ENCLOSURE (B) 35

PHOTOGRAPHIC INVESTIGATIONS OF FLAME PROPAGATION AND DETONATION IN ENGINE CYLINDERS

by

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LIST OF TABLES AND ILLUSTRATIONS

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SUMMARY

A small L-head single-cylinder testing engine was prepared for this work. It had a narrow quartz window as shown in Figure 2(B)35. Flame propagation in the cylinder was studied by photographs taken through the window.

I. INTRODUCTION

A. History of Project

These studies on engine combustion were started in March, 1933.

A small L-head, air-cooled single cylinder engine for agricultural use was installed. Its maximum speed was 2,500 RPM and the power about 1.5 hp.

A new cylinder head was designed, with a narrow slit along the center line of the head. A quartz window was made on this slit. It was constructed by the Hinode Co. in October 1933, and the experiments were performed during the period from April 1934 to March 1935.

B. Key Personnel Working on Project

Civil Eng. K. NAKATA

II. DETAILED DESCRIPTION

A. Description of Test Apparatus

Schematic figure of the test apparatus is shown in Figure 1(B)35. A film drum was mounted above the engine upon which a film of standard size (35mm) was wound. This drum was driven by a small motor of variable speed. A "Tessor" photographic lens of the aperture of f$\fallingdotseq$2.0 and the focal length of 7cm was inserted between the engine and the film drum so as to be moved vertically by adjusting screws. The engine was connected with a D.C. motor of about 2 hp. This was used to start the engine and to give a load to it. Details of the cylinder head are shown in Figure 2(B)35. The window was made of transparent fused quartz. It was a square bar of 13mm x 13mm x 150mm.

B. Test Procedure

The engine was started by the motor. When all the engine conditions were settled after several minutes' running, a small quantity of sodium bicarbonate was put in the air intake to color the flame yellow. The film drum was rotated by the motor and the speed was adjusted to get a satisfactory figure. The cover of the film drum was opened and the shutter was operated.

When the knocking flames were to be photographed, 20-30% of ethyl nitrate was added to the fuel. As the compression ratio of the engine was small ($\approx$4.0), no knocking occurred although an ordinary gasoline of low octane value (O.N.$\fallingdotseq$45) was used.

C. Experimental Results

Many photographs were taken at different degrees of severity of detonation. This was done by the quantity of ethyl nitrate added to the fuel.

The reproductive sketch of these photographs are shown in Figures 3,4,5,6.

Flame speed was calculated from the slope of the flame front, and was the order of 10 m/sec at the middle portion of the combustion chamber. No flame was observed immediately after the ignition, i.e., the induction period was observed and this sometimes amounted to about 10 degrees of crank shaft revolution. This was equal to about 1/1500 second.

Flame velocities of knocking condition and non-knocking condition were compared but no difference was recognized between the portion from the spark position to the knocking position.

Flame speed at the knocking portion was intended to be measured, and the speed of revolution of the film drum was increased 2 or 3 fold, but the flame front was always vertical to the time axis in the knocking region. When the speed was increased, the result was that the image of the flame was faint and that it was difficult to determine the flame speed in the knocking region by such a method.

Vertically striped bright flame patterns were observed in the detonation region. The frequency of the patterns was measured and found to decrease as the piston went down in the cylinder. It was about 6,000 cycles near the T.D.C, and 5,000 at the end of combustion.

III. CONCLUSION

For the first time the author conducted an experiment on the study of combustion. In performing the above mentioned experiment, he had not intended to draw any important conclusion from it but chiefly to enlighten himself. At first he was afraid whether such an engine which was designed by a physicist like himself could run satisfactorily.

But the engine ran successfully and was not destroyed by a severe detonation. He took many photographs of flame propagation. Thus, he became familiar with the engine combustion and also learned how to operate a gasoline engine. The flame speed of the order of 10 m/sec. at the center of the combustion chamber was smaller than he had expected. That was due to the flat combustion chamber and low compression ratio.

At that time there were many theories on detonation. One of them was that the flame propagation velocity before the occurrence of knocking would be faster in the case of the knocking condition than in the non-knocking condition, so the unburnt charge would be compressed adiabatically more in the case of the former than in the latter, and this caused the spontaneous ignition. The results of the author's experiment did not verify this fact. The flame velocities were the same in both cases.

The frequency of knocking sound was determined by tuning forks and decided to be nearly 6,000 cycles.

This coincided with the frequency of striped patterns observed in the knocking flame.

These patterns were supposed to appear by the adiabatic compression of burnt gas due to detonation waves. The next step of his work was to proceed to measure the pressure changes in the engine cylinder.

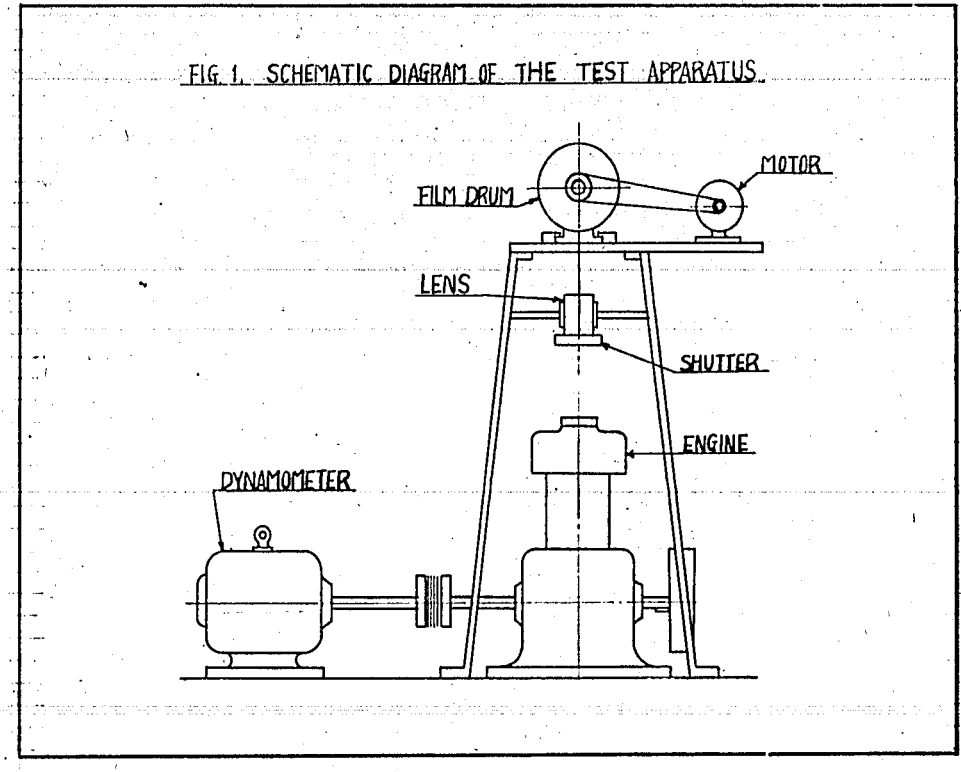

Figure 1(B)35

SCHEMATIC DIAGRAM OF THE TEST APPARATUS

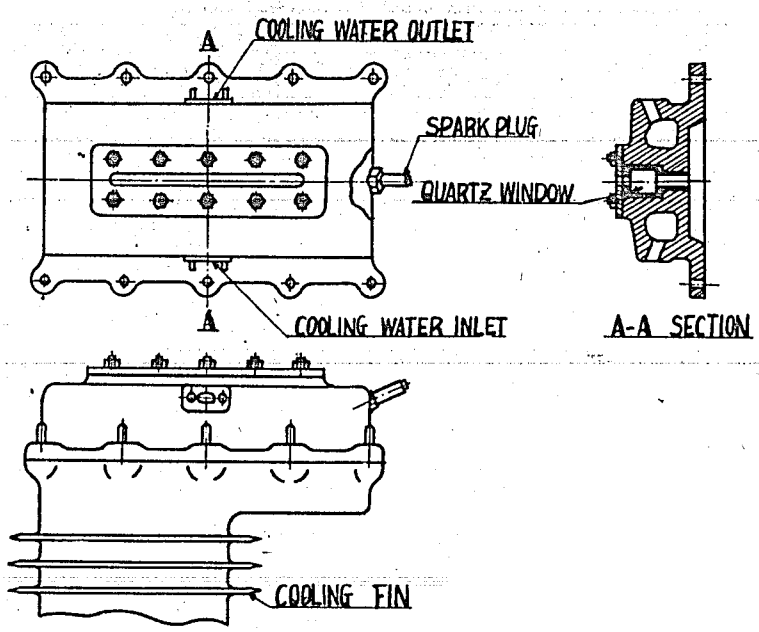

Figure 2(P)35
CYLINDER HEAD

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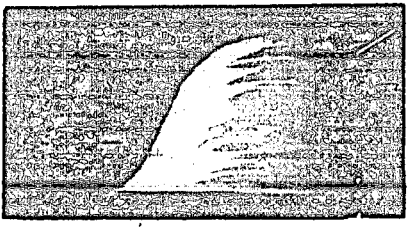

Figure 3(B)35
NO KNOCK

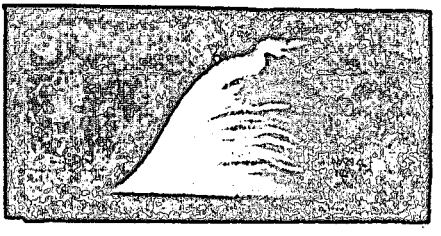

Figure 4(B)35
INCIPIENT KNOCK

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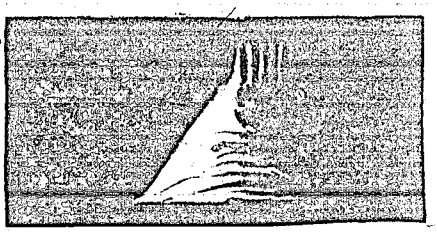

Figure 5(B)35
MODERATE BACK

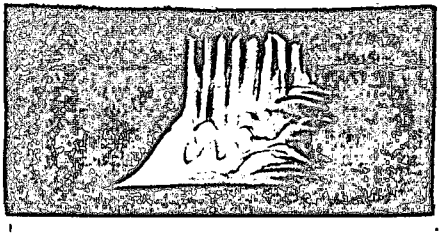

Figure 5(B)36
SEVERE BACK