MEASURING THE VELOCITY OF PLASMA JETS

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A description is given of a photographic method for measuring the velocity of a radiating gas stream using the time shift in the brightness fluctuations of a plasma jet. A prism-diaphragm system is used for isolating two sections of the stream.

For streams with fluctuations in the luminance of the gas that are a periodic function of time, a description is given of a device based on measuring the time interval between the arrival of the plasmoid front at two points a certain distance apart in the direction of the stream. The light signals are converted to electrical signals and fed to a system that transforms them into pulses of fixed amplitude and frequency, whose length is proportional to the transit time, i. e., inversely proportional to the jet velocity.

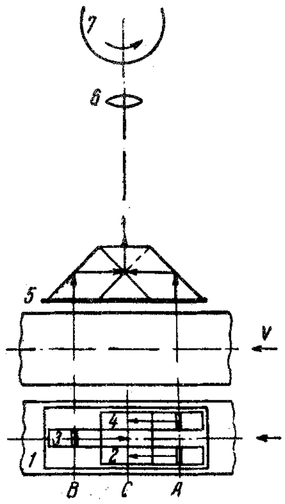

Fig. 1

Usually, transverse high-speed photography is used for measuring the velocity of plasma jets obtained with electric-arc generators [1, 2]. To determine the velocity by this method, the angle of inclination of the bands corresponding to the motion of brightness fluctuations is found. In a number of cases, it is more convenient to measure the linear shift, rather than the angle of inclination. Accordingly, we employed the following means of recording the motion of the brightness fluctuations of a plasma jet (Fig. 1). Close to the investigated stream 1 three prisms 2, 3, 4 and a slitted diaphragm 5 were mounted. Light from the two sections of the stream A and B isolated by the diaphragm were combined with the aid of a prism in section C and, by means of a lens 6, projected on a film attached to a rotating drum 7. Brightness fluctuations at section B lag behind those at section A; therefore, a shift x between the corresponding density fluctuations is obtained on the film. By measuring the magnitude of the shift x, one can find the velocity $V = Lw/x$, where L is the distance between sections A and B, and w is the film speed.

Figure 2 gives an example of a record obtained in this manner. The direction of motion of the film coincides with the direction of the stream; therefore, it is possible to record the fluctuation simultaneously at several points distributed over the cross section of the stream, using two wide prisms inclined at 45° to the scanning direction. A similar method enables one also to find the velocity pulsations in time [3].

Fig. 2

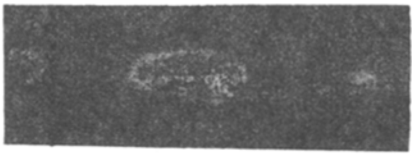

Fig. 3

For regulating and checking the operation of plasmatrons, it is desirable to have velocity measurements in the form of electrical signals. For monophase ac plasmatrons, this problem was solved by registering the motion of the optical fluctuation fronts photoelectrically.

The brightness of the gas at the nozzle exit of an ac plasmatron is a periodic function of time corresponding to the periodicity of arc burning. This is explained by both the different temperature and the different concentration of radiating particles at moments corresponding to arc burning and current pause. Figure 3 shows an instantaneous photograph of a monophase plasmatron jet; the stream consists of clearly defined glowing plasmoids separated by intervals of weakly radiating gas; the brightness build-up time in the plasmoid front was about 5-10 μsec.

The device described is based on measurement of the time interval between the arrival of the plasmoid front at two points a certain distance apart along the stream (Fig. 4). Upon arrival of the luminous front 1 of gas emerging from nozzle 2 at point 3, a light pulse is transmitted through diaphragm system 4 to mirror 5 and thence to photomultiplier 6. Diaphragm system 4 isolates two narrow light beams from the gas stream. When the luminous front reaches point 7, the corresponding light pulse passes through a second aperture in the diaphragm system to strike photomultiplier 8. The time interval between the pulses recorded by the photomultipliers is equal to the time taken by the front to cover the fixed distance determined by the diaphragm. The plasmoids arrive with constant frequency (twice the frequency of the supply current); therefore the time shift between corresponding pulse pairs is converted with the aid of unit 9 into a signal suitable for registration by instrument 10. Signals from the first photomultiplier trigger a slave multivibrator, while signals from the second stop it. Thus, unit 9 delivers pulses of fixed amplitude and frequency whose length is proportional to the transit time, i. e., inversely proportional to the velocity. The results can be registered either by a pointer-type instrument or a recording device. Note that the average values obtained for the velocity are roughly 10% greater than those calculated from the heat balance. This may be because the device measures the gas velocity in the central portion of the jet, which is greater than the mean mass velocity.

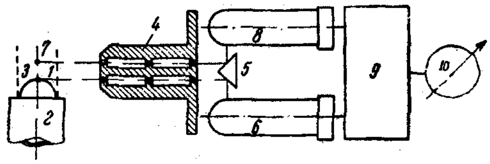

Fig. 4

This method of measuring velocity may also be used for investigating cold gas flows, if there is a possibility of periodically forming optical marks in the stream, for example, with the aid of a beam of fast electrons [4].

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