# Optic and electric methods and test procedures for the pulse spray parameters

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**Abstract**

This report represents the experience on the use of optical observation method and electric measurements for investigation of the pulse spray parameters: liquid droplet size, extension of the droplet area, droplet grouping within this area with a distance from the source. The methods for measurement of liquid and gas phase uniformity in a cross-section of the pulse spray are described.

## Introduction

The spray relates to the nonuniform flows because it includes two components in different aggregative stays. In contrast to the homogeneous flows, characterized by the main parameter: mass velocity (average or local ones), the heterogeneous flows are determined by additional parameters: component concentration and velocity, distribution of particle sizes and different relationships of these parameters.

When generating the pulse spray, different-sized liquid particles, moving with different velocity along the path of distribution, are formed. The initial velocities of phases effect the length of the areas of liquid particles and distribution of droplet mass concentration within the droplet area.

Variety of the studied parameters of the pulse spray has determined the complex investigation approach, which combines the optic and electric measurements of pulse spray characteristics.

## Set-up and Measurement Methods

The air-droplet flow is generated by a pulse liquid source, consisting of 16 ejectors (4 × 4 matrix) and stationary gas flow, formed by 25 (5 × 5 matrix) air nozzles with the outlet diameter of 0.35 mm [1]. The liquid ejector is a sprayer of four nozzles with the diameter of 0.125 mm, equipped by a solenoid valve. The ejector parameters: duration of transitional regime from the open to close (and back) states of $T_{\mathrm{front}} < 0.0002$ s, duration of the open state was measured in the range from 1 ms to 10 ms with frequency of valve opening from 1 to 50 Hz. The instantaneous flow rate through the ejectors, droplet and gas flow velocity were regulated by a change in the inlet pressure ($P_l = 0.05 \div 0.6$ MPa; $P_g = 0 \div 0.6$ MPa). The spray phase velocities changed: from 0 $\mathrm{m \cdot s^{-1}}$ to 25 $\mathrm{m \cdot s^{-1}}$ for air and from 1 $\mathrm{m \cdot s^{-1}}$ to 20 $\mathrm{m \cdot s^{-1}}$ for water. Measurements were carried out under the atmospheric conditions at medium pressure of 0.1 MPa and temperature of $T_0 =$ 20 °C. The temperature of air and liquid spray components were: 7 °C ÷ 13 °C for liquid and 20 °C ÷ 22 °C for air. The pulse gas-droplet flow propagates horizontally in space between the source and heat exchanger ($L$ = 240 mm).

## Results and Discussion

Uniformity of liquid phase distribution in the pulse spray was measured by the meter of local concentration of liquid droplets with a probe in the form of a high-frequency emitter of electromagnetic waves [1]. Its operation principle is based on absorption of energy of electromagnetic field near the emitter by the water component of the flow. According to measurements, carried out at the distance of 210 mm from the source of the pulse gas-droplet flow, nonuniformity of the droplet liquid phase in this cross-section does not exceed 5 %.

The average velocity and temperature of the gas phase were measured by an industrial hot-wire anemometer with an error of $\pm(0.05 \cdot V + 0.2)$, where V is the measured velocity of the air flow.

To observe the behavior of droplets in the flow and determination of their size, the spray was recorded by the high-speed (7000 frames per second) digital video camera. [2]. The picture of two consecutive droplet areas, formed by one solenoid valve is shown in Fig. 1.

Simultaneously with video recording of the liquid train behavior bombardment intensity of the surface of condensing electret pulsation probe by the droplets was registered. Sensitivity of the probe with diameter $D$ = 10 mm was $S$ = 10 $\mathrm{mV \cdot Pa^{-1}}$ within 50 ÷ 15000 Hz. The probe was transported by a programmable coordinate device with a step of 20 mm. The pulsation oscillogram, obtained from the local probe, is shown in Fig. 2.

Analysis and comparison of video data and readings of the pulsation probe allowed determination of droplet sizes at jet outflow from the ejector and in a cross-section at the distance of 210 mm from the source as well as extension of the droplet area with motion from the source.

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A relative change in a pulse of the droplet spray flow was determined by the data of local pulsation probe under the conditions of continuous and pulse flow with and without the co-current air flow (Fig.3). The experimental specific value of integral pulse of the two-phase flow [3] is $K = \frac{1}{(\pi R_0^2)(\sum_{i=1}^{n}[m_{p_i} V_{p_i}).]}$ where Ro is the piezosensor radius, and $m_{Pi}$ and $V_{pi}$ are the mass and longitudinal velocity component of the droplet flow. According to analysis of experimental data, distribution of $K \cdot K_o^{-1}$ is nonuniform ($K_o$ is the spray pulse at the nozzle outlet). With development of the spray with a distance from the source, there is the common tendency to reduction of this parameter both under the continuous and pulse formation conditions. Local nonuniformity can be caused by re-distribution of droplet phase concentration, droplet splitting and their coalescence. The co-current air flow for the continuous spray reduces significantly ratio $K \cdot K_o^{-1}$, what is caused by intensification of spray interaction with the ambient air flow. Simultaneously, the bright maximum at some distance from the nozzle is observed for the pulse spray, and this indicates the effect of droplet "bundling" and maximal droplet grouping in this zone. It is important that at different initial velocity of the flow and frequency parameters of the spray the area with high concentration of spray changes both by coordinate and amplitude.

Application of the above methods allowed us to obtain new ideas about heat transfer process at fast interaction of liquid droplets with the heated surface.

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**References**

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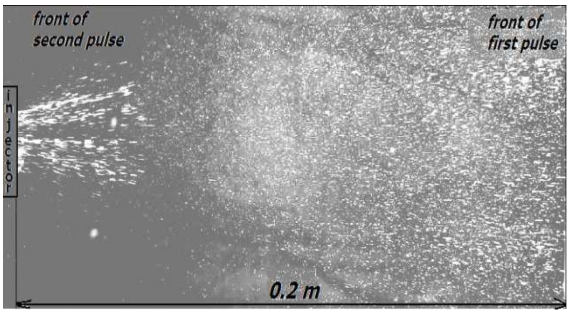


**Figure 1.** Droplet phase from the ejektor

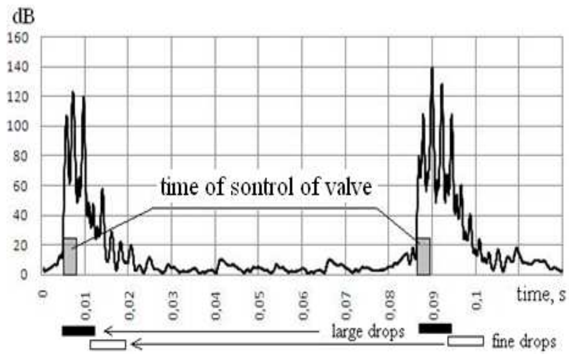


**Figure 2.** Oscillogram of the probe signal on the droplet flow pulsations

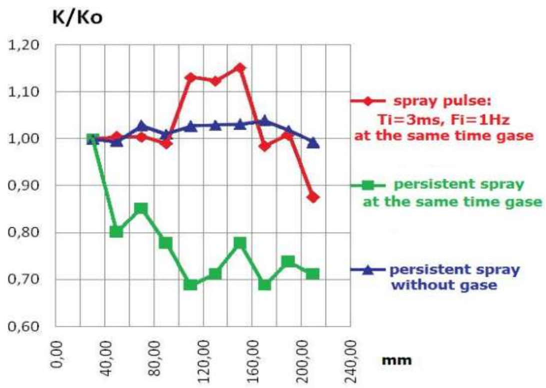


**Figure 3.** Distribution of the relative pulse of the droplet flow at the spray axis. ($K_o$ – spray pulse at the nozzle outlet)