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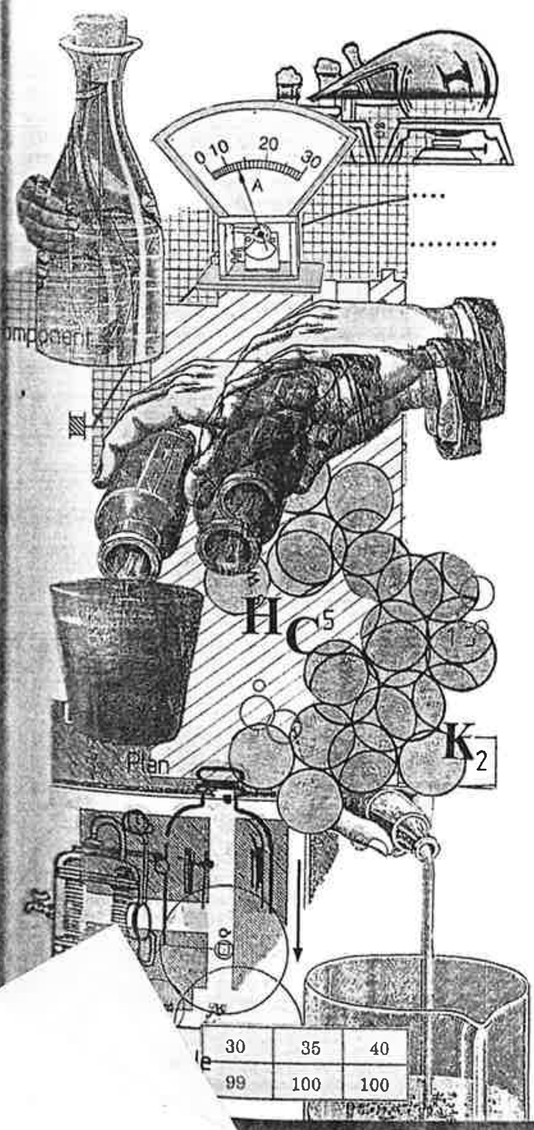
Laboratories



An airing of ideas

by Iain Lyall

Laboratory ventilation needs to be carefully designed to maintain even supply and extract rates and acceptable levels of energy consumption. Iain Lyall explains the options open to a designer and how they all compare.

The priority for a laboratory ventilation system must be to provide a safe working environment for the user. The ventilation designer must therefore create a system that protects the operator by reliably containing the materials used within a fume cupboard or bio-safety cabinet.

Additionally, although aspects such as comfort, noise and economy in operation are all important, safety and reliability should override these.

The design of the fume cupboard and safety cabinet is a key component in laboratory ventilation systems. In general, these perform adequately if they are provided with a well-designed ventilation system, and are located sensibly within the laboratory.

First principles

For a start, fume cupboards and safety cabinets must be located away from doors and circulation routes. The turbulence caused by users walking close to sash openings induces air and entrained contaminants out of the opening, reducing the effectiveness of the system.

The area in the design of a laboratory ventilation system requiring the most detailed effort is the selection of the supply air device. The target air velocity in the space adjacent to an open sash is 50% of the sash inlet velocity. Typically, sash velocities are 0·5 m/s which gives a required room target of 0·25 m/s.

The combination of high maximum air change rates – in excess of 60 ac/h – and

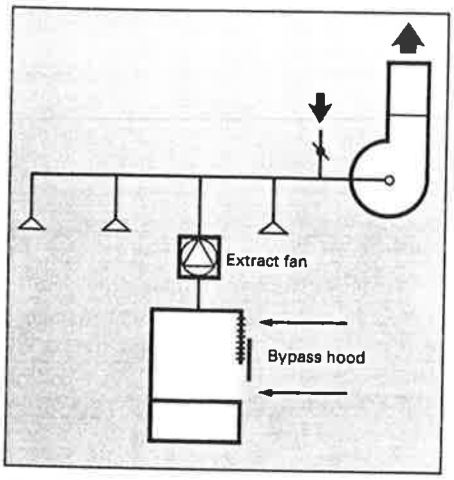


Figure 1: Two position extract.

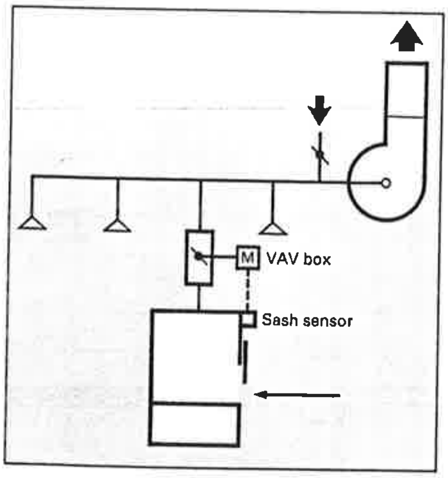


Figure 2: VAV with sash position sensor.

variable volume give a range of volume and temperature conditions which have to be considered.

Computer modelling

The use of computer modelling in the form of finite element analysis and fluid dynamics modelling can be used to visualise and predict air velocity, direction and temperature within the space. These techniques allow a range of supply options to be tested with varying flow rates and internal room heat gain without the cost and time of building a full-scale, thermally correct mock-up.

Using these techniques, Ove Arup & Partners has built up a high degree of confidence in predicting the performance of a range of air diffusion devices for various air change rates to give satisfactory velocities within the space. The following design criteria are based on a conventional, constant volume fume cupboard and dedicated exhaust fan.

Constant versus variable volume

Simple, reliable, easy to maintain? In small numbers, maybe, but on large systems with hundreds of cupboards it becomes a maintenance nightmare with hundreds of small fans; if any one of these were to fail, this would put a workstation out of action. Additionally, the constant volume means high energy use for fan power, heating, humidification and cooling with associated additional maintenance costs on fans, filters, etc on the supply side.

Efficiency can be improved by adopting the variable volume approach. By matching the amount of extracted air to the sash position, a constant face velocity can be maintained as the position of the sash varies.

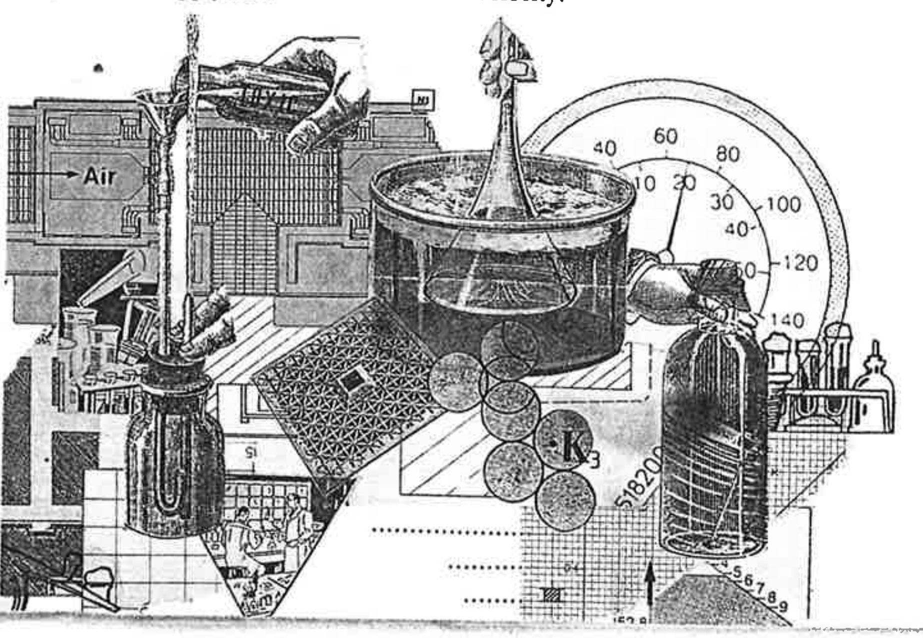
Varible speed fans save energy but add hardware and maintenance elements to the system with no improvement in reliability. Low efflux velocities are also a problem.

Earlier and cruder versions of this type of system were developed by grouping a number of extract ducts onto a single, large extract fan. These were constant volume and developed into a form of vav by the addition of a small extract fan.

These systems gave 100% flow when switched on and 50% flow when off. Significant savings in energy could be expected, but no real advance in reliability. The bleed inlet to the main fan maintains a constant efflux velocity under varying system flow conditions (figure 1).

By replacing the fan with a constant volume box, such systems could operate on a constant volume approach. There is a working position system for day/night and weekends with the addition of a bleed inlet for maintenance of efflux velocity.

This has currently developed to the full vav grouped system, whereby a sash position sensor controls a variable volume valve to give constant face velocity as the sash position varies. This gives good energy consumption, reduced maintenance and the ability to maintain a high efflux velocity.



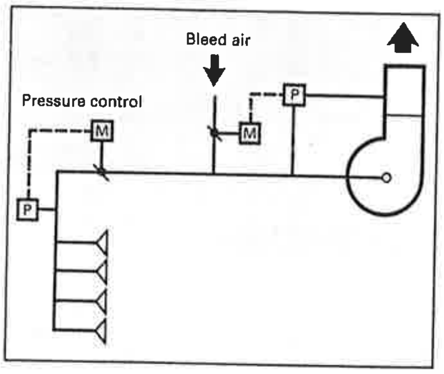


Figure 3: Efflux velocity control.

Main extract systems

There are further steps that can be taken to improve energy efficiency and reliability (figure 2). In this installation, several floors are connected to a single, roof-mounted header and fan. To limit pressure fluctuations under varying flow rates, a simple sensor and modulating damper trim these out, thus limiting the excess pressure taken out at the individual exhaust valve and reducing the noise at point of generation.

The efflux velocity of the fan is maintained under conditions of varying system flow by bleeding untreated air into the inlet controlled by the differential pressure across the fan (figure 3). If you apply this logic to a complete building or wing you end up with a more reliable and safer system.

Each fan is capable of 33% of the total system duty, giving a redundant fan for routine maintenance and breakdown. Full flow can be maintained reliably all the time, and can be backed-up by essential power.

As the system volume decreases, the air flow measuring devices determine that, below 66% of total flow, one fan can be switched off and, on further reduction to 33% of total flow, a further fan can be dropped. Efflux velocity is maintained at all times, as well as stable pressure conditions in the risers.

In this way the number of fans needed to ensure the safe operation of the system at any time can be minimised, thus reducing energy consumption, wear and therefore maintenance.

How to achieve efficiency

Having extracted the air out of the building, there is a need to introduce the make-up air efficiently. An example of this could

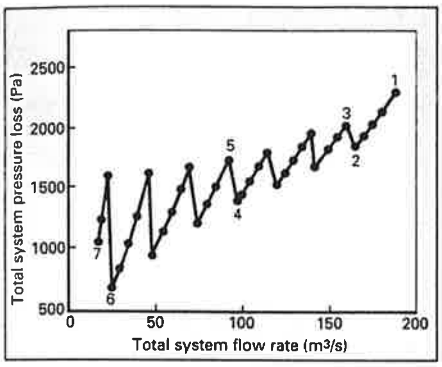


Figure 4: Increases in volume are met by the sequential operation of air handling units.

be where, say, eight air handling units are connected to a common supply header serving a multi-storey system.

As the system volume reduces, the air flow measuring devices summate the total air flow. If the total volume can be satisfied by one less unit this is then switched off and isolated from the system. The remaining seven fans adjust to supply the required pressure and volume needs of the system.

On further reduction in flow, additional units are shut down and isolated in sequence. Thus the minimum number of units are run at any one time, and each unit is always running close to its design volume and maximum fan efficiency.

As volume increases the process is reversed. The air flow measuring devices sense when the running units approach 95% of their design flow rate, start an additional unit and then connect it to the system. The fans then adjust to supply the required pressure and volume needs of the system. Further increase in volume enables additional units to be switched on in sequence (figure 4).

This arrangement clearly needs a simple means of giving stable pressure in the supply network, and an efficient means of reducing the air volume to match the system requirements. This can be achieved by:

☐ inlet guide vanes on centrifugal fans;
☐ variable pitch-in-motion on axial fans;
☐ variable speed on both types.

With the system outlined earlier, the turndown ratio on the fans is relatively small, the target being to run fans close to their maximum volume.

Variable speed drives are more efficient at high turndown ratios than other options, but at ratios down to around 65% there is little significant difference between them.

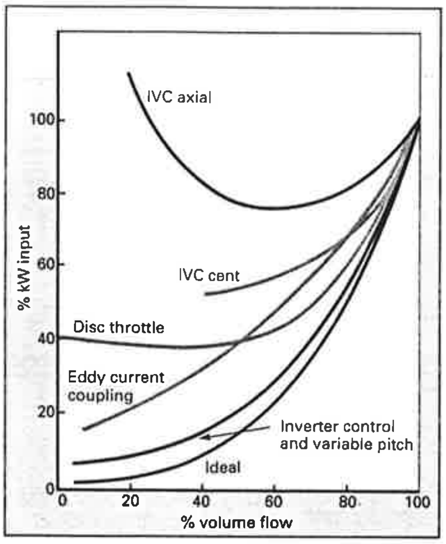


Figure 5: Relative power savings between various types of air flow control methods.

The selection of variable volume control for the fans may thus be based on lowest first cost. This means that inlet guide vanes or variable pitch axial fans can be selected according to the volume flow rate and system pressure characteristics (figure 5).

For high volume, high pressure systems inlet guide vanes give stable and effective control over a reasonable range of volume. The accompanying chart shows the performance of a large centrifugal fan with varying angles of inlet guide vane. Similar performance at lower pressures can be achieved with variable-pitch axial fans

Methods of heat recovery

Having achieved a safe, reliable and efficient means of controlling the fan system, ways of achieving energy efficiency can be considered.

Reclaiming heat from the exhaust air and transferring it to the supply air can be achieved in several ways. The use of a plate heat exchanger where inlet and exhaust air pass through a labyrinth is not recommended, as the corrosive nature of the exhaust may cause failure of the plates and contamination of the inlet air.

Additionally, the supply and exhaust plants must be adjacent to each other, which is not always possible in large installations.

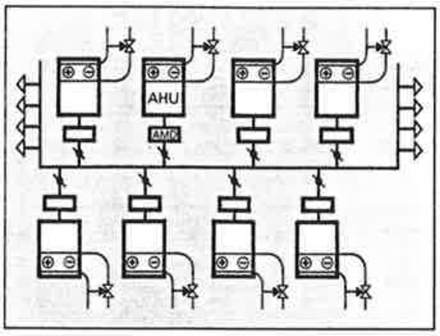


Figure 6: Multiple ahu heat reclaim - efficiencies of around 50% can be achieved.

A thermal wheel also needs inlet and exhaust plant to be adjacent to each other. Again, this is not recommended because of corrosion and possible contamination of inlet air.

Run-around coils offer flexibility in plant location, and no likelihood of contamination. A glycol solution circulating through coils in the exhaust removes heat from the air and transfers it to the supply plants.

However, care is needed in the selection and specification of these coils. They need a protective coating to resist corrosion from the exhaust air, and should be selected to avoid excessive condensation on the coil, again to reduce corrosion risks.

At the supply plant, the system can raise the outside air temperature to a reasonable supply condition, the temperature being controlled by a three-way valve on the supply coil.

In this way, heat reclaim efficiencies in the order of 50% can be achieved, giving huge savings in running costs and the size of boiler plant. Additionally, small but useful savings 99can be made in the peak cooling load, reducing central cooling plant capacities. Payback periods in the order of three years can be achieved with careful design of these systems (figure 6).

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