AD-751 079

EXPERIMENTAL STUDY OF AN INJECTOR WITH A HIGH-FREQUENCY SWIRL GENERATOR

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22 September 1972

FTD-MT-24-1113-72

FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

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DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)* Foreign Technology Division Air Force Systems Command U. S. Air Force	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

EXPERIMENTAL STUDY OF AN INJECTOR WITH A HIGH-FREQUENCY SWIRL GENERATOR

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Translation

5. AUTHOR(S) *(First name, middle initial, last name)*

V. N. Chernykh

6. REPORT DATE 1970	7a. TOTAL NO. OF PAGES 7	7b. NO. OF REFS
8a. CONTRACT OR GRANT NO. b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) FTD-MT-24-1113-72 9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Foreign Technology Division Wright-Patterson AFB, Ohio

13. ABSTRACT

Results are presented from a study of an injector with a high frequency swirl generator. Droplet size was derived as a function of pressure and ratio of air and liquid consumption levels. Results of experiments determining the density of reflux and jet taper angle.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Fuel Injector						
Diesel Engine						
Fuel Atomizer						
Railway Engineering						

FTD-MT- 24-1113-72

EDITED MACHINE TRANSLATION

FTD-MT-24-1113-72

EXPERIMENTAL STUDY OF AN INJECTOR WITH A HIGH-FREQUENCY SWIRL GENERATOR

By: V. N. Chernykh

English pages: 7

Source: Leningrad. Institut Inzhenerov
Zheleznodorozhnogo Transporta.
Sbornik Trudov, No. 307, Izd-vo
Transport, Leningrad, 1970,
pp. 95-102.

Requester: FTD/PDTA

Translated by: John Miller

Approved for public release;
distribution unlimited.

THIS TRANSLATION IS A RENDITION OF THE ORIGINAL FOREIGN TEXT WITHOUT ANY ANALYTICAL OR EDITORIAL COMMENT. STATEMENTS OR THEORIES ADVOCATED OR IMPLIED ARE THOSE OF THE SOURCE AND DO NOT NECESSARILY REFLECT THE POSITION OR OPINION OF THE FOREIGN TECHNOLOGY DIVISION.	PREPARED BY: TRANSLATION DIVISION FOREIGN TECHNOLOGY DIVISION WP-AFB, OHIO.

FTD-MT- 24-1113-72 III Date 22 Sep 19 72

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V. N. Chernykh

In design, an injector with a high-frequency swirl generator is analogous to a centrifugal injector with two tangential channels for feeding the liquid fuel. But in the studied injector (Fig. 1), liquid is fed along one channel and air along the other.

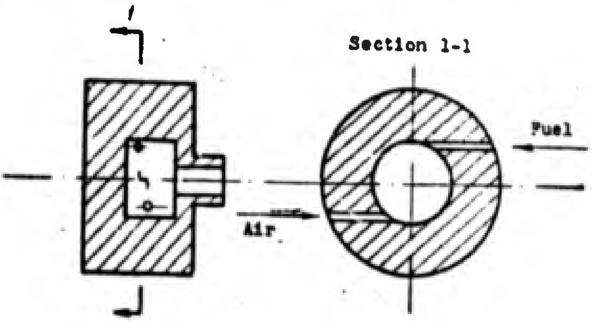

Fig. 1. Injector with swirl generator.

The air core that forms during rotation of the liquid is filled with a twisted air flow. The liquid film from the atomizer is subjected to the action of high-frequency sonic vibrations generated by the air flow.

1. Study of the swirl generator

The effectiveness of the action of sound is determined by its intensity, which can be expressed in terms of sound pressure p, the amplitude of the vibrations A, and the frequency of the vibrations f:

$$I = \frac{p^2}{\rho c} = 2\pi A^2 f^2 \rho c,$$

where ρ is the density of the medium and c is the speed of sound in the medium.

Of all the values in this equality, sound pressure p is the easiest to measure.

To obtain reliable values, the measurement should be made in a soundproof chamber or out in the open. As a rule, the sound pressure should be measured at several points of the sound field, since the characteristic of directivity (the distribution, in space, of sound energy around the sound source) of most aerodynamic generators can change sharply with a change in their working parameters.

In determining the sound pressure created by a swirl generator, the measurements are simplified somewhat. Since the sound field of such a generator is a rotating dipole with its axis in the nozzle-exit plane (Fig. 2), measurements made at a single point can give an idea of the operation of the swirl generator.

To determine the dependence of sound intensity on the shape of a nozzle and its dimensions we prepared six nozzles: three cylindrical and three exponential, with diameters d_c = 2, 3, and 4 mm. The dimensions (diameter D, height H) of the swirl chamber remained unchanged in all experi-

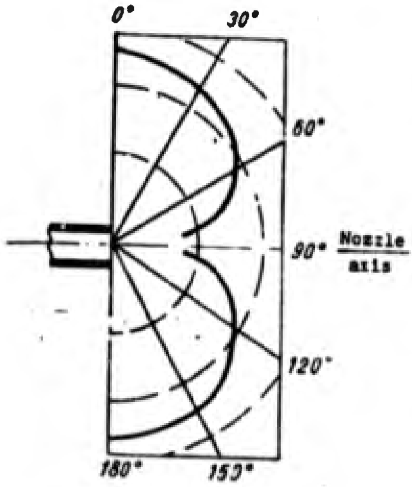

Fig. 2. Sound field of a swirl generator, a rotating dipole with its axis in the nozzle-exit plane.

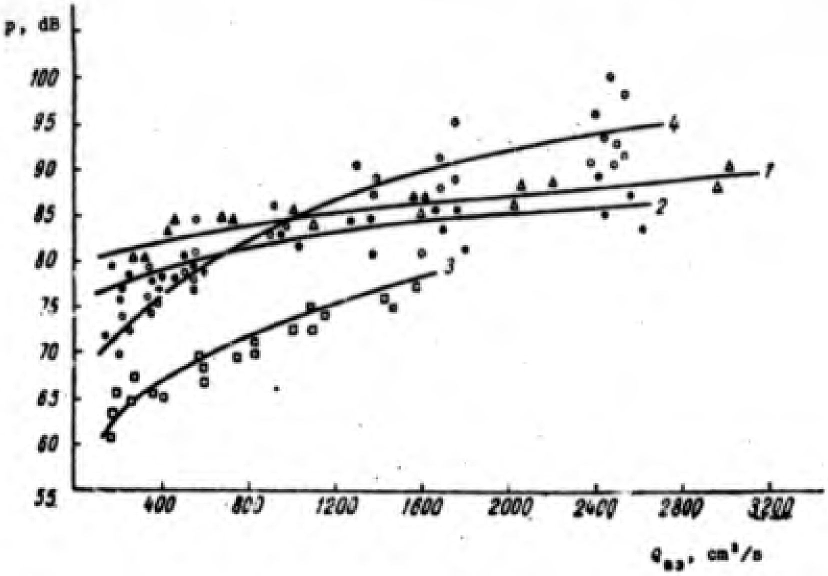

Fig. 3. Dependence of the level of sound pressure on air flow (under standard conditions) with various nozzle diameters and shapes: 1, 2, 3 – for cylindrical nozzles, d_c = 4, 3, and 2 mm; 4 – for an exponential nozzle, d_c = 3 mm.

ments. As measurements showed (Fig. 3), for identical air flow and nozzle shape (cylindrical), the level of the sound pressure increases with a decrease in the ratio of the diameter of the cylindrical chamber to the nozzle diameter D/d_c. An exponential nozzle of the same diameter as the cylindrical one creates greater sound pressure for practically all air flows.

A decrease in nozzle length (with constant values of D, H, and d_c) leads to a certain increase in sound-pressurd level.

2. The average diameter of drops, and their distribution by sizes

Usually, the dimensions of the drops formed with atomization of the liquid are found experimentally, since considerable difficulties are involved in analytically determining the dispersion of a jet.

Widely-used methods of experimenting to determine the fineness of atomization are those based on use of a melted substance with a low melting point (paraffin, paraffin with tartrathene additive, ceresin with isobutylene polymer additive), with subsequent solidification of the drops in flight. The hardened drops have sufficient mechanical strength and make sieve analysis possible.

In our experiments we used melted paraffin at 70°C. Since the air and paraffin enter the same space, they are fed at identical pressure, from 2 atm(abs) ($1.96 \cdot 10^5$ N/m^2) to 7 atm(abs) ($6.86 \cdot 10^5$ N/m^2). The drops, which solidify in flight, were sifted through a set of screens with mesh diameters of 420, 280, 200, 140, 100, and 50 μm. The average drop diameter was defined as the mean-mass diameter:

$$d_{cp} = \frac{\Sigma m_i d_i}{\Sigma m_i},$$

where m_i is the mass of drops of diameter d_i.

The dependences of the average drop diameter on pressure and ratio of air and liquid flows are given in Figs. 4 and 5.

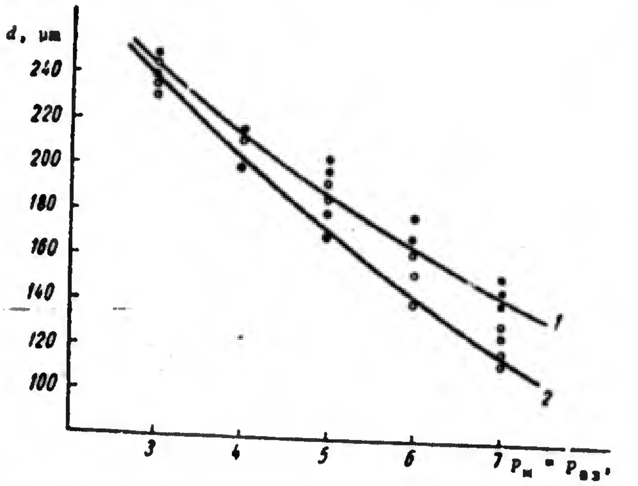

Fig. 4. Average drop diameter vs. feed pressure of liquid $p_ж$ and air $p_{вз}$: 1 – for cylindrical nozzle; 2 – for exponential nozzle.

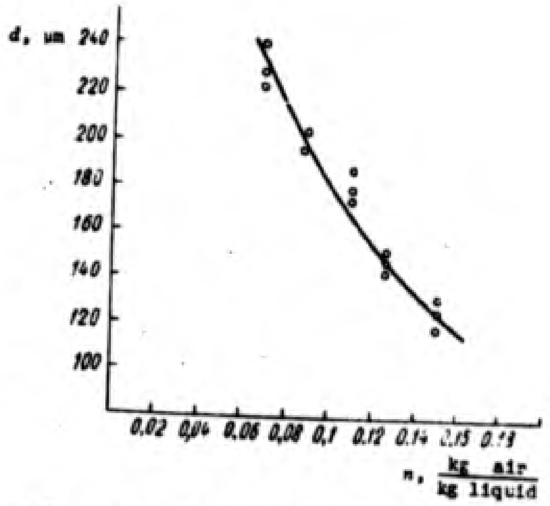

Fig. 5. Average drop diameter vs. air and liquid flow ratio.

As a more complete characteristic of atomization dispersion, Fig. 6 shows drop distribution by sizes. The drop diameter is

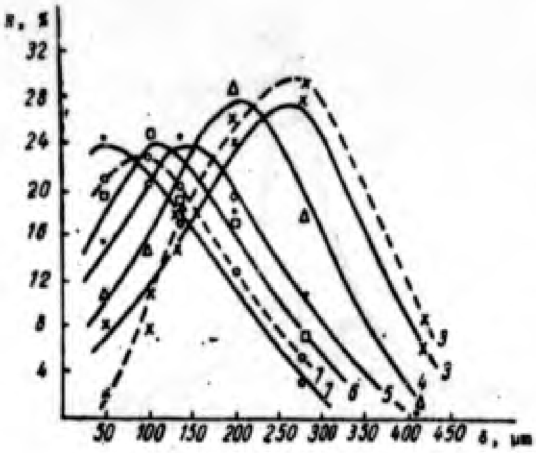

Fig. 6. Distribution of drops by dimensions: ——— injector with exponential nozzle, d_c = 3 mm; – – – injector with cylindrical nozzle, d_c = 3 mm. The numbers of the curves are the working pressures, atm(abs).

plotted along the abscissa; the remainder in the screen (in percents of the total mass of the drops) is plotted along the ordinate.

3. Distribution of atomized liquid across the jet, and the angle of taper of the fuel spray

The distribution of the atomized liquid across the jet is an essential characteristic of an injector, since it has an influence on improvement of the fuel spray process in fuel combustors.

To establish the distribution of the liquid across the jet, or the spray density, the fuel spray cross section was divided into six annular zones along whose axes test tubes were placed.

The experiments were conducted on injectors with cylindrical and exponential nozzles. The injectors were placed vertically to assure the axis of symmetry and facilitate carrying out the experiment.

Water was used as the working liquid. The measurements were made in two mutually perpendicular planes at various distances from the nozzle orifices.

The quantity of liquid in the test tubes was determined by weighing on an analytical balance; we then calculated the spray density at distance *h* from the nozzle exit plane:

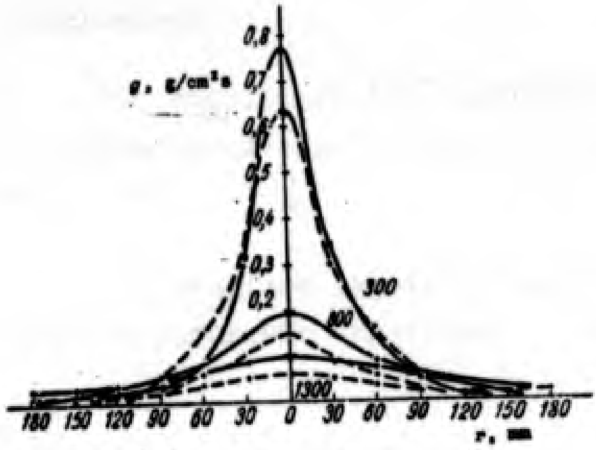

Fig. 7. Distribution of atomized liquid across the jet with pressure $p_{н} = p_{вз}$ = 7 atm(abs): ——— with exponential nozzle, d_c = 3 mm; – – – with cylindrical nozzle, d_c = 3 mm. The numbers of the curves are distances from nozzle orifice, mm.

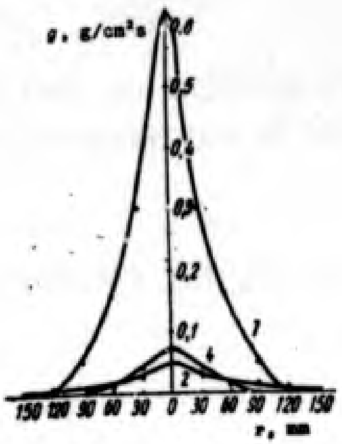

Fig. 8. Distribution of liquid across the jet at a distance of 300 mm from the orifice of a cylindrical nozzle, d_c = 3 mm. The numbers of the curves are pressures, atm(abs).

$$g_i = \frac{m_i}{f_i\tau},$$

where m_i is the mass of liquid in the test tube, f_i is the area of the test tube cross section, and τ is the time of the experiment.

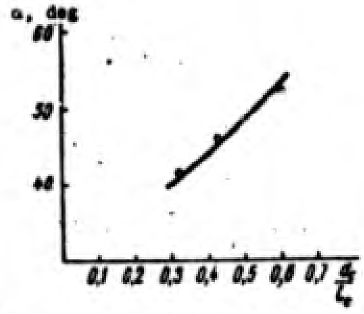

Fig. 9. Angle of taper of jet vs. ratio of nozzle diameter to length.

From the test results we constructed graphs of the distribution of liquid across the jet $g = \varphi(r)$ for injectors with various nozzles under various operating conditions (Figs. 7 and 8).

The function $g = \varphi(r)$ allows us to determine the width of the fuel spray r_0 and the angle of taper α at distance h from the injector orifice:

$$\mathrm{tg}\,\frac{\alpha}{2} = \frac{r_0}{2h}.$$

The angle of taper of the jet vs. the ratio of nozzle diameter d_c to length l_c is shown in Fig. 9.

Conclusions

The results of the experiments showed that an injector with a high-frequency swirl generator assures good atomization at low liquid pressures.

The atomized liquid is distributed across the jet just as in the case of pneumatic injectors.