Measurement of low air flow rates using a simple pressure compensating meter

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Introduction

The accurate evaluation of air flow rates at HVAC supply or extract grilles is difficult. Most air flow meters utilize a cone or hood, and an anemometer (Figure 1).

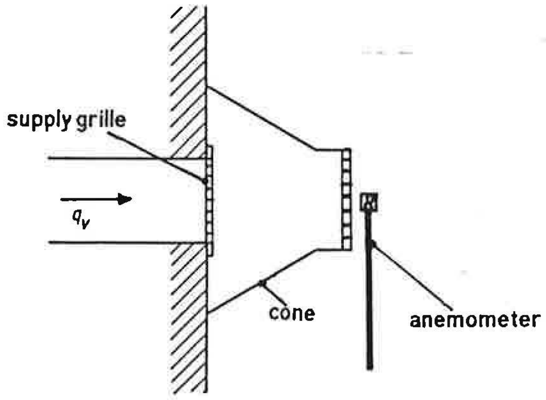

Figure 1: Ordinary flow rate meter with a cone and anemometer

When measuring at supply grilles the velocity profile through the cone is generally not fully developed. This can lead to very large errors and, in some cases, may even indicate a flow rate in the wrong direction.

Another problem is the air resistance of the cone. This introduces a pressure drop which is proportional to the square of the measured flow rate. At low flow rates and air velocities below 4 m/s, this pressure drop is a few Pascals. As duct pressures are often higher than this, no significant error will result. At higher flow rates and velocities the pressure drop over the cone will not be negligible with respect to the duct pressure. In this case the indicated flow rate may be lower than the actual flow rate.

These problems can be overcome by compensating for the pressure drop over the flow meter in such a way that the pressure on the duct side of the grille remains the same before and after the positioning of the flow meter. This is a very well known technique. However in the field of air conditioning, devices using this principle are rare. The compensation of the pressure drop is performed by a fan and regulator which blows just enough air through the flow meter to meet the pressure compensation before the grille. At first we used a large controllable fan, a set of DIN measuring tubes with orifice plates, and a box with a pressure meter to be placed over the grille. All connections were made with flexible tubing. The whole set up was accurate but very large and not easy to move from position to position (Figure 2).

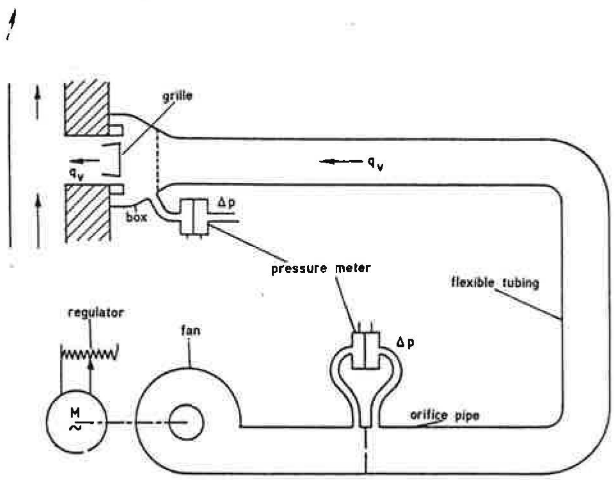

Figure 2: Original large scale flow rate measurement equipment with pressure compensation

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An extra advantage of the use of pressure compensation is that grids can be placed in the meter to prevent eddies from the supply grille entering and disturbing the flow meter. On the other side, grids prevent eddies from the blow side of the meter disturbing the flow through extract grilles (Figure 3).

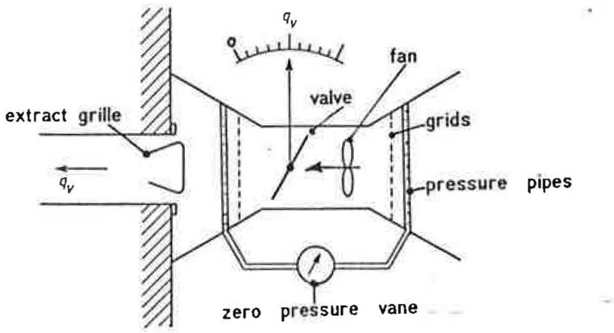

Figure 3: Schematic cross-section of flow meter showing measurement principle

Inexpensive air heating systems with low duct pressures are becoming more popular. Hence the need for an accurate low pressure drop flow meter has grown. In air heating systems the heat distribution over the rooms is proportional to the distribution of the flow rate over the rooms, i.e., half the flow rate and the heat input is also halved. This sensitivity to flow rate is much higher than for hot water central heating systems. This is one of the reasons why there have been many complaints resulting from badly commissioned air heating systems.

Development of the flow meter

Any meter must be able to measure the total flow rate required for the ventilation of one dwelling. In Holland this is 0.063 m^3/s (225 m^3 per hour or 130 ft^3 per minute).

As the pressure drop over the flow meter, including the grids, is less than 100 Pa, a very small battery operated axial fan can be used. Experiments showed that regulating the speed of the fan did not enable a stable indication of the flow rate or a wide flow rate range to be obtained, especially at low air speeds. A simple manually controlled throttle valve gave very good reproducibility and a wide range of flow rates, from zero to the maximum (Figure 3). The relation between valve position and flow rate is not linear. The shape of the valve results in larger scale divisions at low flow rates. The shape of the scale is determined by calibration at a number of flow rates against a reference wind tunnel with an orifice plate. It appeared to be unnecessary to control the fan to a constant speed. A constant voltage gave excellent reproducibility with the fan used. As the fan does not change speed dramatically, repositioning the valve instantaneously changes the flow rate. This allows fast manual operation, without the need to wait until the meter is settled. Automatic zeroing for continuous flow rate read-out was not the aim.

To obtain pressure compensation it is necessary to have an indicator for the pressure difference over the flow meter just outside the inlet and outlet grids. A vane indicator gives the required resolution of less than 1 Pa. In the prototype the mechanism of a milliampere meter, with holes drilled in the housing to the left and right of the needle, was used. This is very sensitive and mechanically well balanced.

It is slightly better to zero the pressure over the meter than to zero the (static?) pressure difference before the grille and outside the cone. At high flow rates the static pressure before the extract grille will be down a few Pascals. If one equals this static pressure with the static pressure outside the cone of the flow meter the indicated air flow rate will be too large. In fact one should balance the total pressure, but this total pressure is difficult to obtain at supply grilles.

On explaining the very simple mechanism of such a meter, people often ask where the flow rate is measured in this flow meter. One would expect an anemometer or pressure transducer somewhere. It must be realised that this flow meter contains no real meters to measure the flow rate. The indicated flow rate is the result of the constant running fan and the positioning of the throttle valve. As long as the fan and the grids are kept free of fouling or dust layers, and the electric motor is free from aging effects, the calibration curve will be maintained.

After the prototype became operational an instrument manufacturer produced several commercial units (1) (Figures 4 and 5). The shape of the hood has, within wide ranges, no influence on the calibration. The hood fits on both sides of the flow meter, allowing supply and extract measurements to be made with the same calibration curve and to the same accuracy. The accuracy claimed, is 5% of the reading with a minimum of ± 0.0005 m^3/s (2m^3 per hour or 1 ft^3 per minute), while in general the difference between measurements of supply and extract flow is less than 2%. Reproducibility is within 1%. Calibrations have been made at different temperatures. The maximum temperature of the supply air is about 80°C. In the present flow meter the pressure vane has a magnetic suspension, which is sensitive to the strong magnetic fields that can occur in some factories. The flow meter can run for more than one hour continuously on the Ni-Cd Battery pack. Normally the battery will not run down during eight hours intensive measurements in the field. The weight of the meter is 3.7 kg. It is easy to handle with a large hand grip and large flow control knob.

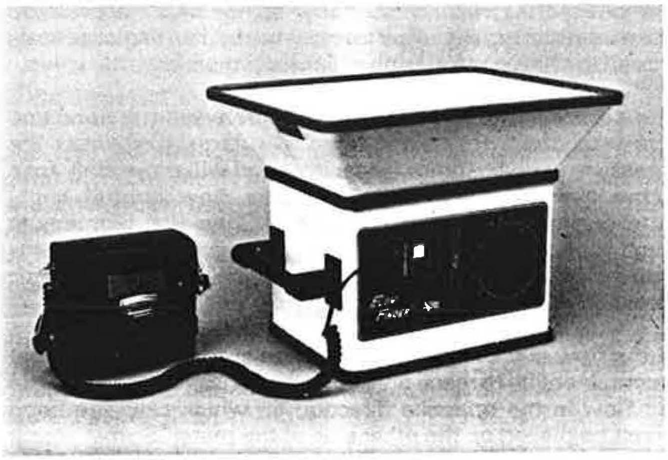

Figure 4: Flow Finder and battery pack. Different hoods fit on both sides

Figure 5: Measurement at a ceiling grille

Measuring flow rates with the meter

The meter is switched on, and placed against the wall over the grille. The flow control knob is turned until the pressure vane reads zero. Then flow rate can be read on the large scale round the flow control knob which is connected to the valve.

For accurate measurements the gap between the hood and the wall must not be too large. If a large gap exists the pressure vane becomes insensitive and will move only for a large change in the position of the flow control knob, introducing a wide inaccuracy band. This also happens at duct pressures of less than 5 Pa. In research situations this can be improved by using a very sensitive 1 Pa electronic pressure transducer on the pressure pipes.

If the flow is too large then pressure compensation cannot occur. Inability to reach pressure compensation may indicate air flow in the opposite direction, in which case the hood must be placed on the other side of the meter. Sometimes it is possible to make a measurement on part of a large grille in order to obtain an estimate of the total flow through the grille. This is the normal technique used for line diffusors.

In many cases it is possible to measure the flow through grilles on ducts of natural or passive ventilation systems. Even if this flow fluctuates, the meter is fast enough to follow the changes. It may require a skilled operator to perform this type of measurement.

In a lot of situations the hood will not fit the grille to be measured, because the wall is not flat or there is some obstacle. An advantage is that the shape of the hood normally does not change the calibration.

Flow distribution during a blower door test

In airtight houses we have succeeded in measuring the leakage flow rate through the facades of the individual rooms during a blower door test. At constant pressure in the house a cardboard shield is placed on the opening of the internal door of the room. The flow meter is pressed on an opening in the board and indicates the flow through the facade. This is done for all rooms with a leakage of less than 0.063 m^3/s. If the leakage of a room to the adjacent internal rooms is much greater than the leakage through the facade the measurement becomes insensitive. The pressure vane stays around zero at all positions of the flow control knob.

This method is the same as using two blower doors. One for the whole house and the second in the opening of the internal door (Figure 6). A blower door could be produced in the same way as the flow meter described here. In 1983 a prototype was produced which worked well. The flow rate calibration curve is only valid for one blower door pressure. The prototype had a set of scales at 0 Pa, 20 Pa and 50 Pa, allowing interpolation.

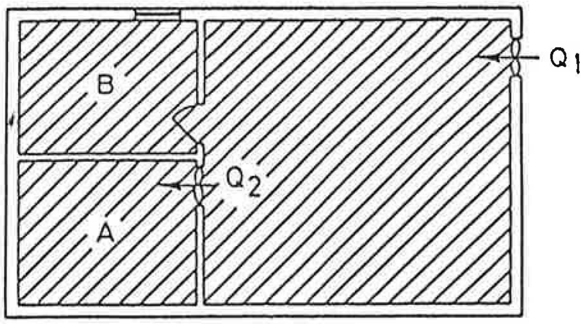

Figure 6: Measurement of facade leakage in one room with two blower doors (2)

If the flow is too large for this flow meter, Wouters' method (2) can be performed.

Direct crack flow measurements during blower door tests have been performed by placing a sealed box on the investigated part of the facade. The flow meter is placed on an opening in this box. The flow meter indicates the leakage flow without influencing the blower door pressure over the cracks.

Concluding remarks

The meter is most useful for short term measurements in which the meter is hand held over the grille. This is because there is no facility for automatic pressure compensation.

For research work the pressure vane could be made more sensitive or pressure transducers could be used.

A flexible hood would increase the number of locations at which the meter could be used.

References

1. ACIN, Manual Flow Finder, 1986, The Hague, Netherlands.

2. Wouters, P, et al, Advanced single fan pressurisation, CSTC/WTCB, Brussels, March 1988.