AIR CONDITIONING AND REFRIGERATION
Journal
The magazine of the Indian Society of Heating, Refrigerating and Air Conditioning Engineers

Issue : January-March 1999

VAV SYSTEMS for office Buildings- Part 1

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Let's start with a quick quiz. If you buy a new 10 hp motor and run it continuously, how long before the energy cost to run the motor equals the capital cost to buy a new motor? If you are like most engineers that we have asked, you will guess two to three years.

Let us share faith you the answer. A 10 hp motor draws about 18 Amps. At Rs. 3.5 per kWh, the running cost comes to about Rs.300 per day. A 10 hp motor will cost about Rs. 12,000 and this means that the energy cost will equal the capital cost in about 40 days!

The point behind this question is that many engineers place greater emphasis on capital cost than on operating cost.

Let's try another question. If the 10 hp motor cost Rs. 300 per day to run at full speed, how much would the motor cot to run at half speed?

Many engineers do not realize that energy varies as the cube of the motor speed. Reducing the speed by half will reduce the energy to one eighth of the full speed value. In other words, the motor would cost about Rs. 38 per day to run at half speed.

The point of this question is to illustrate the significant energy savings that can be achieved by reducing motor speed.

In many Indian offices, 20% to 30% of the total building energy goes to AHU fans. A variable air volume system can significantly reduce the energy consumption associated with AHU fans while actually increasing these reasons that variable air volume air conditioning systems have become the worldwide defacto standard design for office environments. But how much does a VAV system save when compared to a CAV system? The savings are highly dependent on the weather pattern, building usage and control strategies employed. The 19995 ASHRAE Handbook Chapter 38.6 shows simulation data for a temperate climate which indicate that VAV systems use one third of the energy of a CAV system in a large office. In other words, converting from a CAV to a VAV system can save two thirds to three quarters of the AHU energy cost. IIT Kharagpur is preparing similar data under Indian conditions and these results will be the object of a future article.

The benefits of a VAV air conditioning system when applied to offices are summarised in **Table 1**.

Table 1 Benefits of VAV Systems

Benefits of VAV Systems for Office Air Conditioning
Significantly reduced energy cost
Individual zone control
Occupant perception of local control
Flexibility to adapt to change
Reduced size of ductwork and AHU
Facility manager can monitor and record space temperatures

VAV System Basics

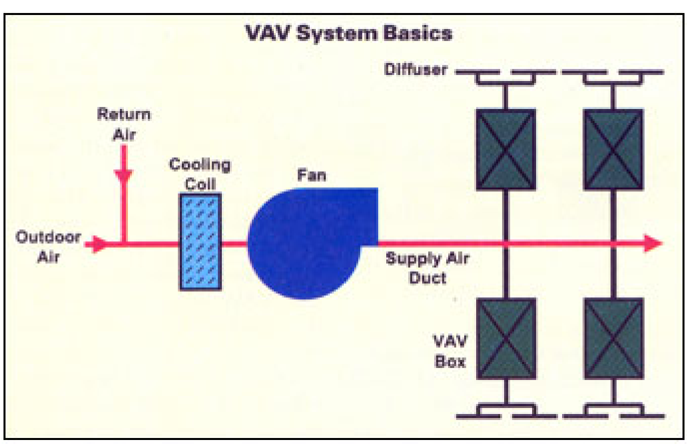


Fig 1 – Simplified Schematic of a VAV System

Figure 1 shows the a simplified schematic of a VAV system. The outdoor air and return air are mixed and drawn through a cooling coil which drops the temperature to a fixed supply air temperature. (or fixed off-coil temperature, depending on where the controlling sensor is located).

This cool air of typically 12 deg. C to 14 deg.C is distributed though the supply air duct.

Each VAV box has a small damper that controls the amount of cool air to be delivered to the zone through the diffusers. Energy savings occur when the fan speed is automatically adjusted to maintain a static pressure setpoint in the supply air duct.

For example, if the is a sudden increase in load in a specific zone, the temperature sensor located in the zone666666 will detect a rise in temperature above setpoint and request the VAV box to increase the amount of cool air being delivered to the zone. The VAV box will adjust its damper to accommodate the request and more air will flow into the zone from the supply air duct to drop and this drop in supply air static pressure a will be detected and used to increase the fan speed.

The details of the control algorithms for the VAV box, supply air static pressure and temperature are the subject of subsequent articles in this series.

Zoning for VAV

In most cases, the consultant engineer is not given details of office partitioning layout when preparing the design. The consultant engineer is simply given an empty floor plan such as in **Figure 2** and must decide the zones, balancing flexibility (more zones) with cost (less zones). Often, the requirements call for the floor to be subdivided among multiple tenants and this will also impact the zoning.

Fig. 2 – Empty Floorplan to be Zoned

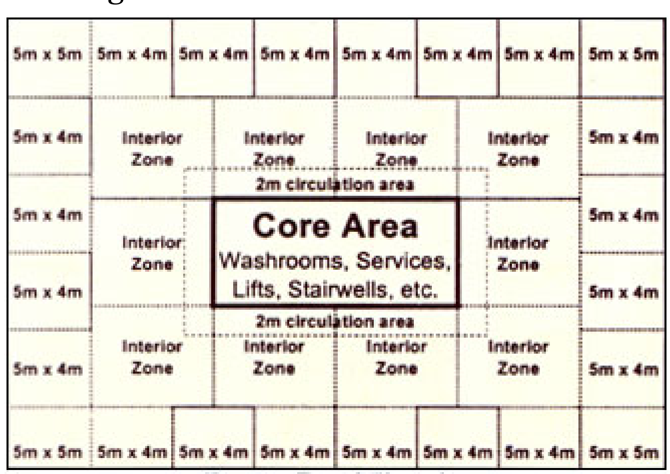


Fig. 3 – Zoned Floorplan

Generally, the areas closest to the windows will be used as closed offices and each office should be an individual zone. A good rule of thumb would be to allow for offices that are five meters deep by four meters wide with five meter square corner offices.

For the interior space, it is a good idea to design for about 1000 CFM per zone as this is the largest capacity of VAV box commonly available and air flows above 1000 CFM will generate excessive noise. If the floor is to be subdivided among multiple tenants, this may increase the number of interior zones. For maintainability, it is a good idea to locate the VAV boxer serving the interior zones within two meters of the core as this is often a circulation area and easily accessible. Though the VAV box is mounted close to the core, the actual diffusers for the interior zone will be distributed though out the space as required.

In projects where the floor layout is known in advance, it is important not to use a single VAV box to supply different types of zones. For example, one should avoid supplying a closed office and a conference room with the same VAV zone. This is because a closed office and a conference room will have different occupancy patterns. If the zone temperature sensor is placed in the office, the conference room will be overcooled when unoccupied and under-cooled when fully occupied. Similarly, placing the zone temperature sensor in the conference room would result in over cooling of the closed office during meetings in the conference room.

Sizing of Ductwork and AHU

Once the zoning has been done, the next task is to design the ductwork. With constant air volume system, it is common to size the main supply duct based on about 1000 ft/min to 1200 ft/min and 500 ft/min at the diffuser. For variable air volume systems, the main supply duct should be designed for 1500 ft/min to 2000 ft/min and the branch leading into the VAV box should be designed for 1000 ft/min.

Each VAV box a small flow measuring station that is sized for a maximum of one inch velocity pressure. If the ductwork at the inlet of the VAV box is too large, the flow measuring station will only be using a fraction of the range resulting in inaccurate readings when there is not much load in the space.

When compared with a CAV system, a VAV has smaller ductwork because of higher airspeeds. The increased airspeed in the ductwork does not compromise noise levels as the VAV boxes are acoustically isolated.

The sizing of a VAV AHU is slightly different from the sizing of a CAV AHU.
With a CAV system it is common practice to size the AHU based on the worst case heat load of the space. When sizing an AHU for a VAV system, the engineer should do heat load calculations for each VAV box zone at different times of the day. The size of the VAV AHU

is then based on worst case summation of zone loads. Not all VAV zones will be at maximum heat load at the same time of the day. This is called a diversity factor. Because of the diversity factor inherent in VAV systems, it is possible to shrink the capacity requirements of the VAV AHU by ten to fifteen percent when compared to a CAV AHU.

The BTU/FT^2 is sometimes used as a rule of thumb benchmark for AHU sizing. If a CAV AHU is sized with a capacity of 50.55 BTU/FT^2 the VAV AHU can be sized with a capacity of 40-45 BTU/FT^2. Reducing the capacity of the AHU reduces the cost of the equipment and the physical space requirements.

Diffusers

Each VAV box can serve multiple diffusers. When designing the diffusers layout, the consultant engineer must consider the throw pattern at both full flow and the throw pattern at part load. In other words, the selection of diffusers becomes an important issue and it may be necessary to consider diffusers with good throw characteristics at low load such as linear diffusers or troffers. With an improperly selected diffuser, low air flow will cause "dumping" of cold air and other air distribution problems in the space.

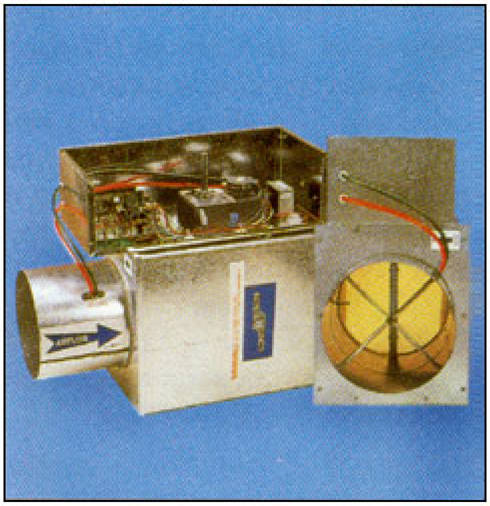
Selection of VAV Boxes

VAV boxes are sized according to the inlet duct. Inlet ducts to VAV boxes are round and sizes range from six inches to sixteen inches in diameter.

The contractor selects a VAV box for a location based on two parameters provided by the consulting engineer.

- The maximum CFM required to be delivered under full load (based on heat load calculations)
- The noise level required (a noise level of NC55 is commonly applied in an office area)

The consulting engineer will also provide the minimum CFM required to be delivered under part load. The minimum CFM is used as part of the control strategy but does not affect the selection of the VAV box. The minimum CFM for a VAV box should be calculated based on delivering six air changes of supply air per hour in the space and is typically about thirty percent of the maximum CFM for the VAV box.



Two views of a VAV box with controls (cover open)

Location of Zone Temperature Sensors

In CAV system, a single temperature sensor was typically installed in the return air duct to measure the average space temperature. One of the advantages of VAV systems is the ability to have a separate temperature sensor to control each zone. The location of the zone temperature sensor is an important issue. Going back to basics, we remember that the control system will try to achieve the desired set-point at the location that the temperature sensor is located and therefore the location of the temperature sensor can impact the comfort level in the entire zone.

For example, if a single VAV box supplies two closed offices, the system will achieve the set-point in the office that has the temperature sensor while the other office (the office without the temperature sensor) will be "floating"

It is not a good idea to mount temperature sensors on exterior walls because exterior walls scan transmit heat from the outside making the temperature sensor think that the room is warm. This can cause overcooling in the room.

The adjustment of the diffusers and the placement of partitions and other large objects in the space impacts air distribution. It is therefore important to place the temperature sensor at about body height (about 1.5 metres from the floor) so that stratification and air pockets do not cause overcooling or under-cooling in the space.

Overcooling of the space will also occur if a temperature sensor is located such that it is exposed to a heat source such as direct sunlight, a kettle or the condenser coils of a refrigerator.

The best location for the temperature sensor is on an interior wall about 1.5 meters from the floor, away from heat sources./ It is important that a facility manager understand the importance of the location of zone temperature sensors when troubleshooting complaints.

To the building occupant, the zone temperature sensor is the most visible part of the system. There are different styles of temperature sensors:

- Sensor only: no local adjustment
- Slider control: zone set-point be adjusted locally using slider
- Digital sensor: zone set-point and other parameters can be adjusted locally using a simple keypad.

Integration with Building Automation System

Many of the Indian office buildings installing Variable Air Volume air conditioning are also installing Building Automation Systems. The controls on the VAV boxes are preconfigured to be connected to the Building Automation System. Connecting the controls on the VAV boxes to the Building Automation System allows the facility manager to:

- Display the current temperature in a zone
- Display all the zone temperatures in an area on a graphic
- Adjust the individual set-points of zones from a central location
- Maintain historical records of zone temperature values.

Conclusion

Variable Air Volume technology is expected to experience widespread adoption in India. Variable Air Volume air conditioning systems are appropriate for many of the new office projects being constructed in India. It may also be justified to convert existing constant volume systems into variable volume.