A NOTE ON MEASUREMENT OF FLAME TURBULENCE

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A relatively new method for the measurement of flame turbulence, by measuring negative static pressure, has been employed for the measurement of turbulence in a cold jet and behind a three dimensional flameholder.

Because of the lack of convenient experimental techniques, practical knowledge of turbulent flames has been largely confined to the fields of mean velocity, temperature and concentration. Till recently no simple method was available for the measurement of turbulence in flames. Williams, Hottel and Gurnitz[1] used the light scatter technique for turbulence measurement. Water-cooled hot wire anemometer probes are also available. They are however, expensive and unreliable to a certain extent because of the fact that the indicated signal is comprised of both velocity and temperature fluctuations.

Miller and Comings[2], by carrying out detailed studies on a cold turbulent jet, showed that in a symmetrical turbulent shear flow there is a static pressure defect, that is the static pressure in the jet is less than that in the surrounding atmosphere and that this defect can directly be related to the radial velocity fluctuations as given by $p - p_\infty = \rho \overline{v'^2}$ where p is the static pressure in the jet, p_∞ is the static pressure at the jet boundary, ρ is the density and $\overline{v'^2}$ is the r.m.s. value of the velocity fluctuations in the radial direction. Their turbulence measurements, obtained by using a hot wire anemometer, agreed well with those, obtained by using a simple static pressure probe. Thus they established the correlation between the static pressure difference and the turbulent intensity.

Becker and Brown,[3] and Eickhoff[4] employed a similar technique to show that this simple method of measuring turbulence could be extended to flames as well, provided they are symmetrical Eickhoff carried out a series of meticulous experiments to determine the effect of the geometry of the probe on the results obtained.

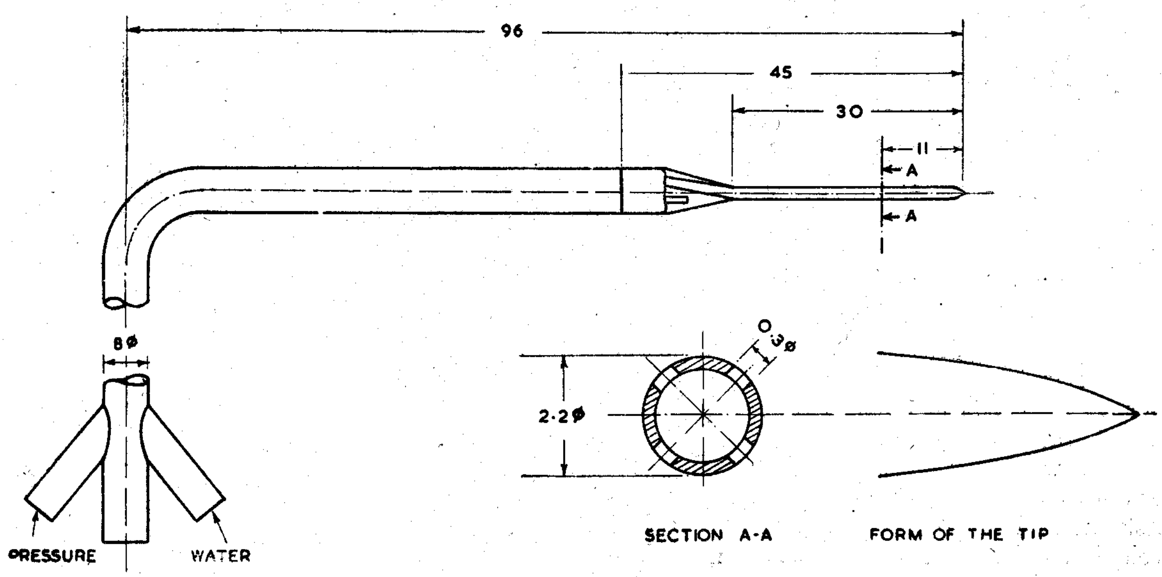

Fig. 1—Static pressure probe.

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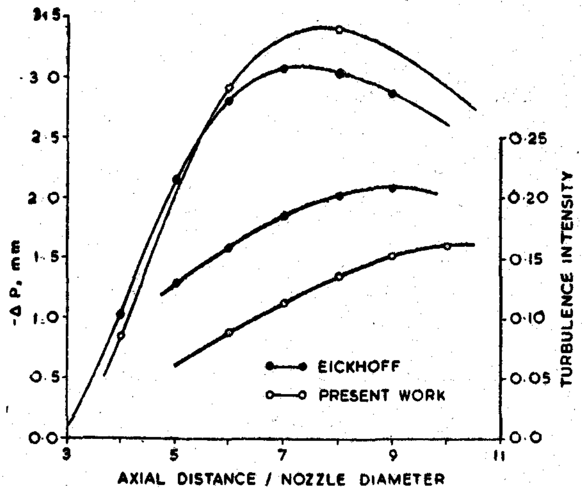

Fig. 2—Variation in static pressure defect and turbulence intensity in a free jet.

Turbulence plays a vital role in the performance of many types of combustion chambers such as in gas turbines, rockets, etc. But its measurement, when flame is present, is extremely difficult and almost always needs sophisticated instrumentation. However, research workers have been trying to devise simple tools for measurement of flame turbulence. Static pressure probes fall in this category and this paper deals with such probes.

RESULTS AND DISCUSSIONS

The method used in the present work to measure the turbulence intensity behind a three dimensional flameholder[5] is rather simple and inexpensive. Fig. 1 shows the details of the water-cooled probe that was used in these measurements. Four holes of each 0·3 mm diameter were drilled around a stainless steel tube of 2 mm diameter. The probe was connected to a micromanometer for accurate measurement of the static pressure.

Pressure traverses were made along the axis of a cold air jet issuing from a nozzle of exit diameter 30mm. Fig. 2 shows the measured variation in static pressure defect along the axis of the jet for $Re = 7 \times 10^4$ where Re is the Reynolds' number based on the average velocity at the exit of the nozzle. Fig. 2 also shows the variation in turbulence intensity. The turbulence intensity, I, is given by the relation

$$I = \sqrt{\frac{|\Delta p|}{2P_{total}}}$$

$$= \frac{v'^2}{\bar{U}}$$

where Δp is the measured relative pressure difference; P_{total} is the total pressure measured by a water-cooled pitot tube and $\bar{U}$ is the average velocity of the stream.

The results obtained by Eickhoff (for the same Reynolds number of 7×10^4) are also shown plotted in Fig. 2 for comparison. But according to Becker and Brown the values reported by Eickhoff are low for the jets used in his investigations. This comparison was carried out to ensure that the procedure employed in the measurement of turbulence intensity was correct. It may be pointed out here that the measured Δp is extremely sensitive to the profile of the tip of the static pressure probe.

This procedure was used also for measuring the static pressure defect and hence the turbulence intensity behind a cylinder in axial flow, used as a flame stabiliser. As the mixture of air and natural gas flowed past the flameholder it was ignited by a spark and the flame anchored to the flameholder. In the immediate wake of the flameholder, there is a zone of recirculation or reverse flow. Beyond the recirculation zone the flow along the axis of the flameholder is in the same direction as the external flow. The turbulence intensities measured outside the recirculation zone for a cylinder in axial flow and a truncated cone are shown in Fig. 3 & 4 respectively. Surprisingly, the general level of turbulence in flame is less than in cold flow under identical conditions of flow. With combustion the temperature of the gases increases and consequently its viscosity increases. Increased viscosity perhaps tends to damp the fluctuations which are mainfestations of turbulence.

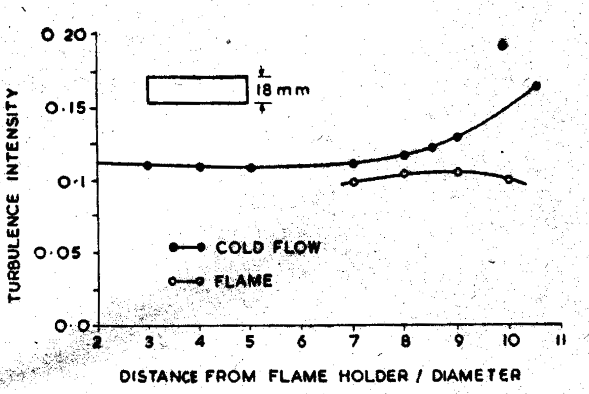

Fig. 3—Turbulence intensity behind a cylinder in arial flow.

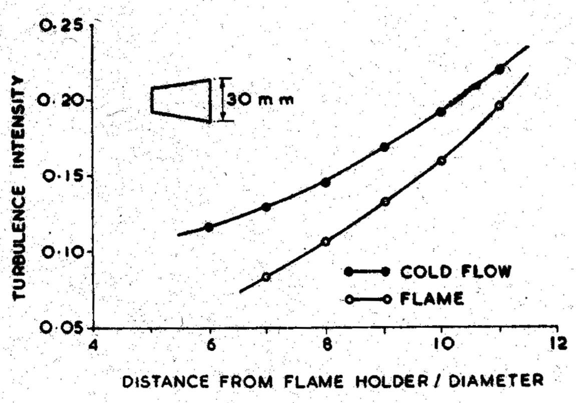

Fig. 4—Turbulence intensity behind a truncated cone.

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