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No. 408

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SUMMARY

High-speed motion pictures were taken of fuel sprays injected into the combustion chamber of the N.A.C.A. combustion apparatus. Three fuels, ethyl alcohol, gasoline, and fuel oil, ~~which~~ differed considerably in volatility were tested. By maintaining the engine temperature below that required for ignition the spray could be studied from soon after the start of injection until 130 crank degrees later. The results show that the sprays vaporize appreciably so that it is possible for the ignition in high-speed compression-ignition engines to take place from the vapor phase.

INTRODUCTION

Preliminary results obtained with the N.A.C.A. combustion apparatus (reference 1) indicated that there was marked vaporization of the fuel during and following its injection into highly heated and dense air. As this phenomenon should have an appreciable effect on the combustion of the fuel, particularly under the conditions which cause combustion shock, a series of tests was outlined to investigate fully the vaporization of the fuel spray. The purpose of this note is to present the first results obtained in these tests. The note is to be followed by a report which will discuss the vaporization and its effect on combustion in more detail.

METHODS AND APPARATUS

The N.A.C.A. combustion apparatus was used in the investigation. The apparatus consists of a single-cylinder test engine and an injection system together with a high-speed motion picture apparatus. The compression ratio of

the engine is 15.8:1. The sides of the combustion chamber of the engine are formed by glass windows through which the photographs are taken. In the operation of the apparatus the engine is driven at the desired speed by an electric motor. By means of a suitable clutch a single charge of fuel is injected into the combustion chamber of the engine during the compression stroke or the first part of the expansion stroke. At the same time that the injection is taking place high-speed motion pictures are taken of the fuel spray. In the present series of tests 13 pictures were taken at the rate of 1,000 per second. The photographs were timed relative to the position of the crankshaft of the engine by means of an electric spark. The temperature of the glycerin circulated in the heads and cylinder jacket of the engine was maintained at 100°F. throughout the tests so that combustion of the injected fuel would not take place. Consequently, at the engine speed used in these tests, 1,500 r.p.m., the physical changes in the state of the fuel could be studied over an interval of 130 crank degrees.

The injection pressure was 4,000 pounds per square inch, the injection valve opening pressure 4,000 pounds per square inch, and the initial pressure in the injection line before injection 1,000 pounds per square inch.

DISCUSSION AND TEST RESULTS

Ethyl alcohol, gasoline, and fuel oil were used in the present tests. These fuels were chosen because they differed considerably in volatility. (See fig. 1.) If the fuels did vaporize in the combustion chamber of the engine, the point at which the condensation of the vapor occurred should vary considerably depending on the boiling point or boiling range of the fuel. Proof of this is shown in Figures 2, 3, and 4. An examination of the figures shows that as the fuel came into the combustion chamber the silhouette of the spray was recorded on the photographic film. The spray then disappeared, or tended to disappear, following the cut-off of injection. Some time after top center the fuel which had vaporized condensed, blocking out the light from the spark discharges so that no light, or very little, was recorded on the photographic film. On each figure a line has been drawn through all the records to indicate top center. A second line has been

drawn through the last photograph after top center in which no fuel appeared with injection starting at 50° or 40° before top center. It will be noticed that the spark discharges were retarded so that the first photograph was taken near or at the end of injection. This was done so that a longer interval on the expansion stroke could be studied.

When ethyl alcohol was used, the vaporization was quite complete as indicated by the clear images of the combustion chamber following injection. The condensation took place between 50° and 60° after top center, the exact time depending somewhat on the injection advance angle (I.A.A.). With injection starting at 50° before top center the vaporization was practically completed at 10° before top center as is indicated by the clear photographs of the image of the combustion chamber. Particularly noteworthy is the speed with which the condensation took place as is shown by the sudden blocking out of the light from the condenser discharges between 55° and 60° after top center. The same is true with injection starting at 40° before top center. With injection starting at 30°, 20°, and 10° before top center and at top center the condensation becomes less rapid, as is indicated by the photographs in which some of the condensate is shown although the light is not completely blocked out.

With gasoline clear images of the combustion chamber were also obtained, indicating that vaporization must still have been quite complete although the condensation was less rapid. Condensation occurred, however, earlier in the expansion stroke (at 42° after top center). With injection starting at 80° and 70° before top center the photographs show that the fuel spray diffused, almost filling the chamber, and then vaporized, condensing on the expansion stroke.

With the fuel oil the vaporization was less rapid and the condensation occurred still earlier in the stroke (at 27° after top center with injection starting at 50° before top center). In no case was the vaporization complete with injection starting between 40° before and at top center. With injection starting at 50° before top center the fuel diffused completely through the chamber, blocking out all the light, and then vaporized.

A comparison of all the figures shows that, under the conditions of operation of high-speed compression-

ignition engines, fuel sprays will vaporize during and following their injection into the engine and that this vaporization takes place even though the temperature in the engine is not sufficient to cause combustion.

CONCLUSIONS

The test results presented show that fuel sprays injected into the combustion chamber of a compression-ignition engine vaporize appreciably so that the combustion can proceed from the vapor phase instead of from the liquid phase.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., January 21, 1932.

REFERENCE

1. Rothrock, A. M.: The N.A.C.A. Apparatus for Studying the Formation and Combustion of Fuel Sprays and the Results from Preliminary Tests. T.N. 389, N.A.C.A., 1931.

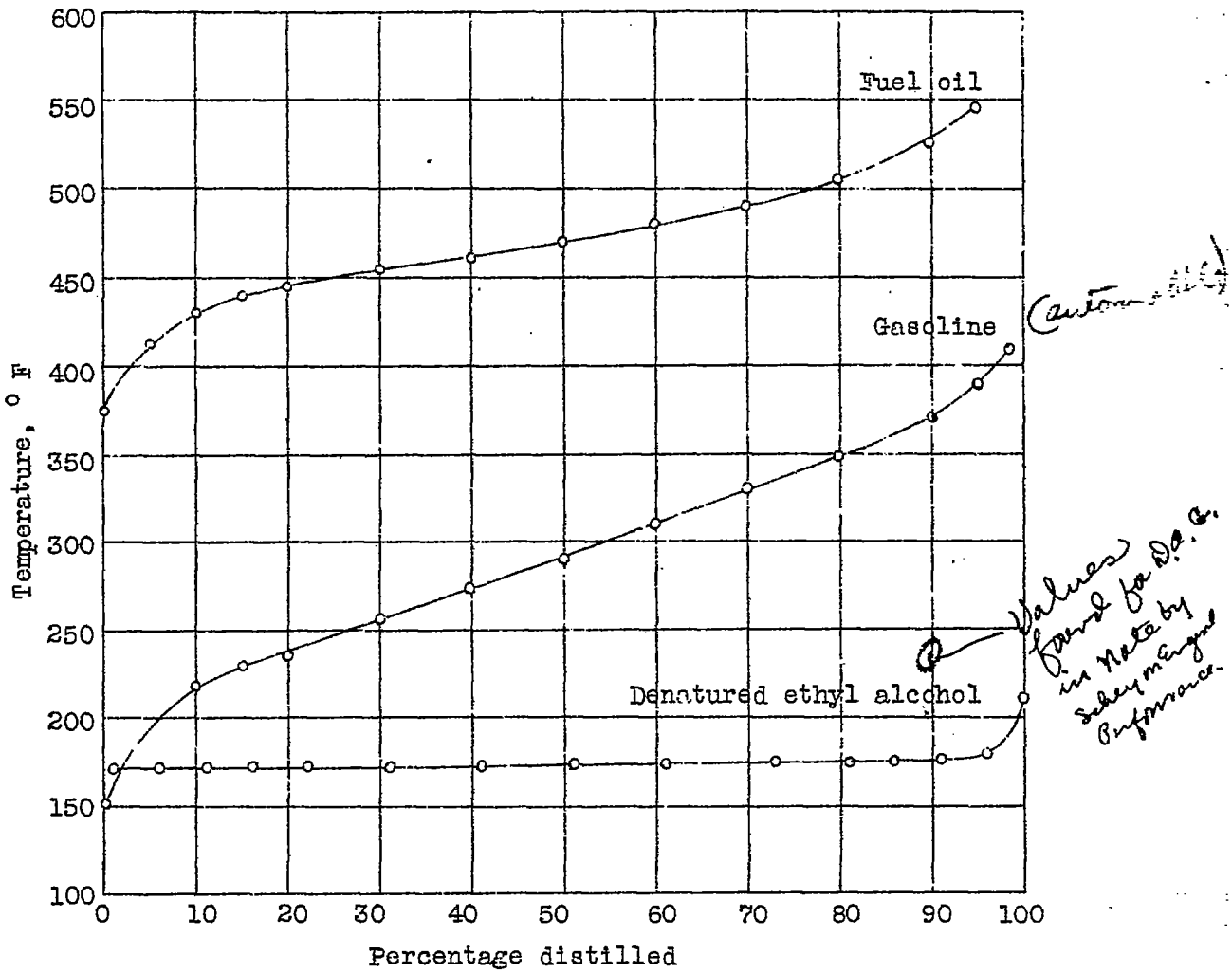

Fig. 1 Distillation curves of fuels tested.

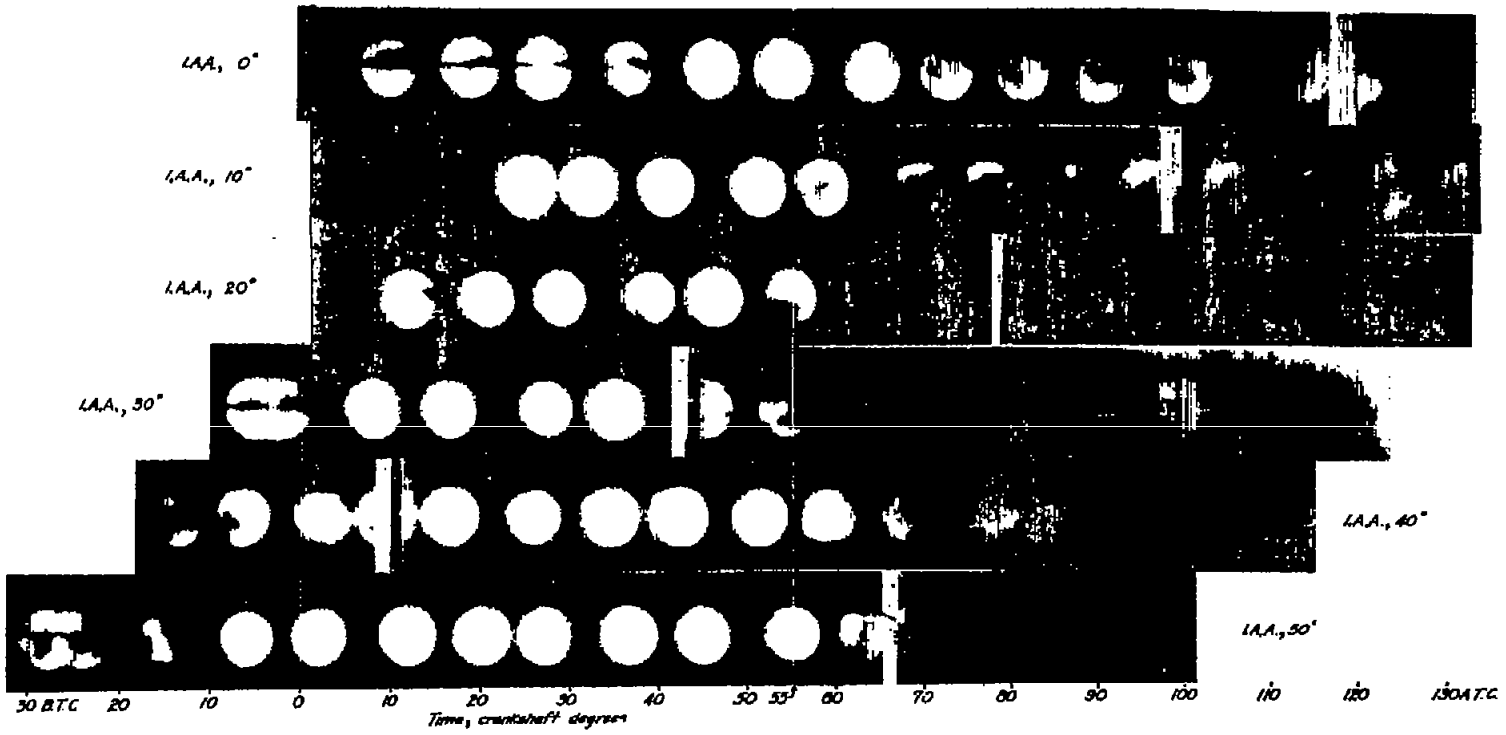

Fig. 2 Vaporization of ethyl alcohol. Engine r.p.m., 1500. Engine temperature, 100°F. Fuel quantity, 0.00025 pound. Discharge-orifice diameter, 0.020 inch.

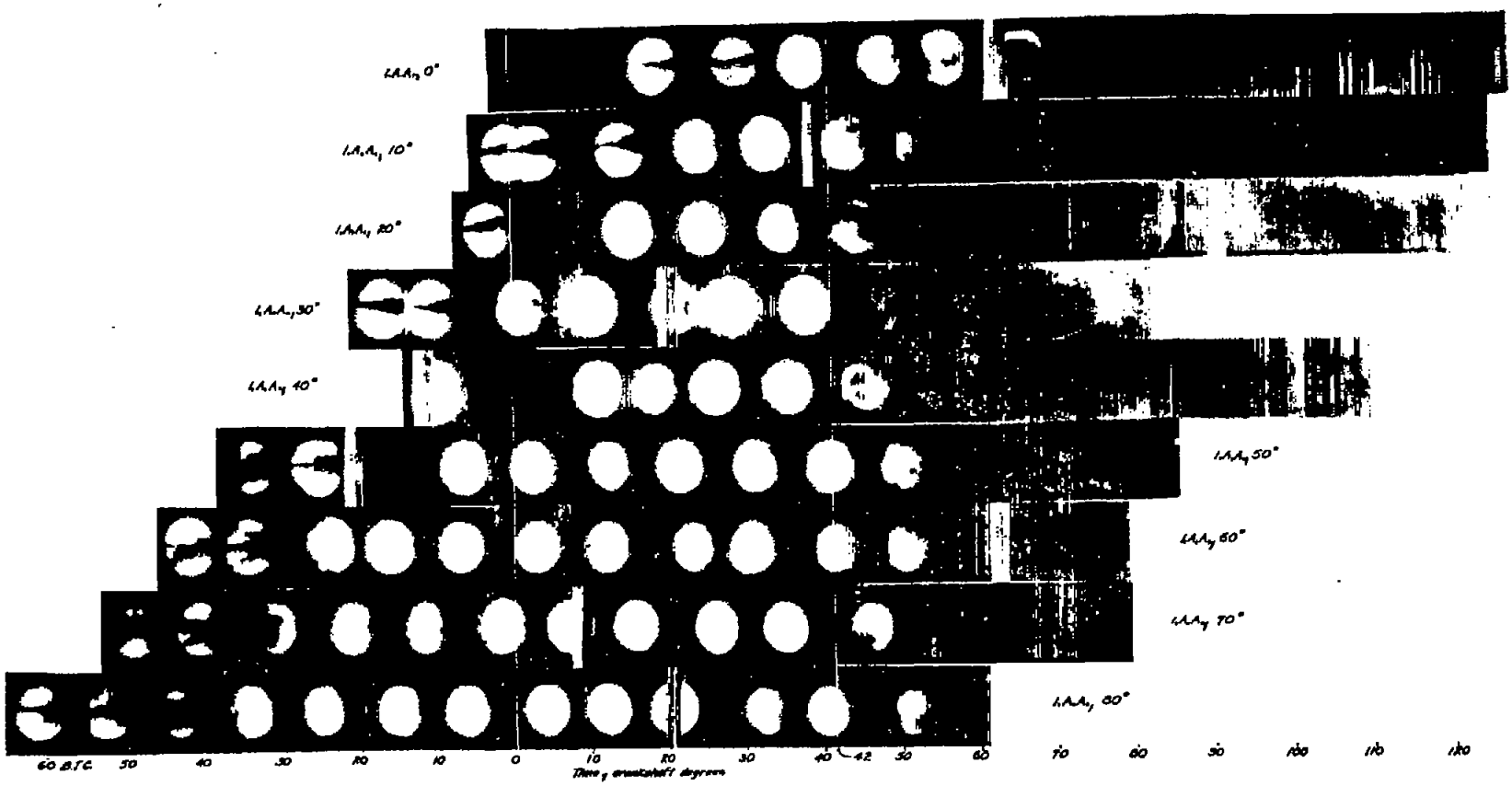

Fig. 3 Vaporization of gasoline. Engine r.p.m., 1500. Engine temperature, 100°F. Fuel quantity, 0.00025 pound. Discharge-orifice diameter, 0.020 inch.

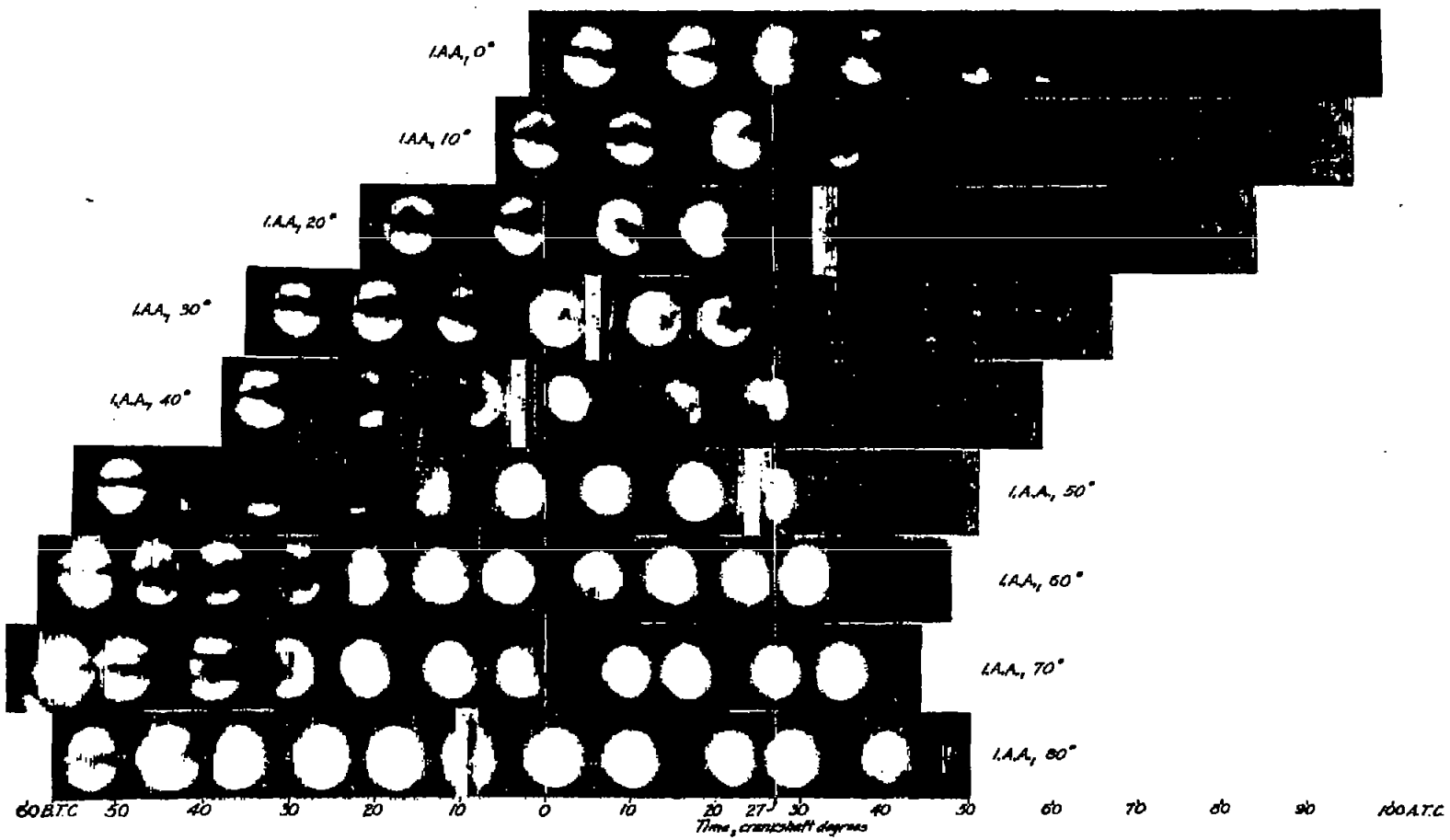

Fig. 4 Vaporization of fuel oil. Engine r.p.m., 1500. Engine temperature, 100°F. Fuel quantity, 0.00024 pound. Discharge-orifice diameter, 0.020 inch.