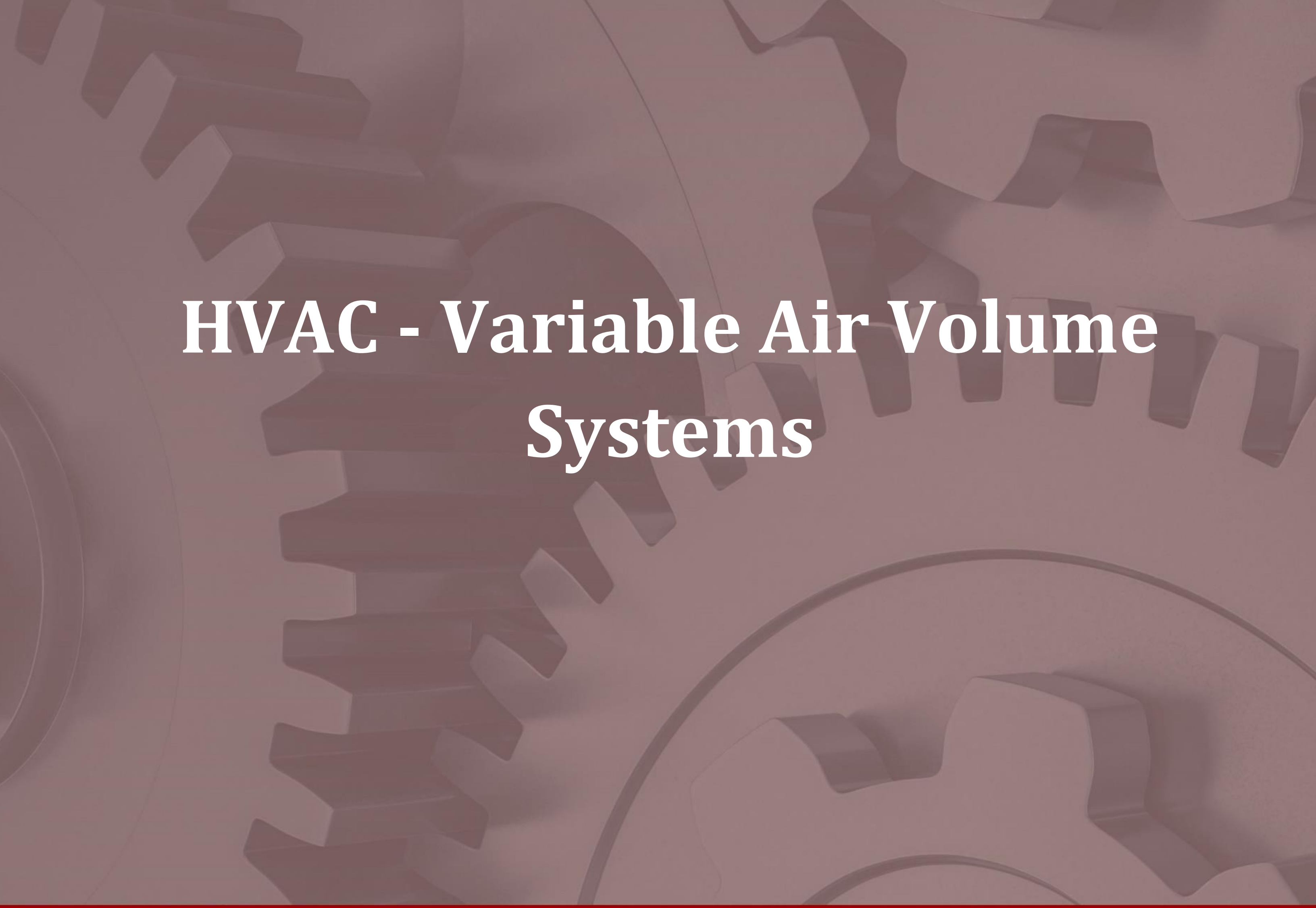


HVAC - Variable Air Volume Systems

An Online Continuing Education Course for Engineers

Course Number: HV-6009

Credit: 6 Hours / 6 PDH / 6 CPD

HVAC – Variable Air Volume Systems

1 Introduction

Background

A variable air volume (VAV) system basically supplies air at a constant temperature and varies the air quantity delivered to each zone to match the change in room load. In a VAV system, an air handling unit (AHU) cools or heats air to accommodate the zone with the most extreme requirements, supplying the air through ducts to various zones. At the individual zone or space, the amount of air to be provided is regulated by dampers within a VAV box or terminal.

Use of VAV systems have been a popular energy conservation choice since the 1970s. After much experience and many customer complaints, it was learned that VAV systems needed to be continually controlled. This is in contrast to constant volume systems that are manually balanced and then left alone. Thermostatically controlled volume dampers (air valves) were used for many years, particularly in low static pressure air distribution systems. In most cases, performance was less than satisfactory. They were often a compromise to achieve lower cost than using proportioning water valves, face and bypass dampers, or other control means. However, the development of higher velocity and higher pressure systems, and nondumping diffusers and grills, combined with larger zones, higher internal heating loads, and the rising cost of energy, have made VAV systems the most popular air distribution systems specified today.

Many VAV systems cause the flow of air, and therefore, the static pressure in both the supply and return duct systems to vary as the space load changes. At any given air valve position, as the static pressure changes, airflow changes. As airflow changes, the space temperature is also changed. If the load throughout the building changed gradually and at the same time, changes in static pressure would be approximately the same at each air terminal. This seldom happens. Due to building diversity, changing solar loads, fluctuating internal loads (from people, lighting, equipment, etc.) and static pressure, airflow fluctuates in trunk ducts and duct runouts as air valve positions change.

When an air terminal valve closes, the static pressure in the adjacent runout and trunk duct will increase, resulting in increased airflow through the adjacent ductwork. This change in airflow will affect the space temperature in the new area supplied by that ductwork because a higher volume of air (usually cooled) is now flowing into the area. The space thermostat in this area will eventually sense this change in temperature, and reposition its air valve for reduced flow. This reduced flow will cause a further increase in static pressure in adjacent ductwork and increase flow even further to other air terminals. If at this time another space has an increasing load, the terminal supplying that space would open, which would reduce static pressure in adjacent ductwork, and reduce airflow to the terminals that were previously throttled back. It is apparent that space thermostats alone can never stabilize a space temperature, since almost constant temperature swings will be the result.

On many systems, airflow is proportioned by "riding the fan curve." Duct static pressure can become quite high, causing increasing airflow and compounding control problems. Therefore, a means to control and at least limit static pressure is used on many systems. Control of static pressure and airflow by using inlet or outlet dampers on fans, or variable speed drives is intended to: (1) maintain a positive pressure to prevent infiltration, (2) assure that a minimum amount of outside air is supplied, and (3) keep duct pressure within the correct operating range of the air terminals. Controlling the central fan system will not completely eliminate fluctuation of duct static pressure in adjacent runouts, but this fluctuation should now be within the "correct operating range" of the air terminals. The next section describes the three primary classes of VAV terminals.

Summary

Advantages of VAV systems:

- Low initial cost for large systems (compared to obtaining the same conditions for conventional systems) due to reduced fan sizes, ductwork, filters, and casings since the capacity is based on the peak instantaneous demand of all the spaces, instead of the sum of all the space peak demands.
- Lower operating costs due to reduced fan horsepower.
- Lower energy consumption since cooling and heating is provided only to the extent that it is required.
- Savings in mechanical space requirements due to smaller fans and ductwork.
- System is virtually self-balancing since boxes are set for maximum and minimum cfm.
- Excellent space condition controls.

Practical problems that may be encountered:

- Acoustical problems—noise generated by a terminal device varies with the static pressure across the device.
- Stratification and drafts—the air distribution patterns of conventional diffusers depend on the outlet air velocity. When airflow is reduced, the distribution pattern is changed and can cause stratification or drafts to occur.
- Unstable operation—variations in airflow cause variations in duct static pressure. As volume is reduced, duct system pressure drop is reduced and fan pressure increases. The combined effect of these two factors is higher static pressure at the terminal device as airflow is reduced. This is only a problem in pressure dependent and volume limiting systems.
- Control problems—(1) How to sense small changes in static pressure, (2) How to balance return air systems with variations in supply air, and (3) How to maintain a constant flow of outside air with variations in supply and return airflows.
- Not acceptable for some specific areas in hospitals because, at low load conditions, less air is discharged from supply outlets. This may not meet strict ventilation or humidity control requirements.
- Not especially adaptable to small volume system unless it is a low pressure system.

General applications:

- Ideal for buildings with internal spaces that have large internal heat gain.
- Most common for new institutional and office buildings where precise humidity control is not critical.
- VAV independent systems are satisfactory in schools when controls are applicable for varying loads.
- Ideal application for pressure dependent controllability is for low pressure systems with minimum load fluctuations.

Controllability Classifications for VAV Systems

Understanding the static and flow variations of VAV terminals is important to understanding how they operate. From a controllability standpoint, all VAV terminals fall into one of three classifications: (1) Pressure Dependent, (2) Volume (CFM) Limiting, and (3) Pressure Independent

Pressure Dependent

Pressure dependent terminals do not have controls that compensate for changes in duct static pressure. Therefore, the air volume delivered depends on upstream static pressure changes. These terminals are composed of air valves or dampers in an enclosure. A change in the thermostat signal will reposition the air valve.

Because they are subject to changes in airflow, these types of terminals seldom deliver the air quantity needed to satisfy space load. They depend on the thermostat sensing the change in room temperature. The room temperature variation is brought on by airflow fluctuations. Required airflow is achieved by the repositioning of the dampers. As airflow fluctuates, the inlet static pressure also changes. These changes in static pressure cause a repositioning of the damper.

If the changes in load and static pressure are great, these devices will continually oversupply or undersupply air, causing temperature fluctuations in the space as well as changes in sound levels as they “overshoot” and “undershoot.”

Volume (cfm) Limiting

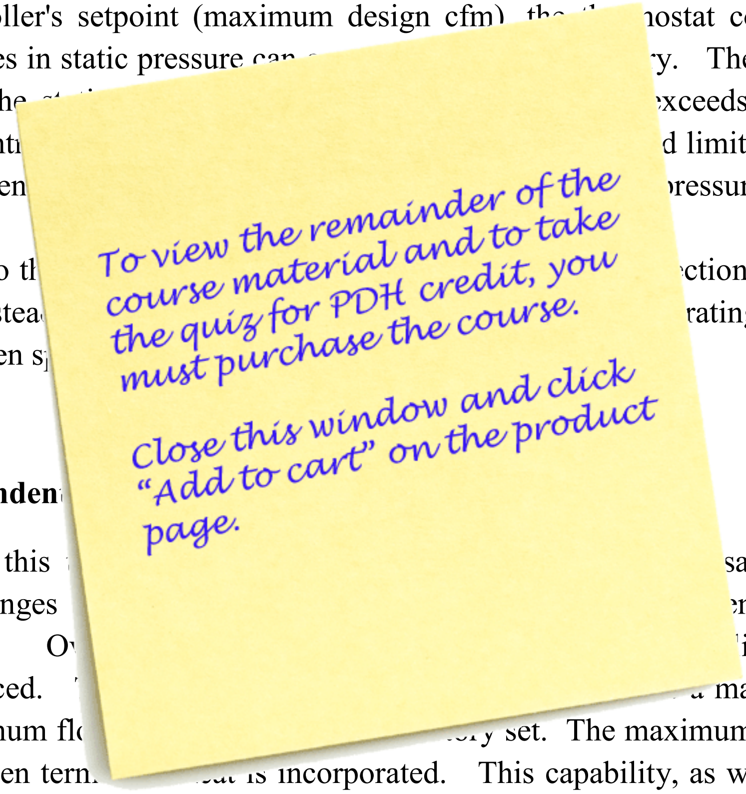
These terminals will compensate for change in inlet static pressure (and provide controlled airflow) only when the cfm is at a maximum. They act as a high limit to prevent the airflow from exceeding the setting of the controller. Maximum load conditions, however, exist only a few hours of the year. As a result, the terminals exhibit the same “overshooting” and “undershooting” of supply air as do pressure dependent devices, except at the maximum setpoint.

There are two types of cfm-limiting air terminal controls: (1) those using mechanical volume regulators (MVR) and (2) those using pneumatic differential pressure controllers in conjunction with either an orifice or velocity sensing probe. The MVR is a spring loaded device. It repositions to reduce airflow when static pressure exceeds the setting. The MVR is used in conjunction with an air valve upstream that is operated by a motor and thermostat.

This provides poor control. As the thermostat attempts to reduce the volume by closing the air valve, the fixed setpoint MVR will attempt to correct for the loss and maintain full volume. Only when the air valve is almost closed and has "starved" the regulator will volume begin to be reduced.

The pneumatic differential pressure controller system replaces the MVR to provide high limit control.

Below the controller's setpoint (maximum design cfm), th nostat controls the air valve actuator. Changes in static pressure ca y. The terminal is pressure dependent. If the xceeds the setpoint on the controller, the cont d limit the volume. In this mode, it is compen ressure controllers require main
control air lines to t ction. They also consume control air at a stea rating horsepower. Cfm limiting is not often s



Pressure Independen

Air terminals of this satisfy the space load regardless of changes nt of upstream static pressure changes. O iminated and system stability is enhanced. maximum flow setting, and often a minimum fl set. The maximum flow setting is most typically used when tern is incorporated. This capability, as well as being pressure compensated, greatly reduces the amount of time and expense associated with field air balancing or the need to rebalance after building tenant changes. The mechanics of maximum and minimum settings are explained in the following paragraphs.

Space demand changes are sensed by the room thermostat whose signal resets the volume control. Therefore, these systems are frequently called Variable Constant Volume Control (VCV) or more accurately Thermostatically Resettable Constant Volume Control.

Pressure compensated air terminals are of two types: (1) those using a mechanical volume regulator and (2) those using pneumatic controllers. Air terminals using mechanical volume regulators are basically the MVR described earlier with the setpoint adjusted or reset by