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FAT vav — a design guide

In this article, *Kenneth Seibel* and *Ray J Clark* outline the concepts and applications of the fan assisted terminal system which has only recently been introduced to the UK.

Many types of air distribution system have been developed and used in buildings over the years, in response to evolving financial, functional and human comfort considerations.

The first heating and air conditioning systems, which were employed up to the early 1970s, were constant volume, variable temperature systems. When properly designed, these systems provided excellent performance in terms of occupant comfort due to the supply of a constant volume of air to a space. Nonetheless, the high level of energy consumption due to the requirements of fan operation and zone control methods, such as dual duct mixing and reheating, made these systems uneconomical.

With the increase in energy costs and the resulting emergence of a more energy-conscious and efficient form of engineering design, variable air volume (vav) systems were introduced to the market. The development of these systems occurred as a result of a large-scale product development programme by several manufacturers who provided vav terminal control boxes and methods of reducing fan output such as inlet vanes, discharge dampers, variable pitch blades and inverter fan motor drives. These systems proved more economical but still offered a fine level of zone control with a significant lowering of energy consumption, and have been widely adopted in office buildings throughout the world.

However, vav systems have their fair share of comfort problems. Energy bills have been lowered at the cost of the comfort of the individual occupant, and as room load is reduced, the volume of air circulated is also reduced, often resulting in stagnant room conditions and insufficient air movement. Various solutions to this basic problem have been attempted, with varying degrees of success.

The current generation of heating and air conditioning systems — the fan powered system, or fan assisted as it is known in the UK — combines the advantages of both the constant volume and the vav systems.

The concept for the fan assisted systems originated in the mid 1970s in Houston, Texas, in an attempt to satisfy the minimal winter heating conditions by adapting all-air vav systems.

The first fan boxes were nothing more than warm air furnace-fans hung on the side of ductwork downstream of vav terminals. They were fitted with backdraught dampers and electrical heating coils. When room conditions warranted, the fans cycled on and, upon need, the heating coils.

Though the implementation was crude the concept was sound. Thus the first generation of fan assisted terminals (fat) was born, and moved into the third and fourth generation of products during the 1980s.

Intermittent flow boxes have since been further developed into series flow, fat units. These systems have led to the recent development of high-induction linear diffusers that resolve the problems associated with overhead, perimeter all-air heating systems.

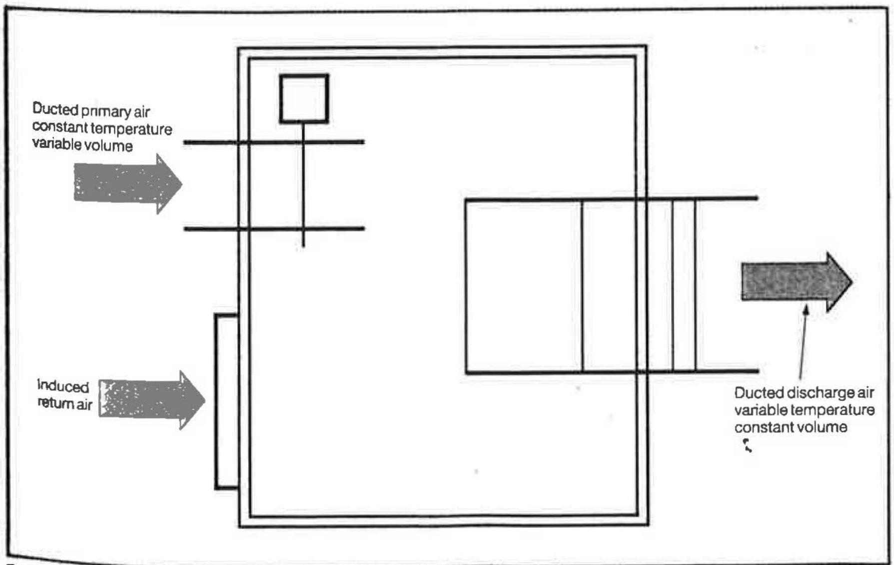

Figure 1: Diagram of a fan assisted terminal unit.

The fan assisted terminal

The fat unit can be defined as a pressure independent, vav control valve mounted within a mixing cabinet with an integral fan supplying air to a room (see figure 1). The unit receives both ducted primary (cold) air, which has been conditioned at a main air-handling plant, and plenum (warm) air from the ceiling void. The two air streams are mixed to the required amount to satisfy room load conditions.

The unit contains a low pressure fan which delivers the mixed air at a constant volume to the room. A heating coil is also attached for space heating requirements. The coil is a "top off" device which only comes on when both the primary air has been reduced to a minimum and the direct local heat recovery from the internal room load is insufficient to maintain required room conditions.

Occupant comfort

One of the main advantages of fat systems is their ability to provide occupant room comfort and accommodate a considerable variation in room load. Given the discrepancy between the current requirement of the commercial property market for internal design loads of 45-65W/m^2, and actual operating loads of 10-20 W/m^2, the standard vav system has to function with a much lower air supply circulation rate than originally intended; ie, the difference between the specified and actual loads of engineering systems has lead to inefficient use and physical discomfort.

This is demonstrated in figure 2, where an interior space would have an air flow rate of 11 ac/h at the design condition socket load of 45 W/m^2. If the actual socket load in the space is only 10 W/m^2, the resulting vav air flow is reduced to less than 7 ac/h.

It is a well documented fact that air

movement plays a significant role in the degree of human comfort. The temperature at which a person is comfortable differs according to the variation of air flows across the individual. This implies that if a space is to have a varied air flow then the comfort temperature setpoint should also be allowed to vary. For the fan assisted vav system, the designer may increase the air volume above the required cooling air volume. This flow rate remains constant independent of the actual load, alleviating the vav problem of reduced air flow. Figures 2 and 3 illustrate the performance of vav and fat systems, respectively, for an interior space.

Figure 4 reveals that the reduction in vav air flow is even more pronounced for a perimeter space due to the effect of solar heat gain. For example, an east or west facing space with a solar intensity of 630 W/m^2 and 1·8 m high heat-absorbing insulated glass, and indoor shading, necessitates 22 ac/h in ideal design conditions. In cloudy conditions, or with indirect sunlight, the air flow drops to 13 ac/h. With a load of 10 W/m^2 the air flow falls to 9 ac/h. Within this considerable range of air changes, a traditional vav system is required to maintain comfort at a constant room temperature setpoint; whereas the fat system maintains a constant rate of space air circulation rate for the occupants regardless of solar or internal load changes.

Energy efficiency

As noted above, one of the prime benefits of a vav system is its energy efficiency, as it allows the primary air distribution fan to reduce the air volume in relation to actual load conditions. The fat system has similar advantages in so far as the primary air fan performs like a vav system, except that the power requirement is less because the air pressure is lower. In addition, because the fan assisted box circulates air from the ceiling void, the first mode of heating is by recovery of heat from occupants and lighting. All in all, the fat system is more energy efficient than a vav system.

Financial considerations

The design of a fat system involves a low or medium pressure duct system delivering cold primary air to both interior and perimeter spaces. As primary air is mixed in the box with ceiling air, much colder primary air temperatures can be provided than with a vav system. This effectively reduces the amount of ductwork required, and the size and power requirements of the primary air fan, with clear financial advantages.

Primary air supply temperatures of 9°C can be used with 5·5°C chilled water temperatures. Low temperature primary air is well integrated with the self-contained local dx air handling plant and/or ice storage systems. Furthermore, the reduced amount of sheet metal and floor fan requirements actually make the fat system less expensive than the vav system.

Application techniques

There are a number of factors which should be taken into account when designing a fat system. All pressure regulating devices such as vav dampers generate noise when throttling. The fat system overcomes this problem because the terminal itself circulates the mixed air to the room. The primary air handling plant can be designed to achieve zero static pressure at the inlet to the fat air valve. Other solutions constitute an inefficient use of energy and contribute to the potential creation of an undesirable noise nuisance.

The fat system requires the designer to control the static pressure of the central air handling plant. In so far as excess static pressure leads to noise, it is important that fat systems be designed with primary air velocities at a maximum of 12 m/s decreasing to an inlet condition of 8-9 m/s at the terminal. By paying careful attention to the selection of primary ahu fans and coil pressure drops (without the need for duct silencers), the local primary plant can be specified with external static pressure requirements of less than 250 Pa.

Recent experience in the design of fat systems confirms that inverter fan motor drives are the best approach to throttling the main fan.

Given the basic simplicity of the fat system, no servicing is required. If a problem exists then the boxes are designed for bottom access which can be easily co-ordinated with ceiling system modules.

No special box hanging techniques are required but many installations in the USA use boxes which are sheet metal strapped to the structure, even though more rigid hangers could be employed for more durable installation. Products available in the UK have built-in points for connection of hanger rods.

Boxes can be snugged tight to the overhead structure, with attention paid to the installer's ability to connect ductwork, wire and service control assemblies.

Even though individual boxes do not present a noise nuisance, it is prudent to ensure fat boxes are not grouped together to avoid aggregative noise disturbance.

Rather than installing permanent filters on the system, it is advisable to provide temporary construction filters on the plenum inlet ports which can be removed at tenant commissioning.

FAT boxes should be connected to the main primary air duct with rigid, externally wrapped, round ducts in so far as air valve inlet design velocities are high enough to preclude the use of flexible ducts. Additionally, the use of rigid ducts does not allow air valve noise "breakout". It is important to clarify that rigid, round ducts do not imply spiral construction. In fact, the appropriate design inlet pressure will be too low to require spiral round ducts. Rigid connections also minimise

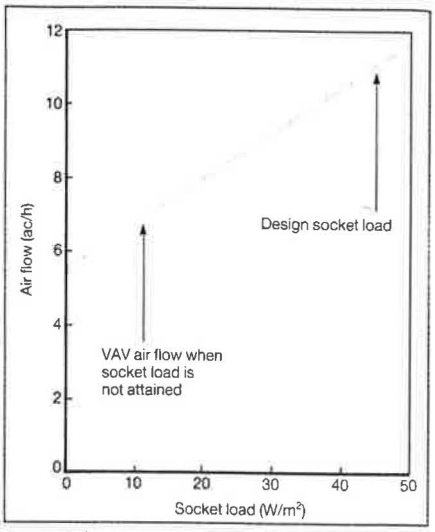

Figure 2: Interior space air flow for vav system.

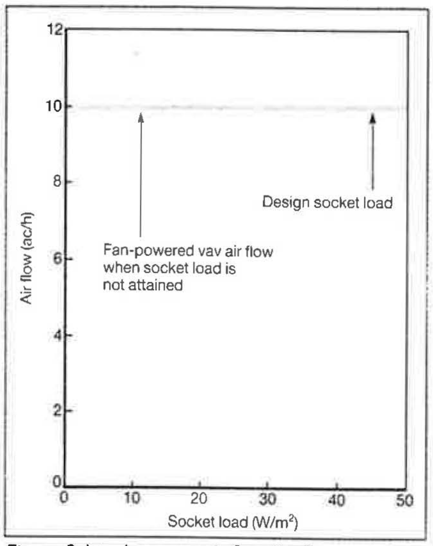

Figure 3: Interior space air flow for fat system.

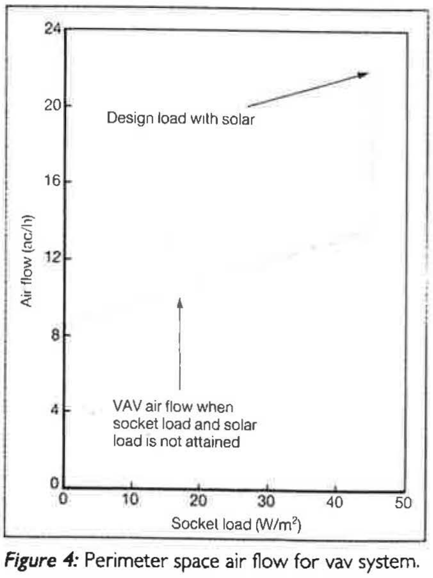

Figure 4: Perimeter space air flow for vav system.

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the potential occurrence of control problems associated with "kinked" flexible ducts adjacent to air valve pressure independent sensors.

Since the fat internal fans are capable of 150-200 Pa static pressure at most, downstream duct velocities must be minimised. Heat gain to the airstream in a low velocity small duct can be significant. Consequently, it is recommended that downstream ducts be internally lined from the fat to the diffuser. Such internal lining further improves acoustical control.

The acoustical information provided in manufacturer's catalogues should be used with discretion when designing fat systems. Particular attention should be paid to the maximum capacity of any size box within its catalogued range and the magnitude of inlet static pressures which may be higher than required.

Final acoustical control within a finished space is dependent upon:

- ☐ room size;
- ☐ the room's materials and finishes;
- ☐ ceiling construction;
- ☐ plenum cavity;
- ☐ method of air supply and return;
- ☐ light fittings;
- ☐ grouping of equipment within the plenum;
- ☐ the fat box itself.

For these reasons, a mock-up test of the planned configuration is strongly recommended before installation, which will also serve as the basis for the required tenant standards.

Heating medium

Either hot water or electric heat can be used with fat systems. While variance control of electric heating coils can provide a fine level of control, in practice multistage contactor control of the electric heating coil provides perfectly acceptable control and is also less expensive.

The relatively low heating temperatures required in modern office buildings (typically a maximum of 27-28°C) and the efficient mixing of high induction perimeter linear diffusers, makes this possible without the occupant being able to perceive the stages of heat gain or loss.

Commissioning

FAT boxes are well suited to commissioning when specified with remote control of the fan speed controller, so that all sensors and controls necessary for commissioning the terminal unit are present in the box. It is interesting to note that the air balance of individual diffusers is not critical to commissioning, in so far as low pressure constant volume perimeter slot diffusers, combined with small control zones, ensure that the inlet static pressure variation from diffuser to diffuser is minimal. This is due to the fact that delivered air quantities will be almost identical.

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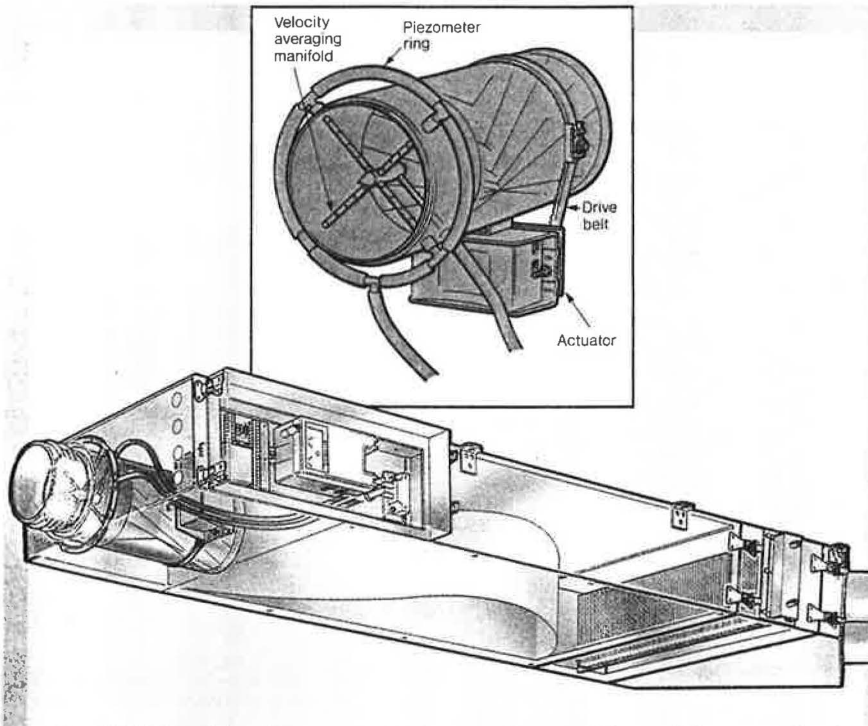

Unreliability of air flow control is frequently a problem with conventional mixing boxes. The Airjet and Fanjet vav terminals from Gilberts incorporate a novel rotating diaphragm air-flow control valve, a simple and reliable design solution which gives improved linear performance, even at very low flow rates. In addition, valve operation is very quiet alleviating the need for silencers.

The damper is formed from a rubber/fabric diaphragm in a upvc casing and has proved extremely durable under test conditions and when installed in the fresh air control system at Broadgate. It can provide turndown from maximum unrestricted air flow right down to 0%. Air flow can be precisely controlled in accordance with a demand signal either preset in the vav controller or remotely through a zone temperature sensor or bms.

Under an electronic control system, a sensor measures the dynamic pressure in the upstream section of the damper and relays it to the air flow controller. The signal is compared to the controller's set point and any difference is eliminated by an actuator adjustment signal. The actuator adjusts the damper position until the measured flow rate matches that signalled by the temperature sensor.

The Fanjet system, developed from the Airjet series, is a single duct, fan assisted vav system. The terminals utilise a dual supply system comprising primary conditioned air mixed by a fan with secondary air to provide constant outlet volume even with a high turndown of primary air.