A LOW VELOCITY HOT WIRE CALIBRATION RIG

T. J. Taylor, C. F. Grainger and W. H. Melbourne.
Department of Mechanical Engineering, Monash University.

Summary
The requirements, design and performance of a low velocity hot wire calibration rig developed at Monash University are discussed. Preliminary results indicate that the rig is suitable for the calibration of air velocity measurement apparatus well below $0.5ms^{-1}$.

1. INTRODUCTION

Scaling requirements for the physical modelling of plume dispersion within wind tunnels result in the need for the tunnels to operate at very low wind speeds (Taylor et. al 1992). The modelling of a typical power station in convective atmospheric conditions using strict Froude scaling (ie. keeping the density ratios constant between model and full scale) requires tunnel velocities of the order of $0.3ms^{-1}$. These velocities can be enhanced by allowing changes in the density ratios, but tunnel wind speeds of less than $1.0ms^{-1}$ are still typical.

Hot wires and films can be used to measure wind velocities of this order, but the usual methods of calibrating the wires, such as the TSI calibration rig, or positioning the wire near a pitot tube in the tunnel, become inaccurate below $1ms^{-1}$. At a wind speed of $1ms^{-1}$ a pitot tube gives a reading of approximately $0.06mm$, and thus the pitot tube is unsuitable for measuring such low wind velocities.

Added to this difficulty is the problem of the effect of the fluid temperature on the hot wire output. As many of the dispersion studies to be performed in the Environmental Wind Tunnel at Monash involve the modelling of non neutral atmospheric boundary layers with airflows of varying temperature, this effect needs to be quantified. Thus the difficulty was not in being able to measure such low wind speeds, but in accurately calibrating the measurement apparatus to ensure confidence in the results under such varying conditions.

2. REQUIREMENTS OF A LVHWCR

A list of requirements for a LVHWCR (Low Velocity Hot Wire Calibration Rig) was developed. This included :

1. An accurate means of measuring low air velocities, with good resolution.
2. Means of varying the temperature of the air flow to enable temperature calibrations to be performed.
3. Stable velocities down to 0.2 or even $0.1ms^{-1}$ and up to $1.5 - 2ms^{-1}$
4. Low turbulence intensity to enable calibration of cross wires and split films with angle of attack
5. Flow volume large enough to put the head of the sonic anemometer in the flow as well as hot wire probes (ie. approximately $250mm \times 250mm$).

With this list of requirements the design of the LVHWCR was commenced.

3. THE RIG

A sketch of the LVHWCR showing the various sections of its design is given in Figure 1. A variac controlled fan pumps air through a venturi which is used to measure the total volumetric flow rate. The air is then diffused out into a larger section and passed through a series of 4 heating elements which enable the air to be heated if required. Following the heating chamber the air is then further diffused into a larger chamber again, where it is passed through a series of screens to smooth out the flow. The flow is then allowed to settle for a suitable distance after the screens before it is contracted into a "jet" of 150 $\times$ 150mm in cross-section.

The hot wire and sonic anemometer can be placed in a protected chamber of 350 $\times$ 350mm at the end of the jet to perform calibrations. This chamber has a door to allow easy access to the jet and minimise damage to the instruments. The door has a smaller two segment slot within it which allows the rotation of the probes to an angle of up to 90^o for the angular calibration of crosswires and split films. The rig is mounted so that the heated air is forced down and thus the buoyancy forces on the heated air stabilise the flow.

The velocity in the jet is calculated from the total volumetric flow rate divided by the cross sectional area of the jet, and making the appropriate corrections for temperature changes due to the heating. Temperatures can be measured by the use of thermocouples inserted in the flow. If no heating is used a reading of 4mm of water gauge on the venturi is equivalent to 0.1ms^{-1} while 1000mm results in a air velocity of 1.75ms^{-1} through the "jet".

4. PERFORMANCE TESTS

The results of a calibration of the theoretical velocity of the LVHWCR by placing the sonic anemometer below the "jet" are given in Figure 2. This set of results was very promising with differences of less than 0.05ms^{-1} between the two velocities, and generally the difference being of the order of 2 or 3% or less.

A hot wire was then calibrated in the LVHWCR and also calibrated alongside the sonic anemometer in the tunnel. The two calibration curves are shown in Figure 3. Once again the two calibrations were in good agreement with differences of less than 0.05ms^{-1}.

To obtain an idea of the smoothness of the flow the hot wire was then used to measure the turbulence intensity of the jet. The results of this experiment are given in Figure 4, where it can be seen that the turbulence level is generally below 2%.

5. CONCLUSION

The LVHWCR enables the calibration of hot wires, as well as other velocity measurement probes, at velocities below 1ms^{-1} with an accuracy of better than 0.05ms^{-1}. It also provides an apparatus that can be used to experimentally investigate the effects of angle of incidence and flow temperature on the hot wire output.

6. REFERENCES

Taylor, T.J. Grainger, C.F. and Melbourne, W.H. (1992), Convective Boundary Layer Flows for Dispersion Modelling <u>2nd AWES Workshop, Melbourne</u>

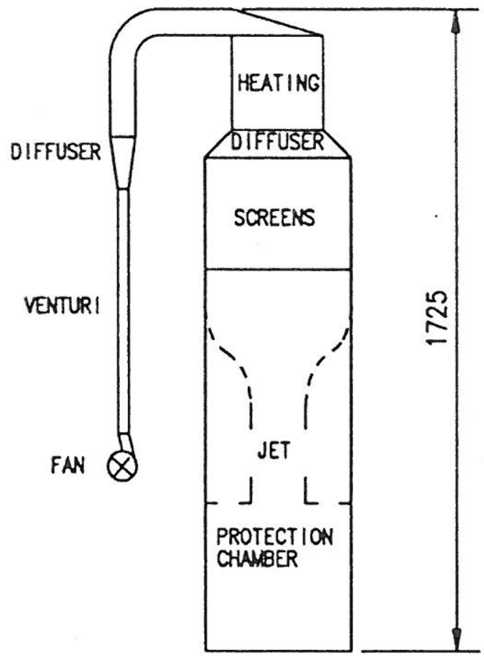

Figure 1. Sketch of the Low Velocity Hot Wire Calibration Rig showing the various sections.

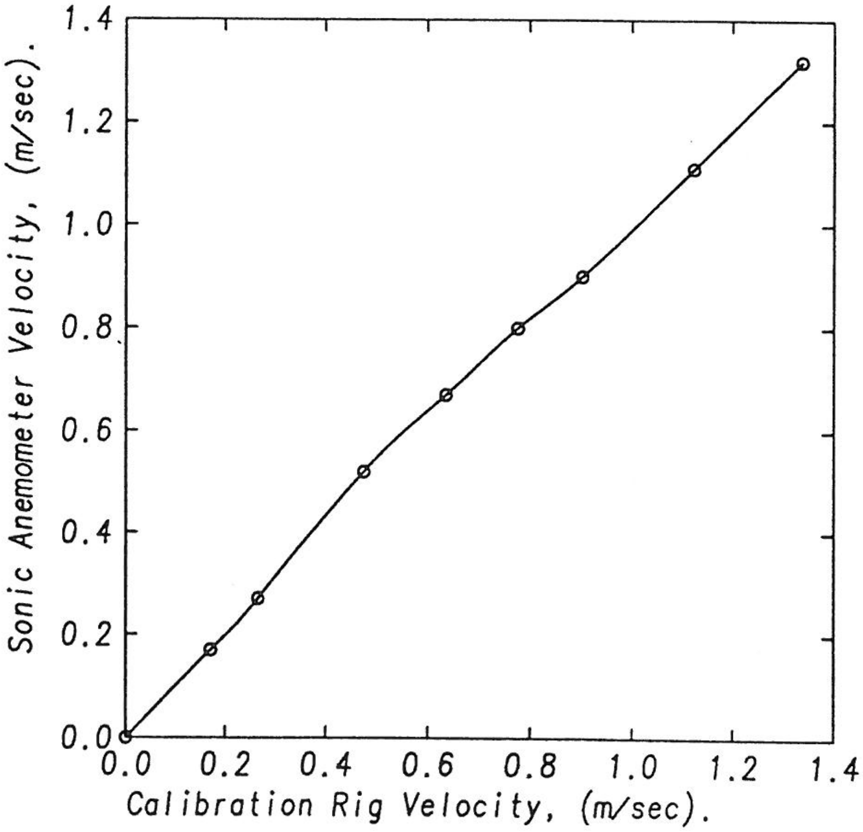

Figure 2. Calibration of the Low Velocity Calibration Rig with the Sonic Anemometer.

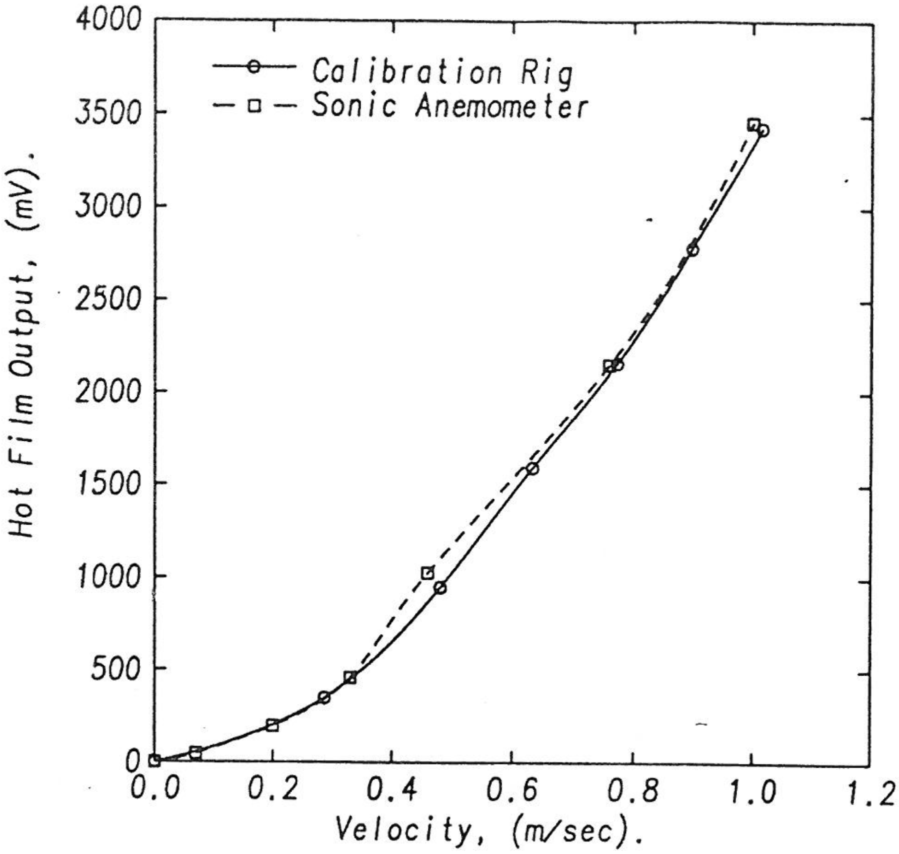

Figure 3. Calibration of the a Hot Film with the Low Velocity Hot Wire Calibration Rig and with the Sonic Anemometer.

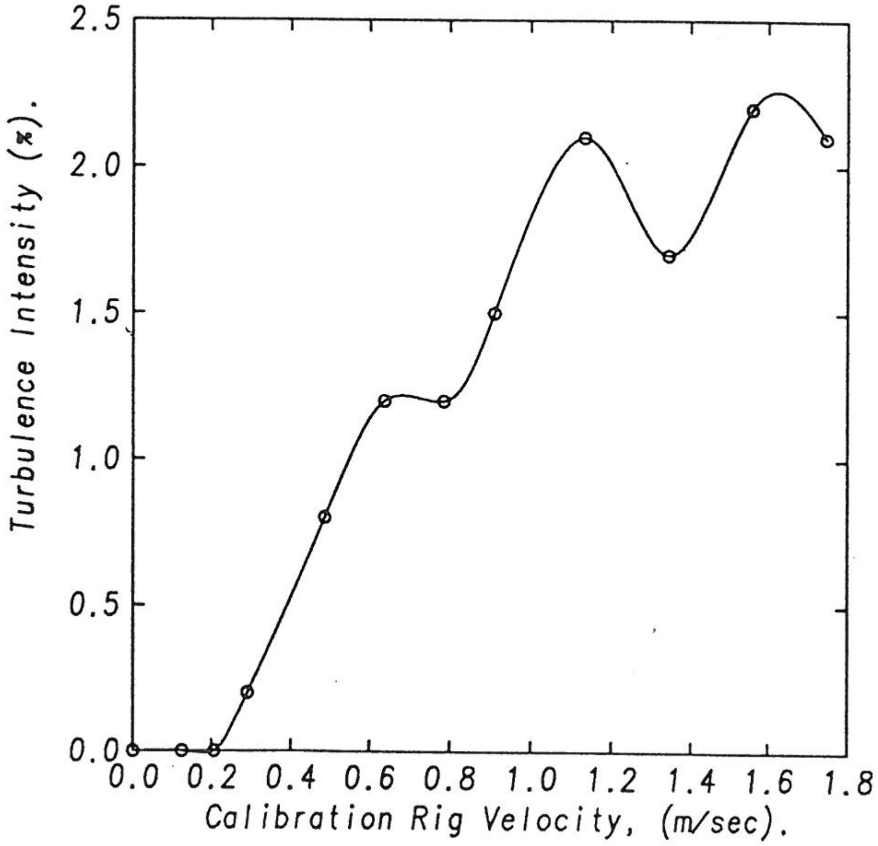

Figure 4. Turbulence Intensity of the Low Velocity Hot Wire Calibration Rig.