

PROGRESS REPORT NO. 13

DIESEL IGNITION AND COMBUSTION

J. A. Bolt
Arpad Miklos

Period: February 1, 1971 - April 1, 1971

April 1971

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

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I. BACKGROUND

An experimental and analytical study of combustion phenomena in highly supercharged diesel engines has been in progress at the University for several years. This program is primarily concerned with the ignition delay and the effect of the several parameters on it. Special attention has been 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. More recently, instrumentation was made ready to permit measurement of the principal exhaust emission constituents which contribute to air pollution.

The different types of ignition 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 refined and a continuous effort is being made to improve their accuracy.

The present contract is a continuation of the work completed under the previous Contract No. DA-20-018-AMC-1669(T) and modification P001, during the period July 1, 1964, to April 30, 1970. The contract has been modified and presently requires the conduct of additional basic combustion studies in accordance with modification P002. A further modification, requiring measurement of exhaust gas constituents has also been negotiated. These modifications extend the contract completion date to October 31, 1971, and provide

additional funds in the amount of \$32,250.00.

This research is being accomplished with the TACOM* high output engine using the open combustion chamber with three different fuels.

*The name "TACOM" will replace "ATAC" in future progress reports.

11. OBJECTIVES OF MODIFICATION 1002

1. Separate the cooling circuits for head and barrel of the TACOM engine.
2. Vary the inlet air temperature from ambient to 500° in 100°F increments.
3. Maintain the coolant temperature at 300°F and oil temperature at 250°F.
4. Fuel/air ratio to be maintained at .035 on CITE, diesel, and gasoline.
5. At the above conditions measure the ignition delay at compression pressure equal to 1000 lb/in.²
6. Measure smoke, mean and transient wall temperature and other parameters.
7. Maintain engine speed at 2000 rpm.

III. CUMULATIVE PROGRESS

The cumulative progress includes both theoretical and experimental studies on two engines. These are the Lister-Blackstone single-cylinder engine with precombustion chamber and the TACOM-1 engine with open combustion chamber.

This work, through December 1, 1968, was reported in the Final Report for the original contract (No. DA-20-018-AMC-1669(T)). This report was entitled, "Diesel Engine Ignition and Combustion," Report No. 06720-11-F, dated February 1969. Subsequent work under the new existing contract was summarized in progress reports.

There reports included the following:

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. TACOM-1 OPEN COMBUSTION CHAMBER ENGINE

The cumulative progress made on TACOM-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. Wall surface temperature during the cycle
- d. Wall temperature in the fire deck near the inlet and exhaust valves
- e. Fuel pressure before the injector
- f. Injector needle lift
- g. Air flow rate into the engine and its temperature and pressure before the inlet valve
- h. Fuel flow rate
- i. Intensity of smoke in the exhaust gases, their temperature, and pressure.

2. Experimental work on TACOM-1 Engine

(a) Experiments were made on the TACOM-1 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 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, 180°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 of the processes taking place during the ignition delay, and to compare 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 REPORT PERIOD

All of the planned tests were finished in accordance with the P0002 project modification. These involved both No. 2 diesel and CITE fuels. All the tests runs were repeated using CITE fuel to double check the high leakage rate from the fuel injector, and other test conditions. For example, the after-injection fuel flow rates and variations of after injection. All the test data were reduced by computer calculations. The data appear to be good. A portion of the results obtained are plotted. The next monthly report will show the curves and give the conclusions concerning this series of tests.

As was reported earlier (by personal contact with Mr. Floyd Lux), the TACOM research single cylinder engine showed excessive blowby. The engine cylinder head, the piston, connecting rod and cylinder sleeve were removed. One piston ring (second from the piston top) groove had heavy carbon deposit, so that the ring was tight in its groove. The other two compression rings and the oil ring were found in good condition. The cylinder sleeve had about .011" wear at about mid-stroke, at 45° to the piston thrust surface. The lower connecting rod upper-half bushing soft bearing material was worn down to the steel backing surface. These failures were due probably to the high supercharging rate, 300° coolant and 250-260°F. lubricating oil temperatures. All the above parts were replaced by new ones. The valve seats were examined and were found to be in good condition. The combustion chamber showed a normal carbon deposit. At one spot the fuel sprayed from the injector hit the cylinder head forming heavier deposits (as was reported in

the past). The newly assembled engine now has about 60 hours running time on it. The blowby rate remains low.

V. PROBLEM AREAS AND CORRECTIVE ACTIONS

The Beckman 106EX heated FID is now in good working condition. It checked out with standard check out gases. Now that we have completed the engine cylinder combustion studies, we expect to move more rapidly toward taking the exhaust emission data required by contract modification P004, on the TACOM engine. Some of the exhaust measuring instruments are in use on another Public Health Service project, but will be connected to the TACOM engine soon.

VI. FUTURE PLANS

The data for the combustion studies of modification P002 are now available, and these results now being plotted and analyzed. The report concerning this work remains to be done.

In accordance with discussions with Floyd Lux on March 10 at the Detroit Arsenal we are making a 100 hour endurance test of the engine to obtain a more clear indication of its ability to operate under high stress and temperature conditions. These conditions are:

Engine speed - 2000 rpm
Supercharge pressure above atmosphere - about 40" Hg.
Coolant average temperature - 300°
Oil sump temperature - 250°F

As stated earlier about 60 hours have now been accumulated. When 100 hours have been logged the cylinder assembly will be taken apart for inspection.

Last week I visited the Mobil Oil Company Research Center at Paulsboro, New Jersey, on other business, and had opportunity to discuss our TACOM engine tests at high supercharge. Their oil men believe that their Mobil Delvac 1330 lubricating oil which we are using is the best oil available for severe diesel operating conditions. They stated that this oil has the best anti-scuffing qualities available. They also thought that a sump temperature of 275°F might be quite tolerable, but had misgivings about a 300°F sump temperature.

We are preparing a summary of the modifications and difficulties experienced with the Beckman 106EX Hydrocarbon Analyzer, and this will be included with the next progress report.

VII. SIGNIFICANT ACCOMPLISHMENTS

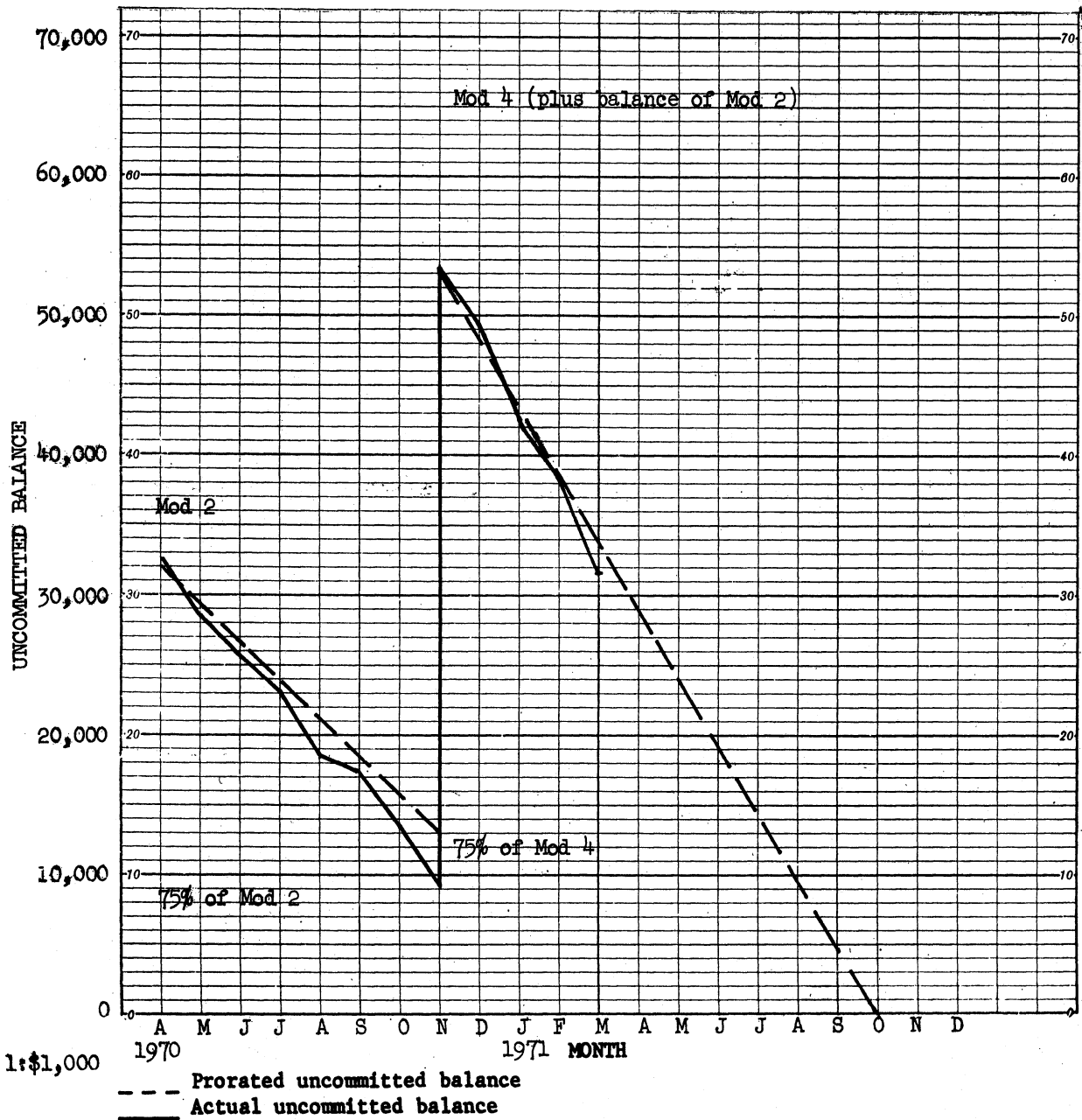
These consist of publications that resulted from the work done on Contract No. DA-20-018-AMC-1669(T). These publications are as follows:

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.
4. "The Effect of Some Engine Variables on Ignition Delay and Other Combustion Phenomena in a Diesel Engine." Paper No. 13, presented at the "Symposium on Diesel Combustion," Institute of Mechanical Engineers, London, England, April 1970. This is available in a Symposium Publication of the IME, entitled "Diesel Engine Combustion," included in the Proceedings, 1969-1970, 184, Part 3. The above paper appears on pages 116-123.
5. The work on the present project has been extended to April 27, 1971, to include basic combustion studies.

PROJECT COMPUTER GRAPH RECORD

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