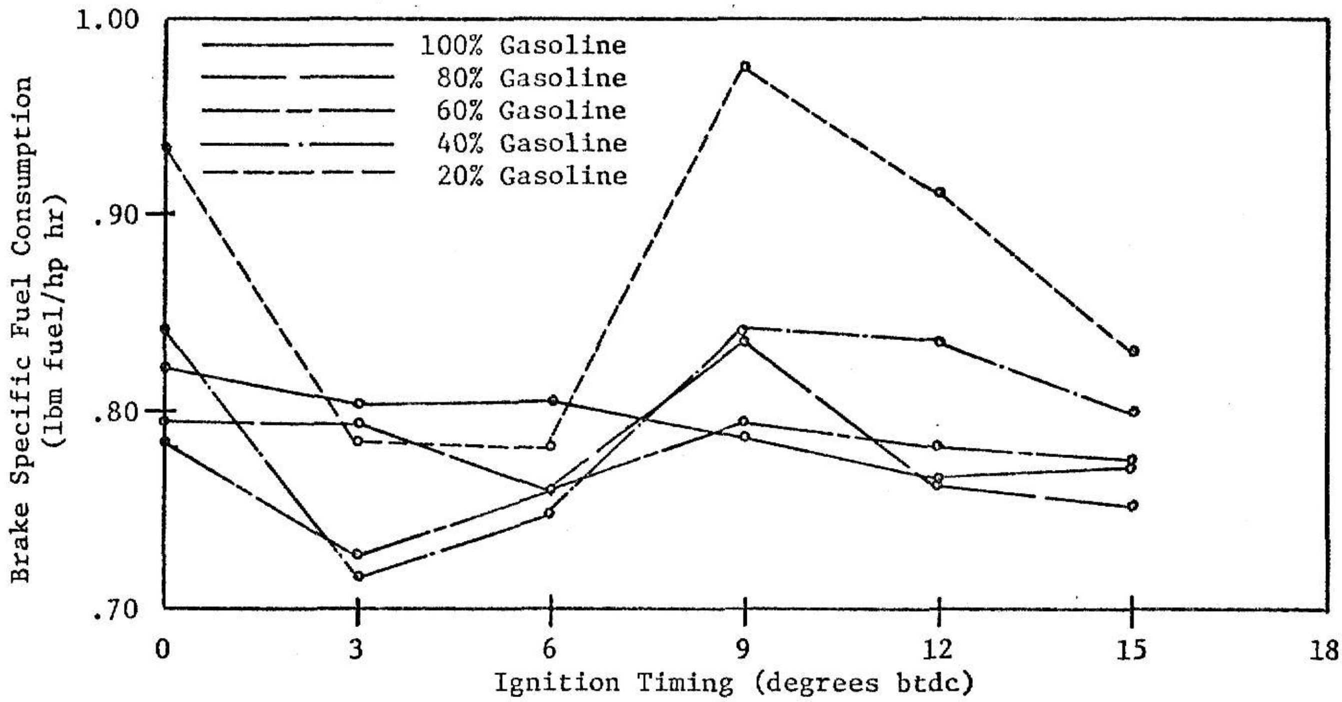

Figure 55. Brake Specific Fuel Consumption at One-Fourth Load as a Function of Ignition Timing and Per Cent Gasoline with a Compression Ratio of 8.8:1

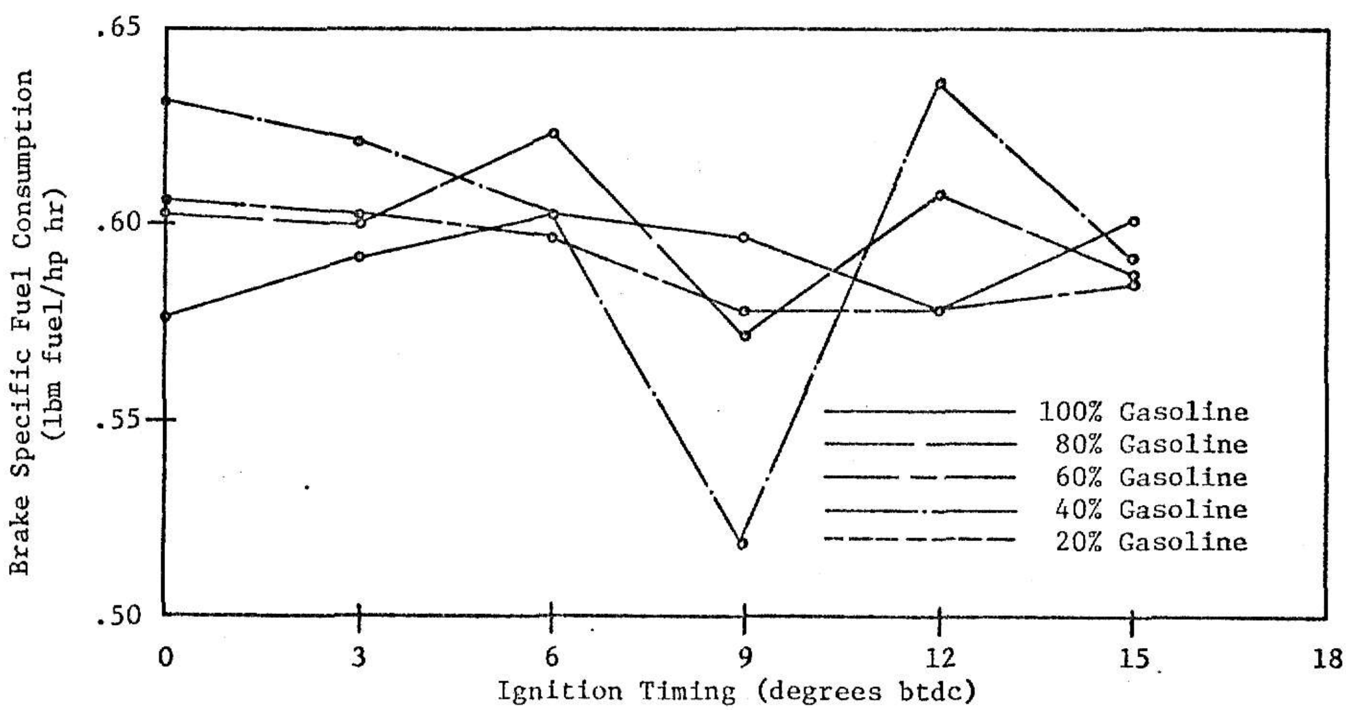

Figure 56. Brake Specific Fuel Consumption at One-Half Load as a Function of Ignition Timing and Per Cent Gasoline with a Compression Ratio of 8.8:1

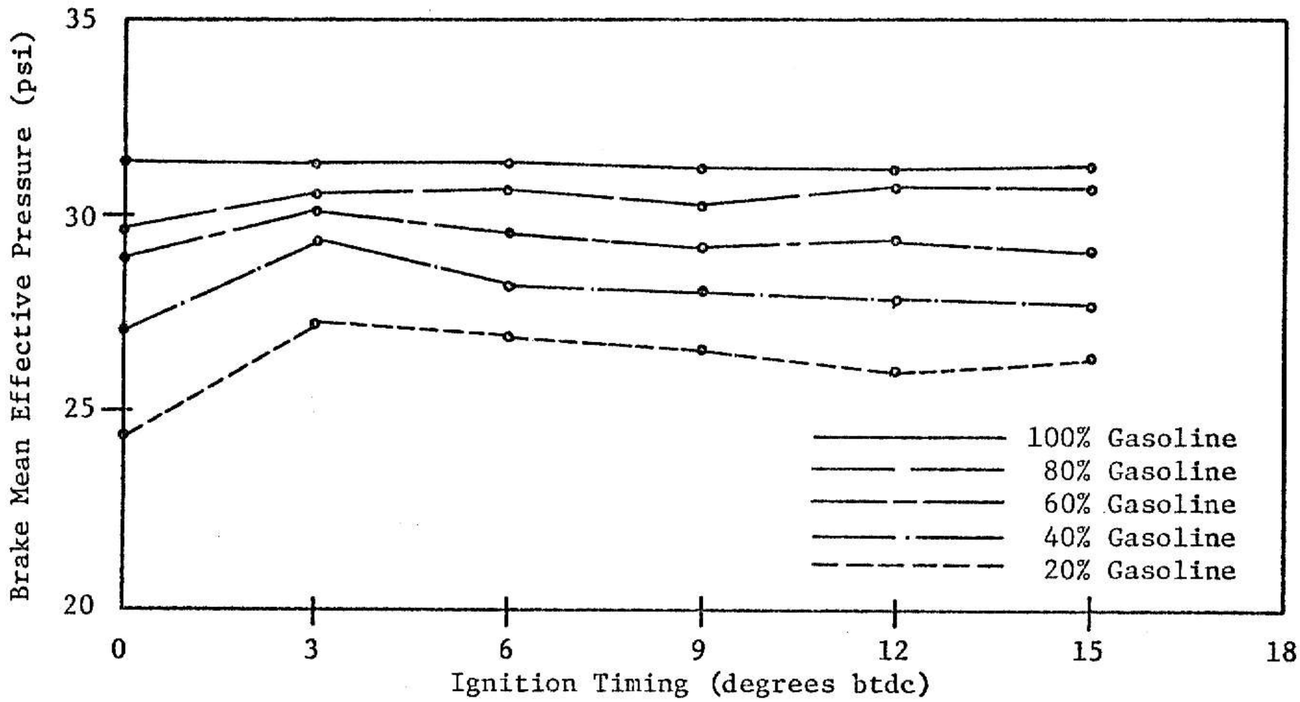

Figure 57. Brake Mean Effective Pressure at One-Fourth Load as a Function of Ignition Timing and Per Cent Gasoline with a Compression Ratio of 8.8:1

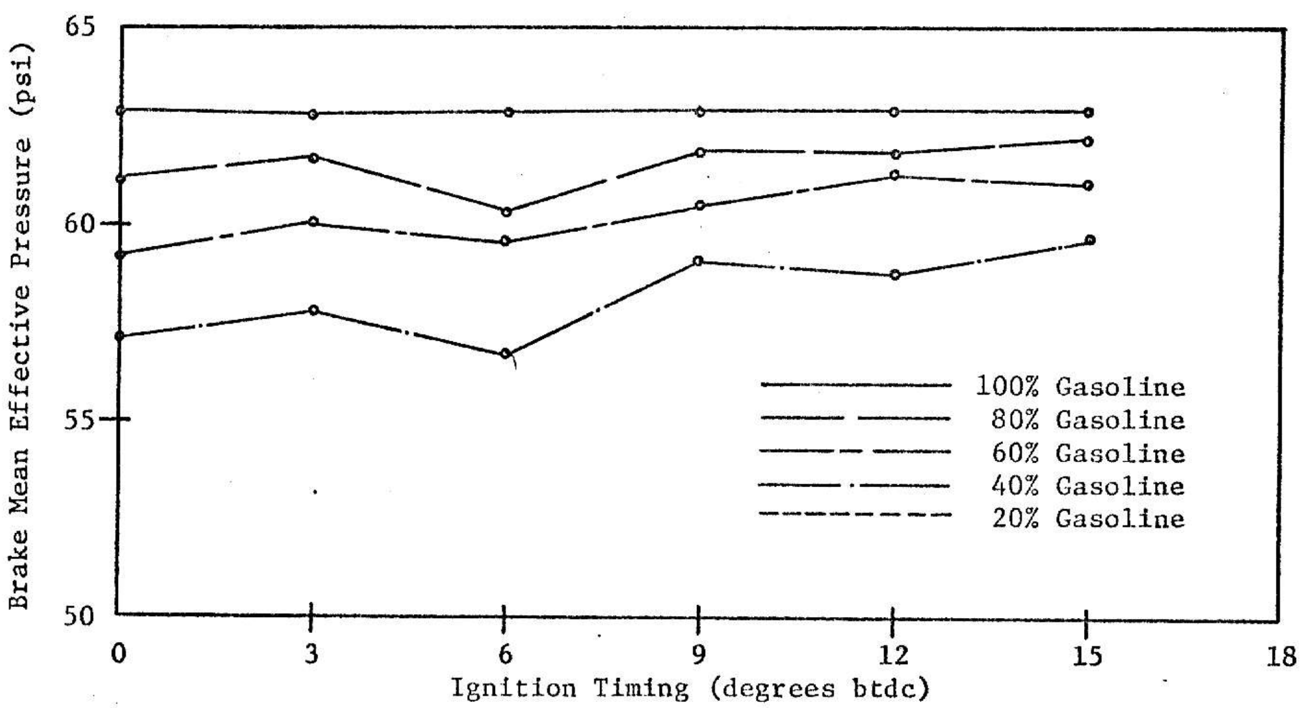

Figure 58. Brake Mean Effective Pressure at One-Half Load as a Function of Ignition Timing and Per Cent Gasoline with a Compression Ratio of 8.8:1

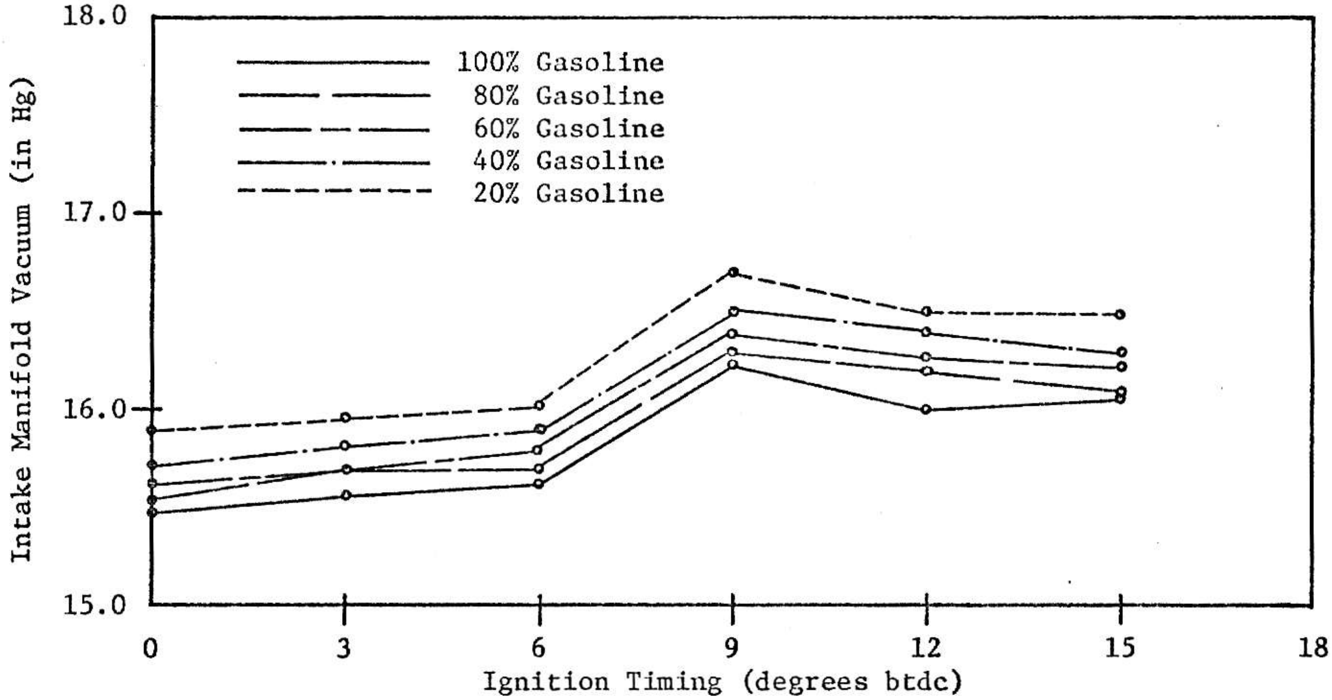

Figure 59. Intake Manifold Vacuum at One-Fourth Load as a Function of Ignition Timing and Per Cent Gasoline with a Compression Ratio of 8.8:1

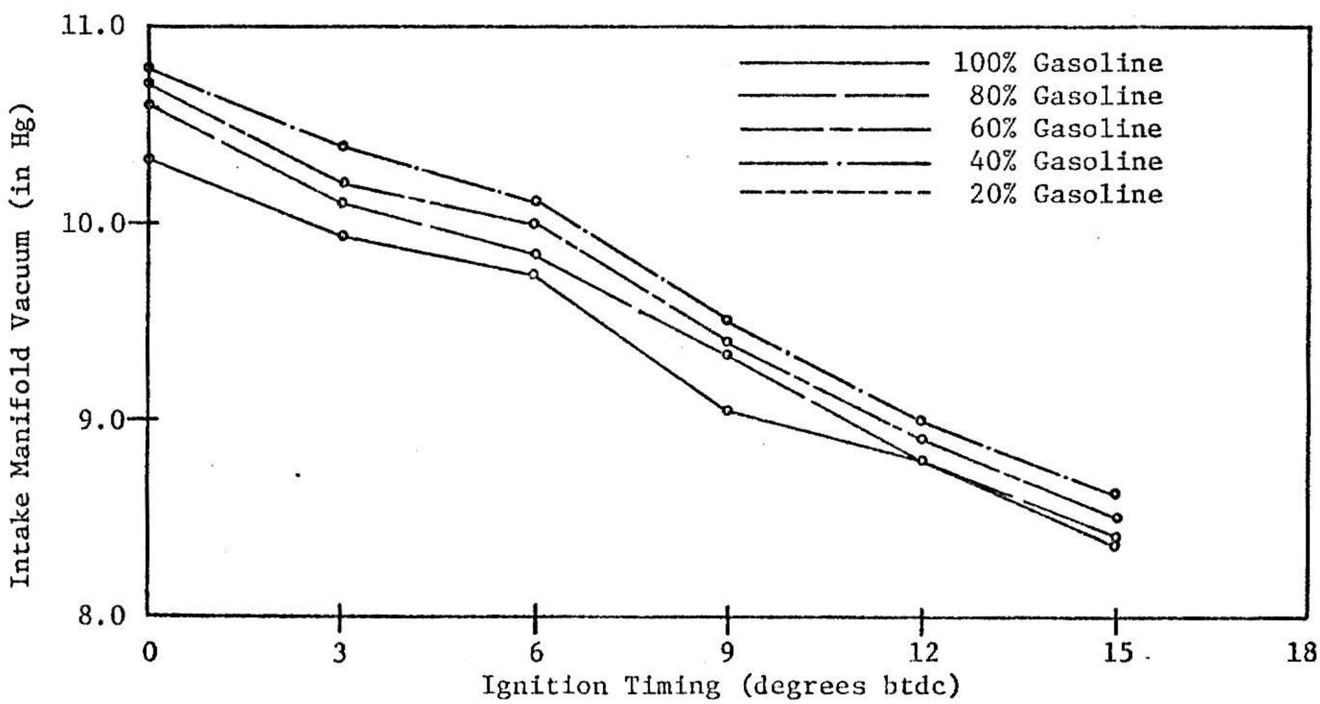

Figure 60. Intake Manifold Vacuum at One-Half Load as a Function of Ignition Timing and Per Cent Gasoline with a Compression Ratio of 8.8:1

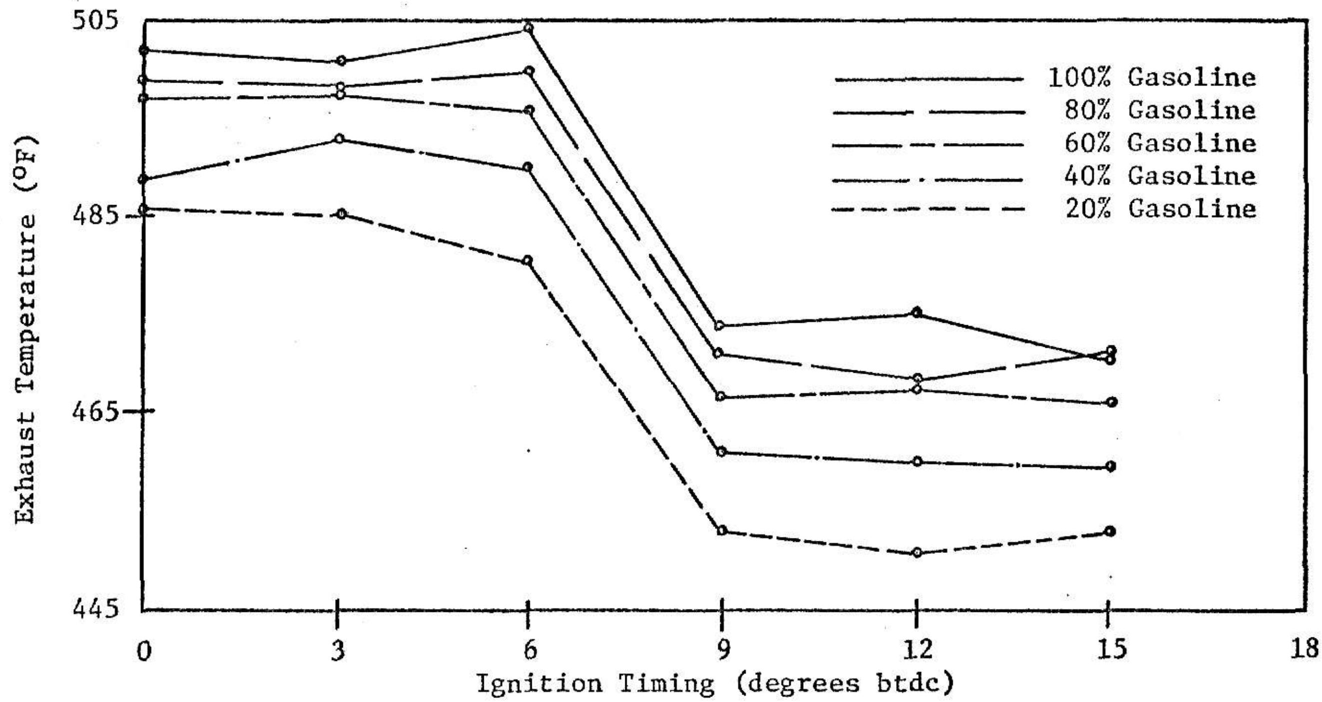

Figure 61. Exhaust Temperature at One-Fourth Load as a Function of Ignition Timing and Per Cent Gasoline with a Compression Ratio of 8.8:1

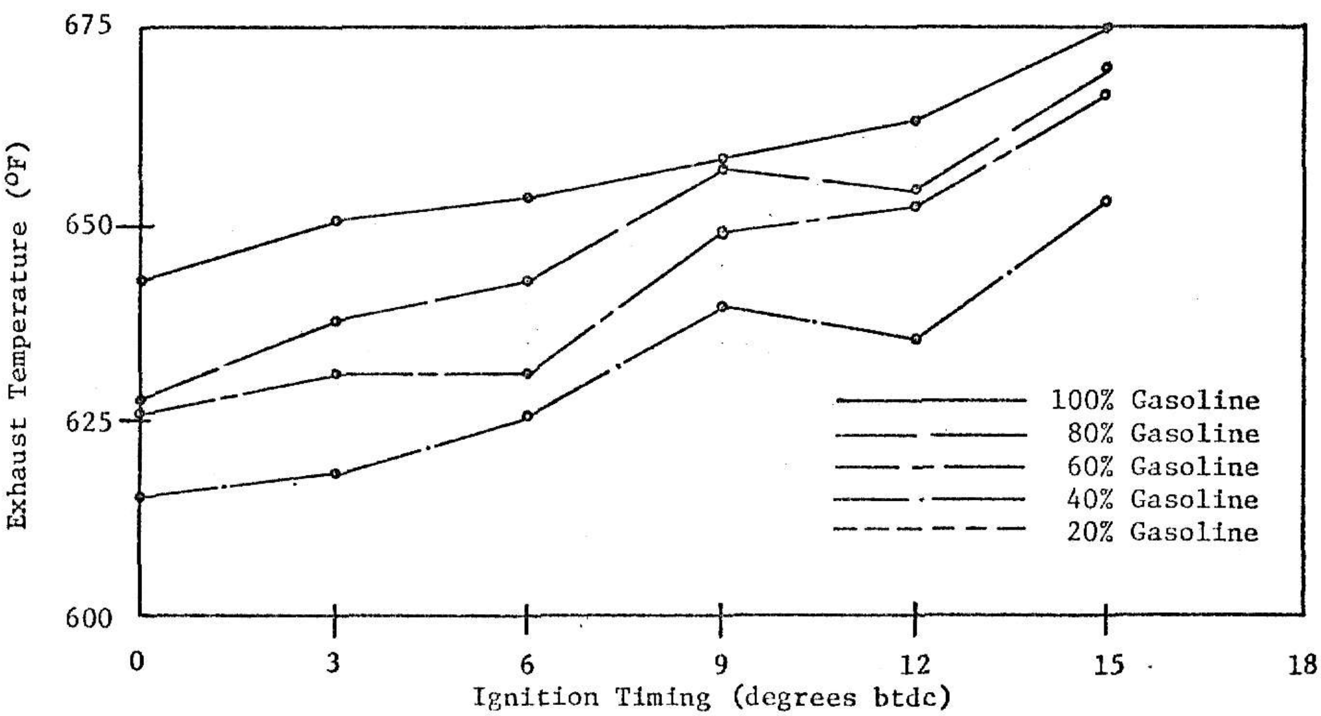

Figure 62. Exhaust Temperature at One-Half Load as a Function of Ignition Timing and Per Cent Gasoline with a Compression Ratio of 8.8:1

thermal efficiency (Figures 53 and 54) and brake specific fuel consumption (Figures 55 and 56) curves.

At this point it is appropriate to note the uncertainties associated with the thermal efficiency, brake specific fuel consumption and air-fuel ratio. The values are calculated in Appendix A as:

$\lambda_{\eta_{th}} = 17.22\%$

$\lambda_{BSFC} = 17.07\%$

$\lambda_{AF} = 17.80\%$

While it is true that these are the values for a worst case analysis, the uncertainty must be assumed to have a sizable effect upon the dispersion of the results.

As one might conclude from the testing method used, the ignition timing had no visable effect upon the brake mean effective pressure (Figures 57 and 58) for either the one-fourth or one-half load testing.

The intake manifold vacuum (Figures 59 and 60) definitely followed a pattern as the timing was advanced. In comparison with the volumetric efficiency curves, one can easily ascertain that the manifold vacuum moved, without exception, in a direction opposite to the volumetric efficiency. This too was to be expected since as the pressure drop across the throttle plate approached zero, the pressure in the intake manifold increased toward atmospheric. This higher pressure in the manifold resulted in a higher volumetric efficiency.

If one compares Figures 59 and 60 with Figures 61 and 62, the reasons for the trends displayed by the exhaust temperature become obvious. As discussed earlier, when the intake manifold pressure rises, a corresponding rise in the exhaust temperature takes place and vice-versa.

Thus far, the trends in the manifold vacuum, and, to a lesser degree, the air-fuel ratio and exhaust temperature have been shown to have varied in some manner with the volumetric efficiency as the ignition timing was advanced. This raises questions as to the causes of the observed variations in the volumetric efficiency.

The most objectionable trend occurred in the one-fourth load group of curves between 6^{o} and 9^{o}btdc. The sudden drop in volumetric efficiency is quite baffling to say the least. There may be several explanations of the drop, but none can be readily extracted from the raw data or results of the testing. For example one might speculate that as the timing was advanced and the idle speed increased, then the closing of the idle bypass orifice to reduce idle speed had a large effect upon the volumetric efficiency at the high speeds. To support this hypothesis, it is necessary to explain why the change was so great only between 6^{o} and 9^{o}btdc and why the same effect was not noticed at one-half load.

The answer to both questions may lie in the proportional magnitude of the required change in the bypass orifice. If the bypass opening had to be changed more between 6^{o} and 9^{o} than between any other two consecutive timings, it would explain why the largest drop in volumetric efficiency occurred there. However, if this was true, then the thermal efficiency should have shown a significant increase between these same two timing settings. This is because the thermal efficiency must increase to get an increase in speed without a reduction in torque or an increase in the fuel available for combustion. The randomness of the thermal efficiency, though, does not allow such conclusions to be drawn.

To answer the second question above it might be argued that at one-fourth load, the orifice opening may have constituted a relatively large proportion of the total opening available for air flow, while becoming a rather small proportion of the total throttle opening at one-half load. If this was the case, then it explains the reason for a change at one-fourth load without a similar change in the one-half load curves.

A second trend in the volumetric efficiency which is somewhat disturbing is the difference in the general shape of the one-fourth load as opposed to the one-half load curves. Even if the large drop of the one-fourth load curve discussed above is ignored, the trend was, at best, no change at all. On the other hand, there was a very positive effect upon the volumetric efficiency when the ignition timing was advanced at one-half load conditions. These variations may take on a new significance if more testing were done in the region between the one-fourth and one-half load curves. This will be discussed further in the chapter on recommendations.

The variation of the results in test groups six and seven with changes in the per cent gasoline are only slightly more predictable than for changes in the ignition time. Once again, trends in air-fuel ratio (Figures 48 and 49), thermal efficiency (Figures 53 and 54), and brake specific fuel consumption (Figures 55 and 56) were nearly non-existent. The problem in this case, however, was most probably one of accurate control over the amount of fuel flow. The greatest problem, as pointed out in Chapter III, was obtaining or repeating desired propane flow rates. The difficulty is revealed most vividly in Figures 49 and 50 and Figures 51 and 52. The volumetric efficiency dropped consistantly with decreasing gasoline percentage which assures the fact that the propane flow increased. The greater the propane flow, the larger became the amount of air it displaced leading to reduced volumetric efficiency. The non-uniform ranking of the air-fuel ratios from rich to lean with respect to the percentage gasoline as the testing moved from one timing to the next is indicative of the lack of ability to repeat the flow rates of the propane.

As always, one must not forget the effect of the uncertainties encountered when calculating these values.

The increased manifold vacuum (Figures 59 and 60) was caused by forcing a relatively constant mass of an increasingly denser vapor through the fixed area of the throttle. The air-propane mixture was more dense than air alone because propane is slightly denser than air. As the heavier mixture was pulled past the throttle plate, the pressure drop was greater than that for air alone.

The brake mean effective pressure was one of the parameters which changed very systematically with increased propane flow. See Figures 57 and 58. As mentioned before, the changes in the brake mean effective pressure were largely the result of the testing sequence, but it does point out the fact that the engine did not continue to deliver a set torque as the proportion of propane was increased.

CHAPTER VI

Summary and Conclusions

Engine performance tests were conducted in which the fuel consisted of mixtures of gasoline and propane. In conjunction with the fuel composition variations, the effect of ignition timing advancement was also investigated.

The results of this testing showed that:

1. Thermal efficiency and brake specific fuel consumption were both highly dependent upon the air-fuel ratio as engine speed was increased, per cent gasoline was decreased, or ignition timing was advanced. Combinations of these control variables led to the same results.

2. Intake manifold pressure closely followed the trends in air-fuel ratio in the case where ignition timing was held constant while the engine speed and per cent gasoline were adjusted. However, when the ignition timing and per cent gasoline were varied, the trends in the intake manifold pressure were most directly related to the volumetric efficiency.

3. Volumetric efficiency changes were difficult to predict. The one common characteristic throughout the testing was that never did the one-half load results agree with the one-fourth load results. Various explanations of this were presented with the results. In very general terms, the one-fourth load volumetric efficiency curves were shaped concave downward in tests where engine speed was a variable whether or not the per cent gasoline was also adjusted. The reasoning behind the one-fourth load results where ignition timing was varied was totally speculation. The conclusion to be drawn from the one-half load volumetric efficiency is that it displayed continually increasing characteristics with increases in either engine speed or ignition timing. In all

cases the volumetric efficiency steadily dropped with decreasing per cent gasoline.

4. The exhaust temperature fell with decreasing manifold pressure but increased with engine speed and load. Of these three, load had the greatest influence and per cent propane had the least.

5. Because of the procedures used, brake mean effective pressure varied in a manner identical to that of maximum torque at wide open throttle when engine speed was a variable. When the ignition timing changed, brake mean effective pressure remained constant. With increasing propane flow, brake mean effective pressure declined.

CHAPTER VII

Recommendations

To make accurate predictions about the behavior of the engine under all operating conditions, some improvements in the instrumentation and testing procedures must be made. Also the amount of testing must be increased in order to obtain a complete operational map of the engine.

The one improvement in instrumentation which most desperately needs to be made, is the method of setting the amount of propane flow. The flow indicators used, must be replaced with devices which allow better determination of the instantaneous propane flow.

If conclusions about the effects of ignition timing and per cent propane upon engine performance are to be made, then it is necessary to be able to contain the air-fuel ratio within limits much narrower than those maintained during this study. With the installation of better propane controls, it will become easier to regulate the flow to obtain the required constant air-fuel ratio. The capability to closely govern the gasoline flow existed through the use of the auxiliary fuel injection control unit, but inexperience in its use led to eratic results, even at 100 per cent gasoline.

As noted in the presentation of results, as well as in the conclusions, some of the performance parameters displayed vastly different trends at one-fourth load as compared to one-half load. For this reason it is suggested that the load be increased in finer steps. Increment sizes of perhaps one-tenth rather than one-fourth load would be appropriate. Besides this, the effect of ignition timing should be determined at all engine speeds rather than being limited to only one.

If further testing is to be conducted at greater than one-half load over the same range of fuel mixtures, then it will be necessary to place the propane outlet at the throat of a venturi placed in the air intake system. This must be done in order to create a pressure drop of large enough magnitude to draw the propane through the converter in the conventional manner.

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APPENDIX A

Uncertainty Analysis

The uncertainty in each of the performance parameters will be calculated with the suggested equations of Sprague and Nash (12). For a variable which is a function of various independently measure values

$$H = f\ (Y_1, Y_2, Y_3, \cdots Y_n),$$

the uncertainty in H is

$$\lambda_H = \sqrt{S_1^{\ 2}\ \lambda_1^{\ 2} + S_2^{\ 2}\ \lambda_2^{\ 2} + \cdots S_n^{\ 2}\ \lambda_n^{\ 2}} \tag{18}$$

where S_n is defined as

$$S_n = \frac{\partial f}{\partial Y_n}\ \frac{Y_n}{f(Y_1, Y_2 \cdots Y_n)} \tag{19}$$

and where λ_n is the uncertainty in the n'th measured value.

If a portion of the measured values are not independent, as would be the case if they were measured with the same instrument, then the equation for the uncertainty is:

$$\lambda_H = \sqrt{\left[S_1\ \lambda_1 + S_2\ \lambda_2 + \cdots S_i\ \lambda_i\right]^2 + S_{i+1}^2\ \lambda_{i+1}^2 + S_{i+2}^2\ \lambda_{i+2}^2 + \cdots S_n^2\ \lambda_n^2} \tag{20}$$

where values 1 through i are dependent measurements and values i+1 through n are independent measurements.

For the calculations presented here, λ_n will be in per cent of reading wherever possible. The uncertainties will be calculated using the smallest measured values in order to find the largest uncertainties encountered. Also, manufacturer's literature was not available for most of the instruments used. In these cases, resolution and linearity uncertainties will both be assumed equal to 1/2 of the smallest scale division of the particular instrument.

Thermal Efficiency

From equation 6, the formula for thermal efficiency is:

$$\eta_{th} = \frac{HP \left(\frac{550}{778}\right) (3600)}{WHG\ (19134) + WHP\ (19768)} \qquad (6)$$

where

$$WHG = \frac{CAMG}{TIMEG} \times 3600 \qquad (3)$$

$$WHP = \frac{CAMP}{TIMEP} \times 3600 \qquad (4)$$

$$CAMG = .9902\ (IMMG - FMMG) \qquad (22)$$

$$CAMP = 1.0234\ (IMMP - FMMP)\ . \qquad (23)$$

To solve for the uncertainty in the thermal efficiency, the uncertainties in several other values must first be found.

Equation 22 is used to find the sensitivities for IMMG and FMMG and equation 23 is manipulated to find the sensitivities of IMMP and FMMP.

$$S_{IMMG} = \frac{IMMG}{IMMG - FMMG}$$

$$S_{FMMG} = \frac{FMMG}{IMMG - FMMG}$$

$$S_{IMMP} = \frac{IMMP}{IMMP - FMMP}$$

$$S_{FMMP} = \frac{FMMP}{IMMP - FMMP}$$

Solving these equations for the worst case is facilitated by finding the smallest values encountered for the denominators. From test number 672:

$$IMMG - FMMG = .55 - .49 = .06,$$

and from test number 529:

$$IMMP - FMMP = .83 - .75 = .08 .$$

Therefore,

$$S_{IMMG} = \frac{.55}{.55 - .49} = 9.17$$

$$S_{FMMG} = \frac{.49}{.55 - .49} = 8.2$$

$$S_{IMMP} = \frac{.83}{.83 - .75} = 10.4$$

$$S_{FMMP} = \frac{.75}{.83 - .75} = 9.4 .$$

The smallest scale division of the gasoline and propane balances was .01 lbm. This allows the following calculation of uncertainties for CAMG and CAMP. Equation 20 is used in this case.

$$\lambda_{CAMG} = \sqrt{\left[(S\lambda)_{IMMG} + (S\lambda)_{FMMG}\right]^2}$$

$$\lambda_{CAMG} = (9.17)\left(\frac{.005}{.55}\right) + (8.2)\left(\frac{.005}{.49}\right)$$

$$= 16.70\%$$

$$\lambda_{CAMP} = (10.4)\left(\frac{.005}{.83}\right) + (9.4)\left(\frac{.005}{.75}\right)$$

$$= 12.5\%$$

The uncertainties in TIMEG and TIMEP are calculated using the smallest measured values of each which were 141 sec and 149 sec respectively. These readings were encountered in test number 779. The smallest scale division used for the timing was 1 sec. Therefore,

$$\lambda_{TIMEG} = \sqrt{(\lambda^2)_{linearity} + (\lambda^2)_{resolution}}$$

$$\lambda_{TIMEG} = \sqrt{2\left[\frac{.5}{141}\right]^2} = .00501 = .501\%$$

$$\lambda_{TIMEP} = \sqrt{(\lambda^2)_{linearity} + (\lambda^2)_{resolution}}$$

$$\lambda_{TIMEP} = \sqrt{2\left[\frac{.5}{149}\right]^2} = .00475 = .475\%$$

From equation 19, the sensitivities for equations 3 and 4 are:

$$S_{CAMG} = S_{CAMP} = \frac{\dfrac{\partial\left[\dfrac{CAMG}{TIMEG}(3600)\right]}{\partial\ CAMG}}{\dfrac{CAMG}{TIMEG}(3600)}(CAMG) = \frac{\dfrac{\partial\left[\dfrac{CAMP}{TIMEP}(3600)\right]}{\partial\ CAMP}}{\dfrac{CAMP}{TIMEP}(3600)}(CAMP) = 1$$

$$S_{TIMEG} = S_{TIMEP} = \frac{\dfrac{\partial\left[\dfrac{CAMG}{TIMEG}(3600)\right]}{\partial\ TIMEG}}{\dfrac{CAMG}{TIMEG}\ 3600}(TIMEG) = \frac{\dfrac{\partial\left[\dfrac{CAMP}{TIMEP}(3600)\right]}{\partial\ TIMEP}}{\dfrac{CAMP}{TIMEP}\ 3600}(TIMEP) = -1\ .$$

The uncertainty in WHG and WHP is calculated from 18 as:

$$\lambda_{WHG} = \sqrt{(S^2\ \lambda^2)_{CAMG} + (S^2\ \lambda^2)_{TIMEG}}$$

$$\lambda_{WHG} = \sqrt{(1)^2\ (.167)^2 + (-1)^2\ (.00501)^2} = 16.71\%$$

$$\lambda_{WHP} = \sqrt{(S^2\ \lambda^2)_{CAMP} + (S^2\ \lambda^2)_{TIMEP}}$$

$$\lambda_{WHP} = \sqrt{(1)^2\ (.125)^2 + (-1)^2\ (.00475)^2} = 12.51\%\ .$$

The Daytronic Modular Instrument System uses the inputs of torque from a strain guage transducer and speed from a magnetic pick-up to calculate horsepower. The instruction manuel listed the accuracies of the various modules as .05 per cent of full scale for the torque from the strain guage conditioner-amplifier, .05 per cent of scale for the speed output derived from the frequency-to-voltage converter and .2 per cent for the multiplier module which gives horsepower. There was also a .02 per cent ± one digit accuracy associated with the display of these quantities.

The .05 per cent of full scale for the torque can be converted to per cent of smallest reading as follows by knowing full scale is 150 ft lb.

$$\lambda_T = \sqrt{(\lambda^2)_{\text{linearity}} + (\lambda^2)_{\substack{\text{accuracy}\\ \text{of display}}} + (\lambda^2)_{\text{resolution}}}$$

$$\lambda_T = \sqrt{(.0005)^2 + (.0002)^2 + \left(\frac{.1}{150}\right)^2} = .086\%$$

$$= (.00086)\ (150) = .129\ \text{ft lb}$$

$$= \frac{.129}{4.1} = 3.15\%$$

Since full scale of the engine speed was 5000 rpm, the uncertainty in the speed can be changed to per cent of reading as follows:

$$\lambda_{rpm} = \sqrt{(\lambda^2)_{\text{linearity}} + (\lambda^2)_{\substack{\text{accuracy}\\ \text{of display}}} + (\lambda^2)_{\text{resolution}}}$$

$$\lambda_{rpm} = \sqrt{(.0005)^2 + (.0002)^2 + \left(\frac{5}{5000}\right)^2} = .114\%$$

$$= (.114)\ (5000) = 5.68\ \text{rpm}$$

$$= .688\%$$

The uncertainty in horsepower can similarly be changed to per cent of reading as:

$$\lambda_{HP} = \sqrt{(\lambda^2)_{linearity} + (\lambda^2)_{\substack{accuaracy\\ of\ display}} + (\lambda^2)_{resolution} + (\lambda^2)_{calibration}}$$

$$\lambda_{calibration} = \sqrt{(\lambda^2)_{armlength} + (\lambda^2)_{weight}}$$

$$= \sqrt{\left(\frac{.1}{24}\right)^2 + \left(\frac{.1}{30}\right)^2} = .534\%$$

$$\lambda_{HP} = \sqrt{(.002)^2 + (.0002)^2 + \left(\frac{.05}{28.55}\right)^2 + (.00534)^2}$$

$$= .59\%$$

$$= .0059\ (28.55) = .17\ \text{hp}$$

$$= \frac{.17}{4.1} = 4.16\%$$

where full scale was 28.55 hp. All the recorded values used in the above conversions were the smallest ones encountered during testing and were the results of test number 3.

The next step in this process is to determine the sensitivities for HP, WHG, and WHP in equation 6.

$$S_{HP} = \frac{\dfrac{\partial\ \eta_{th}}{\partial HP}\ (HP)}{\dfrac{HP\left(\frac{550}{778}\right)3600}{WHG\ (19134) + WHP\ (19768)}} = 1$$

$$S_{WHG} = \frac{\dfrac{\partial\ \eta_{th}}{\partial WHG}\ (WHG)}{\dfrac{HP\left(\frac{550}{778}\right)3600}{WHG\ (19134) + WHP\ (19768)}}$$

$$= \frac{(19134)\ WHG}{WHG\ (19134) + WHP\ (19768)}$$

$$S_{WHP} = \frac{\dfrac{\dfrac{\partial \eta_{th}}{\partial WHP} (WHP)}{HP \left[\dfrac{550}{778}\right] 3600}}{WHG\ (19134) + WHP\ (19768)}$$

$$= \frac{WHP\ (19768)}{WHG\ (19134) + WHP\ (19768)} \quad .$$

It can be seen that S_{WHG} is a maximum of 1 when S_{WHP} is zero and vice versa. However, since 100 per cent propane was never used, the worst case surely occured at 100 per cent gasoline. The uncertainty in thermal efficiency is presented here as being the worst case at 100 per cent gasoline. The uncertainty is calculated from equation 18 as:

$$\lambda_{\eta_{th}} = \sqrt{(S^2\ \lambda^2)_{WHG} + (S^2\ \lambda^2)_{HP}}$$

$$= \sqrt{(1)^2\ (.1671)^2 + (1)^2\ (.0416)^2}$$

$$= 17.22\%\ .$$

Volumetric Efficiency

From equation 14, it can be seen that to calculate the uncertainty in volumetric efficiency, the uncertainty in WHA and TWHA must first be found. These two quantities in turn require the uncertainty in DENSA, CFM, and RPM. Going even further, the uncertainty in TWB, TDB, PATM, PNSD, and PMN must be computed.

Equation 7 gives the relationship for DENSA, however for use in the uncertainty analysis the following expanded form of the equation will be used:

$$DENSA = 1.33\ \frac{PATM}{TDB} - 1.03\ \frac{PW}{TDB} + .00019\ PATM - .00019\ \frac{TWB}{TDB}\ PATM\ . \qquad (21)$$

The uncertainty in TDB and TWB are found by assuming the linearity uncertainty equals the resolution uncertainty of $.5^{o}F$. The smallest value of TDB during testing was 71°F at test point number 108. The smallest value of TWB was 54°F at test point number 186. The uncertainties then are:

$$\lambda_{TDB} = \sqrt{(\lambda^2)_{linearity} + (\lambda^2)_{resolution}}$$

$$= \sqrt{\left[\frac{.5}{71}\right]^2 + \left[\frac{.5}{71}\right]^2}$$

$$= .996\%$$

$$\lambda_{TWB} = \sqrt{(\lambda^2)_{linearity} + (\lambda^2)_{resolution}}$$

$$= \sqrt{\left[\frac{.5}{54}\right]^2 + \left[\frac{.5}{54}\right]^2}$$

$$= 1.31\% \ .$$

The uncertainty in the barometric pressure is also to be calculated with the linearity and resolution uncertainties equal to 1/2 of the smallest scale division on the barometer. This smallest division was .01 in Hg and the smallest pressure reading was 28.54 in Hg. The uncertainty in PATM is:

$$\lambda_{PATM} = \sqrt{(\lambda^2)_{linearity} + (\lambda^2)_{resolution}}$$

$$\lambda_{PATM} = \overline{\left[\frac{.005}{28.54}\right]^2 + \left[\frac{.005}{28.54}\right]^2}$$

$$= .0248\% \ .$$

Now after finding the sensitivities of PATM, TDB and TWB from equation 21, the uncertainty in DENSA can be computed. From equation 19 again:

$$S_{PATM} = \frac{\frac{\partial \ DENSA}{\partial \ PATM} PATM}{DENSA}$$

$$= \frac{\frac{\partial}{\partial \ PATM}\left[\left(\frac{1.33}{TDB} + .00019 - .00019 \ \frac{TWB}{TDB}\right) PATM - 1.03 \ \frac{PW}{TDB}\right] PATM}{1.33 \ \frac{PATM}{TDB} - 1.03 \ \frac{PW}{TDB} + .00019 \ PATM - .00019 \ \frac{TWB}{TDB} \ PATM}$$

$$= \frac{\frac{1.33}{TDB} + .00019 - .00019 \ \frac{TWB}{TDB}}{\frac{1.33}{TDB} - \frac{1.03 \ PW}{PATM \ (TDB)} + .00019 - .00019 \ \frac{TWB}{TDB}} .$$

Now then

$$S_{TWB} = \frac{\frac{\partial \ DENSA}{\partial \ TWB} \ TWB}{DENSA}$$

$$S_{TWB} = \frac{-.00019 \ \frac{TWB}{TDB} \ PATM}{1.33 \ \frac{PATM}{TDB} - 1.03 \ \frac{PW}{TDB} + .00019 \ PATM - .00019 \ \frac{TWB}{TDB} \ PATM} .$$

Next calculate the sensitivity for TDB

$$S_{TDB} = \frac{\frac{\partial \ DENSA}{\partial \ TDB} \ TDB}{DENSA}$$

$$S_{TDB} = \frac{-1.33 \ \frac{PATM}{TDB} + 1.03 \ \frac{PW}{TDB} + .00019 \ \frac{TWB}{TDB} \ PATM}{1.33 \ \frac{PATM}{TDB} - 1.03 \ \frac{PW}{TDB} + .00019 \ PATM - .00019 \ \frac{TWB}{TDB} \ PATM} .$$

The values of TDB, TWB, and PW to substitute into the sensitivity equations for PATM, TDB, and TWB were taken from test number 787. From this point:

TDB = 85^{o}F

TWB = 72^{o}F

TDB - TWB = 13^{o}F

PW = .3887 psi .

A value of 28.8 in Hg was the mean of the atmospheric pressures and is used in calculation of the sensitivities. When these readings are substituted into the sensitivity equations, the result is:

$S_{PATM} = 1.01$

$S_{TWB} = -.0104$

$S_{TDB} = -.99$.

Having finished finding the necessary uncertainties and sensitivities, the uncertainty in DENSA can now be found.

$$\lambda_{DENSA} = \sqrt{(S^2\ \lambda^2)_{PATM} + (S^2\ \lambda^2)_{TDB} + (S^2\ \lambda^2)_{TWB}}$$

$$= \sqrt{(1.01)^2\ (.000248)^2 + (-.99)^2\ (.00996)^2 + (-.0104)^2 + (.0131)^2}$$

$$= .99\%$$

from this the uncertainty in TWHA can be found.

$$\lambda_{TWHA} = \sqrt{(S^2\ \lambda^2)_{RPM} + (S^2\ \lambda^2)_{DENSA}}$$

$$= \sqrt{(1)^2\ (.00688)^2 + (1)^2\ (.0099)^2}$$

$$= 1.21\%$$

To obtain the uncertainty in WHA, the uncertainty in PNSD and CFM must first be found. Since

$$PNSD = \frac{(PMN)\ (.075)}{DENSA} , \tag{8}$$

the task of finding the uncertainty in PMN must be performed. The only uncertainty associated with PMN measurements was the resolution and linearity of the micromanometer. Once again these two uncertainties will be assumed equal to 1/2 of the smallest scale division which is .0005. The uncertainty for the large nozzle then is

$$\lambda_{PMN} = \sqrt{(\lambda^2)_{linearity} + (\lambda^2)_{resolution}}$$

$$= \sqrt{\left[\frac{.0005}{.006}\right]^2 + \left[\frac{.0005}{.006}\right]^2}$$

$$= 11.79\%$$

for the smaller nozzle

$$\lambda_{PMN} = \sqrt{(\lambda^2)_{linearity} + (\lambda^2)_{resolution}}$$

$$= \sqrt{\left[\frac{.0005}{.016}\right]^2 + \left[\frac{.0005}{.016}\right]^2}$$

$$= 4.42\% \ .$$

From equation 8, we see immediately that

$$S_{PMN} = 1$$

$$S_{DENSA} = 1$$

so the uncertainty in PNSD for the larger nozzle is:

$$\lambda_{PNSD} = \sqrt{(S^2\ \lambda^2)_{PMN} + (S^2\ \lambda^2)_{DENSA}}$$

$$= \sqrt{(.1179)^2 + (.0099)^2}$$

$$= 11.83\%$$

and for the smaller nozzle it is

$$\lambda_{PNSD} = \sqrt{(S^2\ \lambda^2)_{PMN} + (S^2\ \lambda^2)_{DENSA}}$$

$$= \sqrt{(.0442)^2 + (.0099)^2}$$

$$= 4.53\% \ .$$

In order to calculate the uncertainty in CFM the sensitivity of PNSD first in equation 10 and then equation 11 must be known. For the larger nozzle and from equation 10

$$S_{PNSD} = \frac{\frac{\partial\ CFM}{\partial\ PNSD}\ PNSD}{CFM}$$

$$= \frac{\frac{\partial}{\partial\ PNSD}\ (98.3596)\ (PNSD)^{.5116}\ (PNSD)}{(98.3596)\ (PNSD)^{.5014}}\ .$$

$$= \frac{(98.3596)\ (.5116)\ (PNSD)}{(98.3596)\ (PNSD)^{.5116}}\ (PNSD)$$

$$= .5116$$

The sensitivity for the smaller nozzle is

$$S_{PNDS} = .5014\ .$$

The uncertainty in CFM can now be found for the two nozzles from equation 18 as

$$\lambda_{CFM} = \sqrt{(S^2\ \lambda^2)_{PNSD}}$$

$$= (S\lambda)_{PNSD}$$

$$= (.5116)\ (.1183)$$

$$= 6.05\%$$

for the larger nozzle. Similarly for the small nozzle

$$\lambda_{CFM} = (S\lambda)_{PNSD}$$

$$\lambda_{CFM} = (.5014)\ (.0453)$$

$$= 2.27\%\ .$$

Since there are two uncertainties for CFM, the largest value of 6.05% will be used from this point on the calculation of the uncertainty in volumetric efficiency. From equation 12 it is obvious that for the calculation of the uncertainty in WHA, the sensitivities of CFM and DENSA both equal 1. The uncertainty is therefore found as

$$\lambda_{WHA} = \sqrt{(S^2\ \lambda^2)_{CFM} + (S^2\ \lambda^2)_{DENSA}}$$

$$= \sqrt{(.0605)^2 + (.0099)^2}$$

$$= 6.13\%\ .$$

Continuing on, the sensitivities of WHA and TWHA in equation 14 are 1 and -1 respectively. The uncertainty in volumetric efficiency is

$$\lambda_{\eta_v} = \sqrt{(S^2\ \lambda^2)_{WHA} + (S^2\ \lambda^2)_{TWHA}}$$

$$= \sqrt{(1)^2\ (.0613)^2 + (-1)^2\ (.0121)^2}$$

$$= 6.25\%\ .$$

Air-Fuel Ratio

The next parameter that the uncertainly must be computed for is the air-fuel ratio. The defining equation for the ratio is:

$$AF = \frac{WHA}{TWHF} \tag{15}$$

where

$$TWHF = WHG + WHP\ . \tag{5}$$

To complete the analysis of uncertainty in AF, all is needed is the sensitivities in WHG and WHP from equation 5 and WHA and TWHF from equation 15.

$$S_{WHG} = \frac{\frac{\partial\ TWHF}{\partial\ WHG}\ WHG}{WHG + WHP}$$

$$= \frac{WHG}{WHG + WHP}$$

$$S_{WHP} = \frac{WHP}{WHG + WHP}$$

By an earlier explanation

$$S_{WHG} = 1$$

$$S_{WHP} = 0$$

which leads to the conclusion

$$\lambda_{TWHF} = \lambda_{WHG} = 16.71\%$$

The sensitivities of WHA and TWHF are easily found to be plus and minus unity respectively. Therefore

$$\lambda_{AF} = \sqrt{(S^2\ \lambda^2)_{WHA} + (S^2\ \lambda^2)_{TWHF}}$$

$$= \sqrt{(.0613)^2 + (.1671)^2}$$

$$= 17.80\% .$$

Brake Specific Fuel Consumption

The calculation of BSFC is performed with the use of equation 17. The uncertainties necessary for obtaining the uncertainty in BSFC were computed above. The sensitivity of the equation to TWHF is 1 and HP is -1. The uncertainty in BSFC is:

$$\lambda_{BSFC} = \overline{(.1656)^2 + (.0416)^2}$$

$$= 17.07\% .$$

Brake Mean Effective Pressure

The uncertainty in BMEP is equal to the uncertainty in the reading of torque.

$$\lambda_{BMEP} = \lambda_T = 3.15\%$$

Manifold Pressure

As explained earlier, the manifold vacuum was read from a vertical mercury manometer. The uncertainty associated with this reading consists of linearity and resolution uncertainties only. The smallest scale division of the manometer was .1 in Hg. The uncertainty in the recorded values of manifold vacuum is:

$$\lambda_{PIM} = \sqrt{(\lambda^2)_{linearity} + (\lambda^2)_{resolution}}$$

$$\lambda_{PIM} = \sqrt{\left[\frac{.05}{8.3}\right]^2 + \left[\frac{.05}{8.3}\right]^2}$$

$$= .852\% \ .$$

Exhaust Temperature

Several uncertainties are associated with the recorded exhaust temperature. These are the uncertainty in temperature sensed by the thermocouple amounting to 4°F, a linearity uncertainty in the millivolt potentiometer of .03% of reading plus 3 μv and thirdly the resolution uncertainty of 1/2 of the smallest scale division. The smallest scale division is .0005 μv. The smallest exhaust temperature read was 350°F which corresponds to a millivolt output of 7.20. The rms value of the uncertainty in exhaust temperature in terms of per cent reading is:

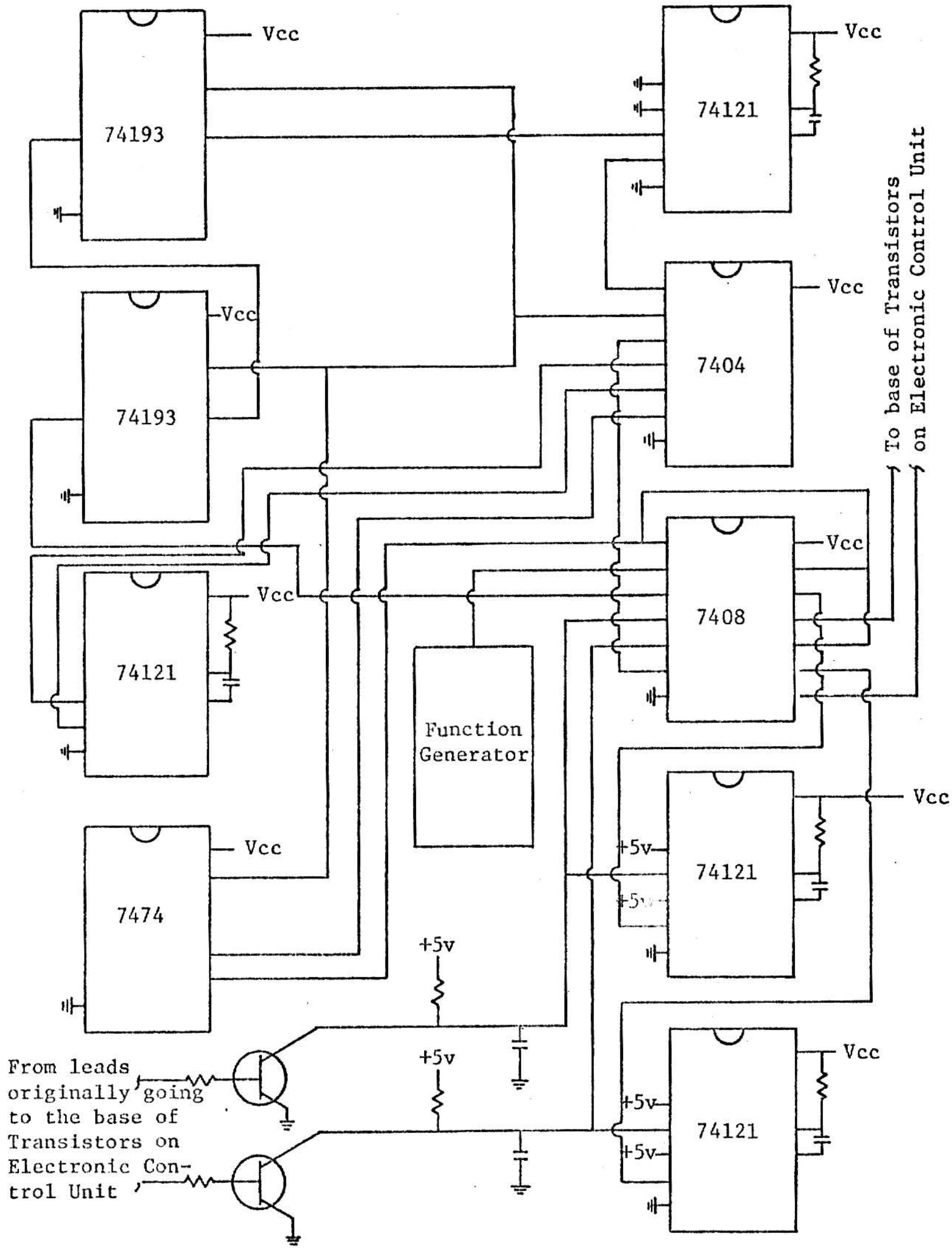
$$\lambda_{TE} = \sqrt{(\lambda^2)_{thermocouple} + (\lambda^2)_{linearity} + (\lambda^2)_{resolution}}$$

$$\lambda_{TE} = \sqrt{\left[\frac{4}{350}\right]^2 + (.0003)^2 + \left[\frac{.3}{7.20}\right] + \left[\frac{.00025}{7.20}\right]^2}$$

$$= 4.3\% \ .$$

APPENDIX B

Detailed Auxiliary Fuel Control Unit Circuit Diagram



Detailed Auxiliary Fuel Injection Control Unit Circuit Diagram

APPENDIX C

Computer Program and Original Data

A short explanation of how the data is arranged on the computer cards is essential for understanding the program and its logic. The first thing to note is that the number furthest to the right on the card is the number of the test. Notice that it required three cards to hold all the necessary information from each test. The first card of a particular test is indicated with just a number. The second card has the test number and a "'" while the third is denoted with ""." Those cards with a "+" in the nomenclature hold data from tests which were re-run because of obvious errors made when the tests were first run.

On the first card, from left to right, are values of atmospheric wet bulb temperature in degrees Rankin, atmospheric dry bulb temperature in degrees Rankin, barometric pressure in inches of mercury, the initial mass differential of the gasoline scale in pounds, the final mass differential of the gasoline scale in pounds, the initial mass differential of the propane scale in pounds, and the final mass differential of the propane scale in pounds. The second card holds the information of recorded time for gasoline flow in seconds, the recorded time for propane flow in seconds, pressure drop across the flow nozzle in inches of water, engine speed in revolutions per minute, torque in foot-pounds, horsepower, and saturated vapor pressure of water in pounds per square inch at the atmospheric wet bulb temperature. On the third card is information of exhaust temperature in degrees Fahrenheit and intake manifold vacuum in inches of mercury.

ILLEGIBLE DOCUMENT

THE FOLLOWING DOCUMENT(S) IS OF POOR LEGIBILITY IN THE ORIGINAL

THIS IS THE BEST COPY AVAILABLE

P-474

```
$JOB            WWW,TIME=(0,8),PAGES=20
C     THERE ARE TWO CARDS THAT GO IN FRONT OF THE '$JOB' CARD FOR RUNNING
C     THE WHOLE JOB THROUGH THE WINDOW.
C     THE VALUES TO BE READ INTO THIS PROGRAM AND THEIR UNITS ARE AS FOLLOWS:
C     WET-BULB TEMPERATURE, DRY-BULB TEMPERATURE, ATMOSPHERIC PRESSURE, INITIAL
C     MASS OF THE GASOLINE, FINAL MASS OF THE GASOLINE, INITIAL MASS OF THE
C     PROPANE, FINAL MASS OF THE PROPANE, THE TIME OF GASOLINE FLOW, THE TIME OF
C     PROPANE FLOW, THE PRESSURE DROP ACROSS THE NOZZLE, THE SPEED OF THE
C     ENGINE, THE TORQUE, THE HORSEPOWER, AND THE SATURATED VAPOR PRESSURE.
C     TEMPERATURES ARE TO BE IN DEGREES RANKIN (EXCEPT EXHAUST TEMPERATURE
C     WHICH IS IN DEGREES FAHRENHEIT), ATMOSPHERIC PRESSURE IS TO BE
C     IN INCHES OF MERCURY,GASOLINE AND PROPANE MASSES TO BE POUNDS,
C     TIMES TO BE IN SECONDS,PRESSURE DROP ACROSS THE NOZZLE IN INCHES OF WATER,
C     ENGINE SPEED IN RPM, VAPOR PRESSURE TO BE PSI, AND INTAKE MANIFOLD
C     PRESSURE TO BE INCHES MERCURY.  THE VARIABLE 'DUMMY' THAT APPEARS IN
C     THE READ LIST IS THE EXHAUST TEMPERATURE.
  504 FORMAT(' ',5E13.4)
  800 FORMAT (7F10.4)
  801 FORMAT(I3)
  917 FORMAT('-', 1X,'THE AVERAGED VALUES OF ENGINE SPEED ARE')
  918 FORMAT('-', 1X,'THE AVERAGED VALUES OF BRAKE SPECIFIC FUEL CONSUMP
     CTION ARE')
  919 FORMAT('-', 1X,'THE AVERAGED VALUES OF AIR-FUEL RATIO ARE')
  920 FORMAT('-', 1X,'THE AVERAGED VALUES OF VOLUMETRIC EFFICIENCY ARE')
  921 FORMAT('-', 1X,'THE AVERAGED VALUES OF THERMAL EFFICIENCY ARE')
  922 FORMAT('-', 1X,'THE AVERAGED VALUES OF BRAKE MEAN EFFECTIVE PRESSU
     CRE ARE')
  923 FORMAT('-', 1X,'THE AVERAGED VALUES OF HORSEPOWER ARE')
  924 FORMAT('1', 1X,'THE AVERAGED VALUES OF EXHAUST TEMPERATURE ARE')
  925 FORMAT('-', 1X,'THE AVERAGED VALUES OF INTAKE MANIFOLD PRESSURE AR
     CE')
  926 FORMAT('-', 1X,'THE PERCENT GASOLINE IS')
      REAL IMMG(500),FMMG(500),IMMP(500),FMMP(500),DENSA(500),WHA(500),
     C WHG(500),WHP(500),RPM(500),T(500),HP(500),TWB(500),TDB(500),
     C PMN(500),PATM(500),PW(500),TIMEG(500),TIMEP(500),TWMF(500),
     C IAMF(500),FAMF(500),DUMMY(500),PIM(500)
      INTEGER N
      READ(5,801) N
      DO 100 I=1,N
      READ(5,800) TWB(I),TDB(I),PATM(I),IMMG(I),FMMG(I),IMMP(I),FMMP(I),
     C TIMEG(I),TIMEP(I),PMN(I),RPM(I),T(I),HP(I),PW(I),DUMMY(I),PIM(I)
  100 CONTINUE
      J=1.
      M=N/3.
      DO 302 L=1,M
      K=J+2.
      SUM=0.
      DO 301 I=J,K
      SUM=SUM+DUMMY(I)
  301 CONTINUE
      DUMMY(L)=SUM/3.
      J=J+3.
  302 CONTINUE
      PRINT 924
      WRITE(6,504)(DUMMY(K),K=1,M)
      J=1.
      M=N/3.
      DO 314 L=1,M
      K=J+2.
      SUM=0.
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      DO 313 I=J,K
      SUM=SUM+RPM(I)
  313 CONTINUE
      DUMMY(L)=SUM/3.
      J=J+3.
  314 CONTINUE
      PRINT 917
      WRITE(6,504)(DUMMY(K),K=1,M)
      DO 200 I=1,N
      IAME(I)=IMMG(I)*.9902+.0177
      FAME(I)=FMMG(I)*.9902+.0177
      DUMMY(I)=IAME(I)-FAME(I)
  200 CONTINUE
      DO 201 I=1,N
      WHG(I)=DUMMY(I)*3600./TIMEG(I)
  201 CONTINUE
      DO 202 I=1,N
      IAME(I)=IMMP(I)*1.0234+.01366
      FAME(I)=FMMP(I)*1.0234+.01366
      DUMMY(I)=IAME(I)-FAME(I)
  202 CONTINUE
      DO 203 I=1,N
      WHP(I)=DUMMY(I)*3600./TIMEP(I)
  203 CONTINUE
      DO 204 I=1,N
      TWHF(I)=WHP(I)+WHG(I)
  204 CONTINUE
      DO 101 I=1,N
      DUMMY(I)=WHG(I)/TWHF(I)
  101 CONTINUE
      PRINT 926
      WRITE(6,504)(DUMMY(I),I=1,N)
      DO 205 I=1,N
      DUMMY(I)= HP(I)*(550./778.)*3600./((WHG(I)*19134.)+
     C (WHP(I)*19768.))
  205 CONTINUE
      J=1.
      M=N/3.
      DO 304 L=1,M
      K=J+2.
      SUM=0.
      DO 303 I=J,K
      SUM=SUM+DUMMY(I)
  303 CONTINUE
      DUMMY(L)=SUM/3.
      J=J+3.
  304 CONTINUE
      PRINT 921
      WRITE(6,504)(DUMMY(K),K=1,M)
      DO 206 I=1,N
      DENSA(I)=((PATM(I)*.491)-.38*(PW(I)-((PATM(I)*.491*(TDB(I)-TWB(I)
     C ))/2700.)))/(.37*TDB(I))
  206 CONTINUE
      DO 207 I=1,N
      DUMMY(I)=PMI(I)*.075/DENSA(I)
  207 CONTINUE
      DO 208 I=1,N
      IF(I.LE.90)GO TO 300
      DUMMY(I)=62.0524*DUMMY(I)**.5014
      GO TO 208
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309 DUMMY(I)=98.3596*DUMMY(I)**.5116
208 CONTINUE
    DO 209 I=1,N
    WHA(I)=DUMMY(I)*DENSA(I)*60.
209 CONTINUE
    DO 210 I=1,N
    DUMMY(I)=(96.6/2.)*(RPM(I)/1728.)*DENSA(I)*60.
210 CONTINUE
    DO 211 I=1,N
    DUMMY(I)=WHA(I)/DUMMY(I)
211 CONTINUE
    J=1.
    M=N/3.
    DO 308 L=1,M
    K=J+2.
    SUM=0.
    DO 307 I=J,K
    SUM=SUM+DUMMY(I)
307 CONTINUE
    DUMMY(L)=SUM/3.
    J=J+3.
308 CONTINUE
    PRINT 920
    WRITE(6,504)(DUMMY(K),K=1,M)
    DO 212 I=1,N
    DUMMY(I)=WHA(I)/TWHF(I)
212 CONTINUE
    J=1.
    M=N/3.
    DO 310 L=1,M
    K=J+2.
    SUM=0.
    DO 309 I=J,K
    SUM=SUM+DUMMY(I)
309 CONTINUE
    DUMMY(L)=SUM/3.
    J=J+3.
310 CONTINUE
    PRINT 919
    WRITE(6,504)(DUMMY(K),K=1,M)
    DO 213 I=1,N
    DUMMY(I)=(150.8/96.6)*T(I)
213 CONTINUE
    J=1.
    M=N/3.
    DO 312 L=1,M
    K=J+2.
    SUM=0.
    DO 311 I=J,K
    SUM=SUM+DUMMY(I)
311 CONTINUE
    DUMMY(L)=SUM/3.
    J=J+3.
312 CONTINUE
    PRINT 922
    WRITE(6,504)(DUMMY(K),K=1,M)
    DO 214 I=1,N
    DUMMY(I)=TWHF(I)/HP(I)
214 CONTINUE
    J=1.
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      M=N/3.
      DO 306 L=1,M
      K=J+2.
      SUM=0.
      DO 305 I=J,K
      SUM=SUM+DUMMY(I)
  305 CONTINUE
      DUMMY(L)=SUM/3.
      J=J+3.
  306 CONTINUE
      PRINT 918
      WRITE(6,504)(DUMMY(K),K=1,M)
      J=1.
      M=N/3.
      DO 318 L=1,M
      K=J+2.
      SUM=0.
      DO 317 I=J,K
      SUM=SUM+PIM(I)
  317 CONTINUE
      DUMMY(L)=SUM/3.
      J=J+3.
  318 CONTINUE
      PRINT 925
      WRITE(6,504)(DUMMY(K),K=1,M)
      J=1.
      M=N/3.
      DO 316 L=1,M
      K=J+2.
      SUM=0.
      DO 315 I=J,K
      SUM=SUM+HP(I)
  315 CONTINUE
      DUMMY(L)=SUM/3.
      J=J+3.
  316 CONTINUE
      PRINT 923
      WRITE(6,504)(DUMMY(K),K=1,M)
      STOP
      END
*ENTRY
489
516.      535.      28.91     1.25      1.0       0.        0.        1
514.      1.        .007      825.      4.2       .6        .2219     1'
350.      -15.7                                                       1  ''
516.      535.      28.91     .99       .74       0.        0.        2
563.      1.        .006      825.      4.2       .6        .2219     2'
354.      -15.7                                                       2  ''
516.      535.      28.91     .73       .45       0.        0.        3
567.      1.        .006      825.      4.1       .56       .2219     3'
359.      -15.6                                                       3  ''
516.      536.      28.91     1.83      1.56      0.        0.        4
446.      1.        .01       1120.     4.4       .9        .2219     4'
375.5     -16.9                                                       4  ''
516.      536.      28.91     1.52      1.26      0.        0.        5
431.      1.        .009      1125.     4.3       .8        .2219     5'
373.5     -16.9                                                       5  ''
516.      536.      28.91     1.2       .9        0.        0.        6
481.      1.        .009      1125.     4.3       .8        .2219     6'
372.5     -16.9                                                       6  ''
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516.	536.	28.91	.75	.44	0.	0.	7
420.	1.	.011	1375.	4.6	1.1	.2219	7'
392.5	-17.6						7 ''
516.	536.	28.91	1.88	1.58	0.	0.	8
437.	1.	.011	1375.	4.5	1.1	.2219	8'
393.	-17.5						8 ''
516.	536.	28.91	1.56	1.25	0.	0.	9
386.	1.	.011	1400.	4.5	1.1	.2219	9'
392.5	-17.6						9 ''
516.	536.	28.91	1.2	.9	0.	0.	10
324.	1.	.0175	1625.	4.8	1.4	.2219	10'
423.	-17.8						10 ''
516.	536.	28.91	.88	.53	0.	0.	11
377.	1.	.0165	1625.	4.8	1.4	.2219	11'
425.	-17.7						11 ''
516.	536.	28.91	1.9	1.55	0.	0.	12
425.	1.	.016	1625.	4.8	1.4	.2219	12'
423.5	-17.8						12 ''
515.	535.	28.91	1.4	1.	0.	0.	13
394.	1.	.02	1850.	5.0	1.7	.214	13'
435.5	-18.4						13 ''
515.	535.	28.91	.9	.5	0.	0.	14
401.	1.	.019	1850.	5.0	1.7	.2140	14'
434.	-18.6						14 ''
515.	535.	28.91	1.51	1.11	0.	0.	15
427.	1.	.018	1860.	5.0	1.7	.2140	15'
434.	-18.7						15 ''
517.	537.	28.91	1.02	.62	0.	0.	16
359.	1.	.021	2050.	5.1	1.9	.2301	16'
432.	-18.8						16 ''
517.	537.	28.91	1.45	1.05	0.	0.	17
391.	1.	.02	2050.	5.1	1.9	.2301	17'
428.	-18.8						17 ''
517.	537.	28.91	.97	.57	0.	0.	18
354.	1.	.02	2050.	5.1	1.9	.2301	18'
426.5	-18.8						18 ''
517.	537.	28.91	1.31	.91	0.	0.	19
344.	1.	.023	2200.	5.2	2.0	.2301	19'
431.	-18.7						19 ''
517.	537.	28.82	.85	.25	0.	0.	20
475.	1.	.0225	2200.	5.1	2.0	.2301	20'
428.5	-18.7						20 ''
517.	537.	28.82	1.93	1.53	0.	0.	21
344.	1.	.0225	2200.	5.1	2.0	.2301	21'
428.5	-18.6						21 ''
517.	538.	28.82	1.37	.83	0.	0.	22
373.	1.	.026	2415.	5.3	2.3	.2301	22'
433.	-18.6						22 ''
517.	538.	28.82	.7	.3	0.	0.	23
276.	1.	.026	2400.	5.2	2.2	.2301	23'
432.	-18.6						23 ''
517.	538.	28.82	1.67	1.27	0.	0.	24
296.	1.	.026	2400.	5.1	2.2	.2301	24'
432.	-18.6						24 ''
518.	539.	28.82	1.17	.77	0.	0.	25
265.	1.	.032	2600.	5.3	2.5	.2386	25'
449.	-19.0						25 ''
518.	539.	28.82	.7	.3	0.	0.	26
263.	1.	.032	2600.	5.2	2.5	.2386	26'
451.	-18.9						26 ''

518.	539.	28.82	1.72	1.32	0.	0.	27
268.	1.	.032	2600.	5.3	2.5	.2386	27 '
449.5	-18.9						27 ''
518.	539.	28.82	1.22	.82	0.	0.	28
240.	1.	.04	2300.	5.4	2.8	.2386	28'
478.5	-19.1						28 ''
518.	539.	28.82	.73	.28	0.	0.	29
275.	1.	.0395	2800.	5.3	2.7	.2386	29'
480.5	-19.1						29 ''
518.	539.	28.82	1.66	1.2	0.	0.	30
289.	1.	.0395	2800.	5.35	2.7	.2386	30'
481.5	-19.1						30 ''
518.	539.	28.82	1.1	.65	0.	0.	31
256.	1.	.05	3000.	5.6	3.1	.2386	31'
515.	-19.2						31 ''
518.	539.	28.82	1.66	1.21	0.	0.	32
273.	1.	.05	3000.	5.6	3.1	.2386	32'
520.	-19.2						32 ''
518.	539.	28.82	1.13	.68	0.	0.	33
258.	1.	.048	3000.	5.5	3.0	.2386	33'
518.	-19.2						33 ''
518.	539.	28.82	1.49	1.03	0.	0.	34
249.	1.	.063	3200.	5.7	3.4	.2386	34'
549.	-19.0						34 ''
518.	539.	28.82	.98	.48	0.	0.	35
260.	1.	.061	3200.	5.7	3.4	.2386	35'
551.	-19.0						35 ''
518.	539.	28.82	1.88	1.38	0.	0.	36
259.	1.	.061	3200.	5.7	3.3	.2386	36'
551.	-19.0						36 ''
516.	534.	28.94	1.53	1.28	0.	0.	37
233.	1.	.033	1480.	19.4	5.4	.2219	37'
480.5	-14.4						37 ''
516.	534.	28.94	1.23	.98	0.	0.	38
235.	1.	.033	1475.	19.4	5.4	.2219	38'
485.5	-14.4						38 ''
516.	534.	28.94	.94	.69	0.	0.	39
234.	1.	.034	1490.	19.4	5.4	.2219	39'
435.5	-14.3						39 ''
516.	533.	28.94	1.71	1.41	0.	0.	41
280.	1.	.041	1740.	19.75	6.4	.2219	41'
510.5	-15.3						41 ''
516.	533.	28.94	1.36	1.06	0.	0.	42
251.	1.	.041	1740.	19.7	6.4	.2219	42'
510.	-15.2						42 ''
516.	533.	28.94	1.03	.73	0.	0.	43
254.	1.	.041	1725.	19.7	6.4	.2219	43'
509.	-15.3						43 ''
515.	534.	28.94	.61	.21	0.	0.	44
297.	1.	.053	1950.	20.1	7.4	.214	44'
541.	-15.4						44 ''
515.	534.	28.94	1.6	1.2	0.	0.	45
279.	1.	.05	1950.	20.1	7.4	.214	45'
541.5	-15.4						45 ''
515.	534.	28.94	1.16	.76	0.	0.	46
300.	1.	.0495	1950.	20.1	7.4	.214	46'
541.5	-15.4						46 ''
515.	534.	28.94	.63	.23	0.	0.	47
245.	1.	.064	2220.	20.5	8.7	.214	47'
566.5	-15.1						47 ''

515.	534.	28.94	1.57	1.11	0.	0.	48
283.	1.	.061	2250.	20.4	8.6	.214	48'
565.5	-15.1						48''
515.	534.	28.94	1.02	.62	0.	0.	49
243.	1.	.061	2250.	20.4	8.6	.214	49'
565.5	-15.1						49''
515.	534.	28.94	1.4	.9	0.	0.	50
261.	1.	.076	2500.	20.2	9.5	.214	50'
587.	-15.0						50''
515.	534.	28.94	.8	.3	0.	0.	51
261.	1.	.076	2500.	20.2	9.5	.214	51'
587.	-15.0						51''
515.	534.	28.94	1.66	1.16	0.	0.	52
264.	1.	.076	2500.	20.2	9.5	.214	52'
587.5	-15.1						52''
516.	535.	28.94	.99	.39	0.	0.	53
280.	1.	.094	2740.	19.8	10.2	.2219	53'
627.	-15.2						53''
516.	535.	28.94	1.53	.93	0.	0.	54
293.	1.	.094	2745.	19.8	10.2	.2219	54'
629.	-15.3						54''
516.	535.	28.94	.9	.3	0.	0.	55
284.	1.	.094	2750.	19.8	10.3	.2219	55'
629.	-15.3						55''
516.	534.	28.77	.99	.39	0.	0.	57
257.	1.	.116	3030.	19.7	11.3	.2219	57'
678.	-15.5						57''
516.	534.	28.77	1.58	.98	0.	0.	58
266.	1.	.111	3015.	19.6	11.2	.2219	58'
675.5	-15.6						58''
516.	534.	28.77	.9	.3	0.	0.	59
267.	1.	.11	3015.	19.7	11.2	.2219	59'
675.	-15.6						59''
517.	537.	28.77	1.31	.61	0.	0.	60
287.	1.	.13	3220.	19.3	11.8	.2301	60'
698.5	-15.4						60''
517.	537.	28.77	1.57	.37	0.	0.	61
274.	1.	.1265	3225.	19.2	11.7	.2301	61'
693.	-15.5						61''
517.	537.	28.77	1.44	.74	0.	0.	62
282.	1.	.127	3220.	19.2	11.7	.2301	62'
698.	-15.5						62''
516.	535.	28.80	1.8	1.38	0.	0.	63
285.	1.	.048	1450.	38.7	10.6	.2219	63'
568.5	-9.6						63''
516.	535.	28.80	1.31	.31	0.	0.	64
272.	1.	.048	1455.	38.7	10.6	.2219	64'
571.	-9.6						64''
516.	535.	28.80	.85	.45	0.	0.	65
269.	1.	.048	1460.	38.7	10.6	.2219	65'
571.	-9.6						65''
517.	535.	28.80	1.25	.35	0.	0.	66
265.	2.	.059	1620.	39.	11.9	.2301	66'
608.	-9.6						66''
517.	535.	28.80	.77	.37	0.	0.	67
248.	1.	.058	1620.	39.	11.9	.2301	67'
612.	-9.6						67''
517.	535.	28.8	1.69	1.29	0.	0.	68
260.	1.	.058	1620.	39.	11.9	.2301	68'
612.	-9.6						68''

516.	536.	28.8	1.16	.71	0.	0.	69
243.	1.	.077	1820.	39.6	13.5	.2219	69'
663.	-10.1						69 ''
516.	536.	28.8	.6	.14	0.	0.	70
229.	1.	.075	1820.	39.8	13.6	.2219	70'
672.5	-10.2						70 ''
516.	536.	28.8	1.55	1.1	0.	0.	71
214.	1.	.075	1820.	39.8	13.6	.2219	71'
668.	-10.3						71 ''
516.	536.	28.8	.92	.41	0.	0.	72
216.	1.	.093	2015.	40.2	15.3	.2219	72'
693.5	-10.2						72 ''
516.	536.	28.8	1.44	.34	0.	0.	73
267.	1.	.093	2015.	40.2	15.3	.2219	73'
699.5	-10.3						73 ''
516.	536.	28.8	.71	.11	0.	0.	74
260.	1.	.092	2015.	40.2	15.3	.2219	74'
699.5	-10.4						74 ''
516.	537.	28.8	1.75	1.1	0.	0.	75
248.	1.	.113	2190.	40.5	16.7	.2219	75'
722.	-10.1						75 ''
516.	537.	28.8	.91	.21	0.	0.	76
280.	1.	.1105	2190.	40.4	16.7	.2219	76'
722.	-10.1						76 ''
516.	537.	28.8	1.8	.46	0.	0.	77
545.	1.	.11	2190.	40.4	16.7	.2219	77'
722.	-10.1						77 ''
516.	537.	28.8	1.47	.73	0.	0.	78
244.	1.	.134	2420.	40.5	18.5	.2219	78'
737.	-9.5						78 ''
516.	537.	28.8	.33	.08	0.	0.	79
260.	1.	.134	2410.	40.5	18.4	.2219	79'
735.5	-9.5						79 ''
516.	537.	28.8	1.74	.94	0.	0.	80
283.	1.	.134	2415.	40.5	18.5	.2219	80'
736.	-9.5						80 ''
517.	538.	28.8	1.64	.79	0.	0.	81
272.	1.	.163	2600.	40.4	19.9	.2301	81'
773.	-9.4						81 ''
517.	538.	28.8	1.5	.7	0.	0.	82
261.	1.	.161	2600.	40.4	19.9	.2301	82'
773.5	-9.4						82 ''
517.	538.	28.8	1.42	.62	0.	0.	83
266.	1.	.161	2600.	40.4	19.9	.2301	83'
773.5	-9.4						83 ''
516.	536.	28.89	1.39	.59	0.	0.	84
249.	1.	.198	2825.	39.8	21.3	.2219	84'
811.5	-9.8						84 ''
516.	536.	28.89	1.85	1.0	0.	0.	85
262.	1.	.195	2845.	39.8	21.5	.2219	85'
816.5	-9.8						85 ''
516.	536.	28.89	.97	.12	0.	0.	86
230.	1.	.187	2795.	39.8	21.1	.2219	86'
806.	-9.8						86 ''
518.	538.	28.89	1.59	.49	0.	0.	87
338.	1.	.223	3000.	39.4	22.4	.2386	87'
852.	-10.3						87 ''
518.	538.	28.89	1.18	.28	0.	0.	88
274.	1.	.221	2990.	39.6	22.4	.2386	88'
852.	-10.2						88 ''

518.	538.	28.89	1.6	.7	0.	0.	89
267.	1.	.221	3000.	39.8	22.5	.2386	89'
850.5	-10.2						89 ''
518.	538.	28.89	1.45	.45	0.	0.	90
262.	1.	.255	3210.	38.9	23.7	.2386	90'
874.	-10.3						90 ''
518.	538.	28.89	1.1	.2	0.	0.	91
244.	1.	.255	3215.	39.	22.7	.2386	91'
877.	-10.4						91 ''
518.	538.	28.89	1.96	1.16	0.	0.	92
214.	1.	.255	3220.	39.	23.9	.2336	92'
877.	-10.3						92 ''
517.	533.	28.88	1.6	1.4	0.	0.	93
512.	1.	.016	900.	4.2	.7	.2301	93'
259.	-16.1						93 ''
517.	533.	28.88	1.39	1.28	0.	0.	94
271.	1.	.016	875.	4.3	.7	.2301	94'
358.	-16.1						94 ''
517.	533.	28.88	1.24	1.12	0.	0.	95
239.	1.	.016	875.	4.3	.7	.2301	95'
360.5	-15.7						95 ''
517.	534.	28.88	.96	.76	0.	0.	96
329.	1.	.021	1140.	4.6	.9	.2301	96'
371.5	-16.9						96 ''
517.	534.	28.88	.72	.52	0.	0.	97
329.	1.	.021	1140.	4.6	.9	.2301	97'
371.5	-16.7						97 ''
517.	534.	28.88	.48	.28	0.	0.	98
324.	1.	.021	1140.	4.6	.9	.2301	98'
371.5	-17.1						98 ''
518.	535.	28.88	1.63	1.43	0.	0.	99
257.	1.	.028	1400.	4.7	1.2	.2336	99'
387.	-18.0						99 ''
518.	535.	28.88	1.39	1.19	0.	0.	100
272.	1.	.028	1425.	4.8	1.2	.2336	100'
387.	-18.1						100''
519.	535.	28.88	1.16	.96	0.	0.	101
281.	1.	.028	1440.	4.7	1.2	.2386	101'
387.	-18.1						101''
516.	532.	28.88	.92	.66	0.	0.	102
319.	1.	.035	1610.	4.9	1.4	.2219	102'
404.	-18.2						102''
516.	532.	28.88	.63	.38	0.	0.	103
304.	1.	.035	1615.	4.9	1.4	.2219	103'
407.	-18.3						103''
516.	532.	28.88	1.73	1.48	0.	0.	104
357.	1.	.035	1610.	4.9	1.4	.2219	104'
407.	-18.3						104''
515.	532.	28.88	1.41	1.11	0.	0.	105
341.	1.	.045	1325.	5.2	1.7	.214	105'
427.5	-18.9						105''
515.	532.	28.88	1.	.7	0.	0.	106
325.	1.	.045	1340.	5.2	1.7	.214	106'
424.5	-19.0						106''
515.	532.	28.88	.62	.32	0.	0.	107
323.	1.	.044	1325.	5.2	1.7	.214	107'
423.5	-18.9						107''
515.	531.	28.88	1.89	1.46	0.	0.	108
447.	1.	.053	2030.	5.4	2.	.214	108'
412.	-19.1						108''

515.	531.	28.88	1.38	1.03	0.	0.	109
333.	1.	.053	2060.	5.4	2.	.214	109'
410.5	-19.2						109''
515.	531.	28.81	.97	.59	0.	0.	110
355.	1.	.052	2050.	5.5	2.	.214	110'
410.	-19.2						110''
516.	533.	28.81	1.13	.78	0.	0.	111
332.	1.	.059	2200.	5.6	2.2	.2219	111'
415.5	-19.0						111''
516.	533.	28.81	.75	.39	0.	0.	112
303.	1.	.059	2190.	5.6	2.2	.2219	112'
414.	-19.0						112''
516.	533.	28.81	1.58	1.23	0.	0.	113
332.	1.	.059	2190.	5.6	2.2	.2219	113'
414.	-19.0						113''
515.	533.	28.81	1.85	1.4	0.	0.	114
332.	1.	.0675	2400.	5.8	2.5	.214	114'
419.5	-18.9						114''
515.	533.	28.81	1.35	.9	0.	0.	115
317.	1.	.0675	2400.	5.8	2.5	.214	115'
417.5	-18.9						115''
515.	533.	28.81	.79	.33	0.	0.	116
328.	1.	.0675	2370.	5.8	2.5	.214	116'
416.5	-18.9						116''
515.	534.	28.81	1.39	.94	0.	0.	117
312.	1.	.081	2595.	5.8	2.7	.214	117'
424.5	-19.2						117''
515.	534.	28.81	.88	.43	0.	0.	118
295.	1.	.081	2615.	5.6	2.7	.214	118'
424.	-19.3						118''
515.	534.	28.81	1.77	1.32	0.	0.	119
307.	1.	.081	2600.	5.5	2.6	.214	119'
424.	-19.2						119''
516.	535.	28.81	1.21	.71	0.	0.	120
305.	1.	.1	2790.	5.6	2.9	.2219	120'
450.	-19.4						120''
516.	535.	28.81	1.62	1.12	0.	0.	121
324.	1.	.1	2820.	5.6	2.9	.2219	121'
452.	-19.5						121''
516.	535.	28.81	1.08	.58	0.	0.	122
306.	1.	.099	2815.	5.6	2.8	.2219	122'
452.	-19.5						122''
516.	536.	28.81	1.55	1.	0.	0.	123
338.	1.	.123	3030.	5.7	3.2	.2219	123'
492.	-19.5						123''
516.	536.	28.81	.96	.41	0.	0.	124
320.	1.	.123	3040.	5.7	3.2	.2219	124'
494.5	-19.5						124''
516.	536.	28.81	1.69	1.14	0.	0.	125
336.	1.	.121	3040.	5.8	3.2	.2219	125'
494.	-19.5						125''
518.	538.	28.81	.96	.39	0.	0.	126
312.	1.	.143	3215.	5.9	3.5	.2386	126'
523.5	-19.5						126''
519.	538.	28.81	1.15	.6	0.	0.	127
316.	1.	.143	3220.	5.8	3.5	.2473	127'
527.5	-19.4						127''
519.	538.	28.81	.88	.32	.0	0.	128
316.	1.	.142	3225.	5.8	3.4	.2473	128'
520.9	-19.4						128''

519.	536.	28.79	1.6	.88	0.	0.	129
681.	1.	.058	1530.	19.4	5.5	.2473	129'
471.	-14.9						129''
519.	536.	28.79	.77	.37	.0	0.	130
297.	1.	.056	1530.	19.3	5.5	.2473	130'
472.	-14.9						130''
519.	536.	28.79	1.67	1.32	0.	0.	131
405.	1.	.055	1500.	19.4	5.5	.2473	131'
472.	-14.9						131''
520.	537.	28.79	1.24	.88	0.	0.	132
329.	1.	.068	1710.	19.7	6.3	.2563	132'
485.5	-15.4						132''
520.	537.	28.79	.83	.58	0.	0.	133
223.	1.	.066	1700.	19.7	6.2	.2563	133'
494.	-15.4						133''
520.	537.	28.79	.5	.15	0.	0.	134
319.	1.	.066	1700.	19.7	6.2	.2563	134'
483.	-15.4						134''
520.	537.	28.79	1.46	1.1	0.	0.	135
338.	1.	.089	1900.	20.	7.2	.2563	135'
503.5	-16.0						135''
520.	537.	28.79	1.06	.71	0.	0.	136
289.	1.	.087	1900.	20.1	7.2	.2563	136'
499.5	-16.2						136''
520.	537.	28.79	.67	.27	.0	0.	137
325.	1.	.087	1920.	20.1	7.2	.2563	137'
497.	-16.2						137''
520.	537.	28.79	1.	.6	0.	0.	138
308.	1.	.108	2125.	20.3	8.1	.2563	138'
515.	-16.1						138''
520.	537.	28.79	.58	.13	0.	0.	139
322.	1.	.108	2125.	20.3	8.1	.2563	139'
515.	-16.1						139''
520.	537.	28.79	1.46	1.01	0.	0.	140
347.	1.	.108	2125.	20.3	8.1	.2563	140'
515.	-16.1						140''
520.	538.	28.79	.83	.33	0.	0.	141
304.	1.	.13	2310.	20.3	8.9	.2563	141'
535.5	-15.8						141''
520.	538.	28.79	1.63	1.13	0.	0.	142
324.	1.	.13	2320.	20.4	8.9	.2563	142'
535.5	-15.8						142''
520.	538.	28.79	1.09	.59	0.	0.	143
303.	1.	.13	2325.	20.3	8.9	.2563	143'
536.	-15.8						143''
520.	538.	28.79	1.12	.57	0.	0.	144
322.	1.	.156	2540.	20.2	9.6	.2563	144'
556.5	-15.7						144''
520.	538.	28.79	1.88	1.33	0.	0.	145
316.	1.	.154	2520.	20.1	9.5	.2563	145'
551.5	-15.7						145''
520.	538.	28.79	1.11	.56	0.	0.	146
300.	1.	.152	2510.	20.1	9.5	.2563	146'
551.	-15.7						146''
520.	538.	28.79	1.67	1.07	.0	0.	147
320.	1.	.189	2740.	20.0	10.3	.2563	147'
591.	-15.9						147''
520.	538.	28.79	.98	.38	0.	0.	148
306.	1.	.187	2750.	19.9	10.3	.2563	148'
591.	-15.9						148''

520.	538.	28.79	1.02	.42	0.	0.	149
306.	1.	.19	2745.	20.0	10.3	.2563	149'
593.	-15.9						149''
520.	538.	28.79	1.63	.97	0.	0.	150
314.	1.	.236	2990.	19.6	11.	.2563	150'
640.	-16.2						150''
520.	538.	28.79	.86	.21	0.	0.	151
303.	1.	.236	2990.	19.6	11.0	.2563	151'
641.5	-16.2						151''
520.	538.	28.79	1.31	.66	0.	0.	152
325.	1.	.235	2990.	19.7	11.1	.2563	152'
641.5	-16.2						152''
521.	540.	28.79	1.38	.63	0.	0.	153
329.	1.	.282	3240.	19.4	11.8	.2655	153'
683.5	-16.0						153''
521.	540.	28.79	1.92	1.17	0.	0.	154
332.	1.	.282	3200.	19.4	11.7	.2655	154'
682.	-16.1						154''
521.	540.	28.79	1.13	.38	0.	0.	155
321.	1.	.282	3195.	19.2	11.6	.2655	155'
680.	-16.0						155''
523.	538.	28.59	1.3	.84	0.	0.	156
349.	1.	.098	1430.	33.6	10.4	.2850	156'
535.5	-10.6						156''
523.	538.	28.59	.75	.3	0.	0.	157
328.	1.	.096	1440.	38.7	10.5	.285	157'
545.5	-10.4						157''
523.	538.	28.59	1.12	.67	0.	0.	158
343.	1.	.096	1400.	38.6	10.2	.285	158'
546.5	-10.3						158''
523.	538.	28.59	.62	.17	0.	0.	159
285.	1.	.123	1600.	39.	11.8	.285	159'
572.5	-10.2						159''
523.	538.	28.59	1.93	1.43	0.	0.	160
343.	1.	.123	1600.	39.1	11.8	.285	160'
580.	-10.2						160''
523.	538.	28.59	1.39	.88	0.	0.	161
309.	1.	.125	1610.	39.	11.8	.285	161'
580.5	-10.2						161''
523.	538.	28.59	.61	.06	0.	0.	162
285.	1.	.1625	1815.	39.9	13.7	.285	162'
633.	-10.7						162''
523.	538.	28.59	1.83	1.28	0.	0.	163
316.	1.	.1625	1820.	39.9	13.7	.285	163'
635.	-10.8						163''
523.	538.	28.59	1.25	.65	0.	0.	164
302.	1.	.1625	1825.	39.9	13.8	.285	164'
637.5	-10.8						164''
524.	539.	28.59	1.26	.61	0.	0.	165
300.	1.	.202	2005.	40.4	15.3	.2952	165'
668.5	-10.9						165''
524.	539.	28.59	1.45	.75	0.	0.	166
327.	1.	.202	2010.	40.4	15.4	.2952	166'
669.5	-10.9						166''
524.	539.	28.54	.73	.03	0.	0.	167
323.	1.	.202	2015.	40.5	15.4	.2952	167'
669.5	-11.0						167''
524.	539.	28.54	1.63	.88	0.	0.	168
335.	1.	.247	2210.	40.6	17.	.2952	168'
693.	-10.7						168''

524.	539.	28.54	.85	.1	0.	0.	169
306.	1.	.244	2215.	40.5	17.	.2952	169'
687.	-10.8						169''
524.	539.	28.54	1.77	.97	0.	0.	170
359.	1.	.243	2210.	40.6	16.9	.2952	170'
684.	-10.9						170''
524.	539.	28.54	1.51	.71	0.	0.	171
304.	1.	.319	2410.	40.4	18.5	.2952	171'
716.	-10.0						171''
524.	539.	28.54	1.29	.49	0.	0.	172
315.	1.	.317	2425.	40.8	18.6	.2952	172'
716.	-10.0						172''
524.	539.	28.54	1.72	.87	0.	0.	173
332.	1.	.309	2410.	40.5	18.5	.2952	173'
712.	-10.2						173''
524.	541.	28.54	1.02	.17	0.	0.	174
306.	1.	.369	2625.	40.3	20.	.2952	174'
742.5	-10.1						174''
524.	541.	28.54	1.57	.72	0.	0.	175
306.	1.	.37	2625.	40.5	20.1	.2952	175'
742.5	-10.1						175''
524.	541.	28.54	1.53	.68	0.	0.	176
302.	1.	.362	2610.	40.3	19.9	.2952	176'
737.	-10.2						176''
524.	541.	28.54	1.74	.74	0.	0.	177
330.	1.	.433	2830.	39.7	21.3	.2952	177'
781.	-10.5						177''
524.	541.	28.54	1.74	.74	0.	0.	178
322.	1.	.433	2830.	39.8	21.3	.2952	178'
782.	-10.4						178''
524.	541.	28.54	1.91	.91	0.	0.	179
320.	1.	.428	2830.	39.7	21.3	.2952	179'
786.	-10.5						179''
525.	543.	28.54	1.79	.74	0.	0.	180
330.	1.	.5	3015.	39.4	22.5	.3057	180'
825.	-10.8						180''
525.	543.	28.54	1.33	.33	0.	0.	181
334.	1.	.5	3020.	39.3	22.5	.3057	181'
828.	-10.8						181''
525.	543.	28.54	1.17	.12	0.	0.	182
325.	1.	.5	3020.	39.3	22.6	.3057	182'
828.	-10.8						182''
525.	543.	28.54	1.97	.79	0.	0.	183
323.	1.	.582	3235.	39.	23.9	.3057	183'
834.5	-10.8						183''
525.	543.	28.54	1.4	.3	0.	0.	184
310.	1.	.582	3225.	38.8	23.8	.3057	184'
834.5	-10.8						184''
525.	543.	28.54	1.7	.6	0.	0.	185
321.	1.	.575	3220.	38.7	23.8	.3057	185'
841.5	-10.9						185''
514.	536.	29.02	1.37	.87	0.	0.	186
293.	1.	.136	3215.	6.6	3.9	.20635	186'
528.5	-19.7						186''
514.	536.	29.02	.84	.29	0.	0.	187
313.	1.	.136	3215.	6.4	3.8	.20635	187'
528.5	-19.7						187''
514.	536.	29.02	1.12	.57	0.	0.	188
337.	1.	.136	3205.	6.3	3.7	.20635	188'
528.5	-19.7						188''

514.	535.	29.02	1.85	1.3	0.	0.	189
336.	1.	.136	3000.	9.2	5.2	.20635	189'
528.5	-19.0						189''
514.	535.	29.02	1.28	.72	0.0	0.	190
327.	1.	.135	3000.	9.2	5.1	.20635	190'
528.5	-19.1						190''
514.	535.	29.02	.68	.13	0.	0.	191
312.	1.	.135	3000.	9.2	5.1	.20635	191'
528.5	-19.1						191''
514.	536.	29.02	1.27	.77	0.	0.	192
311.	1.	.135	2300.	12.3	6.4	.20635	192'
528.5	-18.1						192''
514.	536.	29.02	.75	.25	0.	0.	193
285.	1.	.135	2300.	12.3	6.4	.20635	193'
528.5	-18.1						193''
514.	536.	29.02	1.09	.59	0.	0.	194
300.	1.	.135	2300.	12.4	6.5	.20635	194'
528.5	-18.1						194.''
514.	536.	29.02	.54	.04	0.	0.	195
233.	1.	.135	2605.	16.0	7.8	.20635	195'
524.5	-17.1						195''
514.	536.	29.02	1.75	1.25	0.	0.	196
296.	1.	.135	2605.	16.1	7.8	.20635	196'
527.	-17.1						196''
514.	536.	29.02	1.22	.72	0.	0.	197
289.	1.	.135	2600.	16.1	7.9	.20635	197'
523.5	-17.1						197''
514.	535.	29.02	.63	.13	0.	0.	198
292.	1.	.132	2400.	20.0	9.0	.20635	198'
530.5	-16.1						198''
514.	535.	29.02	.92	.42	0.	0.	199
299.	1.	.132	2405.	20.1	9.1	.20635	199'
535.	-16.1						199''
514.	535.	29.02	1.81	1.31	0.	0.	200
297.	1.	.132	2405.	20.1	9.0	.20635	200'
536.5	-16.0						200''
514.	535.	29.02	1.6	1.1	0.	0.	201
310.	1.	.129	2200.	24.5	10.1	.20635	201'
553.5	-15.4						201''
514.	535.	29.02	1.08	.58	0.	0.	202
299.	1.	.129	2200.	24.5	10.1	.20635	202'
557.	-15.4						202''
514.	535.	29.02	.55	.05	0.	0.	203
299.	1.	.129	2200.	24.5	10.1	.20635	203'
560.5	-15.4						203''
514.	535.	29.02	1.43	.93	0.	0.	204
330.	1.	.127	2000.	29.0	10.9	.20635	204'
571.5	-14.5						204''
514.	535.	29.02	.90	.40	0.	0.	205
297.	1.	.127	2000.	29.0	11.0	.20635	205'
576.	-14.4						205''
514.	535.	29.02	1.61	1.11	0.	0.	206
302.	1.	.128	2000.	29.3	11.1	.20635	206'
579.5	-14.4						206''
514.	536.	29.02	1.05	.54	0.	0.	207
290.	1.	.125	1300.	34.9	11.8	.20635	207'
583.5	-12.9						207''
514.	536.	29.02	.51	.01	0.	0.	208
302.	1.	.125	1310.	34.9	11.9	.20635	208'
593.	-12.8						208''

514.	536.	29.02	1.72	1.22	0.	0.	209
308.	1.	.125	1005.	35.1	12.0	.20635	209'
597.5	-12.6						209''
514.	535.	29.02	1.14	.59	0.	0.	210
318.	1.	.118	1600.	39.5	11.9	.20635	210'
539.5	-10.4						210''
514.	535.	29.02	.51	.01	0.	0.	211
297.	1.	.118	1600.	39.4	11.9	.20635	211'
539.5	-10.3						211''
514.	535.	29.02	1.8	1.3	0.	0.	212
311.	1.	.118	1600.	39.4	11.9	.20635	212'
539.5	-10.3						212''
528.	544.	28.7	1.67	1.2	0.	0.	526
347.	1.	.062	1520.	19.4	5.5	.3391	526'
454.5	-14.8						526''
528.	544.	28.7	1.12	.68	0.	0.	527
323.	1.	.062	1520.	19.4	5.5	.3391	527'
451.5	-14.8						527''
528.	544.	28.7	.59	.16	0.	0.	528
318.	1.	.062	1520.	19.4	5.5	.3391	528'
451.5	-14.8						528''
528.	544.	28.7	1.14	.81	.83	.75	529
315.	310.	.061	1515.	18.6	5.3	.3391	529'
447.5	-14.9						529''
528.	544.	28.7	.68	.35	.72	.63	530
315.	319.	.062	1520.	18.5	5.2	.3391	530'
446.5	-14.9						530''
528.	544.	28.7	1.11	.8	.6	.51	531
314.	339.	.062	1510.	18.4	5.2	.3391	531'
447.5	-14.9						531''
529.	546.	28.7	.55	.3	.41	.24	532
337.	329.	.061	1520.	18.4	5.1	.351	532'
445.	-15.0						532''
529.	546.	28.7	1.93	1.69	1.97	1.82	533
321.	322.	.061	1520.	17.9	5.0	.351	533'
443.5	-15.0						533''
529.	546.	28.7	1.6	1.37	1.76	1.59	534
312.	317.	.061	1520.	18.	5.	.351	534'
443.5	-15.0						534''
531.	545.	28.69	1.94	1.8	1.46	1.21	535+
315.	326.	.059	1520.	17.	4.8	.3758	535+'
409.5	-15.0						535+''
531.	545.	28.69	1.72	1.56	1.09	.85	536+
335.	318.	.059	1520.	17.	4.8	.3758	536+'
409.	-15.0						536+''
531.	545.	28.69	1.5	1.32	.75	.47	537+
370.	373.	.059	1520.	17.	4.8	.3758	537+'
408.5	-15.1						537+''
532.	547.	28.69	1.24	1.15	1.57	1.29	538+
332.	307.	.057	1520.	15.3	4.3	.3887	538+'
407.	-15.2						538+''
532.	547.	28.69	1.13	1.04	1.11	.81	539+
330.	310.	.057	1520.	16.6	4.7	.3887	539+'
407.	-15.2						539+''
532.	547.	28.69	1.02	.92	.73	.43	540+
327.	306.	.057	1520.	15.2	4.2	.3887	540+'
407.	-15.2						540+''
531.	547.	28.7	1.26	.77	0.	0.	541
312.	1.	.108	2015.	20.1	7.6	.3758	541'
522.	-15.6						541''

531.	547.	28.7	.69	.18	0.	0.	542
311.	1.	.108	2020.	20.1	7.7	.3758	542'
521.	-15.7						542''
531.	547.	28.7	1.89	1.38	0.	0.	543
304.	1.	.108	2030.	20.1	7.7	.3758	543'
519.5	-15.7						543''
531.	548.	28.7	1.15	.75	1.75	1.66	544
322.	329.	.106	2040.	19.7	7.5	.3758	544'
520.	-15.8						544''
531.	548.	28.7	1.46	1.03	1.61	1.5	545
326.	357.	.105	2040.	19.9	7.6	.3758	545'
517.5	-15.3						545''
531.	548.	28.7	.8	.36	1.46	1.36	546
335.	326.	.102	2025.	19.7	7.5	.3758	546'
513.5	-16.0						546''
530.	545.	28.6	1.5	1.24	1.9	1.74	547
301.	309.	.101	2040.	19.9	7.6	.3632	547'
517.5	-16.0						547''
530.	545.	28.6	1.12	.84	1.66	1.47	548
322.	317.	.101	2040.	19.4	7.5	.3632	548'
515.	-16.0						548''
530.	545.	28.6	.75	.47	1.41	1.22	549
312.	310.	.101	2040.	19.5	7.5	.3632	549'
513.	-16.0						549''
532.	547.	28.6	1.1	.92	1.0	.73	550
296.	311.	.099	2040.	18.6	7.1	.3887	550'
504.	-16.1						550''
535.	547.	28.6	.81	.55	.59	.28	551
366.	368.	.099	2040.	18.4	7.0	.43	551'
504.	-16.1						551''
535.	547.	28.6	1.35	1.16	1.96	1.75	552
325.	314.	.099	2040.	18.9	7.1	.43	552'
505.5	-16.1						552''
533.	547.	28.6	.77	.63	.45	.1	553
338.	329.	.096	2040.	17.8	6.8	.4021	553'
510.5	-16.2						553''
532.	547.	28.6	.49	.39	1.52	1.16	554
318.	321.	.096	2040.	18.2	6.9	.3887	554'
506.	-16.2						554''
532.	547.	28.6	.35	.25	1.03	.68	555
313.	332.	.096	2040.	18.2	6.9	.3887	555'
506.	-16.2						555''
529.	547.	28.6	1.81	1.12	0.	0.	556
313.	1.	.167	2530.	20.2	9.6	.351	556'
575.5	-15.5						556''
529.	547.	28.6	.99	.32	0.	0.	557
310.	1.	.167	2535.	20.2	9.7	.351	557'
574.	-15.5						557''
529.	547.	28.6	1.96	1.29	0.	0.	558
316.	1.	.167	2535.	20.2	9.7	.351	558'
573.5	-15.5						558''
529.	547.	28.6	.62	.1	1.28	1.16	559
309.	310.	.162	2535.	19.3	9.5	.351	559'
570.	-15.5						559''
529.	547.	28.6	1.74	1.26	1.12	.59	560
302.	310.	.162	2540.	19.7	9.4	.351	560'
570.	-15.5						560''
529.	547.	28.6	1.1	.56	.95	.31	561
317.	322.	.162	2525.	19.5	9.3	.351	561'
569.5	-15.6						561''

529.	548.	28.6	1.87	1.53	.65	.39	562
308.	315.	.158	2535.	19.0	9.	.351	562'
569.5	-15.7						562''
529.	548.	28.6	1.41	.98	1.86	1.53	563
315.	318.	.158	2540.	19.5	9.3	.351	563'
573.	-15.6						563''
529.	548.	28.6	.9	.44	1.52	1.2	564
391.	392.	.158	2530.	19.5	9.3	.351	564'
573.	-15.6						564''
528.	547.	28.6	1.65	1.43	1.49	1.09	565
331.	335.	.153	2540.	18.8	8.9	.3391	565'
573.5	-15.6						565''
528.	547.	28.6	1.32	1.04	.93	.53	566
335.	340.	.153	2540.	18.7	8.9	.3391	566'
569.5	-15.7						566''
528.	547.	28.6	.93	.66	1.32	.95	567
324.	335.	.153	2535.	18.8	8.8	.3391	567'
563.	-15.7						567''
529.	551.	28.6	1.04	.9	1.56	1.12	568
307.	312.	.151	2540.	18.1	8.6	.351	568'
568.	-15.7						568''
529.	551.	28.6	.85	.73	.98	.55	569
297.	305.	.151	2540.	18.4	8.7	.351	569'
566.5	-15.7						569''
529.	551.	28.6	.71	.63	.5	.2	570
191.	206.	.151	2540.	18.4	8.7	.351	570'
573.	-15.7						570''
533.	551.	28.66	1.11	.32	0.	0.	571
313.	1.	.248	3000.	19.7	11.2	.4021	571'
651.5	-16.0						571''
533.	551.	28.66	1.76	1.0	0.	0.	572
314.	1.	.248	3010.	19.7	11.2	.4021	572'
650.5	-16.0						572''
533.	551.	28.66	1.67	.79	0.	0.	573
355.	1.	.248	3010.	19.7	11.2	.4021	573'
649.	-16.0						573''
533.	550.	28.66	1.17	.57	1.64	1.47	574
312.	312.	.242	3005.	19.3	10.9	.4021	574'
657.	-15.8						574''
533.	550.	28.66	1.53	.85	1.41	1.2	575
355.	365.	.242	3005.	19.3	10.9	.4021	575'
655.	-15.8						575''
533.	550.	28.66	.7	.1	1.16	.99	576
308.	302.	.242	3005.	19.3	10.9	.4021	576'
656.5	-15.8						576''
534.	551.	28.66	1.64	1.23	.84	.47	577
331.	330.	.236	3005.	19.0	10.7	.4158	577'
649.5	-15.8						577''
534.	551.	28.66	.9	.42	1.89	1.57	578
359.	357.	.236	3005.	18.7	10.5	.4158	578'
651.	-15.8						578''
534.	551.	28.66	1.19	.78	1.46	1.12	579
328.	334.	.236	3005.	18.7	10.5	.4258	579'
652.5	-15.8						579''
534.	555.	28.66	1.62	1.35	1.15	.65	580
387.	404.	.228	3005.	17.7	9.9	.4258	580'
645.	-16.0						580''
534.	555.	28.66	1.32	1.19	.6	.38	581
168.	168.	.228	3000.	18.2	10.2	.4258	581'
654.	-15.9						581''

534.	555.	28.66	1.17	1.05	.33	.13	582
159.	164.	.228	3005.	19.3	10.5	.4258	582'
658.	-15.9						582''
533.	551.	28.63	1.49	1.36	1.47	1.0	583
326.	324.	.225	3010.	17.2	9.8	.4021	583'
635.	-16.2						583''
533.	551.	28.63	1.29	1.15	.73	.17	584
340.	330.	.225	3010.	17.4	9.9	.4021	584'
640.5	-16.2						584''
533.	551.	28.63	1.11	.99	1.59	1.12	585
334.	318.	.225	3010.	17.6	10.	.4021	585'
642.	-16.2						585''
533.	548.	28.63	1.8	1.12	0.	0.	586
390.	1.	.126	1500.	38.7	11.	.4021	586'
549.	-9.9						586''
533.	548.	28.63	.93	.31	0.	0.	587
332.	1.	.123	1500.	38.8	10.9	.4021	587'
549.	-9.9						587''
533.	548.	28.63	1.88	1.28	0.	0.	588
332.	1.	.13	1500.	38.8	11.	.4021	588'
549.5	-9.8						588''
533.	549.	28.63	1.68	1.15	1.41	1.26	589
367.	360.	.126	1505.	38.	10.8	.4021	589'
546.	-9.5						589''
533.	549.	28.63	.98	.48	1.21	1.07	590
344.	339.	.126	1505.	38.0	10.8	.4021	590'
546.	-9.4						590''
533.	549.	28.63	1.34	.92	1.02	.88	591
293.	339.	.126	1505.	37.9	10.8	.4021	591'
546.5	-9.4						591''
533.	549.	28.63	.69	.35	.75	.5	592
328.	327.	.123	1505.	37.3	10.6	.4021	592'
544.5	-9.6						592''
533.	549.	28.63	1.85	1.57	.42	.2	593
307.	304.	.123	1505.	37.7	10.7	.4021	593'
543.5	-9.5						593''
533.	549.	28.63	1.41	1.08	1.74	1.55	594
324.	328.	.123	1500.	37.7	10.7	.4021	594'
543.5	-9.5						594''
532.	551.	28.63	.94	.68	1.42	1.01	595
424.	416.	.12	1505.	37.1	10.5	.3887	595'
542.5	-9.6						595''
532.	551.	28.63	.62	.33	.9	.38	596
491.	488.	.12	1505.	37.1	10.6	.3887	596'
542.5	-9.6						596''
532.	551.	28.63	1.32	1.17	1.06	.8	597
305.	307.	.12	1505.	37.2	10.5	.3887	597'
541.	-9.6						597''
529.	547.	28.63	1.3	1.21	.8	.39	598
318.	316.	.118	1505.	35.8	10.1	.351	598'
541.	-9.8						598''
529.	547.	28.63	1.16	1.08	1.92	1.54	599
333.	359.	.118	1505.	36.1	10.2	.351	599'
543.	-9.8						599''
529.	547.	28.68	1.06	.97	1.47	1.02	600
359.	372.	.118	1505.	36.0	10.2	.351	600'
544.	-9.8						600''
529.	546.	28.68	1.27	.55	0.	0.	601
326.	1.	.247	2010.	40.2	15.3	.351	601'
713.	-9.9						601''

529.	546.	28.68	1.34	.66	0.	0.	602
310.	1.	.247	2025.	40.2	15.4	.351	602'
714.5	-9.9						602''
529.	546.	28.68	1.46	.75	0.	0.	603
331.	1.	.24	2005.	40.2	15.2	.351	603'
711.	-10.0						603''
530.	546.	28.68	1.24	.75	.81	.69	604
307.	311.	.236	2005.	39.5	15.0	.3632	604'
712.	-10.0						604''
530.	546.	28.68	.62	.05	.66	.53	605
332.	333.	.236	2005.	39.6	15.0	.3632	605'
713.5	-10.0						605''
530.	546.	28.68	1.72	1.22	.5	.38	606
293.	309.	.236	2005.	39.4	14.9	.3632	606'
713.5	-10.0						605''
530.	546.	28.68	1.14	.74	1.67	1.4	607
345.	374.	.231	2005.	38.7	14.6	.3632	607'
714.	-10.1						607''
530.	546.	28.68	.59	.18	1.31	1.06	608
333.	335.	.23	2005.	38.5	14.6	.3632	608'
712.	-10.1						603''
530.	546.	28.68	1.88	1.5	.98	.73	609
313.	322.	.23	2005.	38.4	14.5	.3632	609'
713.	-10.1						609''
528.	546.	28.68	1.39	1.16	.6	.24	610
323.	315.	.225	2005.	37.4	14.1	.3391	610'
713.	-10.1						610''
528.	546.	28.68	1.07	.86	1.75	1.46	611
308.	308.	.225	2000.	37.4	14.2	.3391	611'
715.5	-10.2						611''
528.	546.	28.68	.74	.53	1.3	.96	612
303.	320.	.225	2005.	37.2	14.1	.3391	612'
715.	-10.2						612''
528.	546.	28.68	1.14	1.01	1.43	1.06	613
318.	317.	.221	2005.	36.8	13.9	.3391	613'
698.5	-10.3						613''
528.	546.	28.68	.98	.9	.98	.78	614
188.	214.	.221	2005.	36.8	13.9	.3391	614'
701.5	-10.3						614''
528.	546.	28.68	.88	.8	.76	.58	615
183.	185.	.221	2005.	36.8	13.9	.3391	615'
700.5	-10.3						615''
526.	546.	28.82	1.95	.91	0.	0.	616
331.	1.	.403	2500.	40.4	19.0	.3165	616'
760.5	-8.9						616''
526.	546.	28.82	1.47	.47	0.	0.	617
317.	1.	.403	2505.	40.4	19.1	.3165	617'
763.	-8.9						617''
526.	546.	28.82	1.63	.68	0.	0.	618
320.	1.	.402	2505.	40.4	19.1	.3165	618'
766.5	-8.9						618''
526.	546.	28.82	1.02	.2	1.0	.83	619
319.	322.	.389	2505.	40.2	19.0	.3165	619'
779.5	-8.8						619''
526.	546.	28.82	1.71	.49	.77	.58	620
326.	331.	.389	2505.	40.0	18.9	.3165	620'
772.5	-8.8						620''
526.	546.	28.82	1.91	1.12	.49	.31	621
310.	311.	.389	2505.	39.8	18.8	.3165	621'
776.5	-8.8						621''

526.	546.	28.82	1.51	.93	1.17	.84	622
307.	312.	.38	2505.	39.2	18.5	.3165	622'
769.5	-8.9						622''
526.	546.	28.82	1.49	.96	.66	.31	623
285.	307.	.38	2505.	39.2	18.5	.3165	623'
767.	-8.9						623''
526.	546.	28.82	.7	.1	1.32	1.04	624
312.	312.	.38	2505.	39.2	18.5	.3165	624'
767.	-8.9						624''
527.	546.	28.62	.89	.54	.57	.05	625
314.	313.	.372	2505.	38.8	18.4	.3276	625'
765.	-9.1						625''
527.	546.	28.62	1.29	.93	1.08	.57	626
314.	313.	.366	2505.	39.	18.5	.3276	626'
762.5	-9.2						626''
527.	546.	28.62	.78	.4	1.42	.91	627
325.	327.	.366	2505.	38.8	18.4	.3276	627'
760.5	-9.2						627''
528.	549.	28.62	1.74	.59	0.	0.	628
319.	1.	.578	3000.	39.4	22.3	.3391	628'
859.5	-9.6						628''
528.	549.	28.62	1.84	.59	0.	0.	629
340.	1.	.559	3005.	39.4	22.4	.3391	629'
850.5	-9.9						629''
528.	549.	28.62	1.56	.28	0.	0.	630
353.	1.	.562	3000.	39.4	22.3	.3391	630'
849.5	-9.8						630''
529.	551.	28.62	1.42	.47	.91	.75	631
328.	328.	.552	3005.	39.2	22.3	.351	631'
853.	-9.9						631''
529.	551.	28.62	1.85	.87	.65	.43	632
335.	336.	.551	3005.	38.9	22.1	.351	632'
842.	-9.9						632''
529.	551.	28.62	1.47	.58	.36	.15	633
306.	312.	.551	3005.	38.8	22.1	.351	633'
842.	-9.9						633''
530.	552.	28.62	.84	.15	1.13	.75	634
319.	317.	.54	3005.	37.9	21.5	.3632	634'
845.5	-9.9						634''
530.	552.	28.62	1.65	.99	.53	.13	635
312.	313.	.539	3005.	38.1	21.6	.3632	635'
845.	-9.9						635''
530.	552.	28.62	1.63	.91	1.6	1.25	636
329.	332.	.539	3005.	38.1	21.6	.3632	636'
845.5	-9.9						636''
529.	552.	28.62	1.35	.94	1.62	1.12	637
310.	312.	.528	3005.	37.3	21.2	.351	637'
857.	-10.0						637''
529.	552.	28.62	.8	.38	.94	.4	638
316.	314.	.528	3005.	37.2	21.3	.351	638'
857.	-9.9						638''
529.	552.	28.62	1.27	.92	1.8	1.33	639
285.	314.	.528	3005.	37.6	21.4	.351	639'
856.	-9.9						639''
530.	553.	28.62	.77	.53	1.02	.45	640
321.	316.	.525	3005.	35.8	20.4	.3632	640'
856.5	-10.1						640''
530.	552.	28.62	1.32	1.1	1.75	1.21	641
312.	320.	.525	3005.	36.0	20.5	.3632	641'
857.5	-10.1						641''

529.	551.	28.68	.99	.75	1.63	1.03	642
338.	341.	.52	3005.	36.1	20.5	.351	642'
851.5	-10.1						642''
529.	548.	28.68	1.64	1.05	0.	0.	643
320.	1.	.109	2005.	20.1	7.5	.351	643'
499.5	-15.5						643''
529.	548.	28.68	.94	.41	0.	0.	644
310.	1.	.109	2000.	20.1	7.5	.351	644'
502.	-15.5						644''
529.	548.	28.68	1.16	.65	0.	0.	645
313.	1.	.109	2000.	20.1	7.5	.351	645'
503.5	-15.4						645''
529.	548.	28.68	1.85	1.44	.44	.33	646
323.	347.	.106	2000.	19.0	7.1	.351	646'
499.	-15.5						646''
529.	548.	28.68	.97	.42	1.02	.93	647
410.	406.	.105	2000.	19.0	7.1	.351	647'
499.5	-15.5						647''
529.	548.	28.68	1.48	1.08	.89	.8	648
309.	314.	.105	2005.	18.9	7.1	.351	648'
499.	-15.6						648''
529.	548.	28.68	.8	.5	.7	.5	649
323.	323.	.101	2005.	18.5	6.9	.351	649'
499.5	-15.7						649''
529.	548.	28.68	.43	.11	.45	.23	650
343.	342.	.102	2000.	18.5	6.9	.351	650'
496.5	-15.6						650''
529.	548.	28.68	1.76	1.47	.9	.74	651
325.	324.	.102	2000.	18.7	7.0	.351	651'
496.5	-15.6						651''
530.	550.	28.68	1.17	.94	.49	.18	652
358.	354.	.099	2005.	17.5	6.5	.3632	652'
488.	-15.7						652''
530.	550.	28.68	.82	.62	1.68	1.41	653
328.	323.	.099	2000.	17.1	6.3	.3632	653'
489.5	-15.8						653''
530.	550.	28.68	.56	.37	1.32	1.04	654
318.	308.	.099	2000.	17.4	6.5	.3632	654'
489.5	-15.7						654''
530.	549.	28.68	1.09	1.0	.63	.26	655
306.	306.	.095	2000.	16.0	5.9	.3632	655'
485.5	-15.9						655''
530.	549.	28.68	.91	.79	1.55	1.21	656
335.	319.	.095	2000.	16.1	6.0	.3632	656'
484.5	-15.9						656''
530.	549.	28.68	.75	.63	1.08	.72	657
319.	309.	.095	2005.	15.1	5.6	.3632	657'
485.5	-15.9						657''
531.	546.	28.68	.58	.06	0.	0.	658
308.	1.	.113	2005.	20.1	7.6	.3758	658'
496.5	-15.5						658''
531.	546.	28.68	1.65	1.13	0.	0.	659
305.	1.	.111	2000.	20.1	7.6	.3758	659'
503.5	-15.6						659''
531.	546.	28.68	.98	.44	0.	0.	660
309.	1.	.111	2010.	20.1	7.6	.3758	660'
503.	-15.6						660''
532.	548.	28.68	.85	.42	1.27	1.18	661
329.	328.	.108	2015.	19.7	7.4	.3897	661'
499.5	-15.7						661''

532.	548.	28.68	1.28	.69	1.15	1.01	662
440.	442.	.108	2020.	19.5	7.4	.3887	662'
498.	-15.7						662''
532.	548.	28.68	.56	.13	.98	.37	663
319.	221.	.108	2020.	19.7	7.5	.3887	663'
498.	-15.7						663''
533.	550.	28.68	1.65	1.39	1.62	1.44	664
323.	324.	.105	2020.	19.4	7.3	.4021	664'
497.5	-15.7						664''
533.	550.	28.68	1.31	1.02	1.39	1.19	665
323.	324.	.105	2020.	19.3	7.3	.4021	665'
497.5	-15.7						665''
533.	550.	28.68	.91	.63	1.11	.91	666
313.	308.	.105	2020.	19.4	7.3	.4021	666'
497.5	-15.7						666''
532.	547.	28.68	.56	.4	.82	.52	667
321.	307.	.101	2020.	19.0	7.2	.3887	667'
495.5	-15.8						667''
532.	547.	28.68	1.21	1.04	1.69	1.36	668
379.	384.	.101	2020.	18.8	7.1	.3887	668'
492.	-15.8						668''
532.	547.	28.68	.98	.82	1.25	.95	669
318.	324.	.101	2020.	18.7	7.1	.3887	669'
492.	-15.9						669''
532.	547.	28.68	.77	.7	.76	.36	670
339.	310.	.099	2020.	17.3	6.5	.3887	670'
486.5	-16.0						670''
532.	547.	28.68	.66	.57	1.25	.75	671
453.	453.	.099	2020.	17.7	6.6	.3887	671'
484.5	-15.9						671''
532.	547.	28.68	.55	.49	.63	.25	672
307.	311.	.099	2020.	17.6	6.6	.3887	672'
484.	-16.0						672''
532.	547.	28.68	.8	.27	0.	0.	673
309.	1.	.112	2010.	20.1	7.6	.3887	673'
503.5	-15.6						673''
532.	547.	28.68	1.85	1.32	0.	0.	674
311.	1.	.112	2020.	20.1	7.6	.3887	674'
506.5	-15.6						674''
532.	547.	28.68	1.2	.62	0.	0.	675
336.	1.	.111	2015.	20.1	7.5	.3887	675'
504.	-15.7						675''
532.	548.	28.68	1.61	1.21	1.78	1.7	676
316.	316.	.107	2015.	19.8	7.5	.3887	676'
501.5	-15.7						676''
532.	548.	28.68	1.1	.64	1.68	1.58	677
346.	349.	.107	2015.	19.7	7.4	.3887	677'
499.5	-15.7						677''
532.	548.	28.68	1.4	.98	1.55	1.45	678
335.	330.	.107	2020.	19.4	7.3	.3887	678'
499.5	-15.7						678''
532.	547.	28.68	.88	.48	1.41	1.14	679
449.	446.	.104	2015.	19.0	7.1	.3887	679'
497.	-15.8						679''
532.	547.	28.68	1.26	1.0	1.07	.86	680
320.	334.	.104	2015.	18.9	7.1	.3887	680'
496.5	-15.8						680''
532.	547.	28.68	.92	.64	.8	.6	681
317.	307.	.104	2015.	18.9	7.1	.3887	681'
496.	-15.8						681''

532.	547.	28.68	1.45	1.31	1.28	1.01	682
316.	318.	.1	2015.	18.1	6.8	.3887	682'
492.5	-15.9						682''
532.	547.	28.68	1.27	1.12	.94	.66	683
297.	313.	.1	2015.	18.2	6.8	.3887	683'
489.5	-15.9						683''
532.	547.	28.68	1.08	.92	.59	.3	684
304.	305.	.1	2015.	17.9	6.7	.3887	684'
489.	-15.9						684''
532.	548.	28.68	.85	.78	1.69	1.35	685
337.	307.	.098	2015.	17.0	6.4	.3387	685'
481.5	-16.0						685''
532.	548.	28.68	.75	.58	1.15	.79	686
323.	303.	.098	2015.	17.0	6.3	.3887	686'
480.5	-16.1						686''
532.	548.	28.68	.67	.61	.67	.32	687
302.	303.	.098	2015.	17.1	6.4	.3887	687'
480.5	-16.1						687''
524.	543.	28.99	1.46	.9	0.	0.	688
326.	1.	.105	2020.	20.1	7.7	.2952	688'
474.	-16.3						688''
524.	543.	28.99	.81	.24	0.	0.	689
326.	1.	.106	2015.	20.1	7.6	.2952	689'
474.	-16.2						689''
524.	543.	28.99	1.91	1.41	0.	0.	690
314.	1.	.106	2015.	20.1	7.6	.2952	690'
473.	-16.2						690''
524.	543.	28.99	1.02	.46	1.81	1.68	691
405.	407.	.103	2015.	19.3	7.3	.2952	691'
473.	-16.3						691''
524.	543.	28.99	1.25	.83	1.65	1.54	692
324.	322.	.103	2020.	19.7	7.2	.2952	692'
471.5	-16.3						692''
524.	543.	28.99	.69	.19	1.5	1.38	693
357.	348.	.103	2020.	19.2	7.2	.2952	693'
469.5	-16.3						693''
524.	544.	23.99	.97	.7	1.32	1.11	694
315.	312.	.1	2015.	18.6	7.	.2952	694'
468.5	-16.4						694''
524.	544.	28.99	.64	.35	1.07	.86	695
314.	305.	.1	2015.	18.6	7.0	.2952	695'
467.5	-16.4						695''
524.	544.	28.99	1.96	1.7	.78	.57	696
320.	307.	.1	2015.	18.9	7.1	.2952	696'
467.	-16.4						696''
524.	543.	28.99	1.64	1.45	.46	.14	697
321.	315.	.097	2015.	17.8	6.7	.2952	697'
462.5	-16.5						697''
524.	543.	23.99	1.6	1.43	1.05	.75	698
340.	326.	.097	2015.	17.7	6.6	.2952	698'
461.	-16.5						698''
524.	543.	28.99	1.38	1.2	.64	.33	699
317.	310.	.097	2015.	7.5	6.6	.2952	699'
460.	-16.5						699''
521.	539.	28.99	1.06	.96	1.63	1.25	700
310.	315.	.092	2015.	15.8	5.9	.2655	700'
454.5	-16.7						700''
521.	539.	28.99	.92	.81	1.1	.71	701
320.	312.	.093	2015.	15.8	5.9	.2655	701'
453.	-16.7						701''

521.	539.	28.99	.78	.67	.58	.18	702
317.	312.	.093	2015.	15.9	6.0	.2655	702'
452.	-16.7						702''
520.	540.	28.99	1.61	1.12	0.	0.	703
317.	1.	.109	2020.	20.1	7.6	.2563	703'
474.	-16.0						703''
520.	540.	28.99	1.04	.49	0.	0.	704
322.	1.	.108	2015.	20.1	7.5	.2563	704'
475.5	-16.0						704''
520.	540.	28.99	1.66	1.16	0.	0.	705
306.	1.	.109	2025.	20.1	7.6	.2563	705'
476.	-16.0						705''
518.	538.	28.99	.72	.26	1.75	1.67	706
343.	337.	.104	2010.	19.6	7.4	.2386	706'
470.5	-16.2						706''
518.	538.	28.99	1.63	1.28	1.64	1.54	707
329.	339.	.104	2015.	19.7	7.4	.2386	707'
458.	-16.2						707''
518.	538.	28.99	1.18	.75	1.51	1.41	708
323.	322.	.104	2015.	19.8	7.4	.2386	708'
468.	-16.2						708''
520.	540.	28.99	.64	.33	1.36	1.15	709
337.	338.	.101	2015.	18.8	7.1	.2563	709'
467.5	-16.3						709''
520.	540.	28.99	1.86	1.58	1.1	.89	710
333.	327.	.101	2015.	18.9	7.1	.2563	710'
468.	-16.3						710''
520.	540.	28.99	1.5	1.2	.82	.61	711
320.	319.	.101	2015.	18.9	7.1	.2563	711'
467.	-16.2						711''
519.	539.	28.99	1.13	.94	.53	.22	712
308.	311.	.097	2015.	18.1	6.8	.2473	712'
465.	-16.4						712''
519.	539.	28.99	.89	.67	.94	.64	713
352.	353.	.097	2015.	17.7	6.6	.2473	713'
457.5	-16.4						713''
519.	539.	28.99	.61	.42	.56	.26	714
316.	316.	.098	2015.	17.9	6.7	.2473	714'
455.5	-16.4						714''
519.	542.	28.99	1.37	1.26	1.57	1.2	715
316.	314.	.094	2015.	16.5	6.1	.2473	715'
451.	-16.5						715''
519.	542.	28.99	1.23	1.12	1.09	.72	716
305.	311.	.095	2015.	16.8	6.3	.2473	716'
450.	-16.5						716''
519.	542.	28.99	1.09	.97	.64	.26	717
329.	312.	.096	2015.	16.7	6.3	.2473	717'
451.5	-16.5						717''
521.	543.	28.99	1.44	.91	0.	0.	718
322.	1.	.107	2015.	20.1	7.6	.2655	718'
470.5	-16.1						718''
521.	543.	28.99	.37	.33	0.	0.	719
321.	1.	.107	2015.	20.1	7.6	.2655	719'
470.5	-16.1						719''
521.	543.	28.99	1.06	.56	0.	0.	720
313.	1.	.107	2010.	20.1	7.6	.2655	720'
470.5	-16.0						720''
522.	545.	28.99	.37	.48	1.8	1.69	721
337.	357.	.104	2015.	19.7	7.4	.2751	721'
478.5	-16.1						721''

522.	545.	28.99	1.71	1.34	1.64	1.53	722
312.	325.	.104	2015.	19.5	7.3	.2751	722'
468.	-16.1						722''
522.	545.	28.99	1.21	.31	1.5	1.39	723
304.	320.	.104	2015.	19.7	7.4	.2751	723'
467.5	-16.1						723''
523.	545.	28.99	.68	.41	1.33	1.12	724
306.	311.	.102	2015.	18.7	7.0	.2850	724'
467.5	-16.3						724''
523.	545.	28.99	.67	.44	1.08	.86	725
299.	321.	.101	2015.	18.6	7.0	.285	725'
465.5	-16.2						725''
523.	545.	28.99	1.25	1.0	.8	.58	726
309.	322.	.101	2015.	13.6	7.0	.285	726'
465.5	-16.2						726''
523.	547.	28.99	.8	.65	1.16	.85	727
309.	310.	.097	2015.	17.8	6.7	.285	727'
460.5	-16.3						727''
523.	547.	28.99	.62	.46	.77	.44	728
334.	317.	.097	2015.	17.7	6.6	.285	728'
459.5	-16.3						728''
523.	547.	28.99	.43	.27	1.19	.91	729
330.	318.	.097	2015.	17.7	6.6	.285	729'
459.5	-16.3						729''
523.	546.	28.99	.38	.31	.96	.47	730
368.	372.	.095	2015.	16.9	6.3	.285	730'
452.0	-16.5						730''
523.	546.	28.99	1.28	1.21	1.14	.69	731
342.	395.	.095	2015.	17.0	6.3	.285	731'
452.	-16.5						731''
523.	546.	28.99	1.19	1.13	.63	.23	732
276.	319.	.095	2015.	16.9	6.3	.285	732'
455.	-16.5						732''
523.	544.	29.06	1.32	.38	0.	0.	733
367.	1.	.244	2000.	40.3	15.3	.285	733'
644.5	-10.3						733''
523.	544.	29.06	1.7	.76	0.	0.	734
389.	1.	.243	2005.	40.3	15.3	.285	734'
643.5	-10.3						734''
523.	544.	29.06	1.61	.86	0.	0.	735
306.	1.	.241	2005.	40.3	15.3	.285	735'
640.5	-10.4						735''
523.	543.	29.06	1.82	1.2	1.75	1.6	736
320.	320.	.233	2010.	39.1	14.8	.285	736'
629.	-10.6						736''
523.	543.	29.06	1.51	.86	1.44	1.27	737
326.	327.	.233	2005.	39.3	14.9	.285	737'
627.	-10.6						737''
523.	543.	29.06	1.29	.61	1.18	1.0	738
339.	337.	.233	2010.	38.9	14.3	.285	738'
627.	-10.6						738''
523.	544.	29.06	1.62	1.17	.89	.57	739
319.	317.	.228	2010.	38.1	14.5	.285	739'
628.	-10.7						739''
523.	544.	29.06	.91	.44	.38	.06	740
317.	309.	.228	2010.	37.9	14.4	.285	740'
623.	-10.7						740''
523.	544.	29.06	1.68	1.19	1.96	1.68	741
330.	335.	.228	2010.	37.9	14.4	.285	741'
624.5	-10.7						741''

523.	544.	29.06	1.75	1.47	1.54	1.13	742
307.	302.	.221	2010.	36.9	14.0	.285	742'
618.5	-10.7						742''
523.	544.	29.06	1.21	.9	.73	.24	743
323.	315.	.221	2010.	36.4	13.8	.285	743'
614.5	-10.8						743''
523.	544.	29.06	.76	.46	1.01	.56	744
317.	309.	.221	2010.	36.3	13.7	.285	744'
612.5	-10.8						744''
525.	546.	29.04	1.67	.87	0.	0.	745
306.	1.	.250	2010.	40.3	15.3	.3057	745'
653.5	-9.9						745''
525.	546.	29.04	1.67	.9	0.	0.	746
304.	1.	.25	2010.	40.3	15.3	.3057	746'
651.	-9.9						746''
525.	546.	29.04	1.52	.76	0.	0.	747
304.	1.	.247	2015.	40.3	15.4	.3057	747'
646.5	-10.0						747''
524.	544.	29.04	1.81	1.2	1.43	1.27	748
308.	307.	.24	2010.	39.6	15.1	.2952	748'
640.	-10.1						748''
524.	544.	29.04	1.06	.43	1.23	1.06	749
313.	311.	.24	2010.	39.4	15.0	.2952	749'
636.	-10.1						749''
524.	544.	29.04	1.38	.79	1.03	.86	750
304.	313.	.239	2010.	39.5	15.0	.2952	750'
636.	-10.1						750''
525.	544.	29.04	1.4	.96	1.8	1.51	751
306.	317.	.235	2010.	38.3	14.5	.2952	751'
631.5	-10.2						751''
524.	544.	29.04	.37	.42	1.45	1.14	752
307.	306.	.233	2010.	38.6	14.6	.2952	752'
631.5	-10.2						752''
524.	544.	29.04	1.78	1.35	1.08	.77	753
300.	307.	.234	2010.	38.5	14.6	.2952	753'
631.5	-10.2						753''
524.	544.	29.04	1.18	.9	1.61	1.16	754
308.	313.	.228	2010.	37.2	14.1	.2952	754'
618.5	-10.4						754''
524.	544.	29.04	.86	.57	1.09	.61	755
313.	312.	.228	2010.	37.0	14.1	.2952	755'
618.5	-10.4						755''
524.	544.	29.04	.36	.59	.54	.07	756
308.	306.	.228	2010.	37.0	14.1	.2952	756'
619.	-10.4						756''
524.	545.	29.04	1.66	.86	0.	0.	757
314.	1.	.252	2010.	40.3	15.3	.2952	757'
656.	-9.7						757''
524.	545.	29.04	.83	.05	0.	0.	758
300.	1.	.252	2020.	40.3	15.3	.2952	758'
653.	-9.7						758''
524.	545.	29.04	1.66	.85	0.	0.	759
308.	1.	.252	2015.	40.3	15.3	.2952	759'
652.	-9.8						759''
525.	547.	29.04	1.42	.82	1.78	1.63	760
298.	314.	.248	2015.	38.7	14.7	.3057	760'
647.	-9.8						760''
525.	547.	29.04	.69	.15	1.6	1.47	761
256.	252.	.247	2010.	38.7	14.7	.3057	761'
642.	-9.9						761''

525.	547.	29.04	.39	.35	1.43	1.29	762
266.	263.	.247	2015.	38.8	14.7	.3057	762'
640.	-9.8						762''
525.	544.	28.9	1.57	1.13	1.79	1.51	763
305.	307.	.234	2005.	38.2	14.5	.3057	763'
634.5	-10.0						763''
525.	544.	28.9	1.05	.61	1.46	1.16	764
303.	307.	.234	2005.	38.2	14.5	.3057	764'
630.0	-10.0						764''
525.	544.	28.9	.56	.13	1.13	.83	765
301.	306.	.234	2005.	38.2	14.5	.3057	765'
630.	-10.0						765''
526.	547.	28.9	1.72	1.42	1.98	1.53	766
337.	345.	.228	2005.	36.6	13.9	.3165	766'
626.	-10.1						766''
526.	547.	28.9	1.37	1.08	1.45	1.01	767
311.	314.	.229	2005.	36.3	13.8	.3165	767'
625.	-10.1						767''
526.	547.	28.9	1.03	.74	.95	.51	768
311.	306.	.229	2005.	36.3	13.8	.3165	768'
626.	-10.1						768''
525.	546.	28.9	1.38	.3	0.	0.	769
409.	1.	.261	2015.	40.3	15.4	.3057	769'
652.5	-9.1						769''
525.	546.	28.9	1.3	.52	0.	0.	770
312.	1.	.266	2000.	40.3	15.3	.3057	770'
657.5	-9.0						770''
525.	546.	28.9	1.76	.99	0.	0.	771
300.	1.	.266	2010.	40.3	15.3	.3057	771'
664.5	-9.1						771''
526.	546.	28.9	1.25	.67	1.54	1.4	772
304.	312.	.248	2000.	39.6	15.0	.3165	772'
657.	-9.3						772''
526.	546.	28.9	1.44	.83	1.37	1.22	773
317.	317.	.248	2000.	39.8	15.1	.3165	773'
656.	-9.3						773''
526.	546.	28.9	1.31	.71	1.16	1.02	774
302.	305.	.247	2010.	39.6	15.0	.3165	774'
658.5	-9.4						774''
527.	547.	28.9	1.45	1.02	.95	.65	775
301.	308.	.24	2010.	38.7	14.7	.3276	775'
651.	-9.4						775''
527.	547.	28.9	.95	.51	.6	.3	776
307.	308.	.24	2010.	38.8	14.8	.3276	776'
647.	-9.4						776''
527.	547.	28.9	1.25	.8	1.85	1.58	777
321.	316.	.24	2010.	38.8	14.7	.3276	777'
647.	-9.4						777''
527.	546.	28.9	.62	.44	1.38	1.13	778
202.	203.	.235	2010.	37.9	14.3	.3276	778'
640.5	-9.5						778''
527.	546.	28.9	1.95	1.68	1.05	.86	779
141.	149.	.235	2010.	37.8	14.3	.3276	779'
636.5	-9.5						779''
527.	546.	28.9	1.85	1.71	.79	.58	780
153.	160.	.235	2010.	37.8	14.3	.3276	780'
640.	-9.5						780''
531.	546.	28.71	1.8	1.05	0.	0.	781
303.	1.	.262	2000.	40.3	15.3	.3758	781'
662.5	-8.8						781''

531.	546.	28.71	1.55	.77	0.	0.	782
315.	1.	.264	2005.	40.3	15.3	.3758	782'
663.5	-8.8						782''
531.	546.	28.71	1.61	.86	0.	0.	783
301.	1.	.266	2005.	40.3	15.3	.3758	783'
663.5	-8.8						783''
532.	547.	28.71	1.83	1.19	1.46	1.29	784
319.	330.	.258	2005.	39.5	15.0	.3887	784'
655.5	-8.8						784''
532.	547.	28.71	1.81	1.12	1.23	1.03	785
342.	371.	.258	2005.	39.5	14.9	.3887	785'
655.	-8.8						785''
532.	547.	28.71	1.01	.29	1.0	.81	786
358.	357.	.258	2000.	39.8	15.1	.3887	786'
654.	-8.8						786''
532.	545.	28.71	1.33	1.38	.67	.36	787
305.	304.	.251	2000.	39.3	14.9	.3887	787'
651.5	-8.9						787''
532.	545.	28.71	1.24	.69	1.98	1.69	788
371.	365.	.251	2005.	39.5	15.0	.3887	788'
652.5	-8.9						788''
532.	545.	28.71	1.48	1.05	1.62	1.32	789
304.	305.	.251	2000.	39.1	14.8	.3887	789'
652.5	-8.9						789''
532.	547.	28.71	1.62	1.33	1.67	1.18	790
311.	318.	.245	2000.	37.7	14.3	.3887	790'
637.5	-9.						790''
532.	547.	28.71	1.26	.96	1.06	.56	791
322.	314.	.247	2000.	37.8	14.3	.3887	791'
634.5	-9.0						791''
532.	547.	28.71	.94	.65	.51	.03	792
313.	305.	.247	2005.	37.7	14.3	.3887	792'
634.5	-9.0						792''
531.	546.	28.71	1.46	.6	0.	0.	793
330.	1.	.275	1995.	40.3	15.3	.3758	793'
674.5	-8.3						793''
531.	546.	28.71	1.52	.73	0.	0.	794
308.	1.	.275	2015.	40.3	15.4	.3758	794'
675.5	-8.4						794''
531.	546.	28.71	1.56	.75	0.	0.	795
310.	1.	.275	2010.	40.3	15.3	.3758	795'
675.5	-8.4						795''
531.	547.	28.71	1.53	.85	1.97	1.83	796
328.	334.	.267	2010.	39.9	15.2	.3758	796'
669.	-8.4						796''
531.	547.	28.71	1.83	1.24	1.65	1.5	797
307.	303.	.267	2010.	39.9	15.1	.3758	797'
669.	-8.4						797''
531.	547.	28.71	1.13	.52	1.46	1.3	798
305.	307.	.267	2010.	39.9	15.1	.3758	798'
669.	-8.4						798''
531.	546.	28.71	1.8	1.38	1.18	.87	799
308.	313.	.261	2010.	39.3	14.9	.3758	799'
667.5	-8.5						799''
531.	546.	28.71	1.27	.84	.79	.48	800
307.	308.	.262	2010.	39.1	14.9	.3758	800'
667.5	-8.5						800''
531.	546.	28.71	.76	.23	.42	.06	801
367.	354.	.262	2010.	39.0	14.8	.3758	801'
667.5	-8.5						801''

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531.        546.        28.71       1.81        1.54        1.55        1.1         802
316.        312.        .254        2010.       38.2        14.5        .3758       802'
652.5       -8.7                                                                    802''
531.        546.        28.71       1.49        1.22        1.02        .57         803
304.        302.        .255        2010.       38.3        14.5        .3758       803'
652.5       -8.6                                                                    803''
531.        546.        28.71       1.18        .9          .5          .04         804
308.        309.        .255        2010.       38.1        14.5        .3758       804'
655.5       -8.6                                                                    804''
$STOP
```

APPENDIX D

Computed Results

THE AVERAGED VALUES OF EXHAUST TEMPERATURE ARE

0.3543E 03	0.3733E 03	0.3927E 03	0.4233E 03	0.4345E 03
0.4288E 03	0.4293E 03	0.4323E 03	0.4498E 03	0.4802E 03
0.5177E 03	0.5503E 03	0.4838E 03	0.5093E 03	0.5413E 03
0.5658E 03	0.5872E 03	0.6283E 03	0.6762E 03	0.6982E 03
0.5702E 03	0.6107E 03	0.6678E 03	0.6992E 03	0.7220E 03
0.7362E 03	0.7733E 03	0.8113E 03	0.8515E 03	0.8760E 03
0.3592E 03	0.3715E 03	0.3870E 03	0.4060E 03	0.4252E 03
0.4108E 03	0.4145E 03	0.4178E 03	0.4242E 03	0.4513E 03
0.4935E 03	0.5240E 03	0.4717E 03	0.4842E 03	0.5000E 03
0.5150E 03	0.5357E 03	0.5530E 03	0.5917E 03	0.6410E 03
0.6818E 03	0.5425E 03	0.5777E 03	0.6352E 03	0.6692E 03
0.6880E 03	0.7147E 03	0.7407E 03	0.7830E 03	0.8270E 03
0.8368E 03	0.5285E 03	0.5285E 03	0.5285E 03	0.5267E 03
0.5340E 03	0.5570E 03	0.5757E 03	0.5913E 03	0.5895E 03
0.4525E 03	0.4472E 03	0.4440E 03	0.4090E 03	0.4070E 03
0.5208E 03	0.5170E 03	0.5152E 03	0.5045E 03	0.5075E 03
0.5743E 03	0.5698E 03	0.5718E 03	0.5687E 03	0.5692E 03
0.6503E 03	0.6562E 03	0.6510E 03	0.6523E 03	0.6392E 03
0.5492E 03	0.5462E 03	0.5438E 03	0.5420E 03	0.5427E 03
0.7128E 03	0.7130E 03	0.7130E 03	0.7145E 03	0.7002E 03
0.7633E 03	0.7728E 03	0.7678E 03	0.7627E 03	0.8532E 03
0.8457E 03	0.8453E 03	0.8567E 03	0.8552E 03	0.5017E 03
0.4992E 03	0.4975E 03	0.4890E 03	0.4852E 03	0.5010E 03
0.4985E 03	0.4975E 03	0.4932E 03	0.4850E 03	0.5047E 03
0.5002E 03	0.4965E 03	0.4903E 03	0.4808E 03	0.4737E 03
0.4713E 03	0.4677E 03	0.4612E 03	0.4532E 03	0.4752E 03
0.4688E 03	0.4675E 03	0.4593E 03	0.4503E 03	0.4705E 03
0.4713E 03	0.4662E 03	0.4598E 03	0.4530E 03	0.6428E 03
0.6277E 03	0.6252E 03	0.6152E 03	0.6503E 03	0.6373E 03
0.6315E 03	0.6187E 03	0.6537E 03	0.6430E 03	0.6315E 03
0.6260E 03	0.6582E 03	0.6572E 03	0.6483E 03	0.6390E 03
0.6632E 03	0.6543E 03	0.6522E 03	0.6355E 03	0.6752E 03
0.6690E 03	0.6675E 03	0.6535E 03		

THE AVERAGED VALUES OF ENGINE SPEED ARE

0.8250E 03	0.1123E 04	0.1383E 04	0.1625E 04	0.1853E 04
0.2050E 04	0.2200E 04	0.2405E 04	0.2600E 04	0.2800E 04
0.3000E 04	0.3200E 04	0.1482E 04	0.1735E 04	0.1950E 04
0.2240E 04	0.2500E 04	0.2745E 04	0.3020E 04	0.3222E 04
0.1455E 04	0.1620E 04	0.1820E 04	0.2015E 04	0.2190E 04
0.2415E 04	0.2600E 04	0.2822E 04	0.2997E 04	0.3215E 04
0.8833E 03	0.1140E 04	0.1422E 04	0.1612E 04	0.1830E 04
0.2067E 04	0.2193E 04	0.2390E 04	0.2603E 04	0.2808E 04
0.3037E 04	0.3220E 04	0.1520E 04	0.1703E 04	0.1907E 04
0.2125E 04	0.2318E 04	0.2523E 04	0.2745E 04	0.2990E 04
0.3212E 04	0.1423E 04	0.1603E 04	0.1820E 04	0.2010E 04
0.2212E 04	0.2415E 04	0.2620E 04	0.2830E 04	0.3018E 04
0.2227E 04	0.3212E 04	0.3000E 04	0.2800E 04	0.2603E 04
0.2403E 04	0.2200E 04	0.2000E 04	0.1805E 04	0.1600E 04
0.1520E 04	0.1515E 04	0.1520E 04	0.1520E 04	0.1520E 04
0.2022E 04	0.2035E 04	0.2040E 04	0.2040E 04	0.2040E 04
0.2533E 04	0.2537E 04	0.2535E 04	0.2538E 04	0.2540E 04
0.3007E 04	0.3005E 04	0.3005E 04	0.3003E 04	0.3010E 04
0.1500E 04	0.1505E 04	0.1503E 04	0.1505E 04	0.1505E 04
0.2013E 04	0.2005E 04	0.2005E 04	0.2003E 04	0.2005E 04
0.2503E 04	0.2505E 04	0.2505E 04	0.2505E 04	0.3002E 04
0.3005E 04	0.3005E 04	0.3005E 04	0.3005E 04	0.2002E 04
0.2002E 04	0.2002E 04	0.2002E 04	0.2002E 04	0.2005E 04
0.2018E 04	0.2020E 04	0.2020E 04	0.2020E 04	0.2015E 04

0.2017E 04	0.2015E 04	0.2015E 04	0.2015E 04	0.2017E 04
0.2018E 04	0.2015E 04	0.2015E 04	0.2015E 04	0.2020E 04
0.2013E 04	0.2015E 04	0.2015E 04	0.2015E 04	0.2013E 04
0.2015E 04	0.2015E 04	0.2015E 04	0.2015E 04	0.2003E 04
0.2008E 04	0.2010E 04	0.2010E 04	0.2012E 04	0.2010E 04
0.2010E 04	0.2010E 04	0.2015E 04	0.2013E 04	0.2005E 04
0.2005E 04	0.2008E 04	0.2003E 04	0.2010E 04	0.2010E 04
0.2003E 04	0.2003E 04	0.2002E 04	0.2002E 04	0.2007E 04
0.2010E 04	0.2010E 04	0.2010E 04		

THE PERCENT GASOLINE IS

0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
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0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
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0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
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0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01	0.1000E 01
0.1000E 01	0.1000E 01	0.1000E 01	0.7271E 00	0.7823E 00
0.7825E 00	0.5814E 00	0.6083E 00	0.5708E 00	0.3593E 00
0.3798E 00	0.3854E 00	0.2234E 00	0.2143E 00	0.2318E 00
0.1000E 01	0.1000E 01	0.1000E 01	0.8146E 00	0.3055E 00
0.8056E 00	0.6175E 00	0.5840E 00	0.5862E 00	0.4040E 00
0.4493E 00	0.4582E 00	0.2736E 00	0.2134E 00	0.2267E 00
0.1000E 01	0.1000E 01	0.1000E 01	0.8179E 00	0.7857E 00

0.7913E 00	0.5641E 00	0.6000E 00	0.5824E 00	0.3602E 00
0.4074E 00	0.4220E 00	0.2333E 00	0.2171E 00	0.2177E 00
0.1000E 01	0.1000E 01	0.1000E 01	0.7735E 00	0.7631E 00
0.7700E 00	0.5167E 00	0.5907E 00	0.5430E 00	0.3529E 00
0.3638E 00	0.3745E 00	0.2101E 00	0.1901E 00	0.1904E 00
0.1000E 01	0.1000E 01	0.1000E 01	0.7703E 00	0.7730E 00
0.7706E 00	0.5674E 00	0.5494E 00	0.6298E 00	0.3758E 00
0.3491E 00	0.3597E 00	0.1743E 00	0.1301E 00	0.1670E 00
0.1000E 01	0.1000E 01	0.1000E 01	0.8001E 00	0.3097E 00
0.8096E 00	0.6384E 00	0.6148E 00	0.6021E 00	0.3761E 00
0.4120E 00	0.3869E 00	0.2531E 00	0.3053E 00	0.3030E 00
0.1000E 01	0.1000E 01	0.1000E 01	0.8249E 00	0.3092E 00
0.8099E 00	0.6335E 00	0.6121E 00	0.6746E 00	0.3936E 00
0.4050E 00	0.4204E 00	0.1000E 01	0.1000E 01	0.1000E 01
0.8517E 00	0.8121E 00	0.3070E 00	0.6358E 00	0.6156E 00
0.6676E 00	0.4440E 00	0.4278E 00	0.4425E 00	0.2862E 00
0.2879E 00	0.2808E 00	0.1000E 01	0.1000E 01	0.1000E 01
0.7948E 00	0.8541E 00	0.8138E 00	0.5921E 00	0.5839E 00
0.6361E 00	0.4152E 00	0.4138E 00	0.3887E 00	0.1905E 00
0.2454E 00	0.2380E 00	0.1000E 01	0.1000E 01	0.1000E 01
0.8217E 00	0.8038E 00	0.7919E 00	0.5837E 00	0.5846E 00
0.5714E 00	0.3304E 00	0.3356E 00	0.3446E 00	0.1341E 00
0.1483E 00	0.1340E 00	0.1000E 01	0.1000E 01	0.1000E 01
0.8287E 00	0.8178E 00	0.8001E 00	0.5874E 00	0.5556E 00
0.5674E 00	0.3355E 00	0.3533E 00	0.3488E 00	0.1536E 00
0.1500E 00	0.1427E 00	0.1000E 01	0.1000E 01	0.1000E 01
0.8073E 00	0.7359E 00	0.7939E 00	0.5520E 00	0.5648E 00
0.5347E 00	0.3505E 00	0.3446E 00	0.3546E 00	0.2055E 00
0.2102E 00	0.2075E 00	0.1000E 01	0.1000E 01	0.1000E 01
0.8453E 00	0.7995E 00	0.8057E 00	0.5889E 00	0.5589E 00
0.5795E 00	0.3745E 00	0.4157E 00	0.3800E 00	0.2223E 00
0.2263E 00	0.2247E 00	0.1000E 01	0.1000E 01	0.1000E 01
0.7842E 00	0.7722E 00	0.7874E 00	0.5584E 00	0.5206E 00
0.5340E 00	0.3196E 00	0.3081E 00	0.3476E 00	0.1226E 00
0.1481E 00	0.1436E 00	0.1000E 01	0.1000E 01	0.1000E 01
0.8000E 00	0.7377E 00	0.7842E 00	0.5748E 00	0.5808E 00
0.6322E 00	0.3939E 00	0.3738E 00	0.3860E 00	0.1000E 01
0.1000E 01	0.1000E 01	0.7862E 00	0.7809E 00	0.7757E 00
0.6033E 00	0.5333E 00	0.5787E 00	0.3796E 00	0.3682E 00
0.3558E 00	0.1000E 01	0.1000E 01	0.1000E 01	0.8031E 00
0.7932E 00	0.7368E 00	0.6048E 00	0.5898E 00	0.5850E 00
0.3977E 00	0.3917E 00	0.3855E 00	0.1000E 01	0.1000E 01
0.1000E 01	0.8045E 00	0.7974E 00	0.8072E 00	0.5866E 00
0.5874E 00	0.6135E 00	0.4118E 00	0.2736E 00	0.4028E 00
0.1000E 01	0.1000E 01	0.1000E 01	0.7903E 00	0.7836E 00
0.7852E 00	0.5833E 00	0.6435E 00	0.5813E 00	0.3693E 00
0.3615E 00	0.3629E 00	0.1000E 01	0.1000E 01	0.1000E 01
0.8272E 00	0.7897E 00	0.7878E 00	0.5712E 00	0.5733E 00
0.5788E 00	0.3643E 00	0.3658E 00	0.3714E 00	

THE AVERAGED VALUES OF THERMAL EFFICIENCY ARE

0.4625E-01	0.5242E-01	0.5550E-01	0.5871E-01	0.6459E-01
0.6522E-01	0.6248E-01	0.5809E-01	0.6188E-01	0.6251E-01
0.6672E-01	0.6614E-01	0.1886E 00	0.2033E 00	0.2052E 00
0.1971E 00	0.1857E 00	0.1818E 00	0.1863E 00	0.1758E 00
0.2678E 00	0.2860E 00	0.2553E 00	0.2477E 00	0.2468E 00
0.2366E 00	0.2422E 00	0.2513E 00	0.2534E 00	0.2333E 00
0.6103E-01	0.5496E-01	0.6119E-01	0.6740E-01	0.6970E-01
0.7276E-01	0.7494E-01	0.6702E-01	0.6736E-01	0.6669E-01

0.7193E-01	0.7270E-01	0.2113E 00	0.2107E 00	0.2308E 00
0.2273E 00	0.2061E 00	0.2022E 00	0.1990E 00	0.1979E 00
0.1905E 00	0.2900E 00	0.2825E 00	0.2644E 00	0.2657E 00
0.2694E 00	0.2684E 00	0.2675E 00	0.2576E 00	0.2640E 00
0.2512E 00	0.3352E-01	0.1125E 00	0.1436E 00	0.1691E 00
0.1995E 00	0.2281E 00	0.2541E 00	0.2648E 00	0.2656E 00
0.1513E 00	0.1487E 00	0.1465E 00	0.1401E 00	0.1763E 00
0.1757E 00	0.1750E 00	0.1386E 00	0.1796E 00	0.1707E 00
0.1669E 00	0.1671E 00	0.1630E 00	0.1635E 00	0.1660E 00
0.1689E 00	0.1609E 00	0.1674E 00	0.1829E 00	0.1821E 00
0.2268E 00	0.2137E 00	0.2314E 00	0.2482E 00	0.2501E 00
0.2616E 00	0.2677E 00	0.2719E 00	0.2914E 00	0.3430E 00
0.2265E 00	0.2244E 00	0.2309E 00	0.2357E 00	0.2292E 00
0.2328E 00	0.2359E 00	0.2648E 00	0.2951E 00	0.1624E 00
0.1660E 00	0.1683E 00	0.1550E 00	0.1392E 00	0.1655E 00
0.1668E 00	0.1804E 00	0.1819E 00	0.1654E 00	0.1646E 00
0.1746E 00	0.1729E 00	0.1746E 00	0.1656E 00	0.1692E 00
0.1580E 00	0.1650E 00	0.1553E 00	0.1328E 00	0.1736E 00
0.1732E 00	0.1675E 00	0.1555E 00	0.1423E 00	0.1728E 00
0.1753E 00	0.1689E 00	0.1629E 00	0.1546E 00	0.2307E 00
0.2197E 00	0.2170E 00	0.2073E 00	0.2245E 00	0.2199E 00
0.2183E 00	0.2097E 00	0.2202E 00	0.2115E 00	0.2198E 00
0.2159E 00	0.2228E 00	0.2308E 00	0.2275E 00	0.2531E 00
0.2301E 00	0.2173E 00	0.2270E 00	0.2048E 00	0.2205E 00
0.2251E 00	0.2242E 00	0.2202E 00		

THE AVERAGED VALUES OF VOLUMETRIC EFFICIENCY ARE

0.3279E 00	0.2940E 00	0.2598E 00	0.2734E 00	0.2561E 00
0.2402E 00	0.2369E 00	0.2378E 00	0.2398E 00	0.2485E 00
0.2593E 00	0.2725E 00	0.4266E 00	0.4047E 00	0.4022E 00
0.3876E 00	0.3854E 00	0.3917E 00	0.3908E 00	0.3926E 00
0.5253E 00	0.5214E 00	0.5305E 00	0.5316E 00	0.5373E 00
0.5361E 00	0.5487E 00	0.5520E 00	0.5587E 00	0.5595E 00
0.3235E 00	0.2875E 00	0.2666E 00	0.2622E 00	0.2609E 00
0.2508E 00	0.2509E 00	0.2463E 00	0.2479E 00	0.2553E 00
0.2619E 00	0.2673E 00	0.3549E 00	0.3450E 00	0.3536E 00
0.3522E 00	0.3546E 00	0.3547E 00	0.3610E 00	0.3705E 00
0.3782E 00	0.5000E 00	0.5021E 00	0.5073E 00	0.5130E 00
0.5135E 00	0.5333E 00	0.5321E 00	0.5342E 00	0.5404E 00
0.5444E 00	0.2601E 00	0.2775E 00	0.2972E 00	0.3196E 00
0.3471E 00	0.3694E 00	0.4037E 00	0.4436E 00	0.4857E 00
0.3763E 00	0.3725E 00	0.3739E 00	0.3677E 00	0.3621E 00
0.3749E 00	0.3663E 00	0.3592E 00	0.3566E 00	0.3510E 00
0.3727E 00	0.3666E 00	0.3626E 00	0.3559E 00	0.3546E 00
0.3842E 00	0.3794E 00	0.3751E 00	0.3701E 00	0.3657E 00
0.5516E 00	0.5459E 00	0.5400E 00	0.5335E 00	0.5264E 00
0.5667E 00	0.5590E 00	0.5522E 00	0.5460E 00	0.5406E 00
0.5833E 00	0.5729E 00	0.5662E 00	0.5593E 00	0.5309E 00
0.5736E 00	0.5680E 00	0.5618E 00	0.5594E 00	0.3807E 00
0.3742E 00	0.3676E 00	0.3634E 00	0.3557E 00	0.3842E 00
0.3761E 00	0.3712E 00	0.3630E 00	0.3594E 00	0.3827E 00
0.3746E 00	0.3693E 00	0.3621E 00	0.3583E 00	0.3680E 00
0.3630E 00	0.3586E 00	0.3578E 00	0.3435E 00	0.3713E 00
0.3637E 00	0.3589E 00	0.3519E 00	0.3485E 00	0.3707E 00
0.3659E 00	0.3612E 00	0.3540E 00	0.3500E 00	0.5617E 00
0.5486E 00	0.5426E 00	0.5342E 00	0.5681E 00	0.5567E 00
0.5591E 00	0.5429E 00	0.5700E 00	0.5662E 00	0.5520E 00
0.5481E 00	0.5978E 00	0.5704E 00	0.5602E 00	0.5539E 00
0.5916E 00	0.5655E 00	0.5770E 00	0.5726E 00	0.6029E 00
0.5935E 00	0.5871E 00	0.5791E 00		

THE AVERAGED VALUES OF AIR-FUEL RATIO ARE

0.1919E 02	0.1866E 02	0.1631E 02	0.1675E 02	0.1625E 02
0.1518E 02	0.1459E 02	0.1320E 02	0.1376E 02	0.1419E 02
0.1509E 02	0.1527E 02	0.1995E 02	0.2069E 02	0.1975E 02
0.1791E 02	0.1703E 02	0.1723E 02	0.1759E 02	0.1693E 02
0.1733E 02	0.1822E 02	0.1629E 02	0.1554E 02	0.1556E 02
0.1484E 02	0.1550E 02	0.1652E 02	0.1694E 02	0.1604E 02
0.2251E 02	0.1804E 02	0.1739E 02	0.1841E 02	0.1772E 02
0.1709E 02	0.1689E 02	0.1422E 02	0.1467E 02	0.1498E 02
0.1602E 02	0.1611E 02	0.1357E 02	0.1774E 02	0.1930E 02
0.1876E 02	0.1697E 02	0.1693E 02	0.1707E 02	0.1771E 02
0.1756E 02	0.1761E 02	0.1704E 02	0.1572E 02	0.1572E 02
0.1588E 02	0.1644E 02	0.1637E 02	0.1604E 02	0.1671E 02
0.1619E 02	0.1660E 02	0.1652E 02	0.1676E 02	0.1624E 02
0.1644E 02	0.1662E 02	0.1689E 02	0.1610E 02	0.1570E 02
0.1379E 02	0.1431E 02	0.1464E 02	0.1455E 02	0.1410E 02
0.1513E 02	0.1516E 02	0.1620E 02	0.1631E 02	0.1583E 02
0.1416E 02	0.1446E 02	0.1453E 02	0.1477E 02	0.1527E 02
0.1504E 02	0.1466E 02	0.1564E 02	0.1744E 02	0.1792E 02
0.1482E 02	0.1417E 02	0.1544E 02	0.1667E 02	0.1744E 02
0.1702E 02	0.1760E 02	0.1826E 02	0.2003E 02	0.2391E 02
0.1523E 02	0.1505E 02	0.1573E 02	0.1619E 02	0.1551E 02
0.1572E 02	0.1623E 02	0.1843E 02	0.2133E 02	0.1435E 02
0.1533E 02	0.1573E 02	0.1549E 02	0.1511E 02	0.1463E 02
0.1489E 02	0.1626E 02	0.1663E 02	0.1635E 02	0.1460E 02
0.1557E 02	0.1599E 02	0.1673E 02	0.1679E 02	0.1462E 02
0.1432E 02	0.1526E 02	0.1511E 02	0.1424E 02	0.1540E 02
0.1549E 02	0.1547E 02	0.1506E 02	0.1467E 02	0.1510E 02
0.1566E 02	0.1580E 02	0.1581E 02	0.1574E 02	0.1509E 02
0.1464E 02	0.1478E 02	0.1461E 02	0.1481E 02	0.1465E 02
0.1492E 02	0.1473E 02	0.1467E 02	0.1460E 02	0.1505E 02
0.1538E 02	0.1511E 02	0.1555E 02	0.1548E 02	0.1772E 02
0.1556E 02	0.1490E 02	0.1557E 02	0.1459E 02	0.1518E 02
0.1556E 02	0.1575E 02	0.1575E 02		

THE AVERAGED VALUES OF BRAKE MEAN EFFECTIVE PRESSURE ARE

0.6504E 01	0.6765E 01	0.7077E 01	0.7493E 01	0.7805E 01
0.7961E 01	0.8014E 01	0.8113E 01	0.8222E 01	0.8352E 01
0.8690E 01	0.8898E 01	0.3028E 02	0.3078E 02	0.3133E 02
0.3190E 02	0.3153E 02	0.3091E 02	0.3070E 02	0.3002E 02
0.6041E 02	0.6088E 02	0.6203E 02	0.6276E 02	0.6312E 02
0.6322E 02	0.6307E 02	0.6213E 02	0.6182E 02	0.6083E 02
0.6561E 01	0.7181E 01	0.7389E 01	0.7649E 01	0.8118E 01
0.8482E 01	0.8742E 01	0.9054E 01	0.8794E 01	0.8742E 01
0.8950E 01	0.9106E 01	0.3023E 02	0.3075E 02	0.3133E 02
0.3169E 02	0.3174E 02	0.3143E 02	0.3117E 02	0.3065E 02
0.3018E 02	0.6031E 02	0.6093E 02	0.6229E 02	0.6312E 02
0.6333E 02	0.6233E 02	0.6302E 02	0.6203E 02	0.6140E 02
0.6062E 02	0.1004E 02	0.1436E 02	0.1925E 02	0.2508E 02
0.3133E 02	0.3825E 02	0.4543E 02	0.5459E 02	0.6156E 02
0.3023E 02	0.2688E 02	0.2826E 02	0.2654E 02	0.2451E 02
0.3138E 02	0.3086E 02	0.3060E 02	0.2909E 02	0.2820E 02
0.3153E 02	0.3070E 02	0.3018E 02	0.2930E 02	0.2857E 02
0.3075E 02	0.3013E 02	0.2935E 02	0.2320E 02	0.2716E 02
0.6052E 02	0.5927E 02	0.5864E 02	0.5797E 02	0.5615E 02
0.6276E 02	0.6166E 02	0.6015E 02	0.5328E 02	0.5745E 02
0.6307E 02	0.6244E 02	0.6119E 02	0.6067E 02	0.6151E 02
0.6083E 02	0.5937E 02	0.5833E 02	0.5615E 02	0.3138E 02
0.2961E 02	0.2898E 02	0.2706E 02	0.2456E 02	0.3138E 02
0.3065E 02	0.3023E 02	0.2940E 02	0.2737E 02	0.3138E 02

0.3065E 02	0.2956E 02	0.2820E 02	0.2659E 02	0.3138E 02
0.3028E 02	0.2919E 02	0.2238E 02	0.2472E 02	0.3134E 02
0.3075E 02	0.2945E 02	0.2794E 02	0.2602E 02	0.3138E 02
0.3065E 02	0.2909E 02	0.2768E 02	0.2643E 02	0.6291E 02
0.6104E 02	0.5927E 02	0.5703E 02	0.6291E 02	0.6166E 02
0.6005E 02	0.5786E 02	0.6291E 02	0.6047E 02	0.5963E 02
0.5683E 02	0.6291E 02	0.6192E 02	0.6052E 02	0.5906E 02
0.6291E 02	0.6182E 02	0.6135E 02	0.5890E 02	0.6291E 02
0.6229E 02	0.6109E 02	0.5963E 02		

THE AVERAGED VALUES OF BRAKE SPECIFIC FUEL CONSUMPTION ARE

0.2890E 01	0.2562E 01	0.2406E 01	0.2273E 01	0.2062E 01
0.2043E 01	0.2132E 01	0.2261E 01	0.2150E 01	0.2123E 01
0.1996E 01	0.2013E 01	0.7053E 00	0.6401E 00	0.6452E 00
0.6750E 00	0.7161E 00	0.7319E 00	0.7140E 00	0.7572E 00
0.4967E 00	0.4654E 00	0.5222E 00	0.5371E 00	0.5393E 00
0.5626E 00	0.5492E 00	0.5295E 00	0.5249E 00	0.5703E 00
0.2204E 01	0.2420E 01	0.2175E 01	0.1984E 01	0.1909E 01
0.1832E 01	0.1780E 01	0.1986E 01	0.1976E 01	0.1997E 01
0.1850E 01	0.1830E 01	0.6328E 00	0.6315E 00	0.5793E 00
0.5858E 00	0.6459E 00	0.6584E 00	0.6687E 00	0.6729E 00
0.6983E 00	0.4587E 00	0.4720E 00	0.5031E 00	0.5007E 00
0.4944E 00	0.4957E 00	0.4973E 00	0.5166E 00	0.5039E 00
0.5299E 00	0.1594E 01	0.1184E 01	0.9289E 00	0.7867E 00
0.6667E 00	0.5332E 00	0.5243E 00	0.5032E 00	0.5013E 00
0.8791E 00	0.8890E 00	0.8963E 00	0.9300E 00	0.1030E 01
0.7575E 00	0.7559E 00	0.6972E 00	0.7338E 00	0.7609E 00
0.7973E 00	0.7913E 00	0.8072E 00	0.7981E 00	0.7814E 00
0.7875E 00	0.8204E 00	0.7829E 00	0.7131E 00	0.7143E 00
0.5871E 00	0.6178E 00	0.5687E 00	0.5290E 00	0.5213E 00
0.5085E 00	0.4941E 00	0.4823E 00	0.4490E 00	0.3803E 00
0.5872E 00	0.5692E 00	0.5698E 00	0.5443E 00	0.5803E 00
0.5686E 00	0.5574E 00	0.4943E 00	0.4407E 00	0.3211E 00
0.7963E 00	0.7834E 00	0.8418E 00	0.9353E 00	0.8038E 00
0.7930E 00	0.7293E 00	0.7170E 00	0.7852E 00	0.8031E 00
0.7581E 00	0.7590E 00	0.7482E 00	0.7321E 00	0.7874E 00
0.8363E 00	0.7954E 00	0.8407E 00	0.9765E 00	0.7678E 00
0.7642E 00	0.7840E 00	0.8391E 00	0.9112E 00	0.7701E 00
0.7553E 00	0.7763E 00	0.8005E 00	0.8388E 00	0.5769E 00
0.6017E 00	0.6056E 00	0.6302E 00	0.5926E 00	0.6006E 00
0.6014E 00	0.6216E 00	0.6040E 00	0.6243E 00	0.5973E 00
0.6046E 00	0.5972E 00	0.5727E 00	0.5774E 00	0.5193E 00
0.5781E 00	0.6080E 00	0.5794E 00	0.6361E 00	0.6032E 00
0.5872E 00	0.5854E 00	0.5917E 00		

THE AVERAGED VALUES OF INTAKE MANIFOLD PRESSURE ARE

-0.1567E 02	-0.1690E 02	-0.1757E 02	-0.1777E 02	-0.1857E 02
-0.1880E 02	-0.1867E 02	-0.1860E 02	-0.1893E 02	-0.1910E 02
-0.1920E 02	-0.1900E 02	-0.1437E 02	-0.1527E 02	-0.1540E 02
-0.1510E 02	-0.1503E 02	-0.1527E 02	-0.1557E 02	-0.1547E 02
-0.9600E 01	-0.9600E 01	-0.1020E 02	-0.1030E 02	-0.1010E 02
-0.9500E 01	-0.9400E 01	-0.9800E 01	-0.1023E 02	-0.1033E 02
-0.1597E 02	-0.1690E 02	-0.1807E 02	-0.1827E 02	-0.1893E 02
-0.1917E 02	-0.1900E 02	-0.1890E 02	-0.1923E 02	-0.1947E 02
-0.1950E 02	-0.1943E 02	-0.1490E 02	-0.1540E 02	-0.1613E 02
-0.1610E 02	-0.1580E 02	-0.1570E 02	-0.1590E 02	-0.1620E 02
-0.1603E 02	-0.1043E 02	-0.1020E 02	-0.1077E 02	-0.1093E 02
-0.1030E 02	-0.1007E 02	-0.1013E 02	-0.1047E 02	-0.1080E 02
-0.1083E 02	-0.1070E 02	-0.1907E 02	-0.1810E 02	-0.1710E 02

-0.1607E 02	-0.1540E 02	-0.1443E 02	-0.1277E 02	-0.1033E 02
-0.1430E 02	-0.1490E 02	-0.1500E 02	-0.1503E 02	-0.1520E 02
-0.1567E 02	-0.1587E 02	-0.1600E 02	-0.1610E 02	-0.1620E 02
-0.1550E 02	-0.1553E 02	-0.1553E 02	-0.1567E 02	-0.1570E 02
-0.1600E 02	-0.1580E 02	-0.1580E 02	-0.1593E 02	-0.1620E 02
-0.9867E 01	-0.9433E 01	-0.9533E 01	-0.9600E 01	-0.9800E 01
-0.9933E 01	-0.1000E 02	-0.1010E 02	-0.1017E 02	-0.1030E 02
-0.8900E 01	-0.8800E 01	-0.8900E 01	-0.9167E 01	-0.9767E 01
-0.9900E 01	-0.9900E 01	-0.9933E 01	-0.1010E 02	-0.1547E 02
-0.1553E 02	-0.1563E 02	-0.1573E 02	-0.1550E 02	-0.1557E 02
-0.1570E 02	-0.1570E 02	-0.1583E 02	-0.1597E 02	-0.1553E 02
-0.1570E 02	-0.1580E 02	-0.1590E 02	-0.1607E 02	-0.1623E 02
-0.1630E 02	-0.1640E 02	-0.1650E 02	-0.1670E 02	-0.1600E 02
-0.1620E 02	-0.1627E 02	-0.1640E 02	-0.1650E 02	-0.1607E 02
-0.1610E 02	-0.1623E 02	-0.1630E 02	-0.1650E 02	-0.1033E 02
-0.1060E 02	-0.1070E 02	-0.1077E 02	-0.9933E 01	-0.1010E 02
-0.1020E 02	-0.1040E 02	-0.9733E 01	-0.9833E 01	-0.1000E 02
-0.1010E 02	-0.9067E 01	-0.9333E 01	-0.9400E 01	-0.9500E 01
-0.8800E 01	-0.8200E 01	-0.8900E 01	-0.9000E 01	-0.8367E 01
-0.8400E 01	-0.8500E 01	-0.8633E 01		

THE AVERAGED VALUES OF HORSEPOWER ARE

0.5867E 00	0.8333E 00	0.1100E 01	0.1400E 01	0.1700E 01
0.1900E 01	0.2000E 01	0.2233E 01	0.2500E 01	0.2733E 01
0.3067E 01	0.3367E 01	0.5400E 01	0.6400E 01	0.7400E 01
0.8633E 01	0.9500E 01	0.1023E 02	0.1123E 02	0.1173E 02
0.1060E 02	0.1190E 02	0.1357E 02	0.1530E 02	0.1670E 02
0.1847E 02	0.1990E 02	0.2130E 02	0.2243E 02	0.2343E 02
0.7000E 00	0.9000E 00	0.1200E 01	0.1400E 01	0.1700E 01
0.2000E 01	0.2200E 01	0.2500E 01	0.2667E 01	0.2867E 01
0.3200E 01	0.3467E 01	0.5500E 01	0.6233E 01	0.7200E 01
0.8100E 01	0.8900E 01	0.9533E 01	0.1030E 02	0.1103E 02
0.1170E 02	0.1037E 02	0.1130E 02	0.1373E 02	0.1527E 02
0.1697E 02	0.1853E 02	0.2000E 02	0.2130E 02	0.2253E 02
0.2333E 02	0.3800E 01	0.5133E 01	0.6433E 01	0.7833E 01
0.9033E 01	0.1010E 02	0.1100E 02	0.1190E 02	0.1190E 02
0.5500E 01	0.5233E 01	0.5033E 01	0.4800E 01	0.4400E 01
0.7667E 01	0.7533E 01	0.7533E 01	0.7067E 01	0.6867E 01
0.9667E 01	0.9400E 01	0.9200E 01	0.8867E 01	0.8667E 01
0.1120E 02	0.1090E 02	0.1057E 02	0.1020E 02	0.9900E 01
0.1097E 02	0.1080E 02	0.1067E 02	0.1053E 02	0.1017E 02
0.1530E 02	0.1497E 02	0.1457E 02	0.1413E 02	0.1390E 02
0.1907E 02	0.1890E 02	0.1850E 02	0.1343E 02	0.2233E 02
0.2217E 02	0.2157E 02	0.2130E 02	0.2047E 02	0.7500E 01
0.7100E 01	0.6933E 01	0.6433E 01	0.5333E 01	0.7600E 01
0.7433E 01	0.7300E 01	0.7133E 01	0.6567E 01	0.7567E 01
0.7400E 01	0.7100E 01	0.6767E 01	0.6367E 01	0.7633E 01
0.7233E 01	0.7033E 01	0.6633E 01	0.5933E 01	0.7567E 01
0.7400E 01	0.7100E 01	0.6700E 01	0.6233E 01	0.7600E 01
0.7367E 01	0.7000E 01	0.6633E 01	0.6300E 01	0.1530E 02
0.1493E 02	0.1443E 02	0.1383E 02	0.1533E 02	0.1503E 02
0.1457E 02	0.1410E 02	0.1530E 02	0.1470E 02	0.1450E 02
0.1383E 02	0.1533E 02	0.1503E 02	0.1473E 02	0.1430E 02
0.1530E 02	0.1500E 02	0.1490E 02	0.1430E 02	0.1533E 02
0.1513E 02	0.1467E 02	0.1450E 02		

OPERATIONAL CHARACTERISTICS OF AN INTERNAL COMBUSTION ENGINE USING MIXTURES OF GASOLINE AND PROPANE AS THE FUEL

by

Walter Conley Williams

B.S., Kansas State University, 1975

AN ABSTRACT OF A MASTER'S THESIS

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ABSTRACT

This study deals with the trends in an engine's performance as the composition of the fuel was changed from 100 per cent gasoline to a 20 per cent gasoline-80 per cent propane mixture in four steps. The performance parameters investigated are air-fuel ratio, brake specific fuel consumption, thermal efficiency, volumetric efficiency, brake mean effective pressure, exhaust gas temperature, and intake manifold vacuum. The seven testing groups consisted of various combinations of engine speed, compression ratio, load condition, ignition timing and, of course, fuel composition.

Group one was run at 100 per cent gasoline, 0^{o}tdc ignition timing, 7.7:1 compression ratio, and varying engine speed and load condition. Group two was the same as group one except that the compression ratio was 8.8:1. Group three, unlike any other, was a constant throttle setting sequence with all other settings similar to those in group two. Groups four and five were run with the only difference between them being the load on the engine. The other conditions were 0^{o}tdc ignition timing, 8.8:1 compression ratio, and constant load condition. The variables here were fuel composition and engine speed. Test groups six and seven again only differed in the load on the engine. Constant settings were the engine speed at 2000 rpm, load condition, and compression ratio of 8.8:1. Those items which were altered in these tests were ignition timing and fuel composition.