THE UNIVERSITY OF MICHIGAN
COLLEGE OF ENGINEERING
Department of Mechanical Engineering

Progress Report
For the period 1 September 1965 to 31 December 1965

DIESEL ENGINE IGNITION AND COMBUSTION

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INTRODUCTION

This report covers the work carried out during the period from September 1, 1965 to the end of December, 1965. In the course of planning the program for this period we took into consideration the time available before receipt of the new high output Army Research engine, which is expected to be received during January or February, 1966. The work carried out includes five major items:

1. A study of the work previously done by other investigators, as covered by a previous Bibliography Report,* on the combustion process in diesel engines. This is done with a special concern to the instruments used for such work, and the possible ways for developing them and improving their accuracy.

2. Setting up a second engine (Lister-Blackstone) in a separate room, which will be available for testing while the Army supplied engine is being put into operation, and thereafter. A picture of this set-up is shown in Figure 1.

3. Testing and calibrating the instruments after being fitted on the Lister-Blackstone engine.

4. Running tests on the Lister-Blackstone engine to investigate the several factors that affect ignition delay and combustion in the diesel engine, and to gain experience in the techniques needed for such a research.

5. Planning the procedure of tests to be run on the Army Research engine, and the method of processing the data.

One of the instruments we are using to detect the start of combustion in the engine is the silicon solar cell, described in a previous report.** The first time this cell was used in our laboratory was with the Nordberg Diesel engine, referred to in the same previous report. A study of the combustion process in the Nordberg engine (with a Lanova single lobe combustion chamber) indicated that the combustion is not confined to the main chamber but occurs also in the minor and major cells. Due to the complexity of the combustion

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*Diesel Engine Ignition and Combustion—A Bibliography, by Jay A. Bolt and R. K. Nicholson, 06720-1-P Report, The University of Michigan, Sept. 1965.

**Diesel Engine Ignition and Combustion by Jay A. Bolt and Kenton C. Ensor 06720-2-P Report, The University of Michigan, Sept. 1965.

process in the Lanova combustion chamber it was decided that the use of the solar cell for indicating the start of combustion in this type of chamber is not of great significance for diesel ignition lag investigations. The most suitable type of chamber, for evaluating the solar cell for combustion research, is that in which the fuel injection and the start of combustion is confined to one chamber. In search for such an engine a visit was made to the General Motors Corporation, Diesel Engine Division, in Detroit to investigate a single cylinder, open chamber, research engine. The General Motors engines have 2 or 4 valves in the cylinder head with limited space for mounting instruments. Also, the installation of the injection valve lift measuring equipment would be very difficult for the unit injector of General Motors.

After considering all aspects of the problem, it was decided to use the "Lister-Blackstone" British engine available in our laboratory. This engine has a Ricardo swirl type combustion chamber. This chamber has been modified to allow the mounting and testing of the solar cell, together with a Kistler pressure pickup to be used for this investigation.

Considering the period of time available before receiving the Army engine, it was thought to be useful to begin the experimental program on the Lister engine, after testing and calibrating the instruments. This is being done without affecting the set up prepared and described in the previous report for testing the Army engine.

THE LISTER-BLACKSTONE ENGINE SETUP

This engine is a single cylinder, four-stroke cycle, liquid cooled, 4-1/2 inch bore, 4-3/8 inch stroke, and has a rated power of 8 bhp at 1200 rpm. This engine is especially attractive for combustion research because there is easy access to the swirl chamber, or pre-combustion chamber. The design, therefore, makes it practical to modify the swirl chamber, and to place pressure pickups and other instruments into the wall of the swirl chamber. It was also found to be practical to modify the combustion chamber of the engine to run tests at variable compression ratios. Figure 2 shows a section in the cylinder head with its original auxiliary chamber and the compression ratio change-over valve. Figure 3 shows the cylinder head after modification and shows the variable compression ratio sleeve and the chamber plug. The construction of this plug allows the compression ratio to be varied in the range from 15:1 to 22:1.

Figures 4 and 5 show the chamber plug and the method of mounting the pressure transducer, solar cell and a surface thermocouple.

Shop air is used to supercharge the engine after being passed through a surge tank fitted just before the engine. The pressure in the tank is measured and considered equal to the supercharging pressure. The temperature is measured in the tank and in the cylinder head before the inlet valve. The air consumption is measured by a critical pressure type flowmeter.

The gas pressure inside the cylinder is obtained by the use of an oscilloscope, together with a Kistler pressure transducer and a degree marking unit. The Kistler transducer is mounted on the combustion chamber plug as nearly flush as possible with the inside surface of the combustion chamber. The output of the transducer is fed to a charge amplifier and then to a dual beam oscilloscope. The trace obtained on the screen is photographed by a polaroid camera attached to the oscilloscope.

The degree marks are produced by a steel disc, 20 inches diameter, 1/8 inch thick, mounted on the engine flywheel. The rim of the disc was slotted at 3° intervals, with deeper slots at 45° intervals, Figure 6. A magnetic pick-up was mounted on the engine bedplate, with its pole close to the rim. The alternating voltage generated by the rotation of the disc was applied to channel B of the dual beam oscilloscope mentioned before. The corresponding trace obtained on the screen consisted of a serrated line across the horizontal diameter of the screen as shown in Figure 7. Every 3 and 45° were thereby marked, and one of the deep 45° slots in the disc was aligned at the T.D.C. The crank angle position on the oscilloscope traces can therefore be determined.

The temperature of the inside surface of the combustion chamber is measured by a special Nickel-Steel thermocouple. The location of this thermocouple can be adjusted to coincide with the point where the fuel spray from the injector hits the surface.

The fuel injection system is instrumented, Figure 8, so that the start and rate of injection can be calculated from measurements of the needle lift and fuel pressure before the nozzle. The needle lift is measured by a Bentley D-152 distance detector system. The injection is considered to begin at the instant the needle lift begins. The fuel pressure before the nozzle is obtained by a Kistler transducer fitted on the injector body. The rate of injection (especially during the delay period) will be calculated from the pressure difference before and after the nozzle and the area of flow as computed from needle lift measurements. To ensure reproducibility of the plunger setting in the fuel pump the position of rack is controlled by a micrometer as shown in Figure 9.

A sample of the traces obtained for the gas pressure, fuel pressure, needle lift, solar cell output and crank degrees is shown in Figure 7.

PHOTOGRAPHS

One of the methods which was studied and found to be very useful for the detection of the start of combustion in the engine is high speed photography. To apply high speed photography to this engine, a fused quartz window was obtained to replace the combustion chamber modified plug. As shown in Figure 3 the diameter of this plug is very near to the diameter of the swirl chamber, which makes it feasible to take pictures of the whole combustion chamber. It is hoped that photographs will help in detecting the start of combustion and in analyzing the many processes which occur within the short time from the beginning of injection to the end of combustion. High speed photography equipment and skills are available to us on campus if such work seems desirable.

PLANNED TESTS TO BE RUN ON LISTER ENGINE

The aim of running these tests is to gain experience in the different techniques that will be used on the Army Research engine, as well as to collect data on a swirl type chamber to be compared with the other types of combustion chambers.

Tests are presently planned for the following conditions:

1. Variable inlet pressures to study the effect of gas pressure at the time of injection on ignition delay and combustion characteristics.

2. Variable compression ratios to study the effect of combined pressure and temperature on ignition delay and combustion characteristics.

3. Variable loads.

4. Variable speeds.

5. The above tests are to be carried out by using the following fuels:
    a. CITE referee grade (MIL---45121 B) fuel.
    b. Diesel fuel VV-F-800 Grade II.
    c. MIL-G-3056B referee grade gasoline fuel.

These fuels have been ordered from Ashland Oil and Refining Co., Ashland, Kentucky, and are now stored in the Automotive Laboratory.

The data processing will be done on a digital computer and the necessary programming is now under preparation.

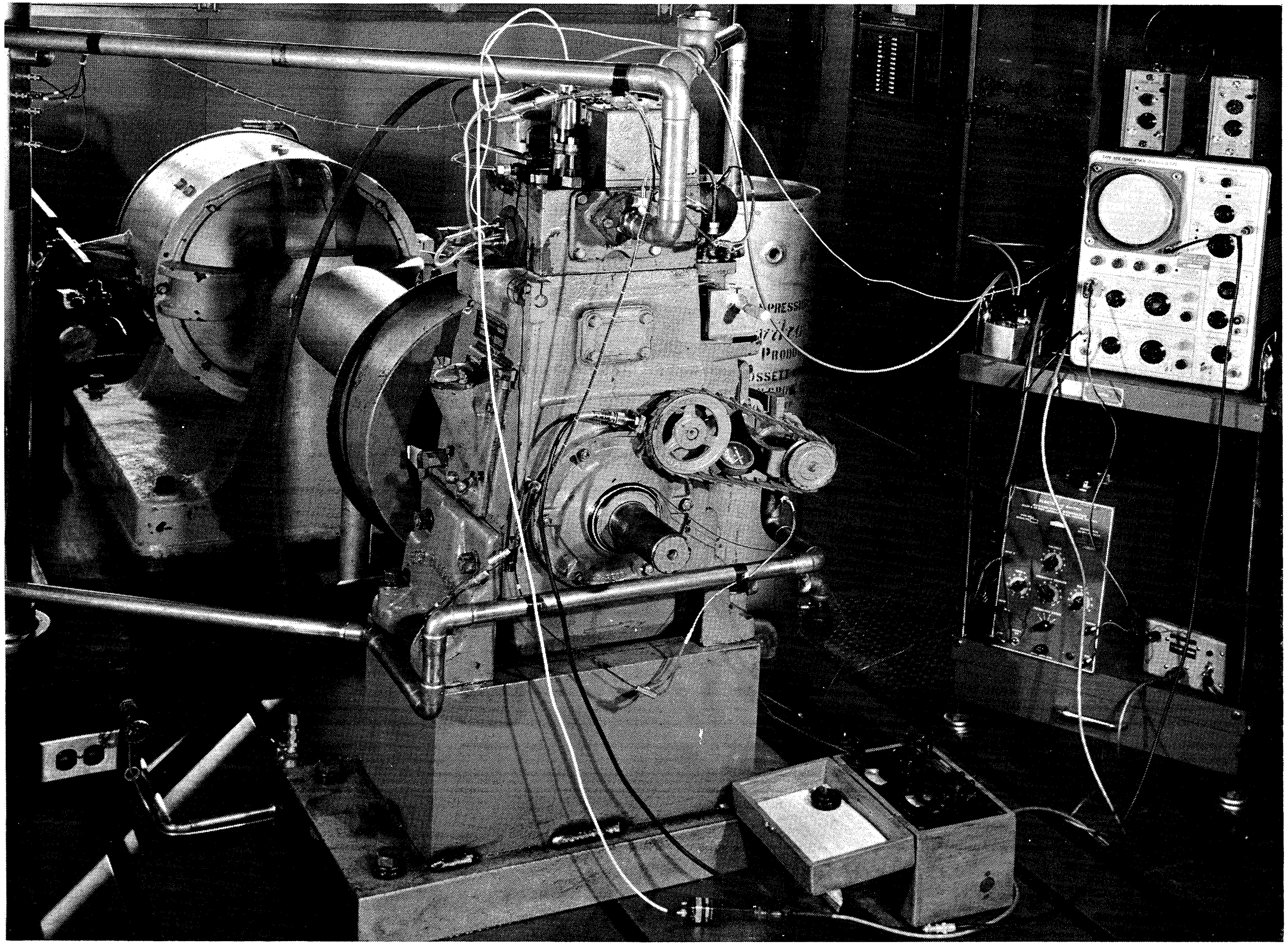


Figure 1. Picture of Lister-Blackstone Setup.

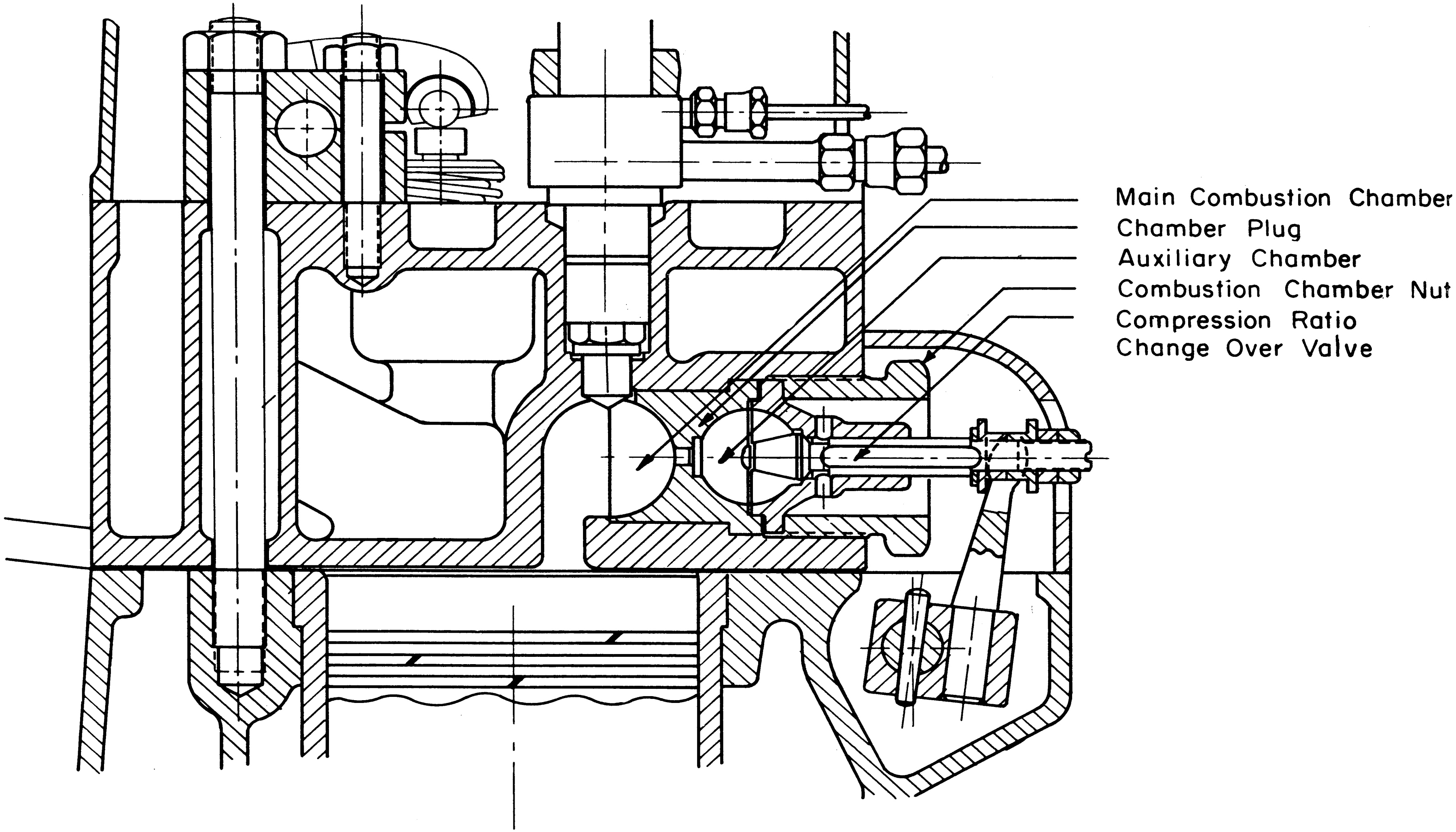


Figure 2. Original Combustion Chamber of Lister-Blackstone Engine.

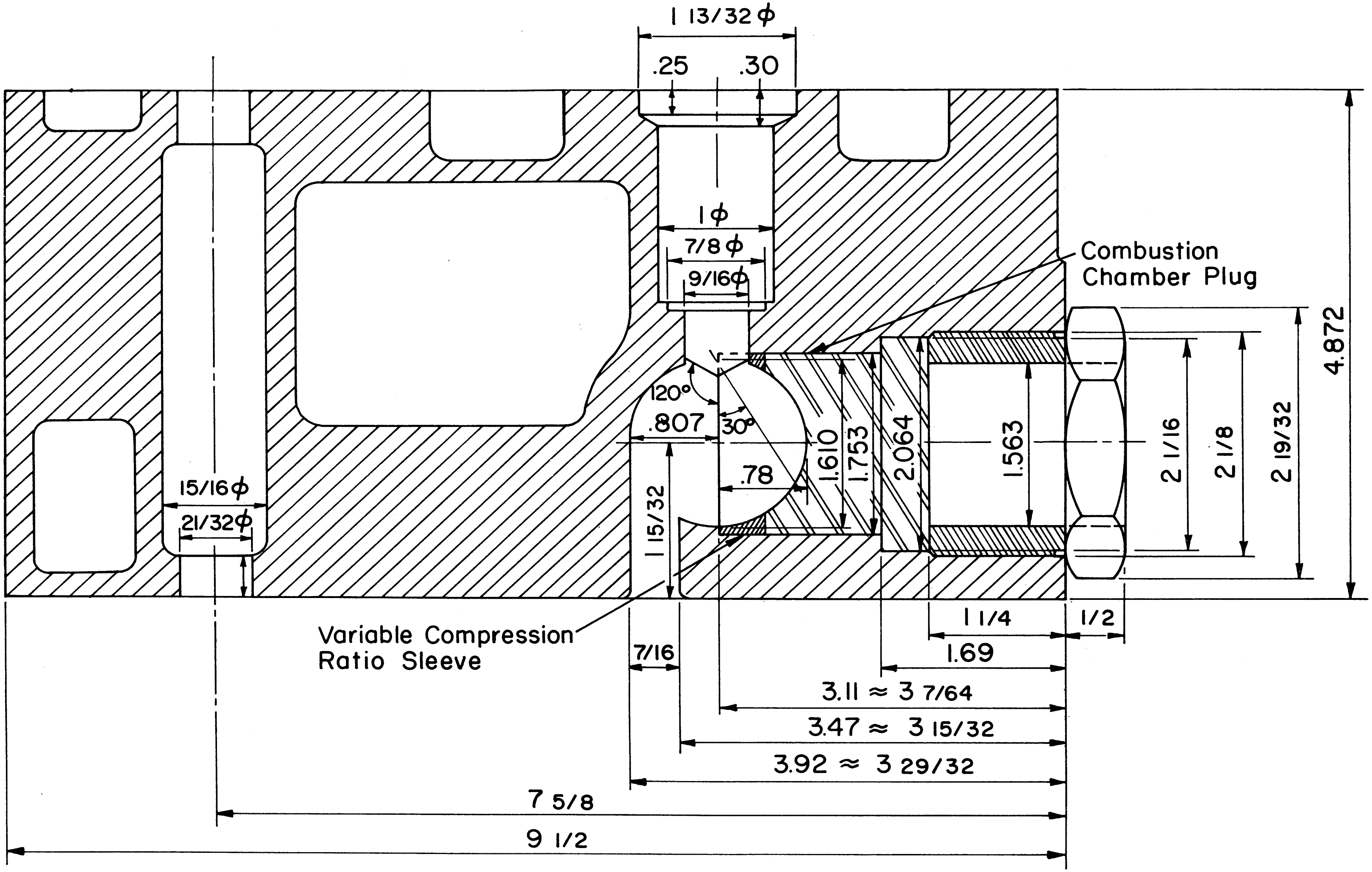


Figure 3. Modified Combustion Chamber of Lister-Blackstone Engine.

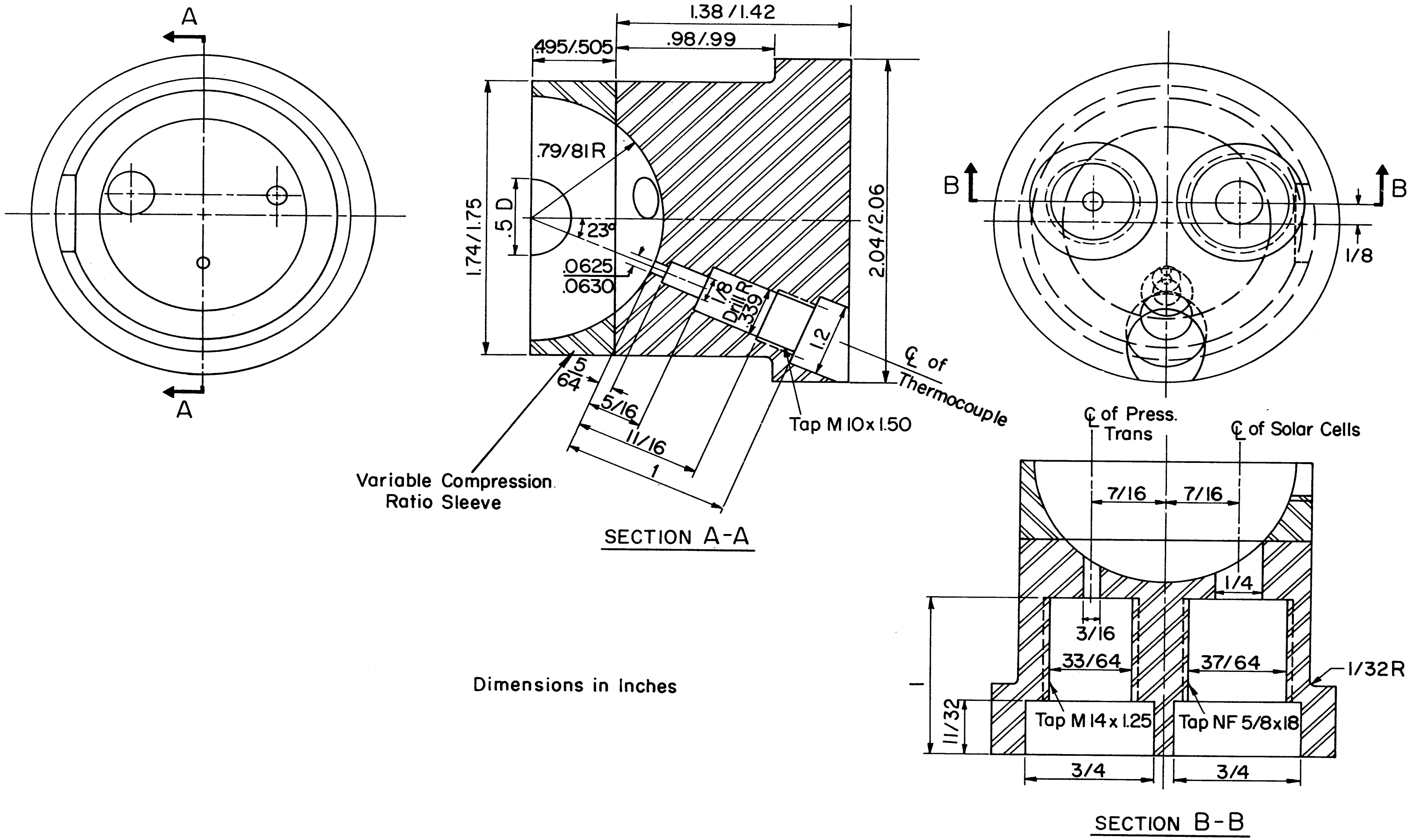


Figure 4. Modified Chamber Plug Showing Positions of Solar Cell and Pressure Transducer and Thermocouple.

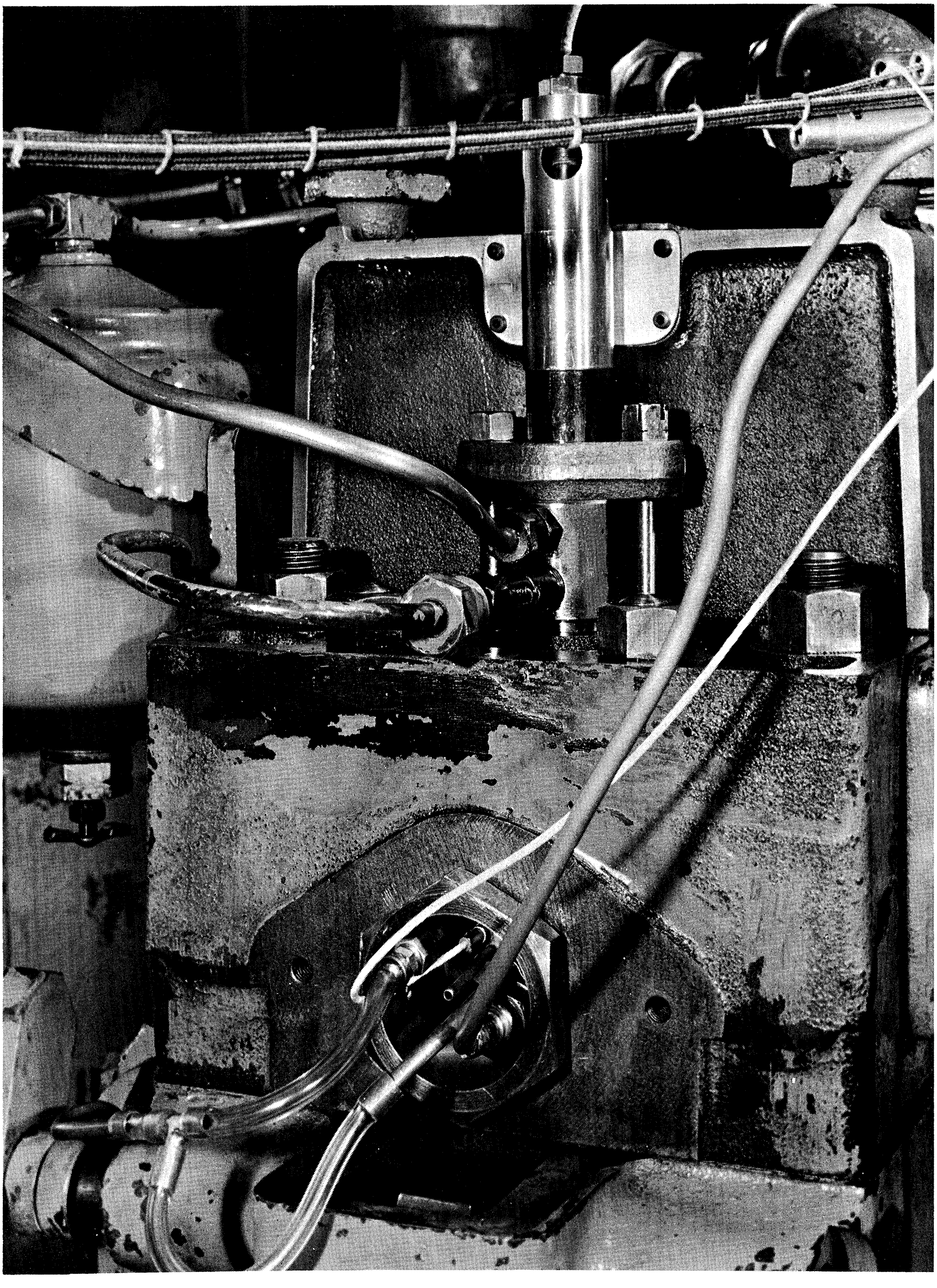


Figure 5. Chamber Plug With Instruments Fitted to Cylinder Head.

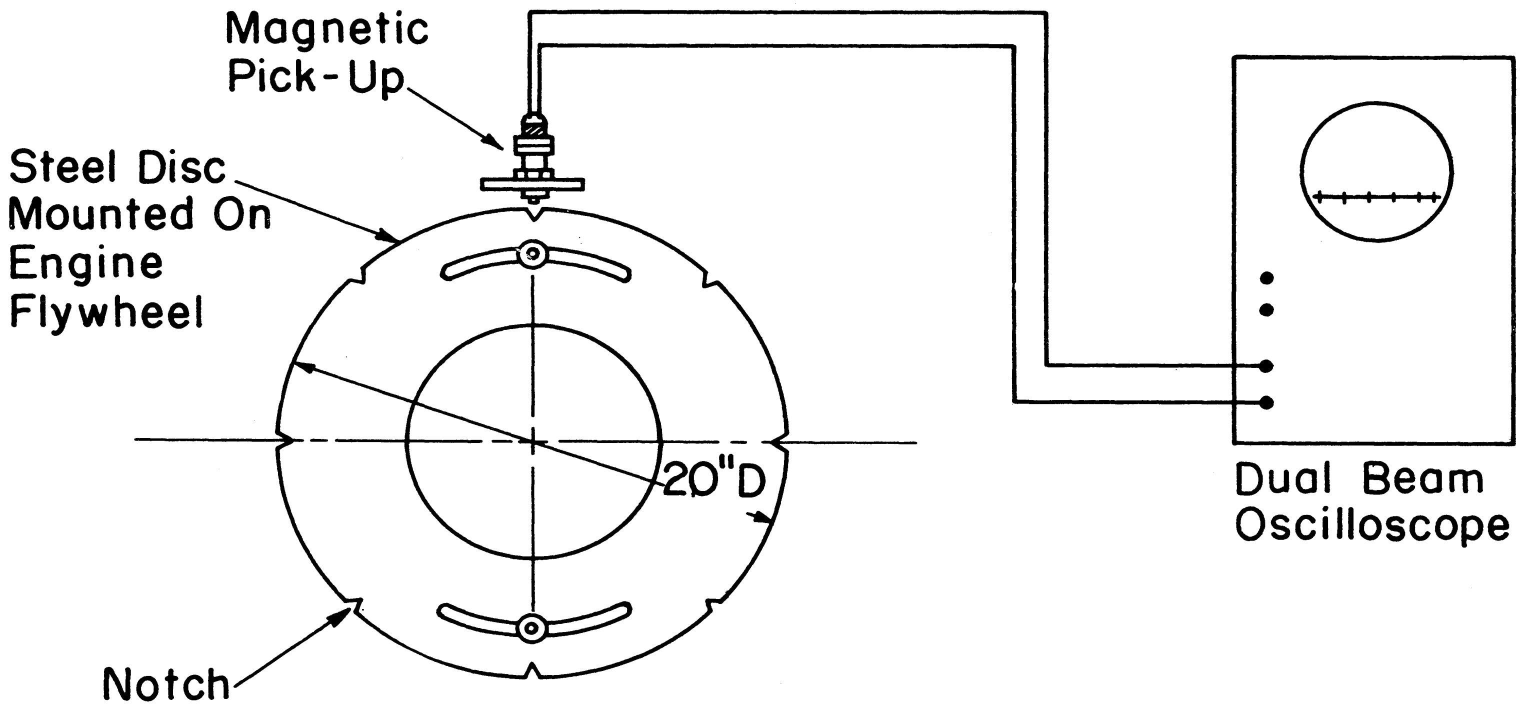
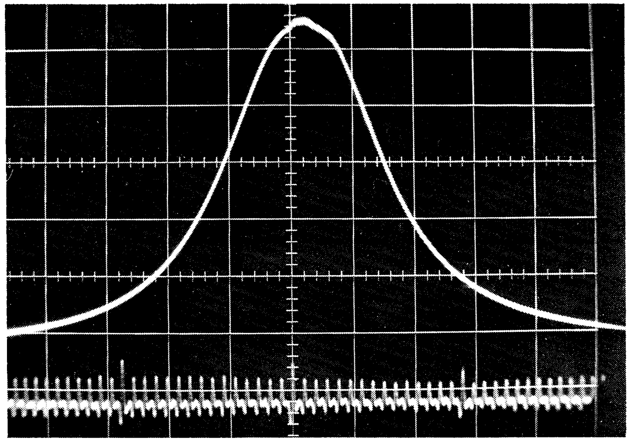
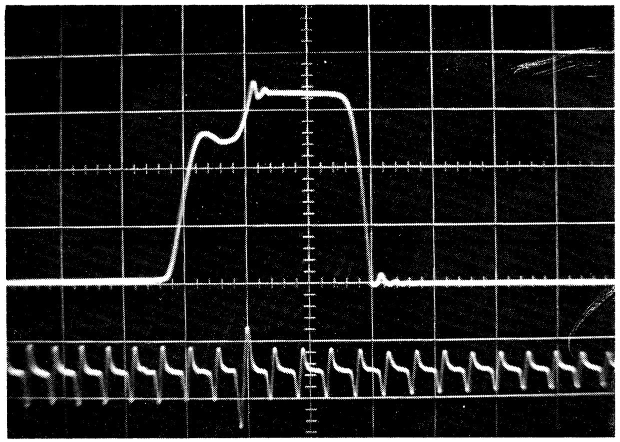


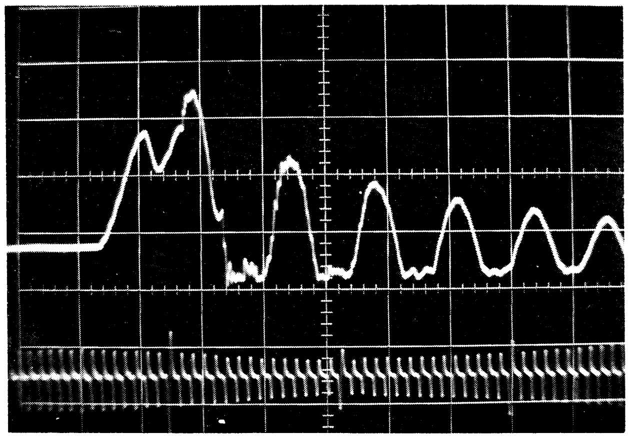
Figure 6. The Degree Marking Unit.



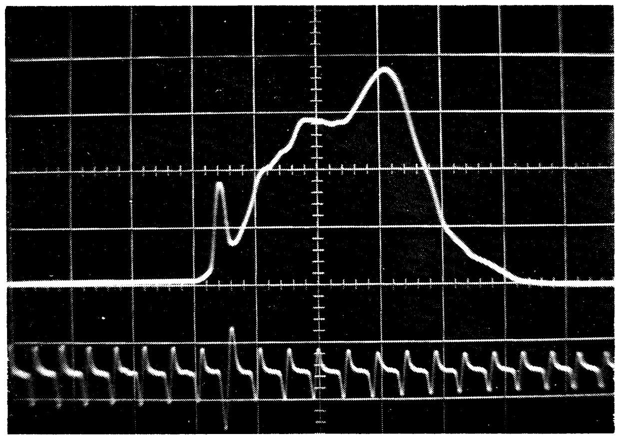
Gas Pressure vs Crank Degrees



Needle Lift vs Crank Angles



Fuel Pressure vs Crank Angles



Solar Cell Output vs Crank Angles

Figure 7. Oscilloscope Traces for Gas Pressure, Fuel Pressure, Needle Lift, Solar Cell Output and Crank Angles.

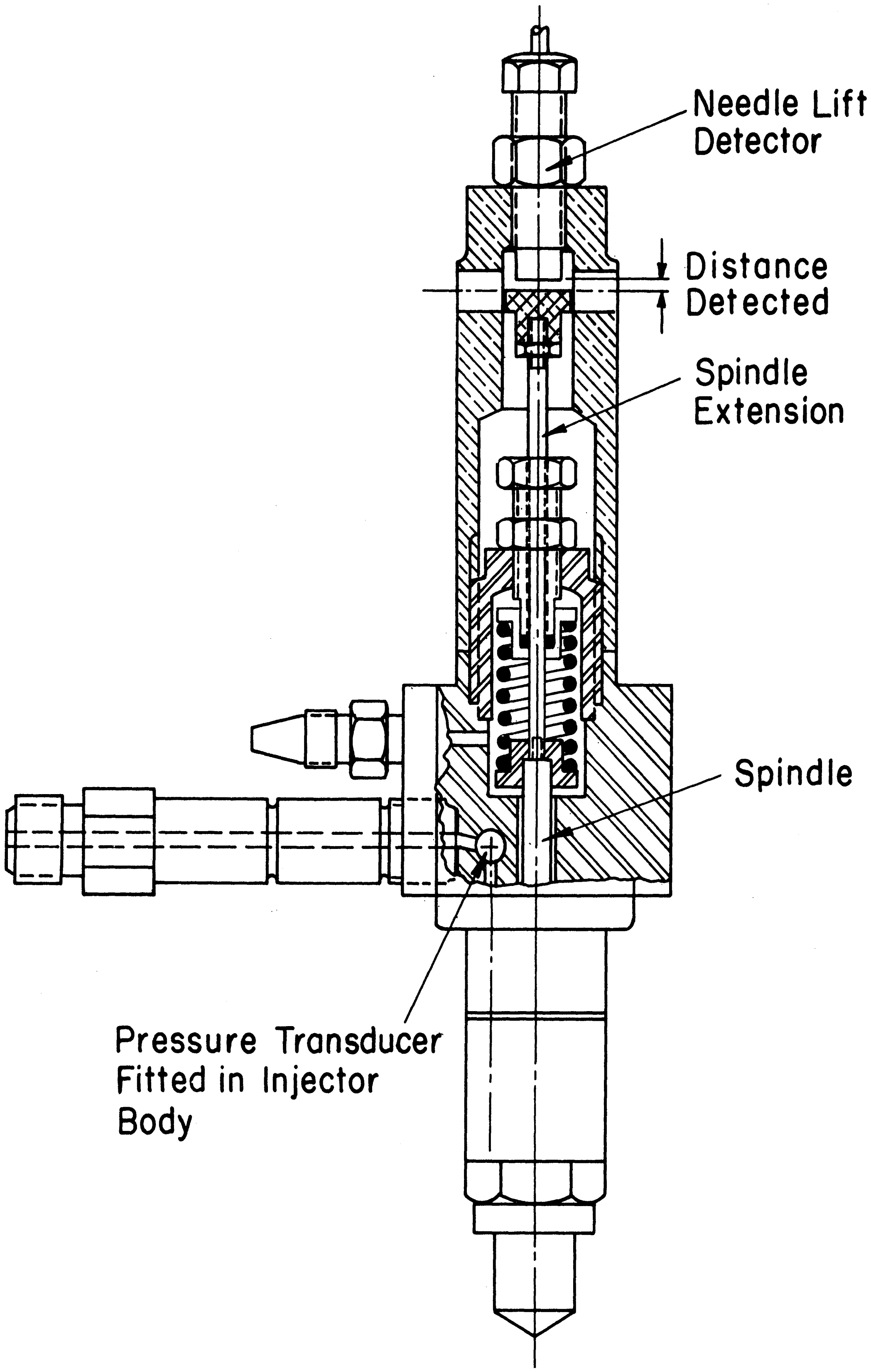


Figure 8. Fuel Injector Fitted With a Needle Lift Detector and a Pressure Transducer.

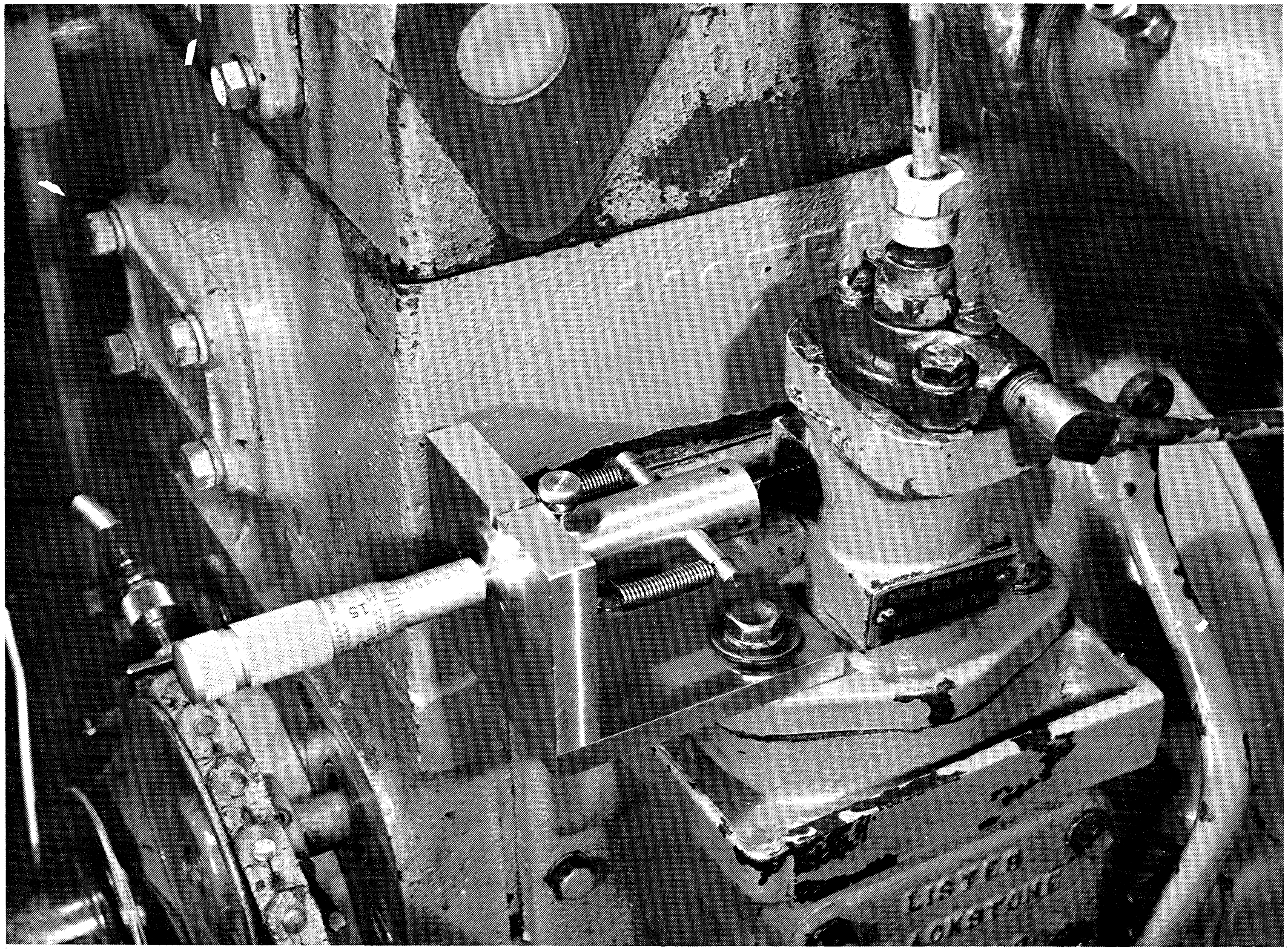


Figure 9. Fuel Pump With its Rack Controlled by a Micrometer.