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Applying electronics to v.a.v. control

The key to a comfortable environment lies not so much in an air-conditioning system itself but in its control system. Mike Hutt considers the latest developments.

Progress in the modern world means that expectations of ventilating and air-conditioning systems in terms of comfort and operating costs are moving steadily higher. To accommodate the demand, the present trend is away from zone control towards individual room control – from constant to variable volume control systems. It is a method which, for the minimum amount of energy, enables comfortable conditions to be maintained in each room of a building.

The technical demands on such systems, and hence also on the equipment comprising them, are constantly increasing. Accurate and stable air flows are of especially great importance, particularly under part-load conditions.

Features

Experienced designers expect the new systems and control terminals to provide the following features.

- Be independent of supply pressure fluctuations.
- Require no minimum supply pressure.
- Have a low noise level.
- Large flow control range.
- Provide a simple adjustment of flow rate.
- Simple monitoring or sensing.
- High accuracy and stability (also under part-load).
- Facility for overriding open, closed/V_{min}/V_{max}.
- Facility for parallel operation (even with different ranges and sizes of equipment).
- Provide supply and exhaust air flow tracking in order to maintain defined room pressure conditions (positive or negative pressure).
- Provide standard control interface points enabling full compatibility with direct digital or analogue control systems.
- Easy installation and servicing.
- Low maintenance, high life expectation.

So what are the requirements for the variable volume control system?

First let us look at the principle of electronic variable volume control (Fig. 1.). The sensor measures the physical variable (v, p) and, together with the geometrical variable (i.e. square root extraction with pressure measurement) converts it into an electrical signal. The v.a.v. controller compares this signal with the setpoint that has been input and generates the appropriate corrective signal for the actuator of the control damper. This changes the volumetric flow rate which, in turn, is measured by the sensor and fed back to the v.a.v. controller.

Quality

The quality of a control loop depends very much on the quality of the individual components in it. Whereas the controllers and actuators for practically all possible applications can be based on industry standard models, in the case of sensors and measuring circuits the design has to be customised for each application.

To regulate volumetric flow with precision, it is essential to measure the flow accurately. However, volumetric flow cannot be measured directly as a physical variable. So two methods have become popular in h.v.a.c. practice.

1. Measurement of air velocity in the duct using a hot wire anemometer.
2. Measurement of differential pressure with an appropriate sensor.

With both methods the measured variable has to be placed in relation to the geometrical form (area, aperture ratio etc.), which means that a local constant has to be taken into account with every measurement of volumetric flow.

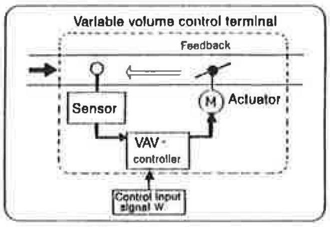

Fig 1: Principle of electronic variable volume control.

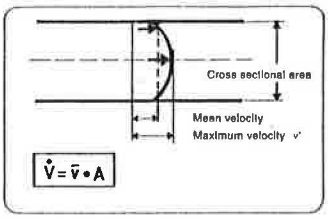

Fig. 2: Profile of flow velocity across a duct.

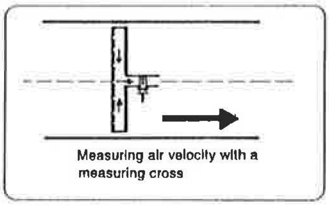

Fig. 3: Measuring air velocity with a measuring cross.

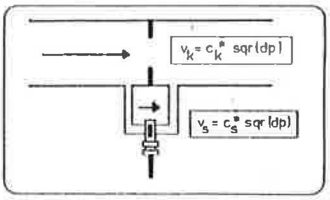

Fig. 5: Measuring flow velocity in an orifice bypass as a function of differential pressure.

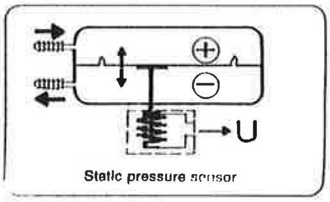

Fig. 6: Principle of static differential pressure sensing.

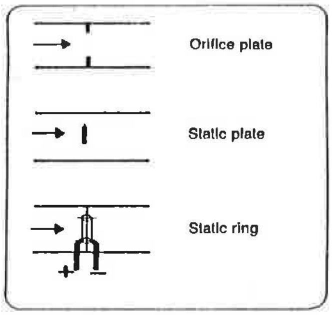

Fig. 4: Various types of baffle can be used to provide a differential pressure.

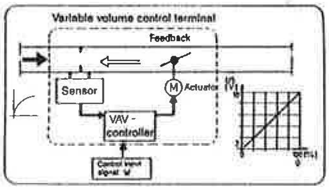

Fig. 7: Schematic of signal conditioning.

Air velocity

There are several methods of measuring air velocity in a duct. One is by measuring the velocity at a single point and multiplying this figure by the cross-sectional area to obtain the volumetric flow (Fig. 2). Due to the non-linear flow profile across the duct, the single-point velocity is not the same as the mean velocity, and a profile factor has to be introduced to obtain the volumetric flow.

To achieve the required accuracy of ±5% with a single point measurement, it is necessary to have precisely defined inlet conditions – straight flow and balanced profile. These conditions are seldom present, and re-calibration is usually impossible because of the lack of a measuring point for checking.

Another option is to use the sensor with a flow-averaging cross, which provides multi-point measurement so that it is possible to obtain a mean value over the whole cross section (Fig. 3).

The cross has a number of small holes in it, and the amount of air entering each one is proportional to the velocity profile across the duct. The collected air flow is channelled into a collector, where the resultant flow velocity is measured by an electronic sensor.

At low flow rates, the flow in the cross can change from turbulent to laminar, so that the volumetric flow is no longer linear.

Advantages

Compared with single-point measurement, the flow-averaging cross has some important advantages.

- Shorter inlet distances are required.
- Average values formed over the cross section of the duct.
- Less susceptibility to blockage.
- Steadier, damped output signal.
- High velocities possible.

Variable volume control terminals based on the measurement of air velocity have undergone rapid development in recent years. Three approaches are in common use.

The first is based on the measurement of differential pressure at baffles. Any flowing medium will exert a pressure on an obstruction. The pressure is proportional to the flow velocity and is called the dynamic pressure. Air flow round the obstruction causes losses which also reduce the static pressure. The resulting differential pressure can be measured and is proportional to the volumetric flow. This is the most popular method of measurement in h.v.a.c. engineering and makes use of many types of baffle (Fig. 4). Low susceptibility to blockage and simple mechanical design are the main reasons for the popularity of this method.

Dynamic differential pressure sensing is based on the fact that if the two measuring sections of a baffle system are linked, the pressure difference caused a flow through the link proportional to the difference in pressure. This effect is used to measure the air (Fig. 5).

This principle exploits the advantages of differential pressure sensing and air-velocity sensors.

- Mutli-point sensing and short inlet connections.
- Low susceptibility to blockage.
- Wide ranges with high accuracy.
- Cost-effective installations.
- Compact independent measurement.

Another method of measuring differential pressure is to use a static pressure sensor. The method is based on the mechanical distortion of a diaphragm, the deflection of which is converted electro-magnetically into an electrical signal.

> ***"The present trend is away from zone control toward individual room control"***

Some relatively cheap electrical pressure sensors have appeared on the market in the last two years and have proved to be suitable for these applications. However, they only solve the problem of the electronic measurement of pressure and not that of the electrical measurement of volumetric flow. The electrical output signal is in linear proportion to the pressure that is measured (Fig. 6).

Converted

Electronic signals from velocity sensors and dynamic pressure sensors are not proportional to the volumetric flow. The signals must therefore be converted by the controller into a linear actual-value signal. This is the only way in which the volumetric flow can be accurately set and measured – and when pre-set and regulated with standard reference signals (Fig. 7).

Clear interfaces and specialised air-flow measurement enable manufacturers of air-conditioning equipment to supply complete variable-volume control terminals ready to install. It can also be possible for a manufacturer to pre-set nominal flow rates and guarantee them; the settings can be easily checked on site and altered if necessary. □

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