APPLICATION OF SPARK PHOTOGRAPHY TO THE INVESTIGATION OF PULSED HIGH-PRESSURE JETS

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Pulsed water cannons developed in the Institute of Hydrodynamics of the Siberian Branch of the Academy of Sciences USSR are capable of producing water jets with velocities of the order of 1 km/sec. Investigation of the process of formation and stability of such jets involves difficulties associated with the high velocities and pronounced nonstationarity of the flow. One method of detecting the sharp velocity variation over the jet length is to measure the pressure in the jet [1].

The processes that take place in a jet can be studied by means of frame photography. High-speed cameras, however, do not yield satisfactory results. If SKS-type cameras (maximum frame rate of 5000 f. p. s.) are used, the jet will have traveled as much as 20 cm during the time required to change a frame. Moreover, using these cameras, it is not possible to photograph the entire jet because its length may exceed 10 m. Similarly, it is difficult to synchronize the initial moment of picture-taking with the initiation of the jet.

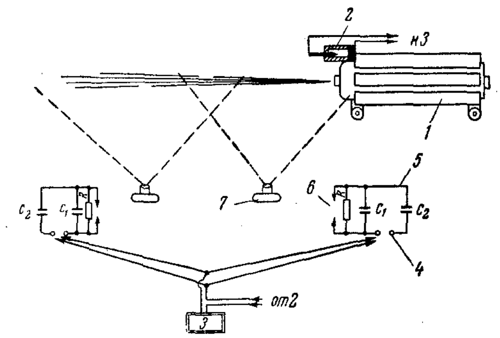

Fig. 1

These difficulties can be easily resolved by using fixed film to photograph the jet and an electrical discharge as illumination pulse. Measurements performed with the aid of a streak camera showed that the duration of illumination in the discharge gap is roughly 3 μ sec. The jet is practically static during such a short period of time. By pacing several cameras side by side along the length of the jet, it is possible to achieve a qualitative picture of an arbitrarily long jet. Uniform illumination of the jet is achieved by distributing several discharge gaps along the jet. Synchronization between exposure and the initial moment of the jet can be achieved with the aid of a simple inertial switch mounted on the water cannon. By adjusting the switch, photographs of the jet can be obtained at any moment after its initiation.

Figure 1 shows the experimental setup used to obtain photographs of the jet. On the water cannon (1) there is mounted an inertial switch (2), the striker of which moves freely in an insulated casing. By adjusting the initial spacing between the striker and the second contact, it is possible to obtain a spark discharge with the required delay. When the switch contacts are closed, an igniting voltage from source (3) is applied to the discharge gap (4) of a capacitor bank (5). By this moment, the capacitance C_2 has been charged to ~ 50 kV from a high-voltage source. The capacitance C_2 exceeds C_1 by a factor of 4. A breakdown in the gap (4) is followed by a discharge between the points of the gap (6), which acts as the illumination pulse. The brightness of this pulse is optimized in advance by adjusting the gap (6). The water cannon is fired in a dark enviroment, and the jet is photographed against a dark background, the light source acting as a shutter.

Photographs were taken of jets produced by IV-4 and IV-5 versions of the cannon. Figure 2 gives photographs of jets produced by the IV-5 cannon at various illumination delays. The numbers on the right-hand side of the frames denote the distance in meters covered by a jet. The white markings on the photographs represent a scale with 20-cm divisions. Frames 1 and 2 show the outward sprays of water that form immediately after the ejection of the jet from the nozzle. This spray is caused by the collision of the weak jet expelled from the nozzle as soon as the locking mechanism opens with the high-pressure jet produced by the piston stroke. Photographs 3–7 reveal that this spray is followed by a new spray cloud, which exhibits a more pronounced elongation downstream and is due to successive acceleration of the jet by a series of waves reflected from the piston and nozzle exit section. After acquiring total acceleration, the jet moves as a single entity (frames 8-12). Frame 8 was obtained in an experiment in which the discharges in two illuminating spark gaps did not coincide in time, so that two positions of the jet are registered on one frame. From this photograph it can be seen that the velocity of the spray produced by collisions inside the jet during the acceleration process is roughly one third the velocity of the main jet.

Figure 3 shows a jet from an IV-5 cannon that has covered a distance of 8 m (to the 20-cm scale). The photograph was made with the aid of two cameras. It can be seen that acceleration is completed after a distance of ~ 3 m; from there on there is an interaction between the jet and the air that leads to flow separation, as a result of which the contours of the jet are blurred by a haze of water droplets.

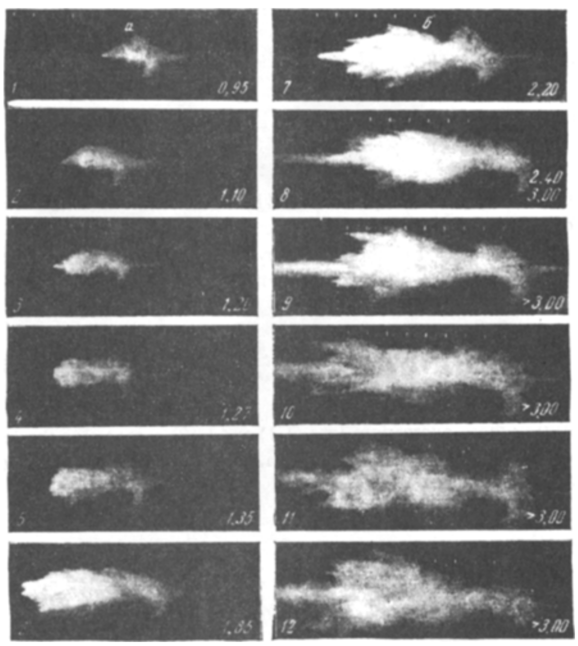

Fig. 2

Figure 4 shows the front of the jet after traveling ~ 6m. It can be seen that the front begins to separate into several parts. Experiments in which jets were studied from imprints (on plane obstacles) showed that the destructive power of the jet abruptly decreases beyond the

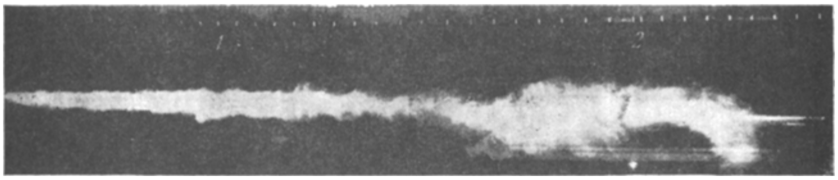

Fig. 3

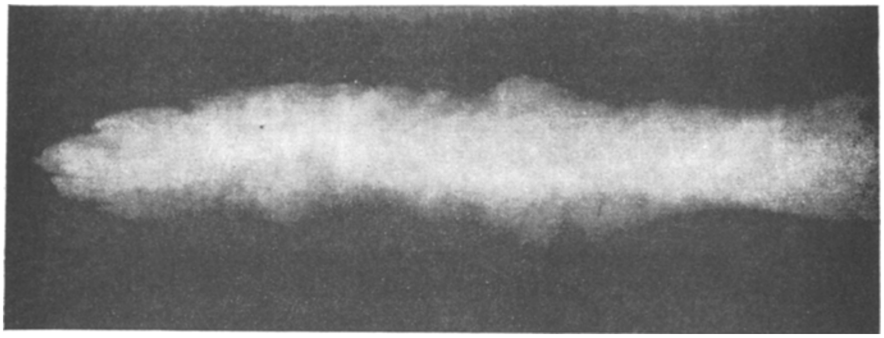

Fig. 4

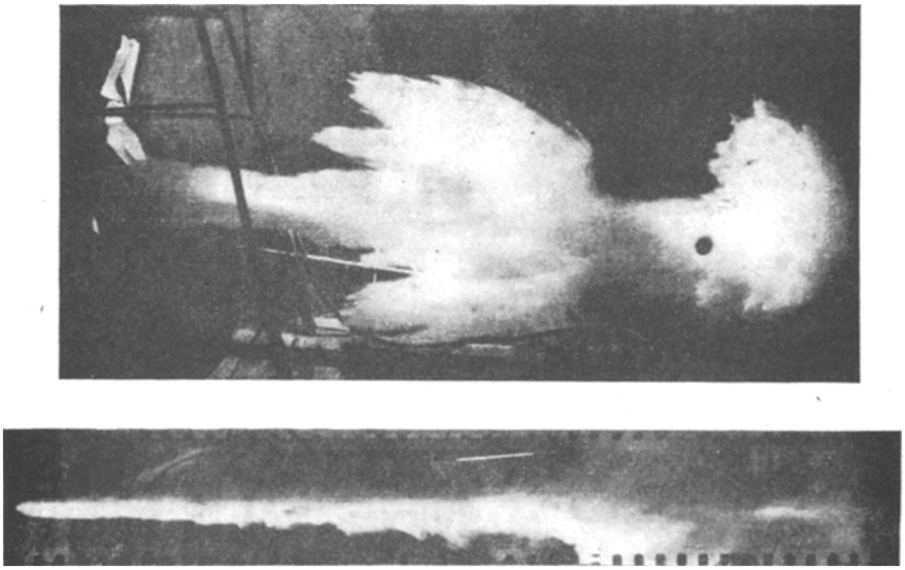

Fig. 5

distance (different for different nozzles) at which the jet front starts to separate.

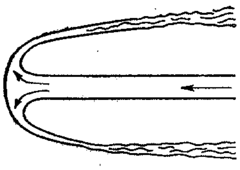

Fig. 6

The upper photograph in Fig. 5, made with a 13 × 18 cm camera, shows the moment of collision of the weak and high-pressure jets for the IV-4 cannon; the lower photograph shows the jet after acceleration.

The method used to obtain the photographs provides information on the development and stability of pulsed jets. By employing this method in combination with other methods used to study jets (pressure measurement, imprints made by impinging jets, etc.) it is possible to obtain more complete information. Spark photography, however, provides no information on the close structure of jets, since the latter are enveloped by a haze of water droplets.

A jet injected into an air medium diffuses in the manner shown in Fig. 6. This effect was first noted by M. A. Lavrent'ev as a peculiarity of cumulative jet flows [2]. The water veil that forms about the jet prevents the application of spark photography to the investigation of jet structure.

REFERENCES

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2. M. A. Lavrent'ev, "The cumulative charge and its working principle," Uspekhi matemat. nauk, vol. 12, no. 4, 1957.

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