

Development of In-situ Fan Curve Measurement for VAV AHU Systems

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Pressure control is critical for comfort and prevention of damage to the structure and systems of a building. If the pressure is improperly controlled or maintained at negative pressure, the humid air can leak through the building structure and cause condensation, fungi and other uncontrolled pollution. If the building pressure is too high, it can cause excessive energy cost and other unexpected problems. For example, if security doors cannot be closed, due to high building pressure, in a constant air volume system, the return air can be properly balanced with the supply air during the startup process since the airflows are always constant. In a Variable Air Volume (VAV) system, on the other hand, supply airflow varies with building load as well as the supply air temperature. To maintain the appropriate positive building pressure, the return air must be properly tracked with the supply airflow. The return airflow should be slightly less than the supply airflow. The difference of the supply and the return airflows depends on the building exhaust airflow and the envelope tightness.

Air volume tracking is often indirectly implemented due to the difficulty of airflow measurement. One of the implementation methods is fan tracking (sometimes referred to as Variable Frequency Drive (VFD) proportional drive-slaving), which resets the return fan speed at or slightly lagging behind the supply fan speed. Normally, the supply fan is controlled with constant static pressure at some remote point in the ductwork. Both the supply and return fans slow down when less supply air is needed. The problem is that the system flow resistance characteristics change on the supply side (the terminal box dampers) only, but do not change on the return side. This means that the supply fan is running at a different speed and encountering different resistance from the design conditions, and hence the airflow is not proportional to the speed. However, the return fan *is* operating at a fixed flow resistance. Thus the link between the speeds of the return fan and supply fan cannot maintain correct building pressures except at the point for which the system is balanced.

A second method of air volume tracking is direct building pressure control. The return fan speed is directly controlled to maintain positive building pressure. If the building is under-pressurized, the return fan slows down. Less return air is drawn back from the

space, and less air is sent to the relief air duct. Theoretically this is an excellent solution. But it is very difficult to accurately measure the small static pressure differences required for building pressurization (typically 0 Pa (0.00 in. w.g.) to 12 Pa (0.05 in. w.g.) depending on the climate). The sensors need to be calibrated, and anecdotal evidence reveals that few facility managers know the location of the pressure sensor. If the pressure sensor is subject to wind, it will not serve its purpose. Also, the pressure may vary throughout the building, particularly in a multi-story building. This method, using existing technology, is extremely difficult to implement.

Volumetric tracking measures the airflows using flow stations in the main supply duct and in the main return duct, or turbo meters in the fan inlets. To control the return fan speed a comparison is done between the flow rates in the supply and return ducts. The fan is modulated to keep this difference at a constant set point, ensuring a constant exfiltration rate (assuming exhaust as a constant). For accuracy within 5% to 10%, the airflow measurement station requires a straight duct for 6-10 duct diameters upstream and 3 duct diameters downstream.

There are very few systems that have such duct runs in the main supply and return ducts. To increase the accuracy, it is recommended to measure the airflow at the location with the highest velocity. The fan inlet is such a place. Fan inlet technology can measure the airflow at the fan inlet mounted in the intake bell of the fan. However, the airflow profile in the fan inlet varies with the total airflow, which results in high uncertainty and difficulty of measurement. This method cannot provide the accuracy required for the volumetric tracking, and the cost of the turbo meter can become another limitation.

Therefore, it is very important to find an effective way to measure the airflow accurately. An airflow control named VSD volumetric tracking (VSDVT) has been recently developed. This method uses a fan airflow station to control the fan airflow. The fan airflow station uses the fan speed and fan head as inputs, with a second-order relationship with fan airflow. The theoretical model has been experimentally tested and resulted in excellent agreement between the model and the experimental values. The accuracy of the fan airflow station primarily depends on the accuracy of the fan curve, since both the fan speed and fan head can be measured accurately.

Typically, the fan curve under full speed can be expressed using second-order polynomial equations. The fan curve may be obtained from the manufacturer directly. However, the validity of the manufacture's curve is impacted by the actual fan installation configuration and the actual location of the sensor for the fan head measurement. Therefore, an in-situ measurement is required. However, an accurate airflow measurement in-situ takes significant effort. Directly measuring fan curve under full fan speed is extremely difficult, if not impossible. Therefore, a method has been developed that requires only one airflow measurement and maintains normal system operations.