TECHNICAL NOTES

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SOME CHARACTERISTICS OF SPRAYS OBTAINED FROM PINTLE-TYPE INJECTION NOZZLES

By E. T. Marsh and C. D. Waldron
Langley Memorial Aeronautical Laboratory

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SUMMARY

This report presents the results of tests made with two pintle-type injection nozzles, one having a pintle angle of 8°, the other a pintle angle of 30°. The fuel was injected into a glass-windowed pressure chamber and the spray photographed by means of the N.A.C.A. spray-photography apparatus.

Curves are presented that give the penetration of the spray tips when fuel oil is injected by pressures of 1,500 to 4,000 pounds per square inch into air at room temperature and densities of 11 to 18 atmospheres. High-speed spark photographs show the appearance of the sprays in air at a density of 18 atmospheres. The results indicate that the pintle angles have little effect on the size of the spray cone angle, which is about the same as that of sprays from plain round-hole orifices. The penetration of the spray from the nozzle with an 8° pintle is slightly higher than that of the spray from the nozzle with the 30° pintle. The penetration of the sprays from the pintle nozzles, for comparable conditions of injection pressure and air density, is about the same as that of sprays from plain round-hole orifices. Increase in air density decreases the penetration in about the same ratio with all the injection pressures.

INTRODUCTION

Previous N.A.C.A. publications have given the characteristics of sprays obtained from nozzles having plain round-hole orifices of various sizes and various length-diameter ratios (references 1 - 10), from centrifugal-type nozzles having round-hole orifices of different sizes and used with valve stems having different helix angles (references 6 and 11), from an annular-orifice nozzle (reference 12), and from an impinging-jet nozzle (reference 13). In order to make the available information as complete as possible, the results of tests made to determine the characteristics of sprays obtained from pintle-type injection nozzles are here presented.

The photographs obtained show the spray appearances and from these photographs the penetration for two different pintle nozzles was obtained when using injection pressures of 1,500 to 4,000 pounds per square inch and valve-opening pressures of 600 to 3,600 pounds per square inch, and injecting into air at densities of 11 to 18 atmospheres and at room temperature. As explained in reference 5, the density and not the pressure of the air controls the penetration of sprays. Although the Committee completed the experimental part of these tests in 1930, the urgency of other work has delayed publication until the present time.

APPARATUS AND METHODS

The spray photographs were taken with the N.A.C.A. spray-photography apparatus described in reference 4. (See fig. 1.) The apparatus consists of an air-tight chamber with glass windows into which the fuel is injected, a high-speed camera containing a film moving 2,000 inches per second, and a spark gap across which a series of sparks jump at rates from 2,000 to 4,000 per second inside a reflector focused on the spray chamber. Each spark gives an instantaneous photograph of the spray and successive photographs show its development.

The pintle-type injection valve and nozzles were standard commercial products. The nozzle shown in figure 2 was designed to have a spray dispersion angle of 30°. This nozzle had a tapered pintle with a maximum diameter of 0.059 inch and had an orifice whose projected area was 0.000325 square inch with the stem seated and 0.000683 square inch with the stem lifted for injecting. The second nozzle was similar to the first one but, by making the pintle angle 8° instead of 30°, this nozzle was designed to give a spray dispersion angle of 8°. This nozzle had a pintle with a maximum diameter of 0.039 inch and had an orifice whose projected area was 0.000357 square inch with the stem seated and 0.000543 square inch with the stem lifted for injecting.

The steel injection tube was 50 inches long and had inside and outside diameters of 1/8 and 1/4 inch. The fuel oil had a specific gravity of 0.83 and a viscosity of 0.02 poise at 100° F.

The values of spray-tip penetration were obtained by measuring the heights of the spray images and were plotted against the measured time after the start of the spray. The start of the spray was taken as the point at which a smooth curve drawn through the tips of the spray images intersected a line drawn through the bases of the spray images. Because of their being recessed slightly into the chamber walls the nozzles are not visible in the photographs.

TEST RESULTS AND DISCUSSION

Nozzle with 8° pintle.- Figure 3 shows the appearance of the spray obtained from the nozzle with the 8° pintle when injected by a pressure of 1,500 pounds per square inch into air at a density of 18 atmospheres and at room temperature. This spray was similar to sprays obtained from plain round-hole orifices, although there were some slight differences. Sprays from plain round-hole orifices usually have smaller cross sections near the nozzles. Also, the spray from the pintle nozzle had a smaller cone angle than sprays from plain round-hole orifices during the early period of injection, but after the spray became fully developed there was little difference in cone angle. Although the spray had the appearance of being well atomized, no definite conclusions can be drawn about the atomization of a fuel spray from its external appearance.

Figure 4 shows, plotted against time, the distance the tip of the spray from the 8° pintle nozzle penetrated in the dense air at room temperature when the injection pressure was 1,500 pounds per square inch and the valve-opening pressure 600 pounds per square inch. The curves show that the spray penetrated 5 inches in 0.0025 second when injected into air at a density of 11.2 atmospheres, wheres it penetrated only 3.3 inches in the same time when injected into air at a density of 18 atmospheres.

Figures 4 to 7 show that as the injection pressure was increased the penetration in a given time steadily increased until with an injection pressure of 4,000 pounds per square inch the spray traveled a given distance from the nozzle in about one half the time required with an injection pressure of 1,500 pounds per square inch. The increase in penetration also was due partly to the increase in valve opening pressure for, as shown in reference 14, penetration increases with increase in valve opening pressure as long as the valve opening pressure is not greater than the injection pressure. These figures also show that increasing the chamber-air density decreased the penetration in about the same ratio with all the injection pressures. The appearance of the spray changed little with increase in injection pressure, but the cone angle increased slightly.

Nozzle with 30° pintle.- Figure 8 shows that the sprays from the 30° pintle nozzle had an appearance similar to that of sprays from the 8° pintle nozzle. The bulging at the tip of the spray was due to some peculiarity of this injection, for other pictures of sprays from this nozzle did not have bulging tips. This photograph had to be used for publication because the other photographs either were not good for reproduction or the photographs of the spray from the 8° nozzle taken under corresponding conditions were not good. Figures 9 to 12 show the penetration obtained with the 30° pintle nozzle under the same conditions that were used in testing the nozzle with an 8° pintle. For corresponding conditions, the penetration was slightly less with the 30° pintle nozzle. The density of the air seemed, however, to have less effect on the penetration when using this nozzle. These figures show that an increase in the chamber air density decreased the penetration in about the same ratio with each of the injection pressures used. In figure 10 part of the penetration curve for an air density of 11.2 atmospheres lies below that for a density of 14.6 atmospheres. This fact should not be taken as a disproof of the above statement concerning the effect of air density on spray penetration, but should be attributed to some experimental variation. The pintle nozzles used in this work are no longer available, so that the usual procedure in such cases of obtaining check data cannot be followed.

CONCLUSIONS

The data presented show that:

1. The cone angles of sprays from nozzles having pintle angles of 8° and 30° are different during the early

part of their injection periods but are approximately the same during the later stages, and are approximately the same as the cone angle of sprays from plain round-hole orifices.

2. The penetration per unit of time of sprays from the 8° pintle nozzle is slightly higher than that of sprays from the 30° pintle nozzle, and is about the same as that of sprays from plain round-hole nozzles.

3. Increasing chamber density decreases the penetration of sprays from pintle nozzles in about the same ratio for both high and low injection pressures.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., July 5, 1933.

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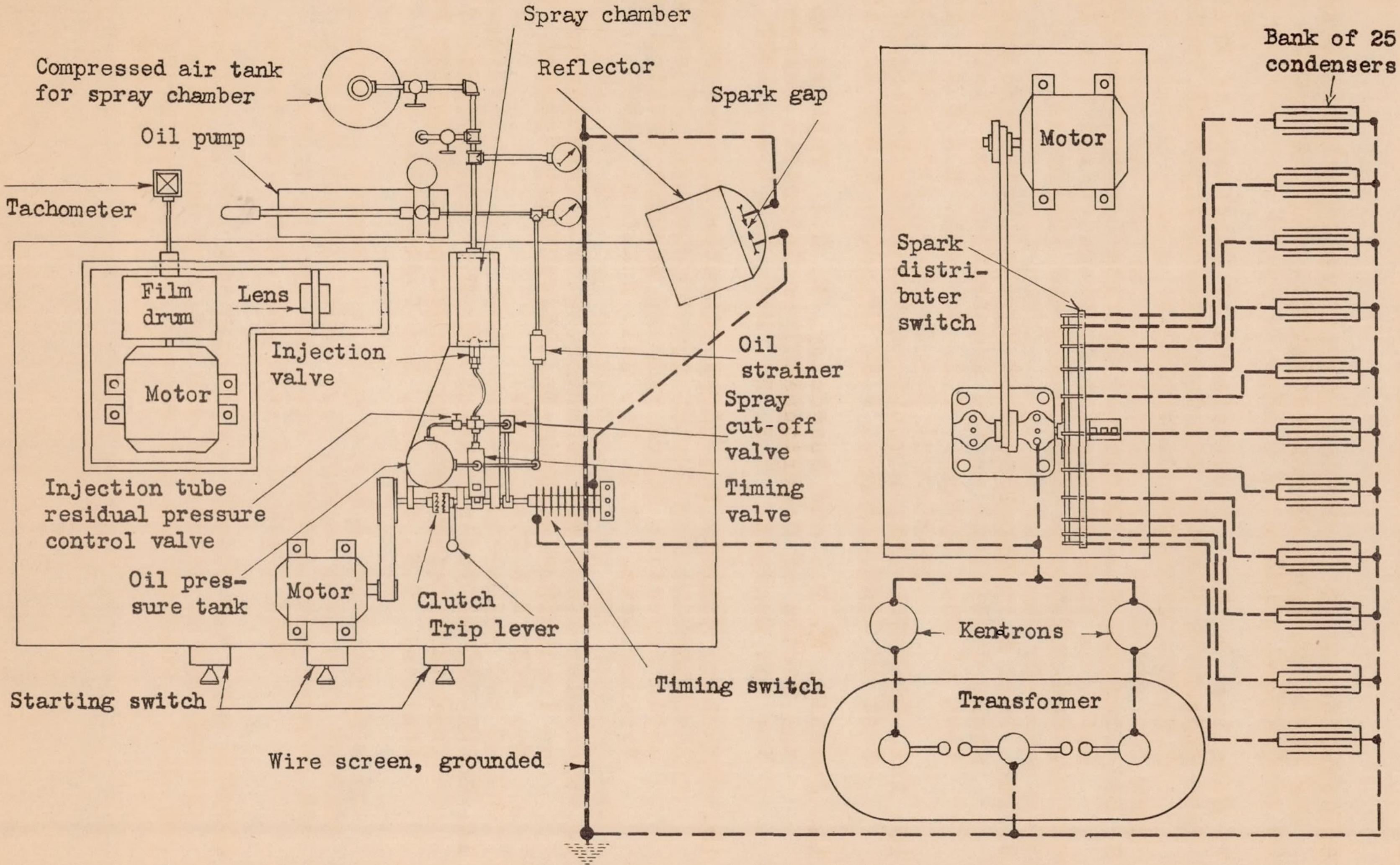

Figure 1.- Diagrammatic arrangement of spray-photography apparatus

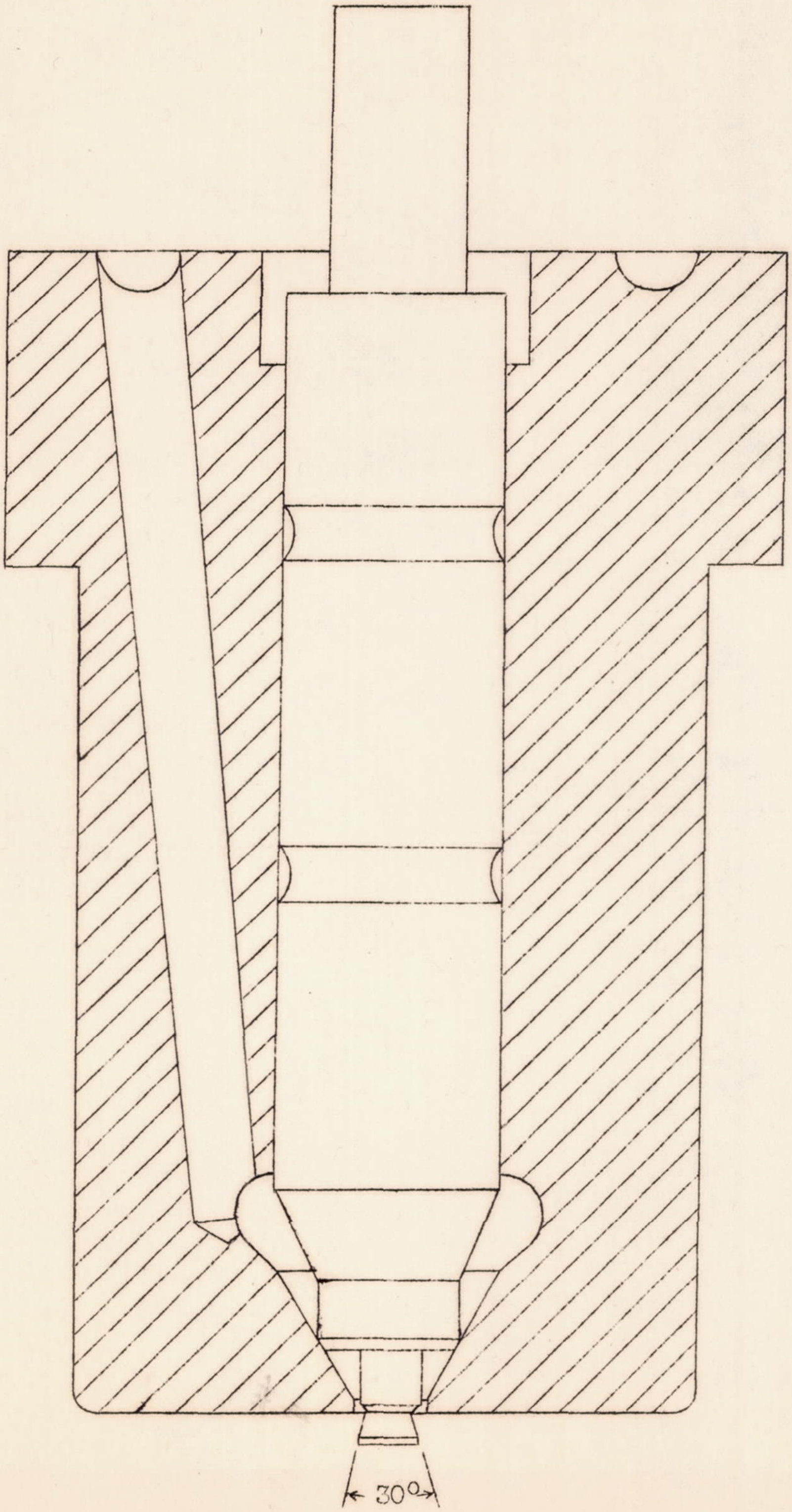

Figure 2.- Sketch of the nozzle with 30° pintle.
Pintle diameter, 0.059 inch.

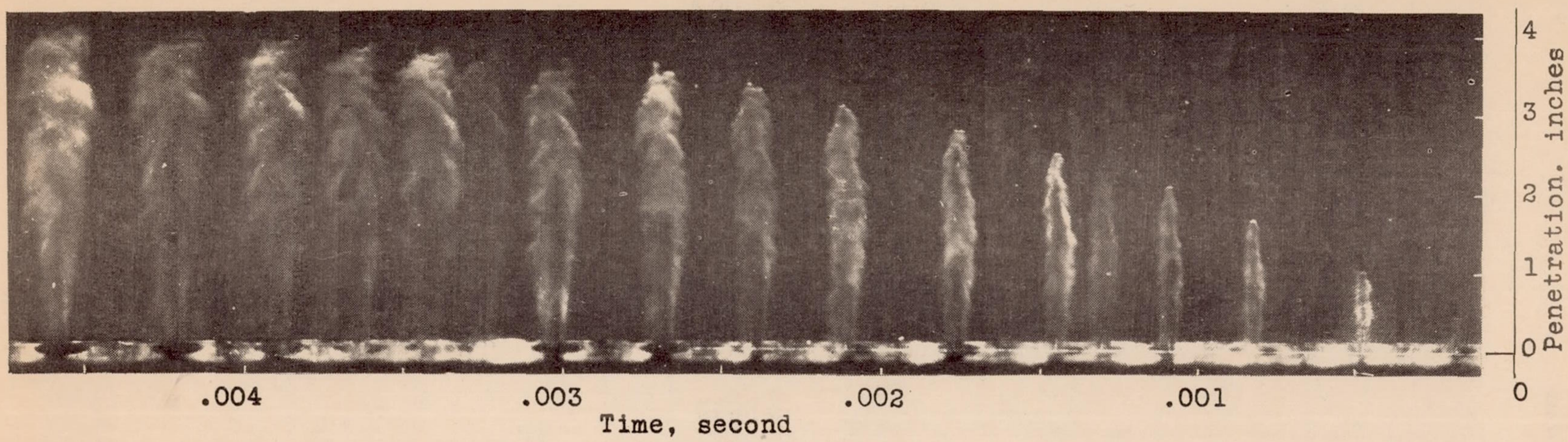

Figure 3. Spray from nozzle with 8° pintle, injection pressure 1500 lb./sq.in., valve opening pressure 600 lb./sq.in., chamber density 18 atmospheres

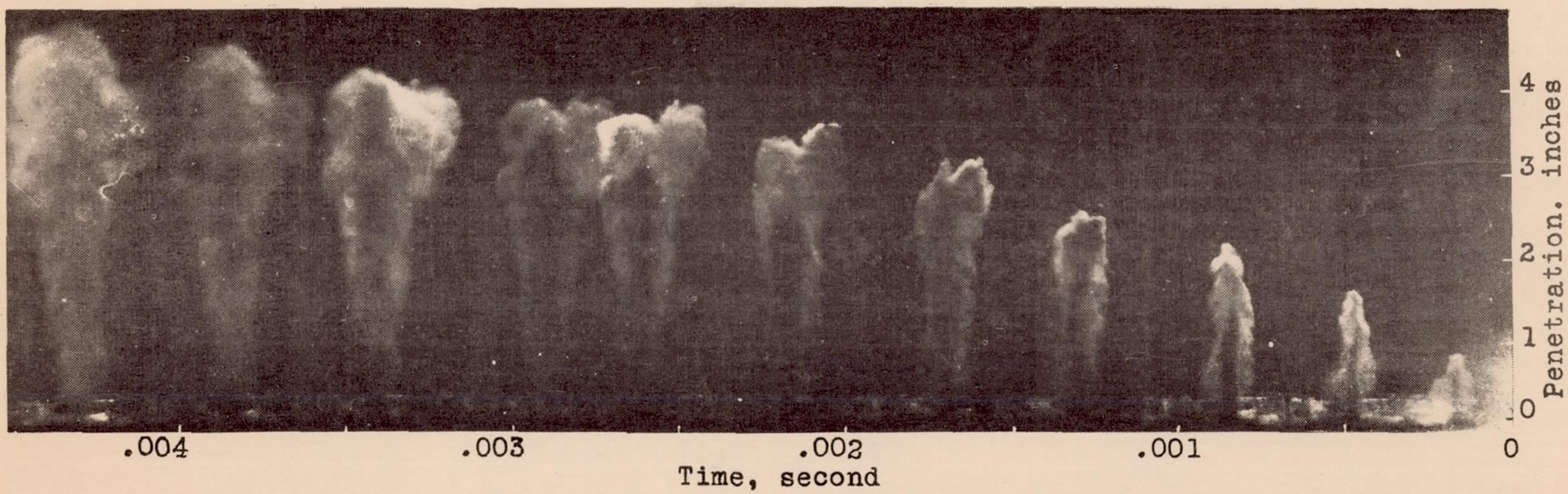

Figure 8. Spray from nozzle with 30° pintle, injection pressure 1500 lb./sq.in., valve opening pressure 600 lb./sq.in., chamber density 18 atmospheres

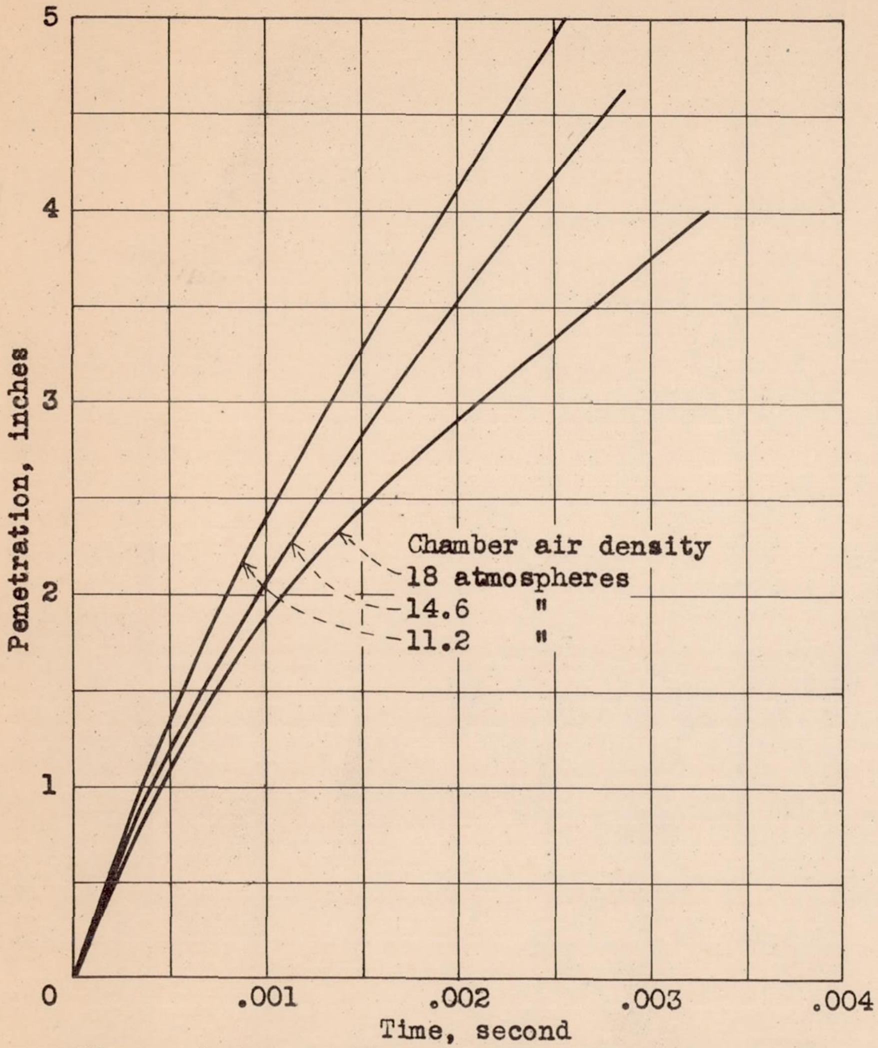

Figure 4.-Penetration of spray tip from nozzle with an 8° pintle, injection pressure 1500 lb./sq. in., valve-opening pressure 600 lb./sq. in.

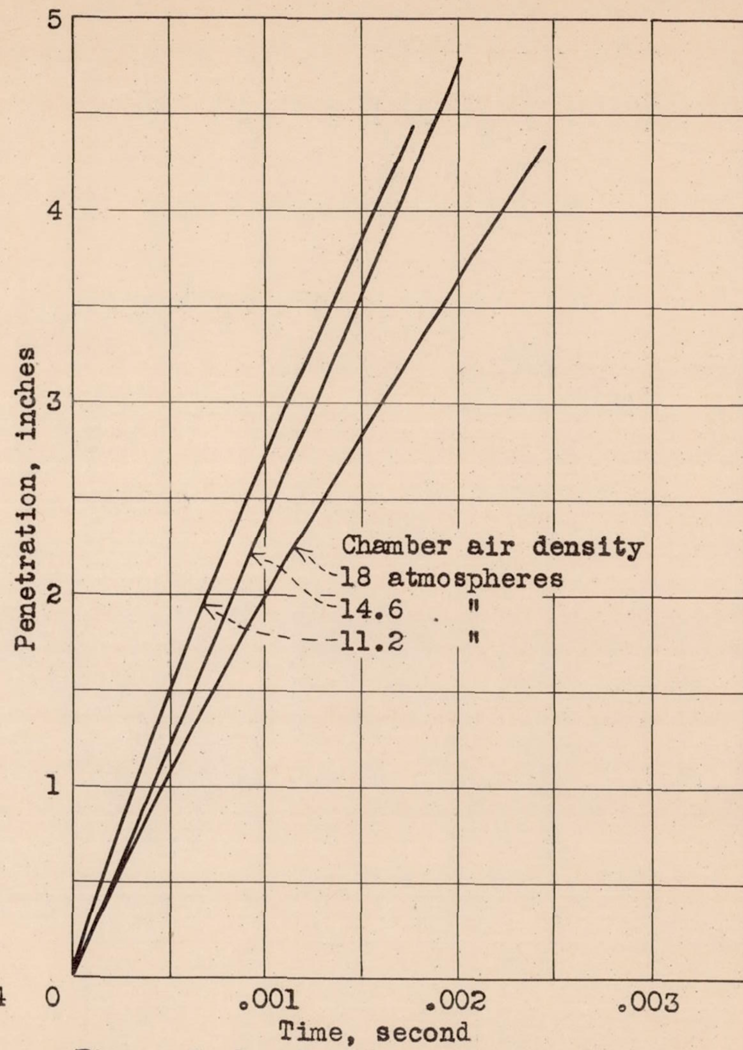

Figure 5.-Penetration of spray tip from nozzle with an 8° pintle, injection pressure 2000 lb./sq. in., valve-opening pressure 1600 lb./sq. in.

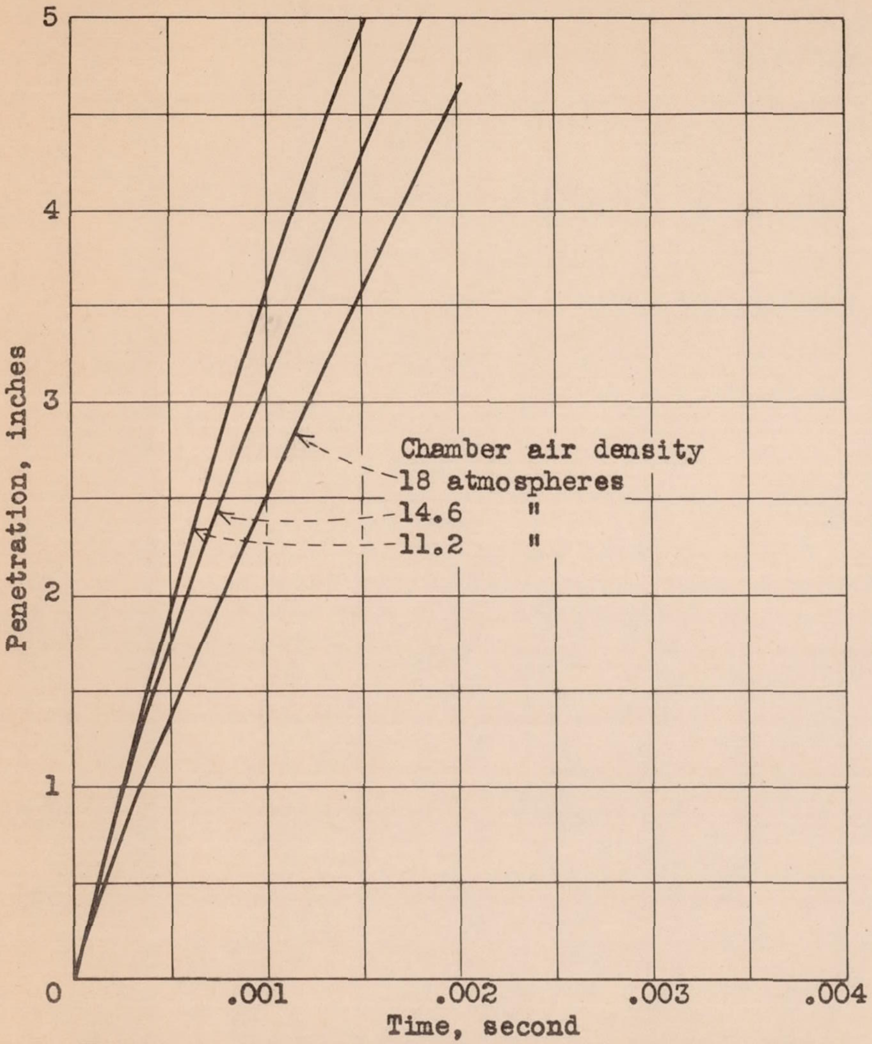

Figure 6.-Penetration of spray tip from nozzle with an 8° pintle, injection pressure 3000 lb./sq. in., valve-opening pressure 2600 lb./sq. in.

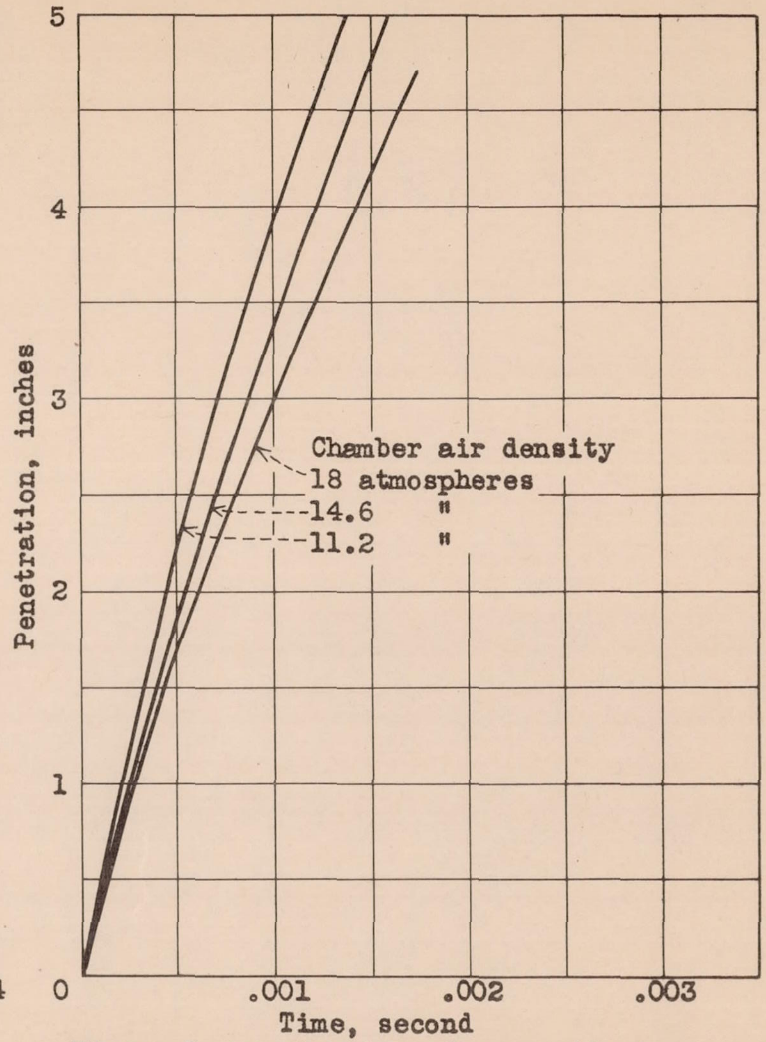

Figure 7.-Penetration of spray tip from nozzle with an 8° pintle, injection pressure 4000 lb./sq. in., valve-opening pressure 3600 lb./sq. in.

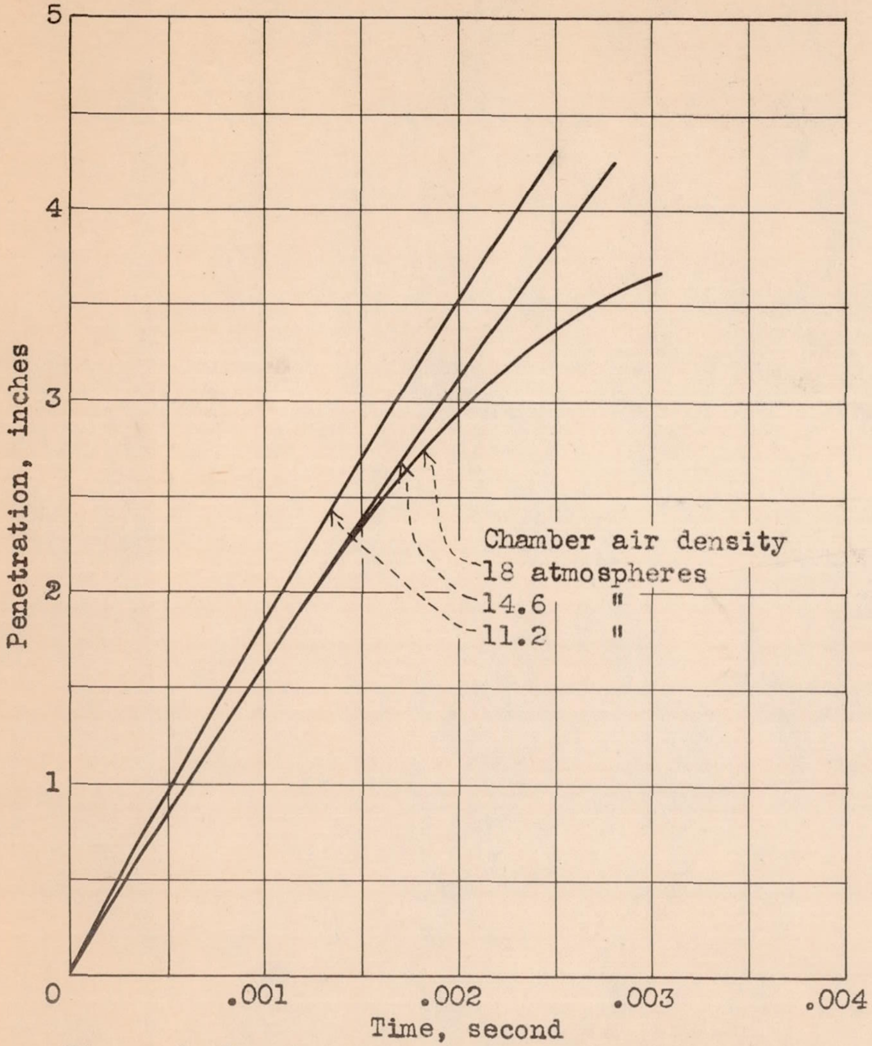

Figure 9.-Penetration of spray tip from nozzle with a 30° pintle, injection pressure 1500 lb./sq. in., valve-opening pressure 600 lb./sq. in.

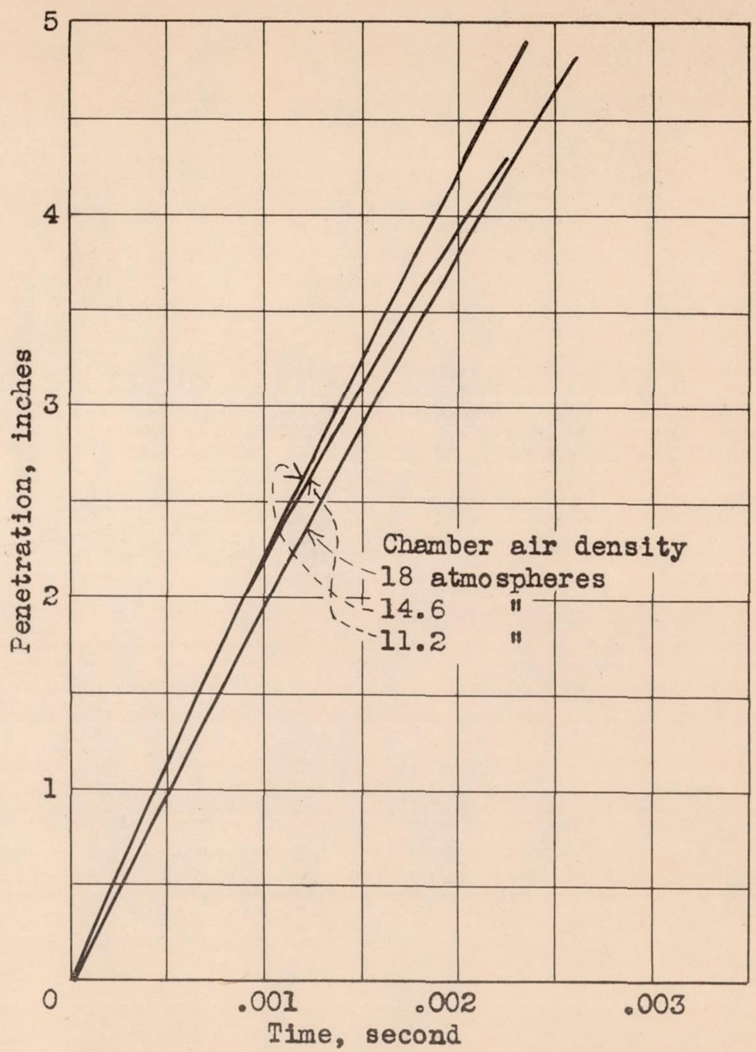

Figure 10.-Penetration of spray tip from nozzle with a 30° pintle, injection pressure 2000 lb./sq. in., valve-opening pressure 1600 lb./sq. in.

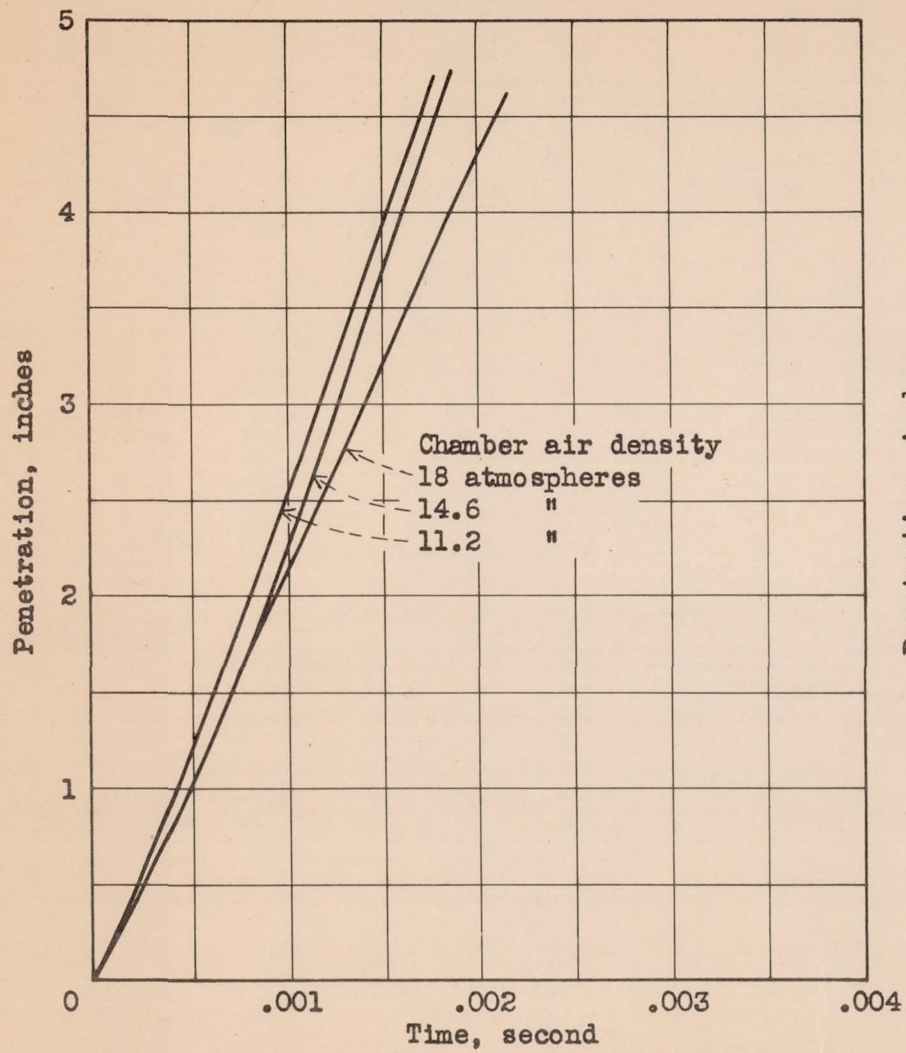

Figure 11.-Penetration of spray tip from nozzle with a 30° pintle, injection pressure 3000 lb./sq. in., valve-opening pressure 2600 lb./sq. in.

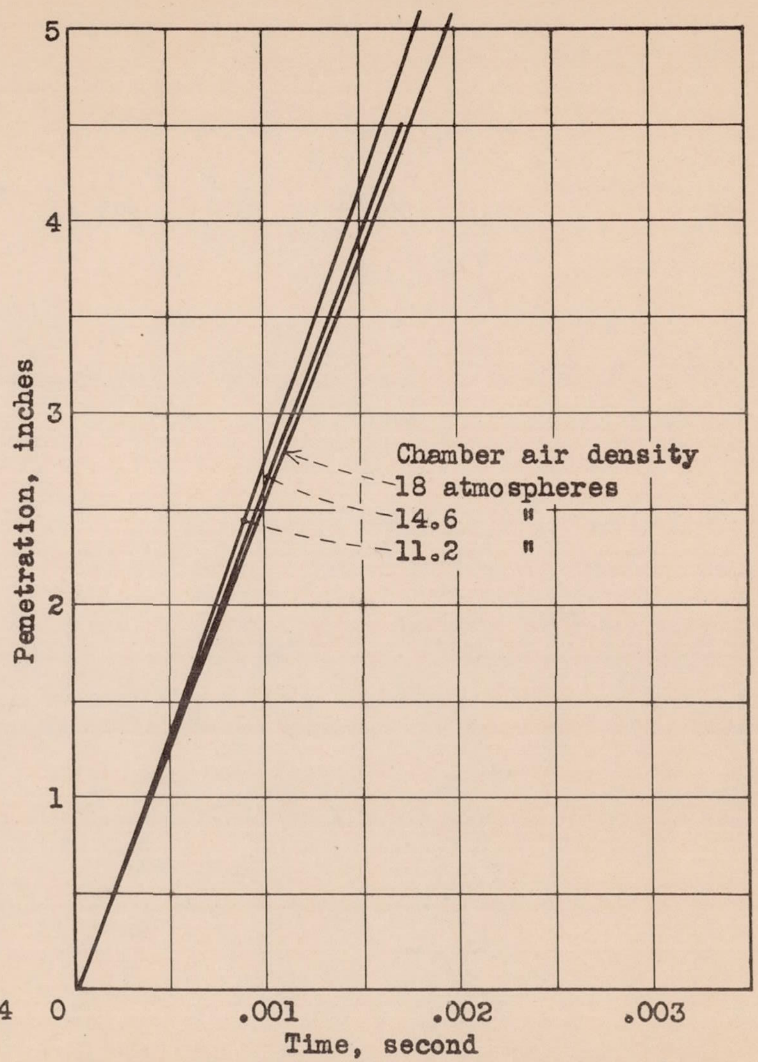

Figure 12.-Penetration of spray tip from nozzle with a 30° pintle, injection pressure 4000 lb./sq. in., valve-opening pressure 3600 lb./sq. in.