PROGRESS REPORT NO. 5

DIESEL IGNITION AND COMBUSTION

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N. A. Henein

Period: January 1, 1970 - January 31, 1970

February 1970

This project is under the technical supervision of the:

Propulsion Systems Laboratory
U. S. Tank Automotive Command
Warren, Michigan

and is work performed by the:

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

Under Contract No. DA-AE07-69-1289

I. BACKGROUND

A program of activity to study the combustion process in supercharged diesel engines has been developed at The University of Michigan. This program is primarily concerned with the ignition delay and the effect of the several parameters on it. A special concern is given to the effect of the pressure and temperature of the cylinder air charge and engine speed on ignition delay. The program also includes the study of the effect of these variables on other combustion phenomena such as smoke, rate of pressure rise, maximum pressure reached in the cylinder, and rate of heat release.

The different types of delay have been studied in detail and an emphasis is made on the pressure rise delay and illumination delay. The instruments needed for the measurement of these two delay periods have been developed and a continuous effort is being made to improve their accuracy.

The present contract is a continuation of the work completed under previous Contract No. DA-20-018-AMC-1669(T) during the period July 1, 1964 to December 1, 1968. The contract has been modified to call for measurement of exhaust emission data in accordance with modification P001. This extends the contract completion date to April 30, 1970, and provides additional funds in the amount of $11,102.00. These supplemental funds are being supplied through joint sponsorship with the National Air Pollution Control Administration, Motor Vehicle R&D Division, Department of Health, Education, and Welfare.

This research is being made on the ATAC high output open combustion chamber engine, with CITE referee grade (Mil-F-45121) fuel.

II. OBJECTIVES

1. To extend the experimental engine combustion studies to gas pressures, at the start of injection, higher than the 1200 psia reached in Phase IVa of Contract DA-20-018-AMC-1669(T). This will require supercharging pressure up to four atmospheres, and pressure at the start of injection to 1600 psia.

2. Determine the wall temperatures and thermal loading on the cooling system over the complete range of supercharging pressures of item (1).

3. Analyze the experimental data of the complete range of the supercharging pressures and find a correlation between the ignition delay and the gas pressure.

4. Observations include the ignition delay, rate of pressure rise, maximum cylinder pressure, and exhaust smoke.

5. Separate the thermal load on the cylinder head from that on the cylinder jacket, and determine their variation with the engine variables.

6. Measure the exhaust emission.

III. CUMULATIVE PROGRESS

The cumulative progress on this work consists mainly of the previous study made under the Contract No. DA-20-018-AMC-1669(T). This work included both theoretical and experimental studies on two engines. The Lister-Blackstone engine has a precombustion chamber and the ATAC-1 engine has an open combustion chamber.

A. LISTER-BLACKSTONE ENGINE

Cumulative progress has been made in the following areas:

1. Review and analysis of previous work
2. Theoretical analysis
3. Experimental work on Lister-Blackstone engine
4. Comparison between the present work done on the Lister engine and previous work in bombs and engines

B. ATAC-1 OPEN COMBUSTION CHAMBER ENGINE

The cumulative progress made on ATAC-1 engine can be divided into three major areas:

1. Engine instrumentation
2. Experimental work
3. Theoretical work

1. Engine Instrumentation

The engine has been instrumented and all the instruments calibrated to measure the following:

a. Power output and engine speed
b. Gas pressure during the cycle
c. Illumination due to combustion
d. Wall surface temperature during the cycle

e. Wall temperature in the fire deck near the inlet and exhaust valves
f. Fuel pressure before the injector
g. Injector needle lift
h. Air flow rate into the engine and its temperature and pressure before the inlet valve
i. Fuel flow rate
j. Intensity of smoke in the exhaust gases, their temperature, and pressure

2. Experimental Work on ATAC

(a) Experiments were made on the ATAC engine to study the effect of temperature on ignition delay and combustion characteristics of the following fuels:

(1) CITE referee grade (Mil-F-45121) fuel
(2) Diesel No. 2 fuel
(3) Mil-G-3056 referee grade gasoline fuel

(b) Experimental work to compare between the combustion phenomena and the rate of heat release for the three fuels, under naturally aspirated conditions.

The several computer programs made for these elaborate computations proved to be very successful, and can be used in future heat release computations under any set of running conditions.

(c) Experimental work to study the effect of engine speed on the ignition delay and other combustion phenomena. Engine speeds covered a range from 1000 rpm to 3000 rpm.

(d) Experimental work to study the effect of coolant temperatures on the combustion process of CITE fuel. The coolant used for these tests was ethylene glycol at temperatures up to 305°F.

(e) Experimental work to study the effect of fuel-air ratio on ignition

delay and other combustion phenomena of CITE fuel. This work was done at two levels of coolant temperatures, 170°F and 250°F. The coolant was ethylene glycol.

(f) Experimental work to study the effect of the air-charge pressure on ignition delay and other combustion phenomena of CITE fuel.

3. Theoretical Analysis

(a) A thermodynamic analysis was made to study the different types of energy and processes taking place during the ignition delay, and to compare between the different definitions used in the literature for the ignition delay.

(b) A correlation was reached between the pressure rise delay and the air-charge temperature.

IV. PROGRESS DURING THIS PERIOD

(1) The experimental work on the effect of air-charge pressure on the ignition delay and the other combustion phenomena has been completed. The analysis of the data is in progress.

(2) The exhaust system of the engine has been modified to provide for exhaust sampling probes at several points along the engine exhaust pipe as shown in Figure 1.

The concentration of unburned hydrocarbons was measured by a Horiba (Japanese) Heated Flame Ionization Detector (FID), instrument which was loaned to us without cost by Olson Laboratories of Dearborn. This unit was modified by Horiba representatives to operate at 300°F in the chamber, and is fitted with electrically heated sampling line. This unit uses 100% hydrogen as fuel. Different capillary tubes and settings are needed to permit it to use 40% hydrogen - 60% nitrogen.

The preliminary results for the unburned hydrocarbon concentration showed considerable variation between the three probes, as shown in Figure 2. The sample drawn at the furthest point from the exhaust valve showed the highest unburned hydrocarbon concentration.

Other published data on diesel engine emissions showed similar behavior. However, the reasons behind such a variation in unburned hydrocarbon concentration were not given in the literature.

It is our feeling that this variation in concentration requires a more thorough study which is now under way.

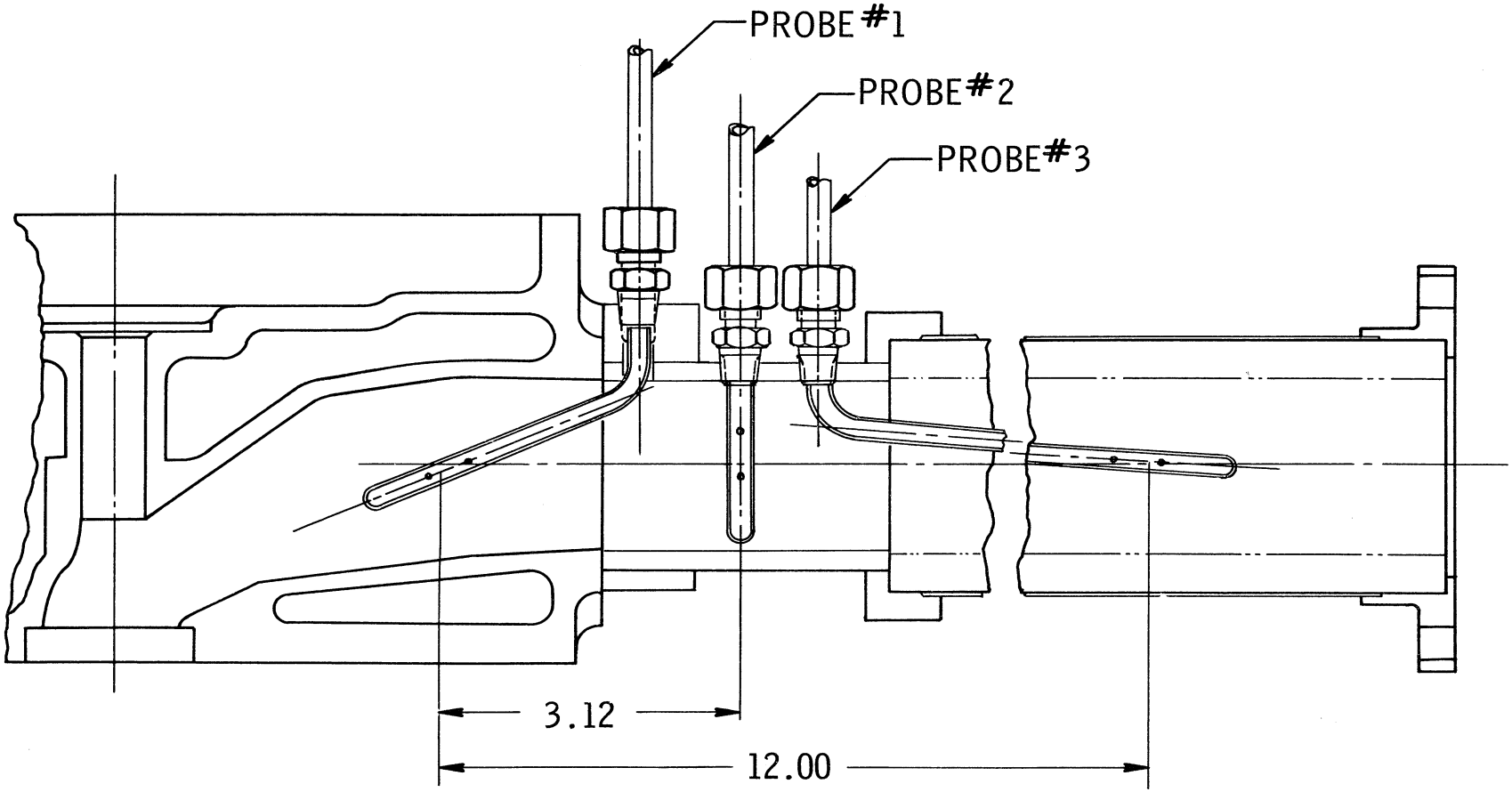


Figure 1. Exhaust sampling probes at three locations along the exhaust pipe.

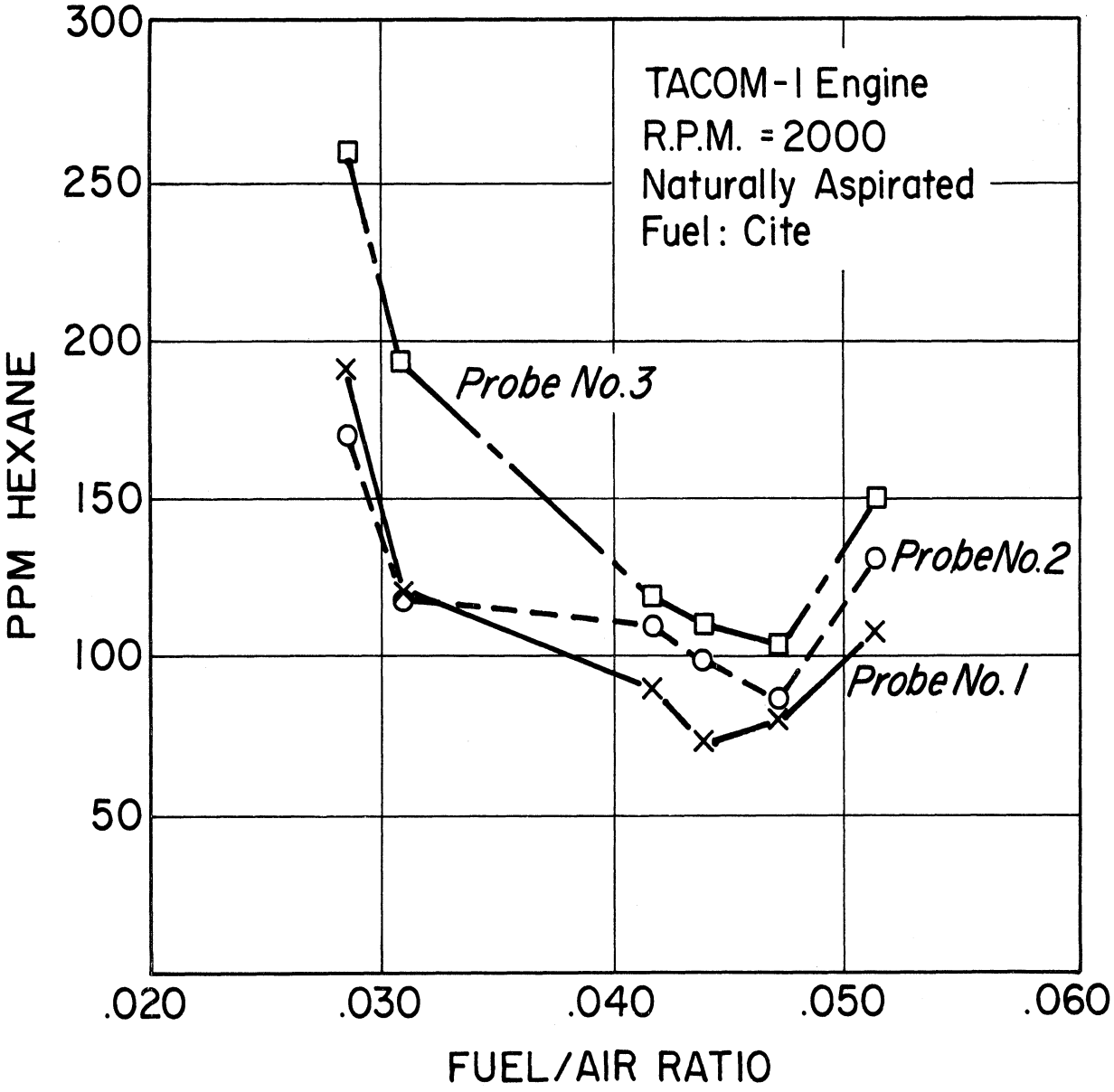


Figure 2. Effect of fuel-air ratio on the unburned hydrocarbons concentration. Sample is taken at three different locations along the exhaust pipe.

V. PROBLEM AREAS AND CORRECTIVE ACTIONS

Work was done with the Beckman 106EX Heated Flame Ionization Detector Instrument (for measuring unburned hydrocarbons in diesel exhaust). We experienced difficulty in igniting and maintaining a flame with the 106EX unit when using 40% hydrogen - 60% nitrogen as fuel. These difficulties are continuing, and we have been unable to obtain much help from the supplier, Beckman.

We are planning a visit to International Harvester Company, who have used this instrument quite successfully.

VI. FUTURE PLANS

A. NEXT PERIOD

(1) To report the results for the effect of gas pressure on the ignition delay and the other combustion phenomena.

(2) To make further studies on the factors that affect the unburned hydrocarbon concentration in the exhaust pipe.

(3) To make a survey of the literature for the exhaust emission in diesel engines.

B. OVERALL

(1) To reach a correlation between the air-charge pressure and ignition delay.

(2) To study the effect of the different engine variables on the exhaust emissions, and thermal loading on the engine.

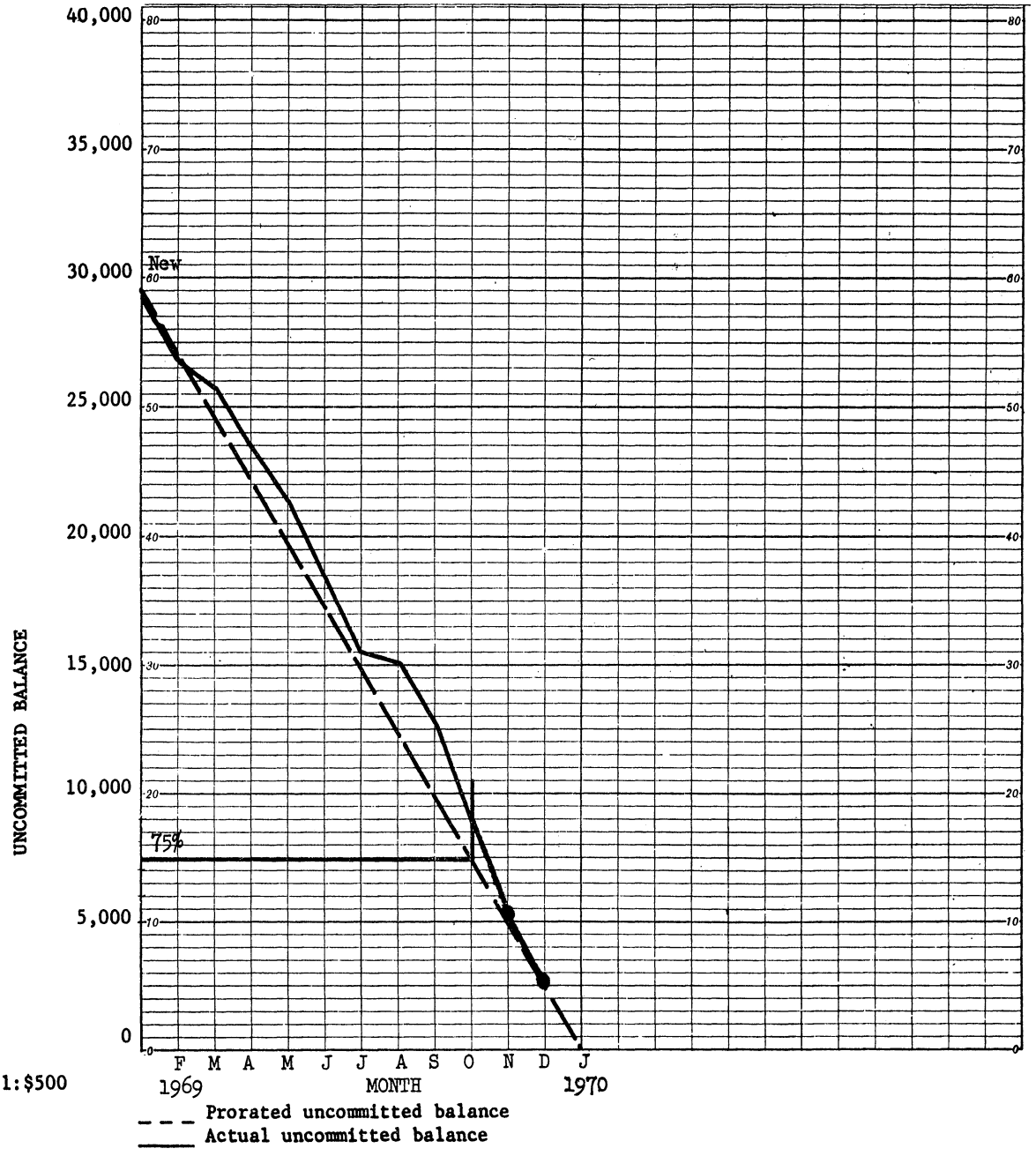
VII. SIGNIFICANT ACCOMPLISHMENTS

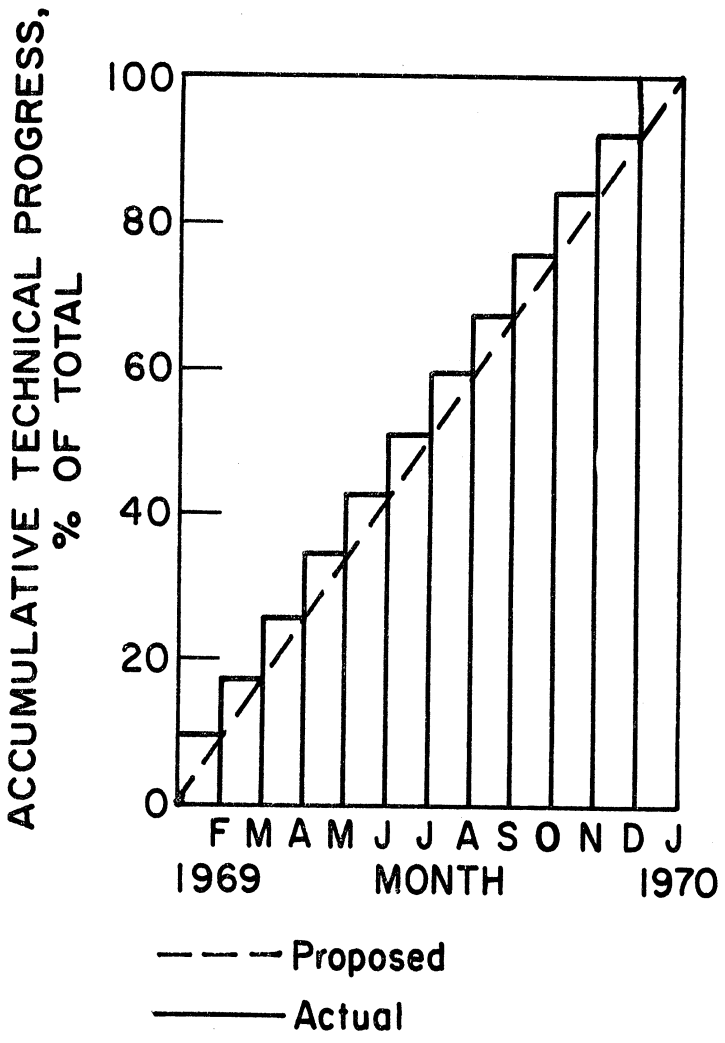
These consist of publications that resulted from the work done on Contract No. DA-20-018-AMC-1669(T). These publications are as follows:

1. "Ignition Delay in Diesel Engines." Presented at the SAE Annual Meeting in January 1967. Published in the SAE Transactions, 76, paper No. 670007.
2. "Correlation of Air-Charge Temperature and Ignition Delay for Several Fuels in a Diesel Engine." SAE paper No. 690252 presented at the SAE Annual Meeting, Detroit, on January 17, 1969.
3. "Diesel Exhaust Smoke: Effect of Some Fuel and Engine Factors on Its Formation." SAE paper No. 690557, presented in the SAE West Coast Meeting held in Seattle, Washington, August 14, 1969. This paper is given in Appendix B.
4. "The Effect of Some Engine Variables on Ignition Delay and Other Combustion Phenomena in a Diesel Engine." Paper No. 39, to be presented at the "Symposium on Diesel Combustion," Institute of Mechanical Engineers, London, England, April 1970. The paper has been approved with minor corrections by TACOM, and has also been accepted for publication by the Institution.
5. The work on the present project has been extended to April 30, 1970, to include exhaust emission studies.

VIII. PROJECT COMPUTER GRAPH RECORDS

Proj. Beg. Date: 1-28-69 **P.D.:** J. A. Bolt **Account No.:** A 2431
Total Auth'n.: $29,609 **P.R.:** D. M. Plawchan **Sponsor:** DAAE07-69-C-1289
Proj. Exp. Date: 1-27-70 **Current Auth.:** $29,609 New 1-28-69 **to** 1-27-70
Final Report Due: 2-27-70 **Funds Available October 31:** $8,753.46




ACCUMULATIVE TECHNICAL PROGRESS, % OF TOTAL
100
80
60
40
20
0
F M A M J J A S O N D J
1969
MONTH
1970
Proposed
Actual

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