Dan Int-Hout

VAV Series Fan Terminals

BY DAN INT-HOUT, FELLOW ASHRAE

Fan-powered terminal units have been a key component of many building HVAC systems over the years, as they are largely responsible for helping move air through a building to occupant spaces. Depending on the design of the system, an engineer can select one of two types. One type is a series unit, commonly referred to as a constant volume unit. The other type is parallel, which is typically referred to as a variable air volume or VAV unit. Both, historically speaking, have used permanent split/capacitor start (PSC) motors, but over the years, the industry has begun to shift toward using electronically commutated motors (ECM). Consequently, industry experts have become more familiar with the technology and have discovered new applications, one of which is through the ability to dynamically control a series fan-powered terminal unit.

Unit Descriptions

For series units *(Figure 1a)*, the fan is located at the discharge of the unit, so all air entering the unit must pass through the fan, including the air that is induced from the ceiling plenum. Therefore, it is necessary that the fan be running whenever primary air (VAV system) is supplied. The fan airflow is typically set equal to or greater than that of the maximum primary (cooling) air. For units with PSC motors, an SCR speed controller allows the fan to be set to the designed airflow rate. Alternatively, units that have an ECM motor will have a similar looking speed control device, some of which can regulate the fan airflow through an analog output from the DDC system. Because the central system fan needs only to move the air to the VAV inlet, a series fan-powered terminal unit operates with a lower inlet duct static pressure than that of a parallel unit. The integral fan handles the downstream pressure resistance between the unit and room outlets.

On the other hand, parallel units (*Figure 1b*) are configured such that all entering air does not pass through the fan. Instead, the primary air and ceiling plenum (fan) air enter the unit independently of each other to feed a common discharge plenum. Recall that in the series unit configuration, the central system needs only to move air to the unit. With a parallel configuration, the central system must now move the air not just to the unit, but all the way through to the room outlets. As a result, the total airflow from a parallel unit will always vary as it responds to loads. It will also require a higher inlet supply duct pressure and thus use greater amounts of fan energy to move the air through to the space. With regard to controllability, the parallel unit is typically installed with an SCR speed control to set the fan airflow to handle the heating demand.

Research Project

Overview

In an effort to provide the engineering community with more realistic data for total system energy use of series and parallel units, a study was performed at Texas A&M, sponsored by ASHRAE, AHRI, and a consortium of manufacturers. Both types of fan-powered units, as well as the HVAC system in which they were installed, were evaluated using both a PSC and ECM motor. What the data shows is what many have known for some time, which is that a series unit with an ECM motor (operating at constant volume) is more efficient than a parallel unit with a PSC motor.

ECM Data

This is largely due to the fact that an ECM motor can be turned down, so by equating fan speed with energy usage, the more we can reduce the speed, the more energy we can save. While it may go against logic, the

Dan Int-Hout is a chief engineer at Krueger in Richardson, Texas. He is a member of SSPC 55, SPC 129 and consultant to SSPC 62.1.

data actually shows that the larger the capability of the ECM motor, the more efficient it becomes at reduced rpms. Analysis of several manufacturers' units, of several sizes, indicates that they all operate in a similar manner. As seen in *Figure 2*, if there are three units capable of 3,500, 3,000, and 2,500 cfm (1652, 1416, and 1180 L/s) at 100% flow, turning each down to 2,000 cfm (944 L/s) would result in an energy consumption of 301, 407, 526 W, respectively. In other words, the largest unit would operate at approximately 9% wattage of its full flow potential, whereas the smallest unit would operate at roughly 21%.

FIGURE 1A (LEFT) Series unit. FIGURE 1B (RIGHT) Parallel unit.

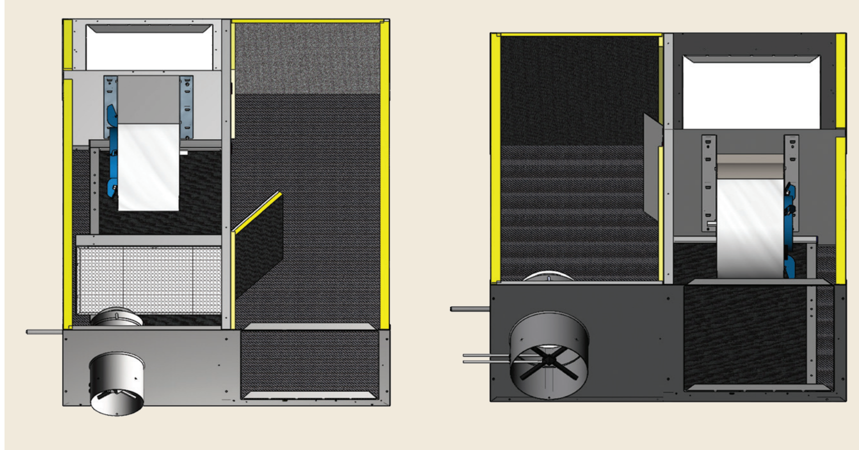
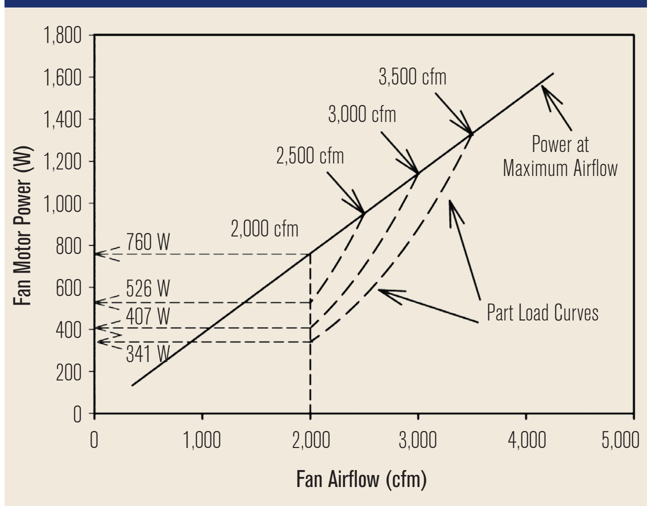


FIGURE 2 Simplified performance evaluation of ECM fan-powered terminal unit energy use.



(Courtesy of Dennis L. O'Neal, Ph.D., P.E., Dean of Engineering and Computer Science, Baylor University)

PSC Data

As we look at the equivalent series unit with a PSC motor and an SCR speed controller, it uses nearly the same amount of energy at reduced flow as it does at full flow. This means that the W/cfm actually increase as the fan is turned down. PSC motors also use a sleeve bearing, which limits the turn down to about 600 rpm, whereas ECM motors with ball bearings can operate as low as the motor has been programmed.

Results Integration

Of course, documentation of these particular measurements (W/cfm) is not often seen as a requirement in specifications, but it can certainly allow design engineers to better calculate and predict building energy use. By late 2015, we should see the results of this study available in several building energy models (through an ongoing program at AHRI).

Reducing Fan Airflow in Proportion to Space Loads

Provides Acceptable Air Distribution with Turndown

Series units have traditionally been used as constant airflow/variable temperature devices, providing relatively constant sound and airflow to a given space. Contrary to popular belief, it does not ensure constant air motion in the space. Even with properly selected air-distribution components, air motion at a point in the room is much more a result of load-driven convection currents than it is of air supply rates. As was shown in the recent ASHRAE Research Project 1515, conducted in California last year, supply airflow rates as low as 0.25 cfm/ft^2 (1.27 L/s·m^2) can provide a highly acceptable environment, provided that the air-distribution outlets provide uniform temperatures and are free of unwanted drafts.

Provides Controllability Using Existing Technology

Most ECM motors used to power fan terminal units are programmed to be "pressure independent." This means that they will deliver a desired airflow without regard to the external pressure on the fan. Even if there are variations in the supply airflow rate, which can have a significant effect on fan cabinet pressures, the fan will adjust its rpm to compensate. In fact, this generally holds true within 5% of desired flow rate. Because it is important that the fan in a series unit always deliver more air than what is supplied through the primary air inlet and because the DDC controller manages both the primary and fan airflow control signals, it is a relatively simple operation to ensure that the primary air CFM does not exceed the fan CFM. Furthermore, applications already installed with constant volume ECM series units could very well be retrofitted to be variable volume with the incorporation of the appropriate controls.

Provides Superior Occupant Conditions

Operating a series unit at the lowest possible airflow offers two important advantages, namely the reduction of system generated noise and the ability to use the least amount energy to satisfy system requirements. It can also prevent undesirable conditions, such as sub-cooling, which is typically caused when minimum ventilation rates are greater than the load requires. To avoid this, the fan airflow needs to be increased just enough to induce warmer plenum, which will eliminate the need to reheat the air. In heating mode, the airflow can easily be set to control both the heating load Btu/h requirements and room-supply ΔT (which should be less than 15°F [8°C] to meet both ventilation and comfort requirements of ASHRAE Standards 62.1 and 55).

Summary

As we reflect upon the data obtained in the joint study between ASHRAE and AHRI, we have been able to gather a number of valuable takeaways. First, it gives us confirmation that a series fan-powered terminal unit with ECM technology offers the greatest opportunity for energy savings of any fan-powered unit available. It also says that we do not have to sacrifice comfort—neither thermal, nor acoustical—to achieve these efficiencies, as airflow rates as low as 0.25 cfm/ft^2 (1.27 L/s·m^2) have been proven to provide a highly acceptable environment. Of course, as the information is integrated into building energy models, engineers will better be able to calculate, and thus predict energy usage; but above all, we will have hard data at our fingertips to justify the products we specify. ■