TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 384

THE EFFECT OF INJECTION-VALVE OPENING PRESSURE ON SPRAY-TIP PENETRATION

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SUMMARY

The effect of various injection-valve opening pressures on the spray-tip penetration was determined for several injection pressures. A common-rail fuel injection system was used. For a given injection pressure a maximum rate of penetration was obtained with an injection-valve opening pressure equal to the injection pressure. As the excess of the injection pressure over the injection-valve opening pressure was increased for a given injection pressure, the effect of the injection-valve opening pressure on the spray-tip penetration was increased.

INTRODUCTION

The rate at which the tip of a spray from an automatic injection valve penetrates through compressed air depends on the initial velocity with which the spray starts, the succeeding velocities of the rest of the spray as it issues from the discharge orifice, the discharge-orifice shape, the injection valve design, the physical properties of the fuel, and the physical properties of the air. The effect on the penetration of all these variables, with the exception of the initial spray-tip velocity, has been investigated by the National Advisory Committee for Aeronautics.

The test results presented in reference 1 show that when the injection-valve opening pressure was increased 150 per cent neither the maximum injection pressure nor the mean effective pressure showed much variation. Consequently, any appreciable change in the spray-tip penetration obtained by varying the injection-valve opening pressure is due to the change in the velocity and therefore in the kinetic energy of the spray at the start of injection. From these tests it can be definitely concluded that the spray-tip penetration is affected not only by the kinetic energy of the fuel as it leaves the nozzle, but also by the kinetic energy of the fuel which issues from the discharge orifice during the remainder of the injection period.

The purpose of the present report is to present the results of an investigation to determine the effect of the injection-valve opening pressure, which controls the initial spray-tip velocity, on the penetration of the spray tip. The research was conducted at the Langley Memorial Aeronautical Laboratory, Langley Field, Va.

METHODS AND APPARATUS

High-speed motion pictures were taken with the N.A.C.A. spray photography equipment (reference 2) of the start and development of a fuel spray from an automatic injection valve. From the pictures the penetration of the spray tip was measured. A common-rail fuel injection system was used. The injection valve was the same as Gelalles used (reference 3) in his investigation of the effect of orifice length-diameter ratio on the spray characteristics. The discharge orifice had a diameter of 0.020 inch and a length-diameter ratio of 6. The density of the air in the spray chamber was maintained constant at 1.11 pounds per cubic foot and the temperature of the air was that of the room. The fuel was Diesel oil with a specific gravity of 0.86 at 80°F. and a viscosity of 0.03 poise (38.5 seconds Saybolt Universal) at 73° F. and atmospheric pressure.

Injection pressures of 4,000, 6,000, and 8,000 pounds per square inch were used with valve-opening pressures from 500 to 8,000 pounds per square inch. An initial pressure of 500 pounds per square inch was used in the injection line.

Figure 1 shows the effect of injection-valve opening pressure on the spray-tip penetration for an injection pressure of 4,000 pounds per square inch. As the injection-valve opening pressure was increased from 1,000 pounds per square inch to a value equal to the injection pressure the penetration increased, but as the injection-valve opening pressure was further increased the penetration decreased.

The decrease in penetration as the injection-valve opening pressure was increased to a value greater than the injection pressure was caused by the fact that the injection-valve stem lift was small, producing a throttling action at the valve seat, and by the fact that the pressure rise after the injection valve opened was not sufficient to keep the stem lifted. In reference 1 are shown stem-lift records for injection pressures above and below the injection-valve opening pressure. These records show that for injection pressures below the injection-valve opening pressure the injection-valve stem may seat several times during the injection period. A discussion of the pressure waves which cause these phenomena is given in reference 1.

Figure 2 shows the effect of injection-valve opening pressure on the spray-tip penetration for an injection pressure of 6,000 pounds per square inch. The same general effects are noticed as those shown in Figure 1, the penetration up to 0.001 second after the start of injection reaching a maximum at an injection-valve opening pressure equal to the injection pressure.

With an injection pressure of 8,000 pounds per square inch (fig. 3) it can not be definitely decided whether or not a maximum penetration was obtained. Because of the limitations of the injection valve the injection-valve opening pressure could not be increased to a value greater than 8,000 pounds per square inch and consequently the last point on the curve is not reliable.

Figures 1, 2, and 3 show that for a given injection pressure as the excess of the injection pressure over the injection-valve opening pressure was increased, the effect of the injection-valve opening pressure on the spray-tip penetration was increased.

A comparison of the results presented in this report with those obtained with the open nozzle (reference 4) shows that considerable variation in the rate of spray-tip penetration can be obtained by varying the injection valve opening pressure. What the relationship is between the mass rate of penetration throughout the spray and the rate of spray-tip penetration is not known. Investigations of this relationship such as are being conducted by De Juhasz (reference 5) will materially aid in the interpretation of the spray photographs.

CONCLUSIONS

1. For a given injection pressure, using an injection-valve opening pressure of the same value as the injection pressure resulted in a maximum rate of penetration.

2. As the excess of the injection pressure over the injection-valve opening pressure was increased for a given injection pressure the effect of the injection-valve opening pressure on the penetration was increased.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., July 11, 1931.

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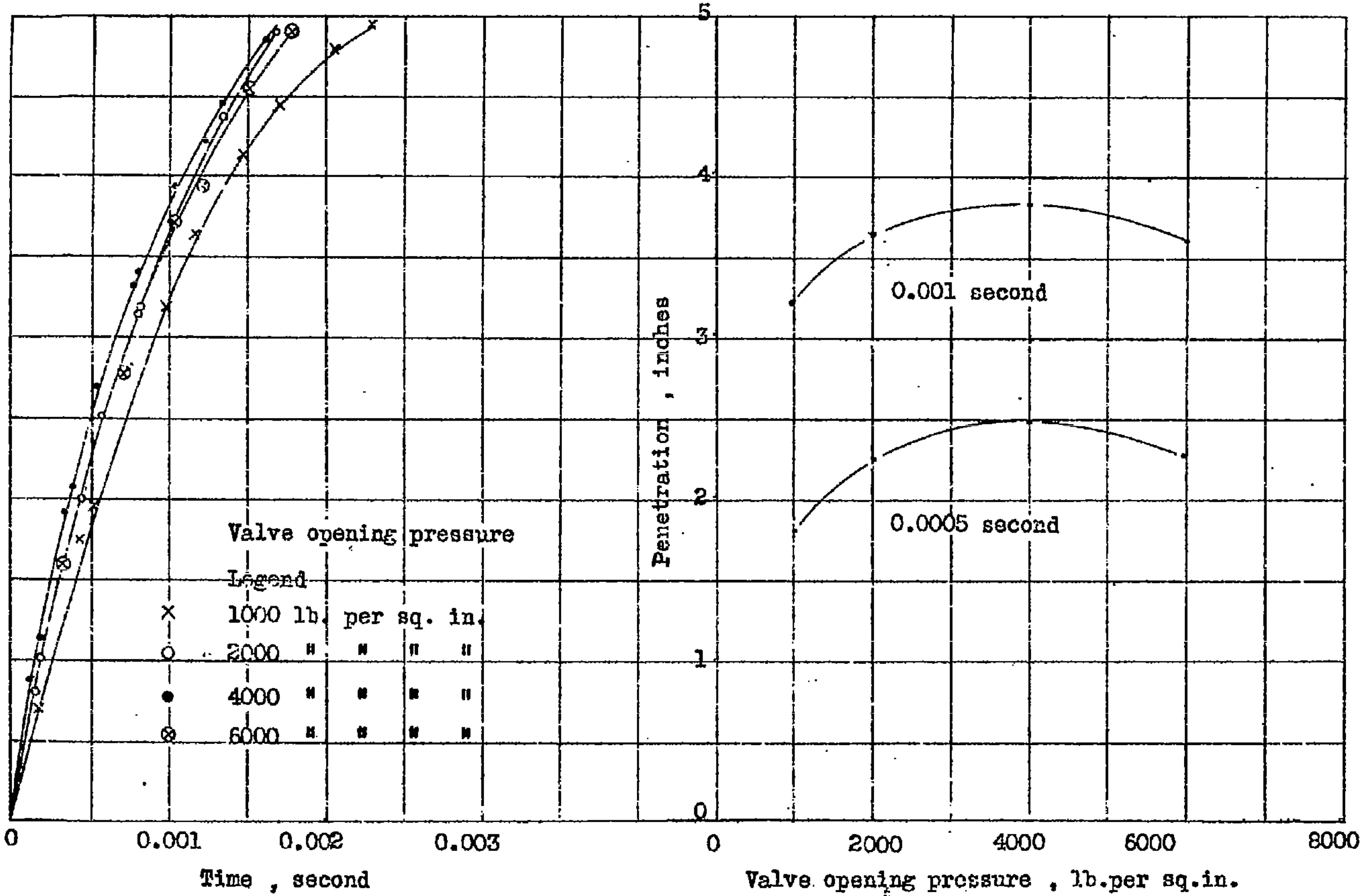

Fig. 1, Effect of valve opening pressure on penetration.
Injection pressure = 4000 lb. per sq. in.

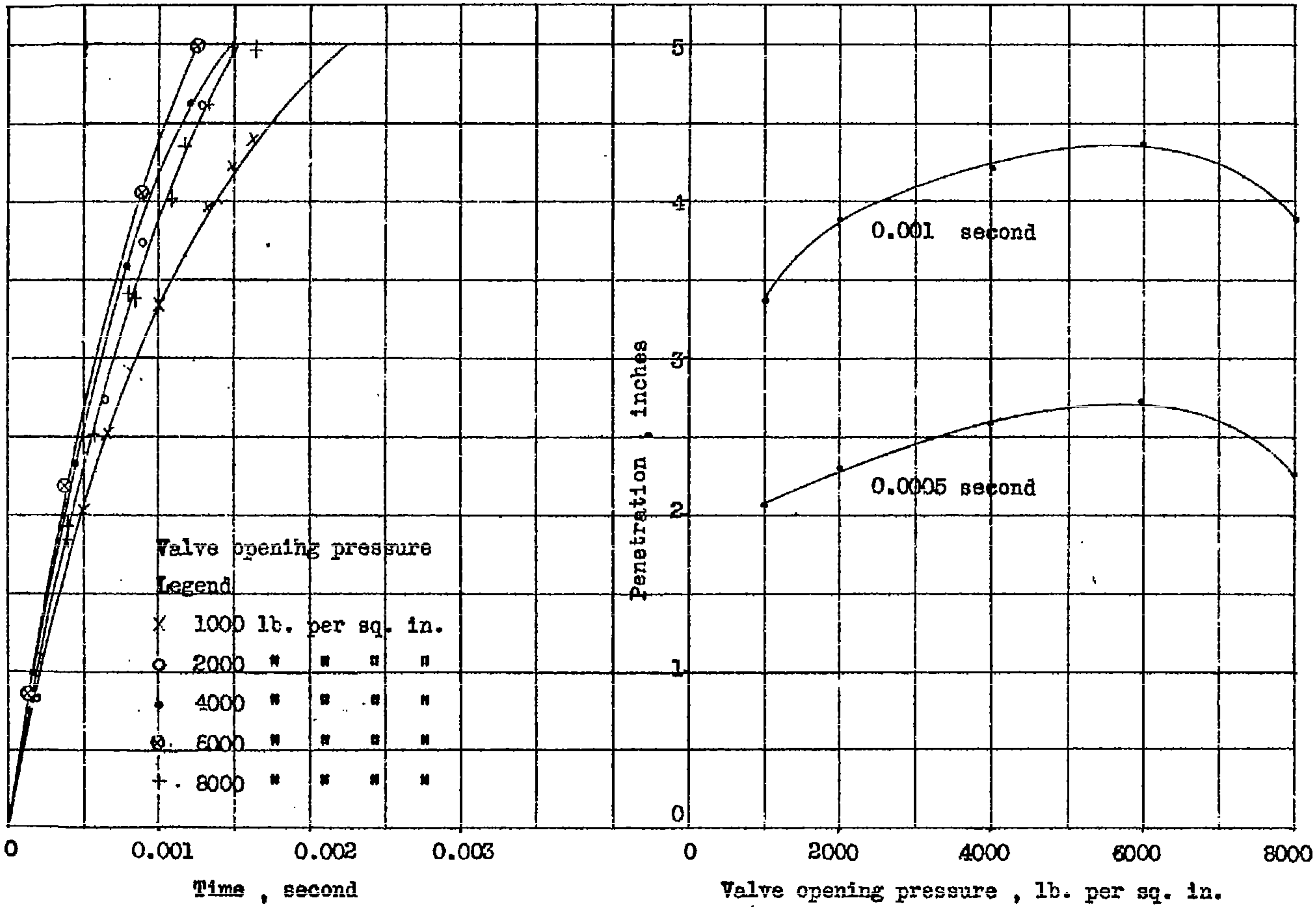

Fig. 2, Effect of valve opening pressure on penetration.
Injection pressure = 6000 lb. per sq. in.

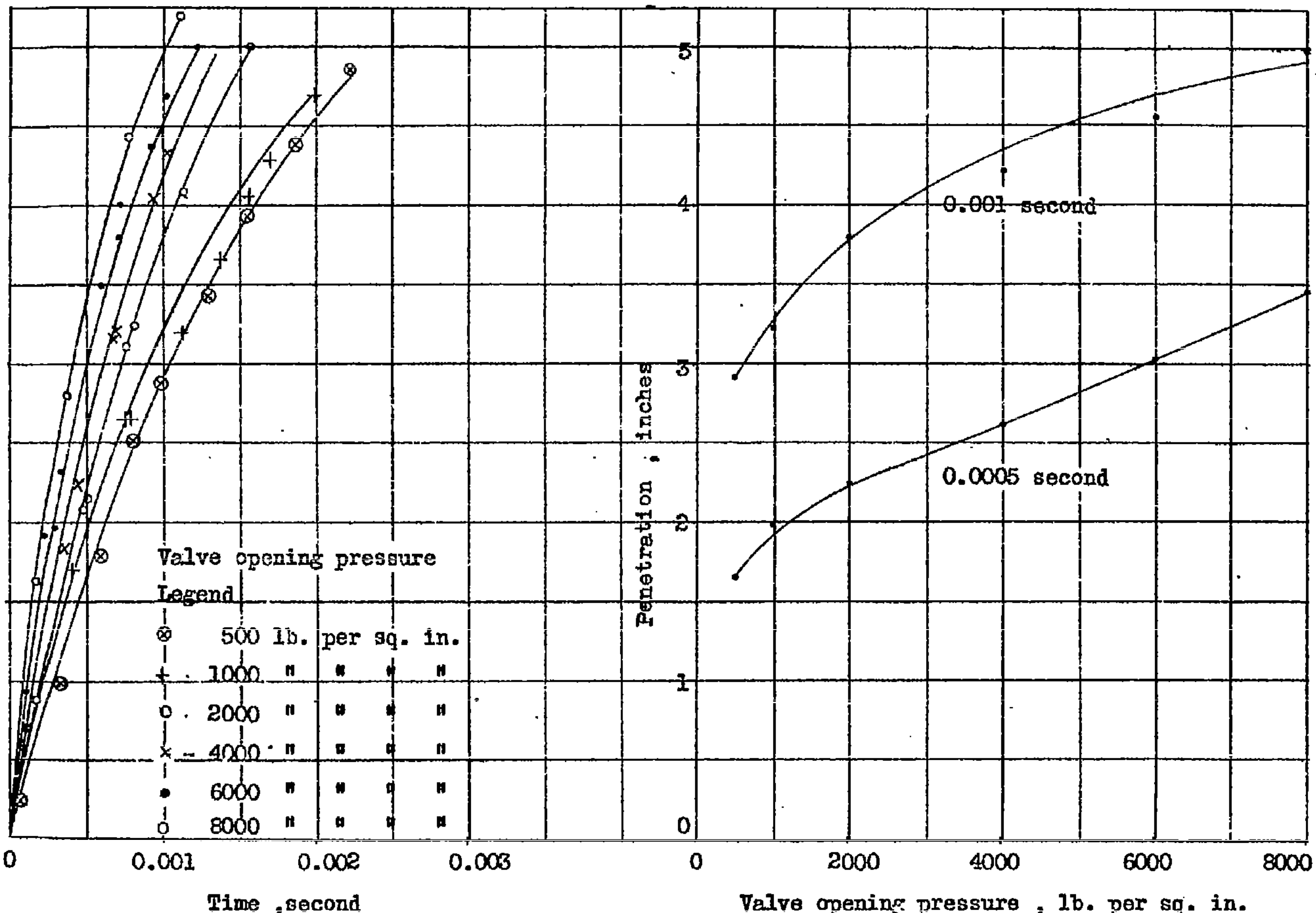

Fig. 3, Effect of valve opening pressure on penetration. Injection pressure = 8000 lb. per sq. in.