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THE MEASUREMENT OF RAPIDLY FLUCTUATING AIR FLOWS

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INTRODUCTION

For research into wind induced natural ventilation effects we required an anemometer capable of measuring the rapidly fluctuating flows through a window opening. As we wished to correlate these velocities with ventilation rates we were interested in the component of velocity normal to the opening and an indication as to whether the flow was inward or outward. To detect the rapidly fluctuating flows we required good frequency response up to at least 20 Hz. A small computer was to be used to log all the data and perform much of the processing.

In order that we could satisfy the above requirements our choice of instrumentation was between the pulsed wire anemometer (Bradbury and Castro, 1971) and the B.R.E. shielded hot wire anemometer (Cook and Redfearn, 1976). Unshielded hot wire anemometers do not have the ability to sense direction or give the required velocity component and a vibrating low velocity anemometer which does have these abilities is limited to velocities below 0.3 m/s. In order to maintain compatibility with our existing stock of instruments we dediced to adopt the shielded hot wire technique.

BRE SHIELDED PROBE

Shown in Fig.1 is the BRE shielded hot wire probe which was developed from an original design by McGill University. The shield was of plastic with wire supports. It was mounted on a standard DISA dual parallel sensor hot wire probe, such that the air flowing through the hole in the shield would pass round one sensor and then the other. The downstream sensor wire would thus be in the thermal wake of the other. The sensors were driven by two DISA K-series linearised constant temperature anemometers, and because of the thermal wake, the anemometer associated with the downstream wire would give the lower output. The output signals from the two anemometers were signed, compared and gated to the readout or recording device by an analogue switching circuit. The response of the system to varying the angle of incidence of the airstream to the probe was fairly close to the ideal cosine curve which would give the true velocity component. However, at certain angles of incidence the system gave output signals of opposite direction to that which was occurring. This was termed "ghosting" and was caused by the downstream sensor being out of the thermal wake of the upstream sensor and/or being subject to a higher velocity.

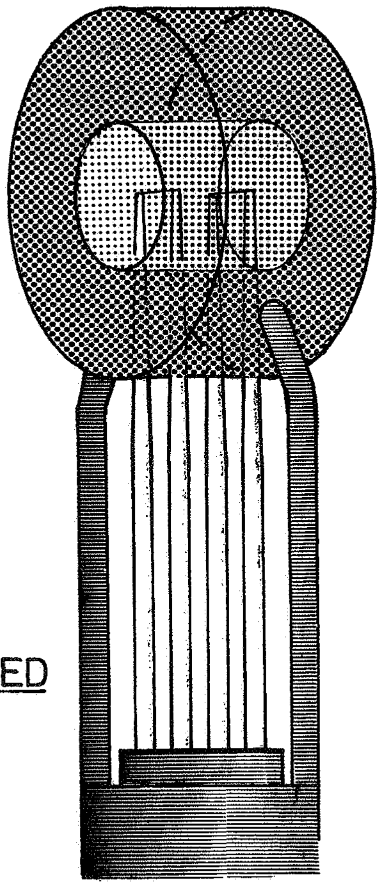

FIGURE 1. BRE SHIELDED HOT WIRE PROBE

BSRU SHIELDED PROBE

In order to alleviate the problems of ghosting and to improve upon the cosine response to the BRE probe, the effects of modifying the probe were studied. Various shapes of shield were tested and it was confirmed that the shape used by BRE was close to the optimum in terms of cosine response. A thicker shield was found to give more stable zero readings with the flow at 90^0 to the probe, but unfortunately this persisted over a considerable band above and below 90^0. Reducing the outer diameter had the effect of decreasing the directional sensitivity until one approached a tube shape with almost a square wave response. The resultant probe is shown in Fig.2, the outer diameter having been increased from 5mm to 6.5mm and the diameter of the hole decreased from 2.0mm to 1.8mm . The final shield thickness was 1.3mm.

OUTSIDE DIAMETER	6·5 m.m.
HOLE DIAMETER	1·8 m.m.
THICKNESS	1·3 m.m.
SENSOR LENGTH	1·25 m.m.
SENSOR SPACING ≈	0·2 m.m.
SENSOR DIAMETER	5 μm.

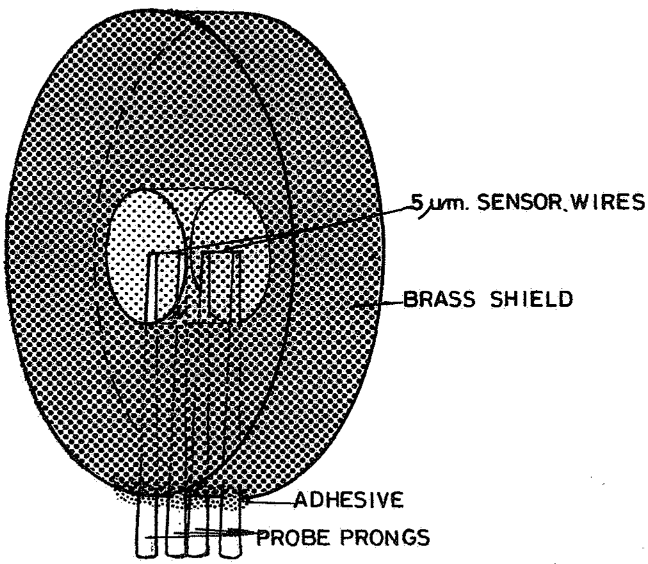

FIGURE 2. BSRU. SHIELDED HOT WIRE PROBE

Decreasing the hole diameter was also beneficial in helping to remove the "ghosts" or spurious direction signals at certain angles of incidence. The ghosts were finally removed however by modifying the hot wire probe itself to bring the sensor wires closer together. The wire spacing on the standard dual parallel sensor probe is 0.4mm and this was reduced to about 0.2mm, at which point the probe prongs almost touch. The length of the sensor wires was left at the standard 1.25mm. To achieve this modification the wires were broken, the prongs adjusted and then new 5 micron wires spot welded to the prong tips - a rather delicate and challenging task.

BSRU SHIELDED PROBE (continued)

The shield, made of brass, was then fixed to the probe prongs using an adhesive which was soluble to allow removal yet sufficiently flexible not to distort the prongs. Most solvent based adhesives contracted and broke the wires as they dried. The shield was electrically insulated from the prongs by a layer of adhesive.

The sensors were driven by two DISA K-series, temperature compensated anemometers, the temperature being sensed by a pair of single sensors adjacent to the shielded probe. Temperature compensation was necessary to avoid errors caused by fluctuations between cold outside air and warm room air around the probe. As the signals were to be processed digitally, linearised output was not required and hence linearisers were not fitted to the anemometers.

The signal processing was as shown in Fig.3. The signals from the two anemometers were fed to the analogue inputs of an Altair microcomputer, where individual calibration was applied to each and comparison made to detect the higher and hence the upsteam signal. This velocity was then output. For very rapid sampling the raw data could be stored in RAM and analysed subsequently. In this way 8 channels could be scanned at frequencies up to about 50 Hz.

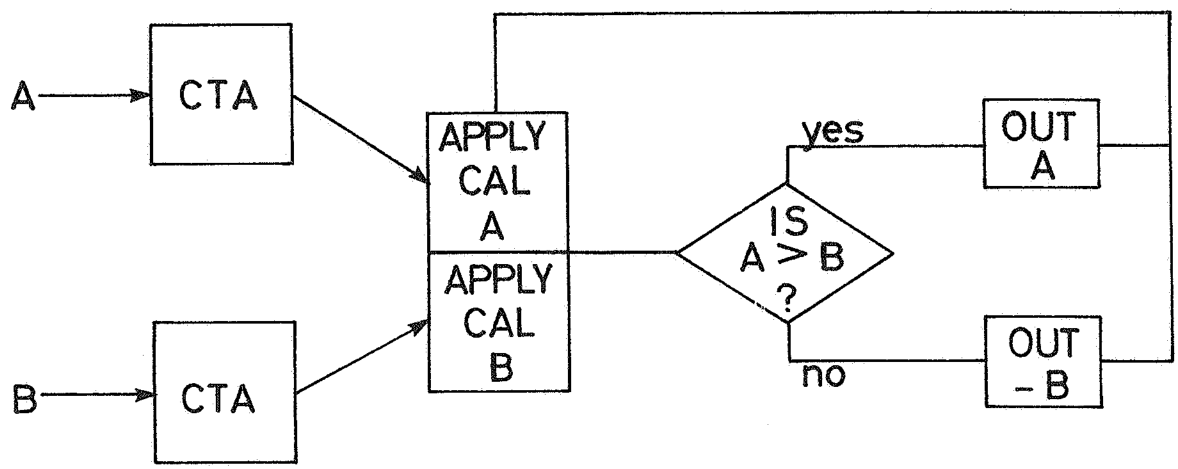

FIGURE 3. B.S.R.U. PROCESS

BSRU SHIELDED PROBE (continued)

The results of performance tests are shown in Fig.4 where the velocity indicated is plotted against the angle of the probe to the airstream. The response of the probe to rotation about the axis of the probe stem (yaw response) is seen to be close to the ideal cosine curve to give the component of velocity normal to the probe. The response to rotation about the axis of the sensor wires (pitch response) is not quite so good at small angles of inclination to the flow. This could be attributed to the fact that the sensor wire is itself insensitive to rotation about its own axis but sensitive to rotation about the axis of the probe stem.

The system is accurate down to 0.2 m/s. We have not tested the frequency response of the shielded probe but by calculation it should be good up to 100 Hz at 5 m/s (Cook and Redfearn, 1976).

A simple application is shown in Fig. 5. This represents the velocity, normal to the direction of travel, induced by a walking subject passing within 100 mm of the probe at a speed of 1.0 m/s. It may be seen that there is an initial outward gust rapidly followed by an inward flow. Clearly a normal hot wire anemometer would never have been capable of resolving the direction and would have indicated two positive peaks.

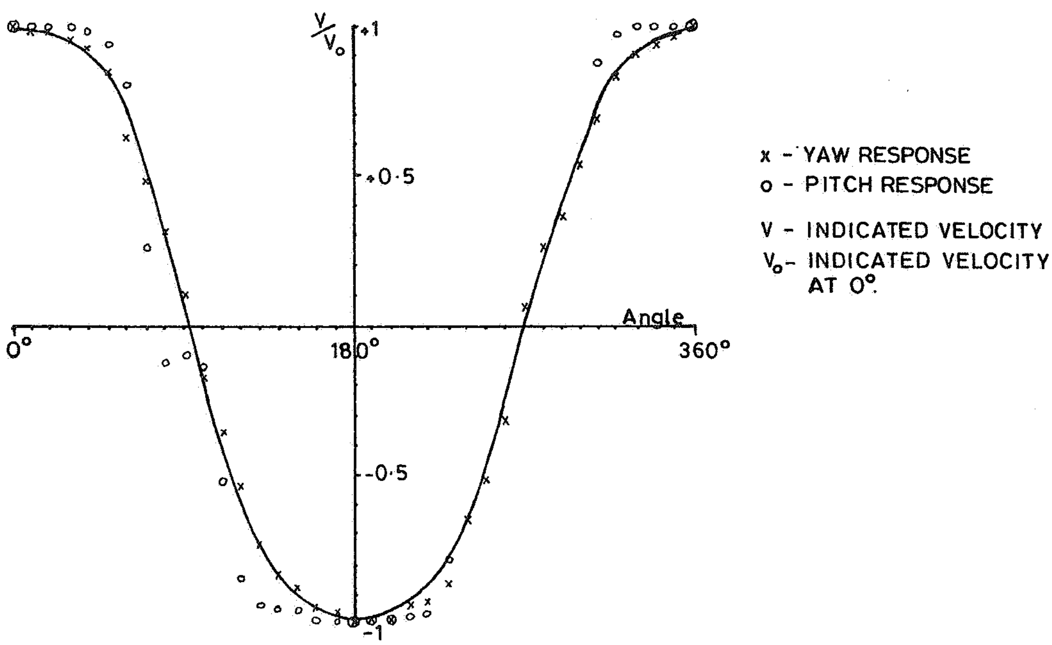

FIGURE 4. RESPONSE TO VARYING ANGLES OF IMPINGEMENT OF AIR FLOW

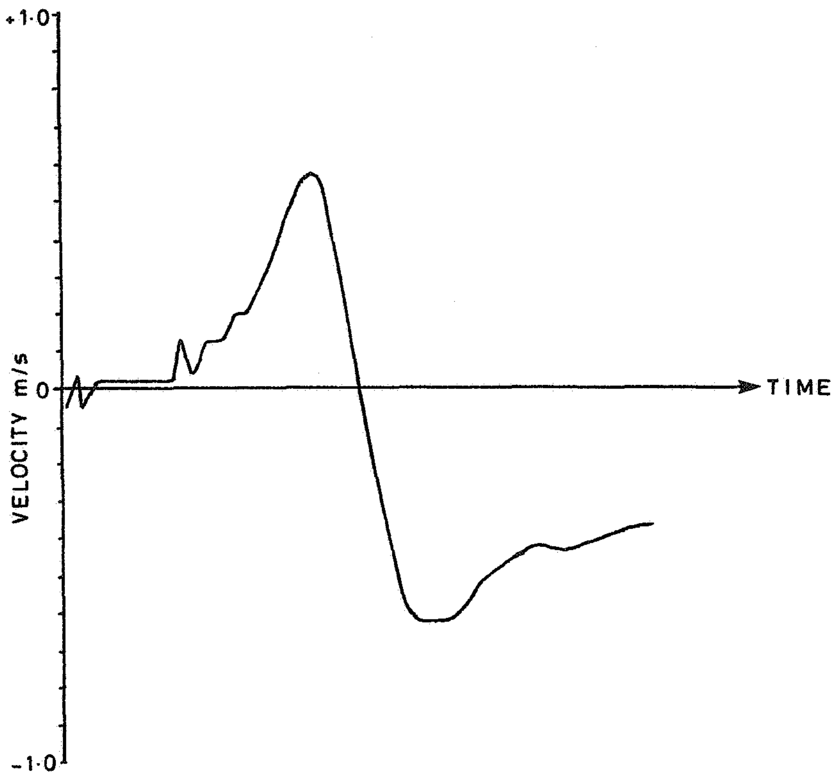

FIGURE 5 APPLICATION OF SHIELDED PROBE - the velocity normal to the direction of movement as a subject walks past at 1·0 m/s.

REFERENCES

Bradbury, L.J.S. and Castro, I.P. (1971) A Pulsed Wire Technique for Velocity Measurements in Highly Turbulent Flows. Journal of Fluid Mechanics, 49, 657 - 691.

Cook, N.J. and Redfearn, D. (1976) Calibration and Use of a Hot Wire Probe for Highly Turbulent and Reversing Flows. Journal of Industrial Aerodynamics, 1, 221 - 231. Also BRE current paper CP 18/76.