PROGRESS REPORT NO. 6

# KINETICS OF OXIDATION AND QUENCHING OF COMBUSTIBLES IN EXHAUST SYSTEMS OF GASOLINE ENGINES

D. J. PATTERSON

PERIOD: AUGUST 1, 1969 to AUGUST 31, 1969

AUGUST 1969

This project is under the technical supervision of the:

Coordinating Research Council
APRAC-Cape 8-68 Steering Committee

and is work performed by the:

Department of Mechanical Engineering
The University of Michigan
Ann Arbor, Michigan

Under Contract No. CAPE-8-68(1-68)-CRC
and Contract No. CPA-22-69-51-HEW

## LONG-RANGE OBJECTIVES

It is well-known that a significant amount of CO and unburned fuel may be consumed in the exhaust system of gasoline engines. Such combustion phenomena in exhaust reactors may be used to advantage to reduce the emission of these undesirable constituents. This process is the basis of exhaust air injection systems currently installed on some automobiles.

The overall objectives of this three-year research program are:

- To determine the chemical and physical processes which affect the emission characteristics of exhaust reactors installed on selected typical engines operating at various conditions on a dynamometer test stand.
- To identify the chemical species and significant chemical reactions present before, within, and after the reactor.
- To obtain information which will be helpful in predicting the design of the next generation of gasoline engine exhaust reactors.

## PHASE I PROGRESS

A group of preliminary engine tests were run in order to check out procedures and equipment, and determine emission levels from the standard 350 CID Chevrolet engine. NDIR and FID hydrocarbons, CO, $CO_2$, and oxygen concentrations were measured by continuous sampling at the tailpipe, wye, and exhaust ports for a variety of engine operating conditions. The General Motors test code was followed for performance testing. Water out temperature was set at 190$^{\circ}$F and oil temperature was limited to 230$^{\circ}$F. Tailpipe emissions from two data sets are discussed below.

## ENGINE SPEED

Data was taken to study the effect of engine speed on emissions. Operating conditions were:

Speed: 800 to 2400 rpm at 200 rpm increments

Load: constant at about 17 Bhp (calculated road load at 45 mph)

Ignition Timing: minimum advance for best torque

Air-Fuel Ratio: approximately 15.5:1

Figure 1 shows the hydrocarbon concentrations measured at the tailpipe. Both FID and NDIR readings are shown. As expected, the HC concentration decreased as speed was increased. Figure 2 shows tailpipe, CO, $CO_2$, and oxygen concentrations. All three remained constant because the air-fuel ratio was held constant. The manifold vacuum as a function of engine speed is plotted in Figure 3. For this constant horsepower test, vacuum increased at the higher engine speeds. BSFC is plotted in Figure 4. As expected increased friction at higher speed increased BSFC.

## IGNITION TIMING

Data was also taken to study the effect of ignition timing on performance and emissions at constant load. Operating conditions were:

Speed: 1200 rpm

Load: road load, 10.44 Bhp

Ignition Timing: 10,18,26,34,42,50 degrees before TC

Air-Fuel Ratio: 15.5:1

Figure 5 shows tailpipe NDIR and FID hydrocarbons as influenced by ignition timing. The data at $50^{\circ}$ BTDC is not included as poor combustion sent hydrocarbon readings off scale. Hydrocarbon concentration increased markedly when the spark was advanced beyond MBT ($34^{o}$). As a result, at this operating condition small errors in timing while having practically no effect on load, have considerable effect on hydrocarbon emissions levels.

Figure 6 shows tailpipe CO, $CO_2$, and $O_2$ concentrations. All are nearly constant for advances up to about MBT since air-fuel ratio was held constant. The decreases in $CO_2$ and increase in $O_2$ when the spark was over advanced arose from incomplete combustion. Figure 7 shows manifold vacuum and bsfc as a function of ignition timing.

## ALDEHYDES

The DNPH method has been set up for aldehyde measurements. Calibration tests have been run using standard formalin solution as the formaldehyde source. Limited analysis of engine exhaust gas has been made also to assess repeatability.

## OTHER

Construction of the subtractive column analyzer is underway.

# PHASE II PROGRESS

Preliminary studies aimed toward developing a first generation reactor model continue. A literature search is underway. A trip to Mobil Scientific Laboratory will be made to discuss their modeling approach.

# PHASE III PROGRESS

Studies of both timed and continuous sampling techniques continue. An electronic control has been built up for the Cox timed sampler. The control is being debugged at the present time. A student studying for his Ph.D. in Chemistry has been hired to do chromatographic analysis of exhaust hydrocarbons.

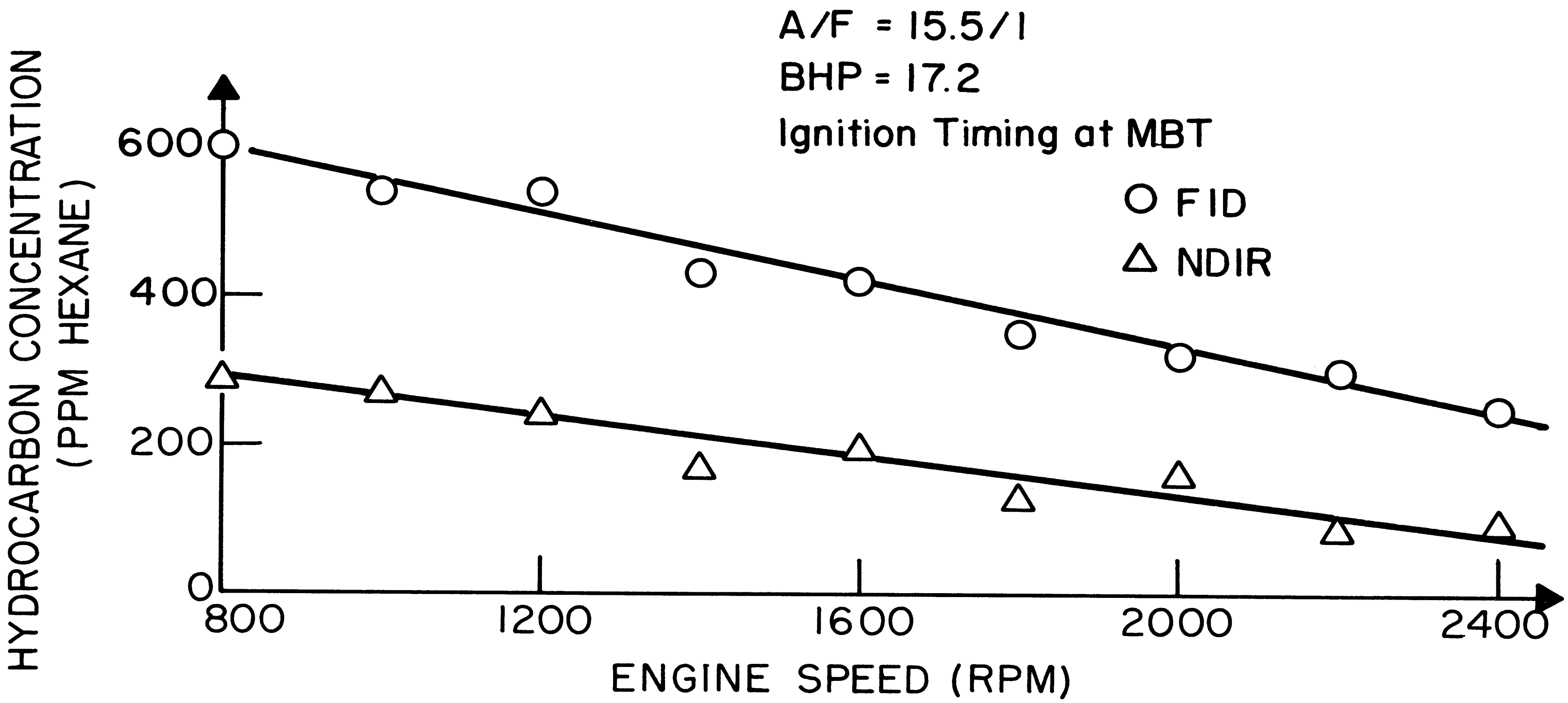



Figure 1. Tailpipe hydrocarbons versus engine speed.

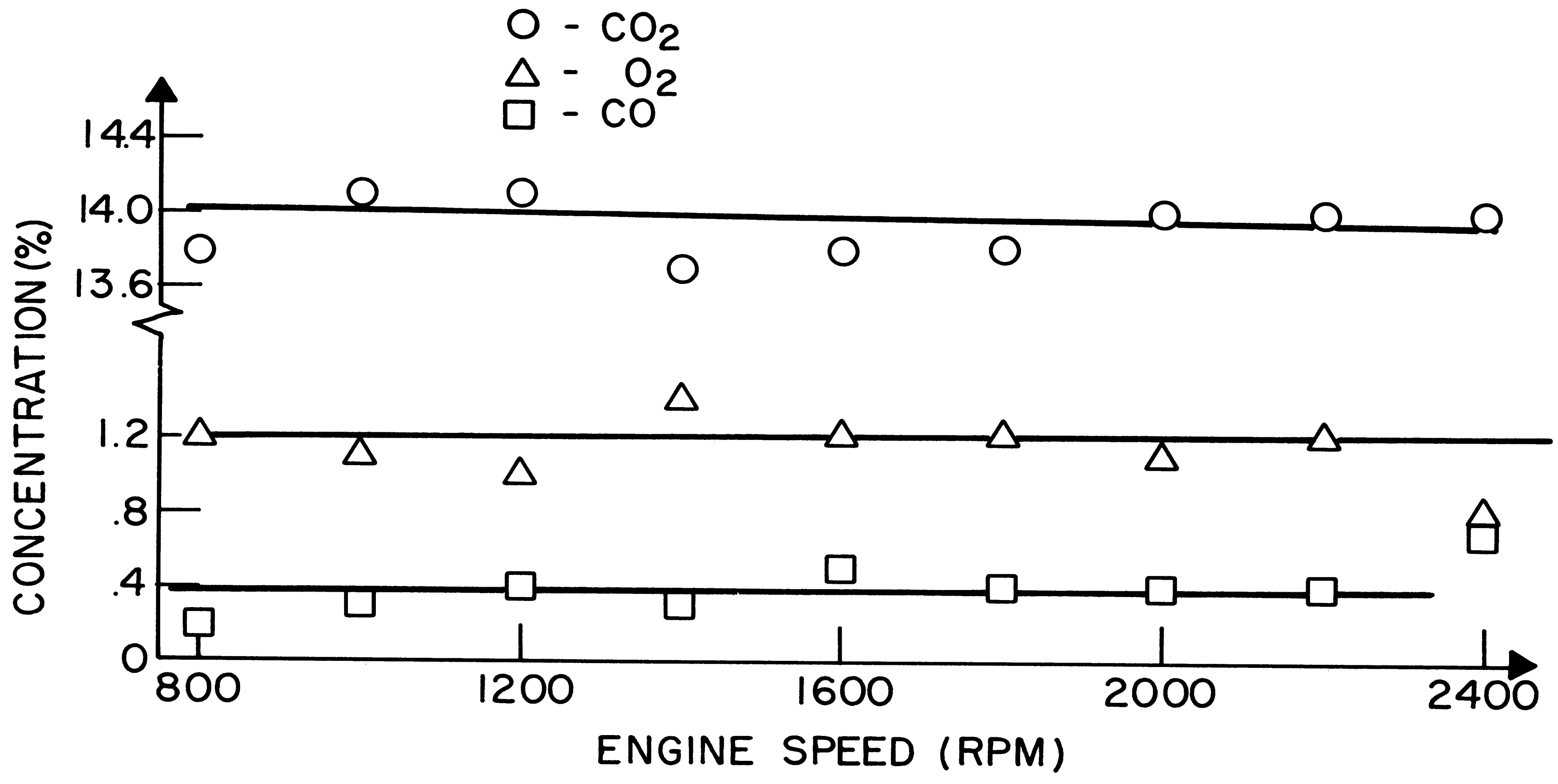



Figure 2. CO, $CO_2$, $O_2$ concentration versus engine speed.

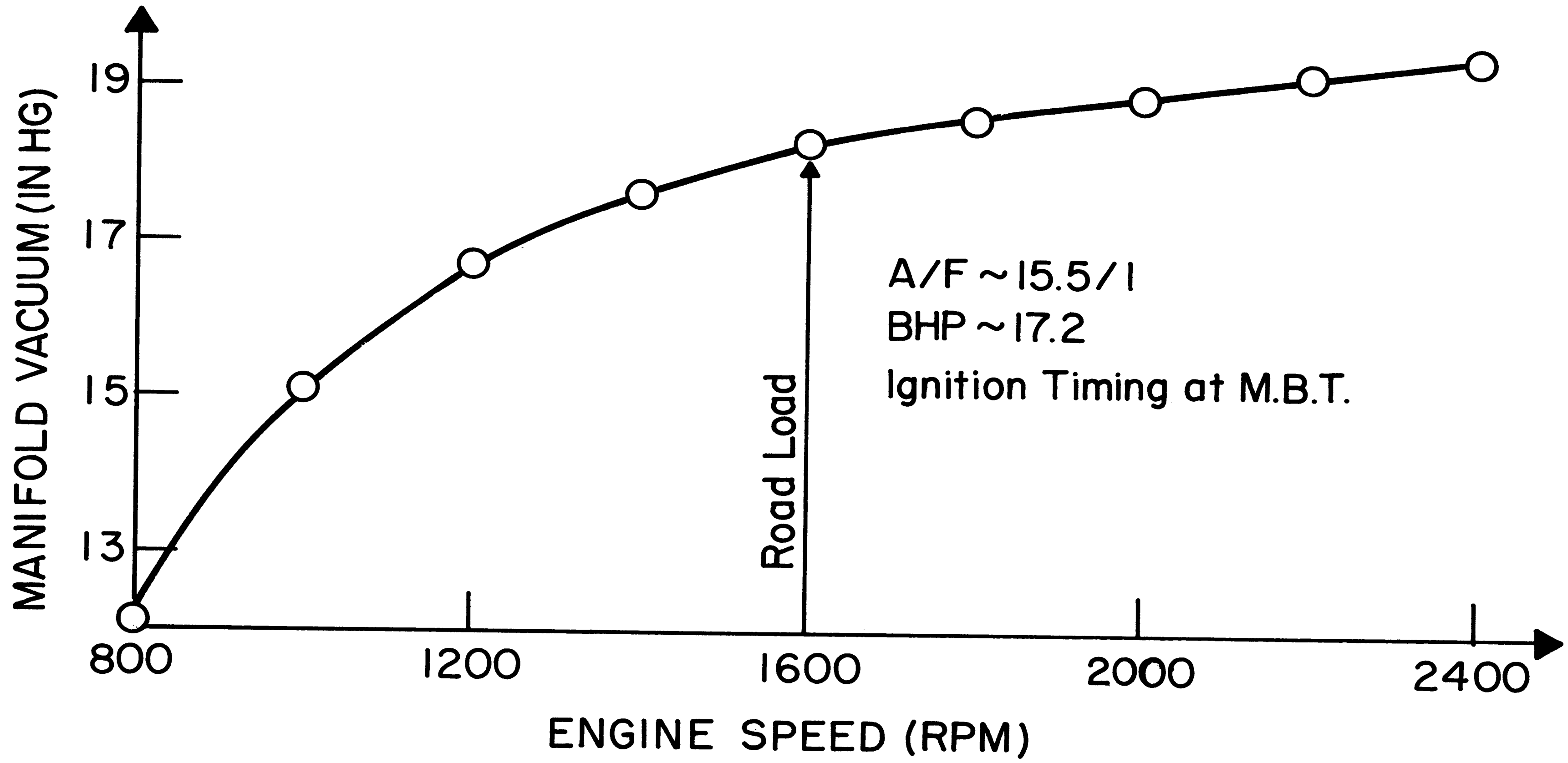



Figure 3. Manifold vacuum versus engine speed.

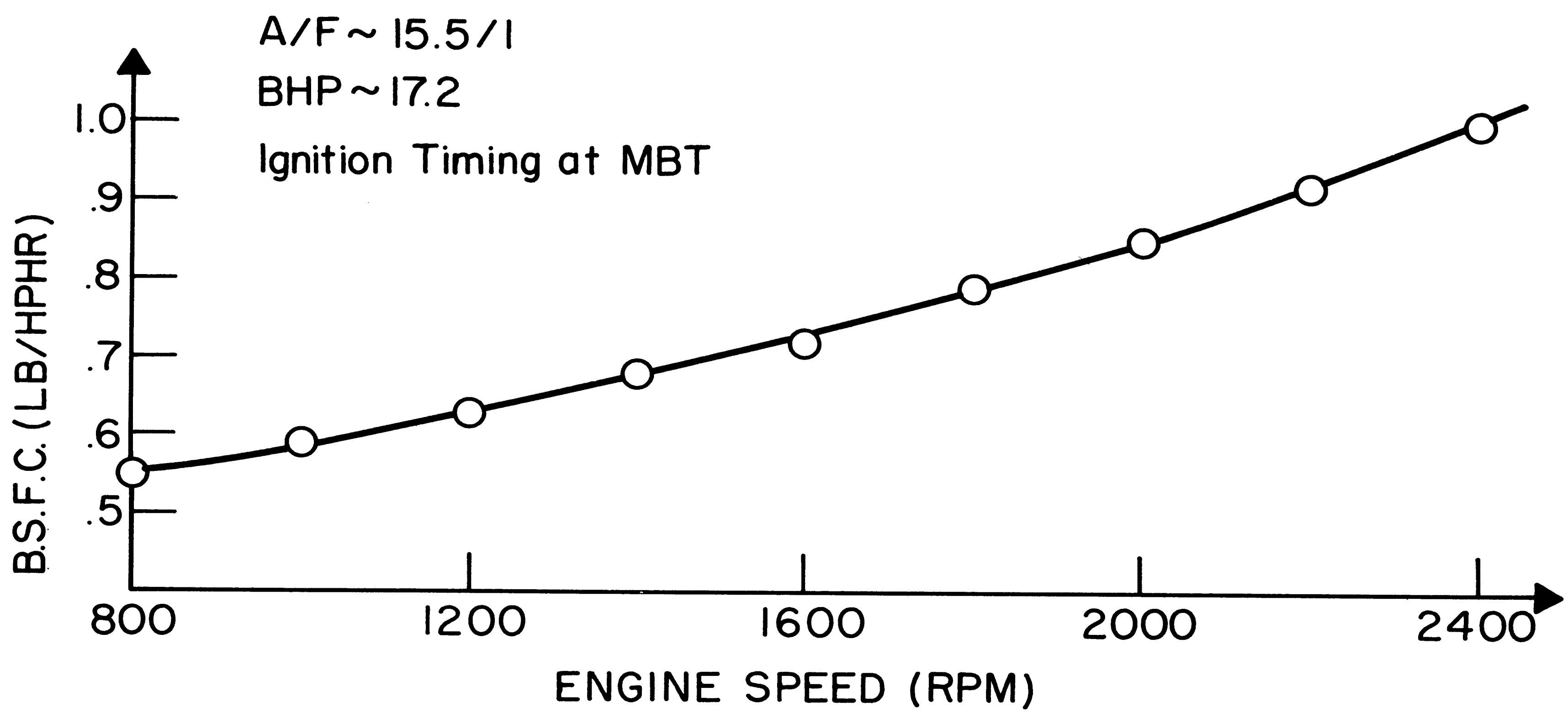



Figure 4. Brake specific fuel consumption versus engine speed.

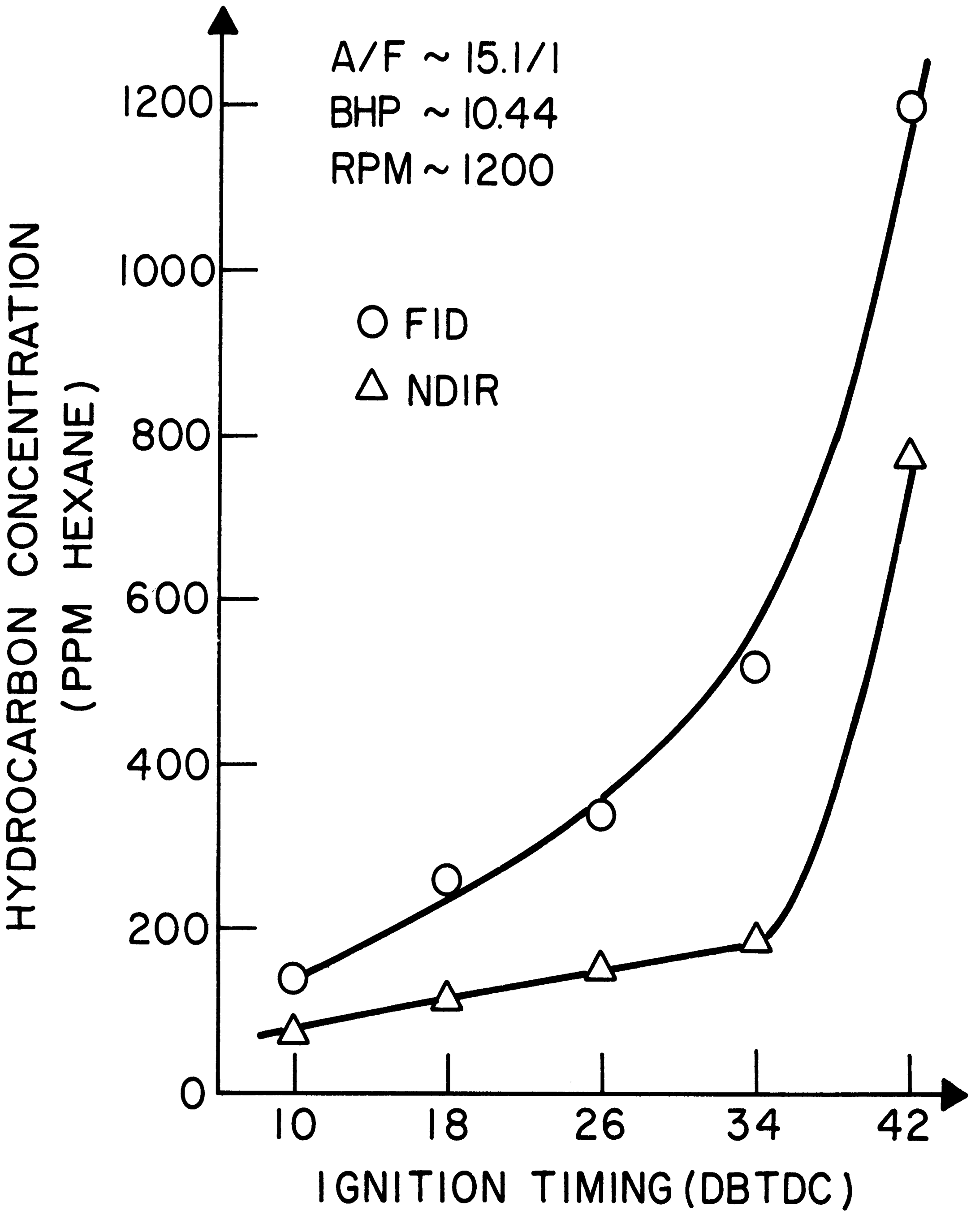



Figure 5. Tailpipe hydrocarbons versus ignition timing.

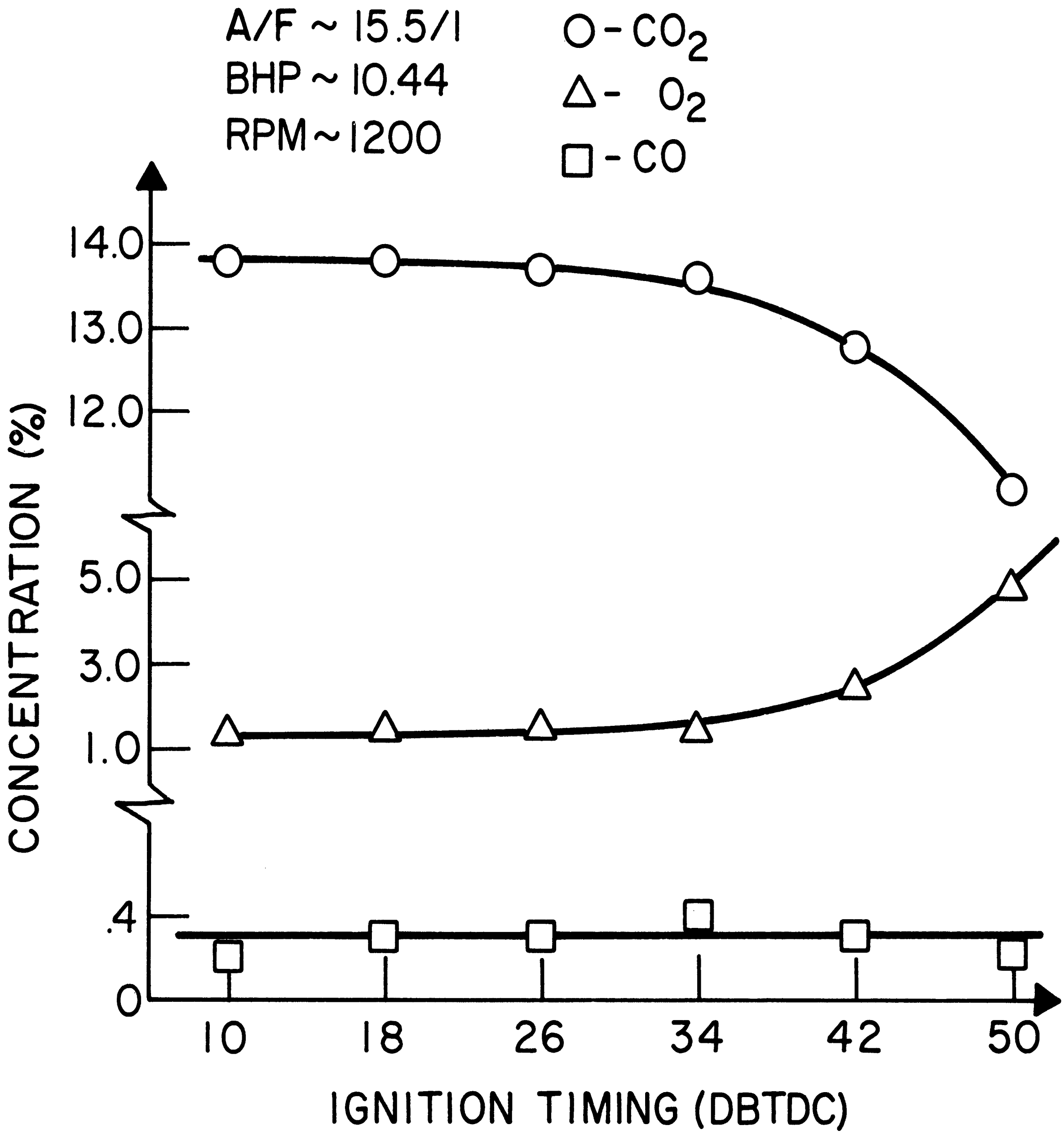



Figure 6. CO, $CO_2$, $O_2$ concentration versus ignition timing.

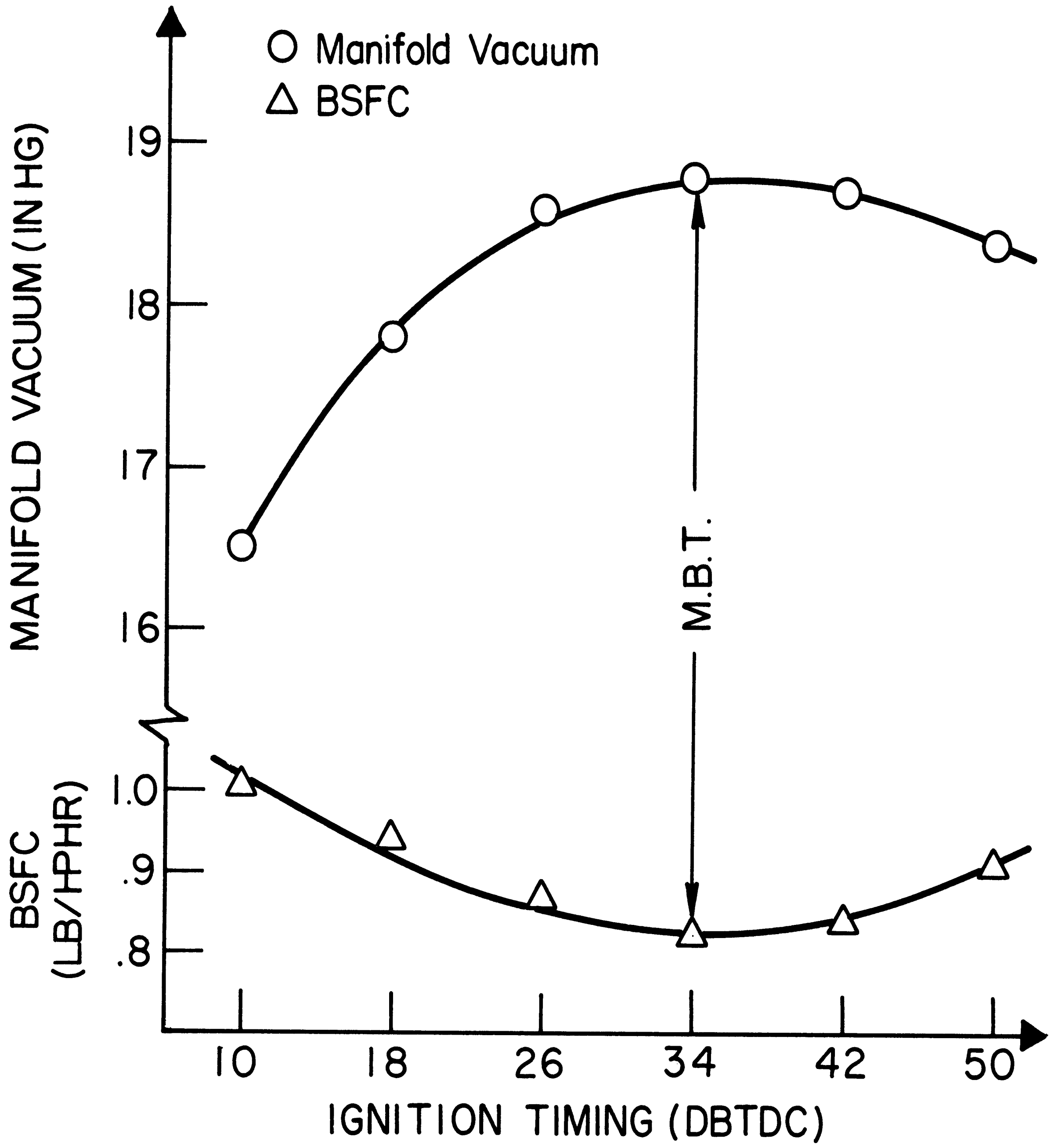
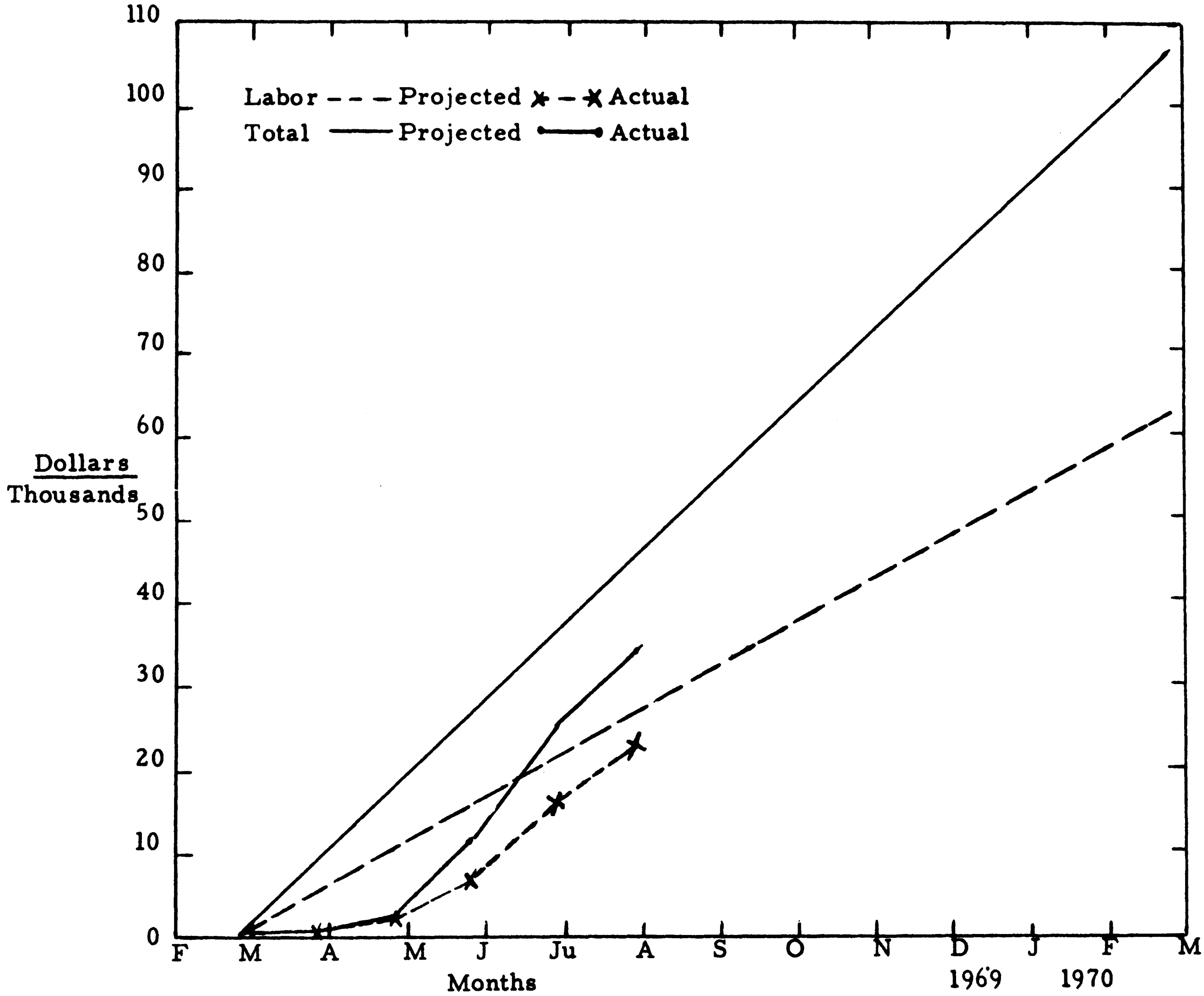



Figure 7. Manifold vacuum and brake specific fuel consumption versus ignition timing.

CRC CAPE 8-68 PROGRAM

OVERALL FINANCIAL SUMMARY

| | | |
|---|---|---|
| Program Total: February 24, 1969 - February 23, 1970 | | $106,455 |
| Cumulative Expenditures through July 24, 1969 | | 33,290 |
| | Balance | $ 73,165 |



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