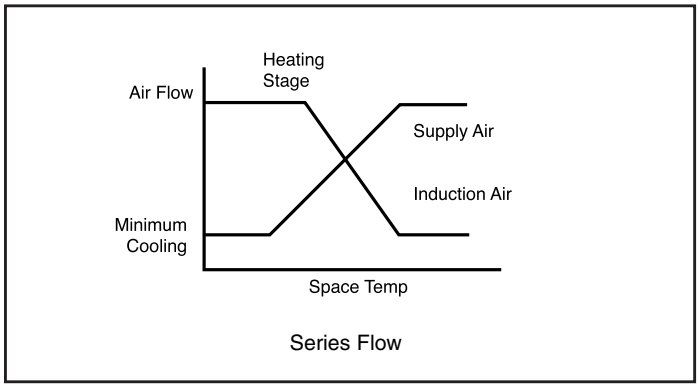
Series Fan-Powered VAV Systems

System Description

In a series fan-powered variable air volume (VAV) system, each zone is conditioned by a box with a small fan that draws-in plenum return air and mixes it with supply air from a primary system. The primary system is similar to variable air volume (VAV), with the primary air supplied at a fixed temperature. Series fan-powered systems provide each zone with variable temperature-constant flow supply air.

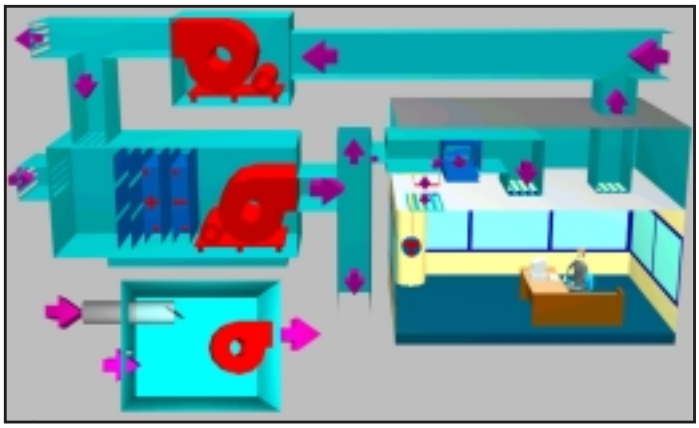
The fan operates constantly while the space is occupied. As the primary air is reduced to minimum flow, the fan draws in more plenum air, raising the supply air temperature delivered to the zone. If the primary air is at minimum flow and more heat is required, a reheat coil (either electric or hot water) can be used to further raise the supply air temperature. In many cases baseboard perimeter heating is not required, offering capital savings.

As more boxes reduce the primary air, the duct system static pressure increases. The primary supply fan is then modulated to maintain duct static pressure either by discharge dampers (FC fans only), inlet guide vanes, or variable frequency drives (VFDs).



Series Flow

Series boxes use the warm air in the plenum to heat the building. This is energy efficient since it moves heat from the core of the building to the perimeter zones.



Series boxes are often used with low temperature primary systems. Cold primary air (39-42°F) is mixed with plenum air to produce 55°F supply air for the zone. The warmer supply air resolves issues with air distribution (dumping) within the zone. The cold primary air significantly reduces duct and air handling unit sizes and fan power.

Air Handling Systems

Some form of centralized air handling unit supplies the primary air. These can be Vision™ type air handling units, vertical self-contained units, or rooftop units. Most can incorporate either air- or water-side economizers to take advantage of free cooling during mild weather.

The air handling systems can be either blow-through or draw-through. Blow-through units add the fan heat (usually equivalent to 2-3°F) before the cooling coil. The leaving air temperature from the cooling coil then becomes the supply air temperature. This provides the maximum temperature rise between the cooling air and the space design temperature. (The least amount of supply air will be required.) Since the air is often fully saturated and moisture problems may be an issue, blow-through should not be used with final filters downstream of the coils.

Draw-through units typically require 10% more supply air than blow-through systems for the same temperature off the cooling coil. This will increase duct size and fan operating cost. The fan heat ensures the supply air is not fully saturated, avoiding moisture issues.

IAQ Considerations

ASHRAE Standard 62.1-1999, Ventilation for Acceptable Indoor Air Quality, provides a procedure for calculating the minimum outdoor air volume for a system serving multiple zones.

Series boxes ensure good air movement within the zone. They also can be set-up to always supply a minimum amount of primary air, which includes ventilation air. Ventilation air is introduced at the primary air handling unit. Two issues occur with primary air systems. First, as the total primary air to a space is reduced, the percentage ventilation air is also reduced. The central air handling system must be able to maintain a fixed amount of outdoor air while varying the primary air volume. Technology such as DesignFlow™ can be very helpful here.

System Pros

- Only the necessary amount of primary air is used, conserving primary fan power.
- Diversity is applied to supply air volume, reducing duct and fan system sizes.
- Fixed supply air temperature maintains humidity control in space.
- Air- or water-side economizers can be added easily to the design to minimize mechanical cooling during cooler weather.
- Strong candidate for low temperature air systems.

System Cons

- Many small electric motors are distributed throughout the building, creating sound and efficiency issues.
- Providing each zone with the correct amount of outdoor air is more difficult.
- More sophisticated controls are required.
- Large duct shafts from centralized air handling systems are required.
- Typically more costly than standard VAV systems.

Energy Considerations

Series fan-powered VAV systems are very efficient when used in low temperature applications; however, the large number of fractional fan motors becomes an energy penalty at conventional supply air temperatures. The following are some considerations outlined in ASHRAE Std 90.1-1999. The numbers in brackets refer to Std. 90.1-1999 sections.

- Energy efficiency tables for HVAC equipment (6.2.1).
- Equipment must be scheduled off automatically during unoccupied hours (6.2.3.1).
- Demand Controlled Ventilation is required for systems with at least 3,000 cfm of outdoor air and occupant density greater than 100 people per 1,000 ft^2 (6.2.3.9).
- Air- or water-side economizers are required. There are several exceptions to this rule, particularly when dealing with heat recovery (6.3.1).
- Where humidification is required to maintain humidity above 35°F dewpoint, waterside economizers must be used when economizers are required. Introducing large amounts of cool, dry air while meeting the sensible cooling load adds significantly to the humidifier load. Process loads, including hospitals, are exempt (6.3.2.4).
- For systems under 20,000 cfm, VAV is limited to 1.7 hp/1,000 cfm. For systems over 20,000 cfm, VAV systems are limited to 1.5 hp/1,000 cfm (6.3.3.1).
- 30 hp and larger fan motors must use no more than 30% of design power at 50% airflow (6.3.3.2).
- The power consumption of small fans (fancoils, WSHPs, fan powered VAV) is not regulated.
- Energy recovery is required for systems with at least 5,000 cfm supply air and a minimum of 70% outdoor air. This is specifically aimed at schools and labs (6.3.6.1).

A thorough explanation of the Standard is beyond the scope of this document. The designer should have access to the Standard and a complete understanding of its contents. The ASHRAE 90.1-1999 Users Manual is also very helpful. ASHRAE considers Standard 90.1-1999 a high profile standard and continuously updates it.

Typical Applications

Series fan-powered VAV systems are used in low temperature air systems and systems requiring a high minimum turndown on primary air (typically a requirement for high ventilation air).

Common applications include:

- Office Buildings
- Schools