Terminal Unit Airflow Calibration for Significant Energy Savings

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Introduction

Calibration of pressure-independent Terminal Unit (TU) airflow indications presents a significant energy savings opportunity for any commercial building owner or operator. It is largely an untapped energy conservation opportunity because its benefits are not immediately obvious. This concept requires a bit more explanation in order to fully understand it. My experience indicates that energy cost reductions of 20%-35% are possible through TU airflow calibrations. There are millions of buildings that could immediately benefit from this simple yet effective Energy Conservation Measure (ECM). This article explains how the calibration of TU airflow indications generates significant energy savings.

Photograph 1 – Typical Single Duct Terminal Unit

Pressure-Independent Terminal Unit

Pressure-independent Terminal Units (TUs) are an integral part of any variable volume air-handling system. They allow the cooling capacity to be controlled by modulating the flow of primary air (also referred to as supply air) delivered to the space(s). A TU controller uses an airflow pickup, Air Differential Pressure Transmitter (ADPT), and control damper to measure and control the airflow. This ensemble of components is typically referred to as an Airflow Measuring Station (AFMS). The airflow control capability is what allows "pressure-independent" operation. This means that they control airflow to setpoint even as the supply duct static pressure varies. The cooling airflow is modulated between maximum and minimum airflow setpoints. If the TU is equipped with hot-water or electric resistance coils, the TU controller also controls the heating capacity to maintain the space temperature at setpoint.

Terminal Unit Controller

The TU controller modulates the primary airflow delivered to the space(s) to maintain the space temperature, as indicated by the wall-mounted space temperature sensor, at the cooling setpoint. As the cooling load reduces, so does the primary airflow rate. When the primary airflow has reduced to the minimum airflow setpoint, it maintains this airflow rate until the cooling load increases. When the space temperature drops further to the space heating setpoint (typically 2°F to 4°F below the cooling setpoint), the heating capacity (if equipped) is enabled to maintain the space temperature at the heating space temperature setpoint. As the cooling load increases, the opposite occurs.

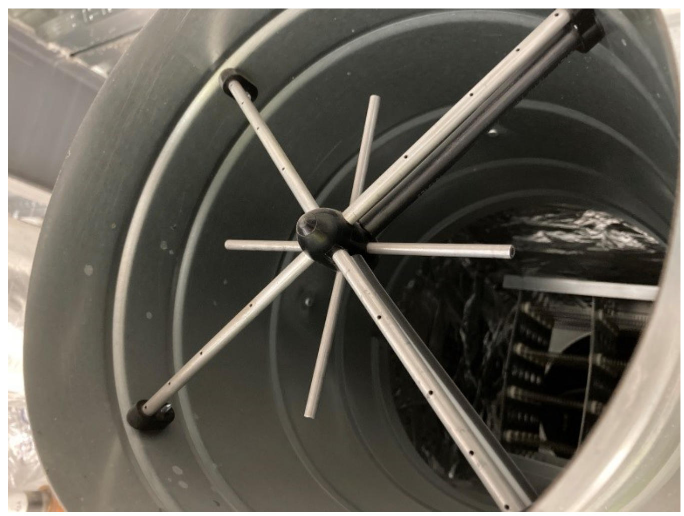
Photograph 2 – Terminal Unit Controller

Air-Handling Units

The air-handling unit that supplies the primary air modulates its fan speed through a Variable Frequency Drive (VFD) to deliver the airflow required to maintain the supply duct static pressure at setpoint. Throughout the day, each TU modulates its control damper to maintain their respective space temperatures at setpoint. During peak cooling periods, a large percentage of TUs will have higher damper position commands to deliver more cooling airflow. The supply duct static pressure reduces because of the more open TU damper positions and the supply fan modulates to a higher speed to maintain the supply duct static pressure at setpoint. When the cooling demand reduces, the TU damper position commands will generally be at lower values. Consequently, the supply duct static pressure will increase causing the supply fan speed to reduce. This exemplifies the relationship between the supply duct static pressure control and TU airflow demand. The supply duct static pressure setpoint is typically determined by the Testing, Adjusting, and Balancing (TAB) firm that originally balanced the systems. The supply duct static pressure setpoint is the minimum value that allows the majority (or all) of the TUs to reach their design maximum airflow setpoint during normal operation. If a TU is unable to reach its design cooling airflow rate (after airflow calibration), the supply duct static pressure setpoint may be too low.

Causes of Airflow Measurement Error

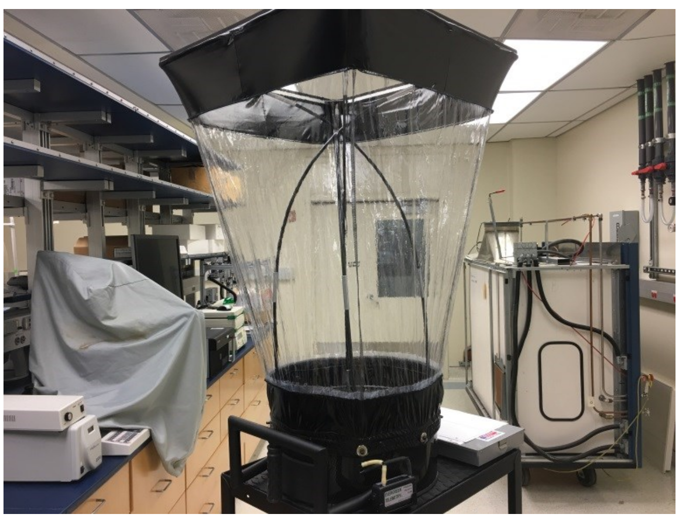
Over time, TU airflow indications drift and they typically indicate airflow rates below the actual values. This tendency occurs primarily because of sensor drift in the ADPT. Debris can also accumulate in the upstream sampling ports of the airflow pickup. These blockages artificially reduce differential pressure sensed by the ADPT. This is a huge problem in AFMSs installed in outdoor air ducts. Some ADPTs have a porous membrane which allows airflow through them. Therefore; it is possible for them to become contaminated with debris and moisture which can affect its pressure-sensing accuracy. ADPTs of this type should be equipped with an inline filter on the high pressure line to prevent debris from reaching the ADPT. These issues may occur individually or concurrently resulting in the TU controller providing more airflow than indicated through the Building Automation System (BAS). For example, a TU may indicate a flow of 500 Cubic Feet per Minute (CFM). Airflow readings (by a calibrated airflow capture hood) of the supply air diffusers connected to the same TU may indicate a supply airflow of 620 CFM. This additional cooling airflow would not exist if the TU were properly calibrated and will overcool the space(s). The required reheat will be augmented by the excess supply airflow which unnecessarily increases energy use and reduces the heat capacity actually delivered to the space(s). If this scenario is multiplied 50 or 100 times, the energy impact can become enormous. TUs serving zones with variable occupancy (conference rooms, classrooms, lobbies, corridors, cafeterias, locker rooms, waiting rooms, etc.) operate for extended periods of time in heating mode and will expend significantly more energy (cooling, heating, and fan) than would be required had the correct airflow been provided. Even in tropical climates, it is surprising to observe how many TUs operate in the heating mode throughout the day. This emphasizes the need for airflow calibration to ensure that the proper amount of supply air is delivered and heated.



Photograph 3 – Airflow Pickup Example

Airflow Calibration

TU airflow calibration simply requires a comparison of the actual and indicated airflow rates (through the BAS) and an update of the K-factor which determines how the airflow is calculated. The K-factor may be updated through the space temperature sensor user interface or through the BAS. An effective evaluation strategy is to evaluate a sample of TUs. Select a group of 10 to 20 TUs and set them to their maximum cooling airflow setpoints. Measure the delivered supply airflow noting the supply duct static pressure and setpoint. Comparison of the TU indicated versus actual supply airflow rates will indicate how accurately the airflow is calculated. If the differences are higher than ±20% of the design airflow rate, this provides a clear indication that TU airflow calibration is required. This test will also indicate whether the TUs are capable of reaching their design airflow setpoints at the current supply duct static pressure setpoint. If your BAS has TU summary screens, set the TUs to full heating demand and review the TU discharge air temperatures while the air-handling unit supply air temperature is at design setpoint (typically 55°F) and the hot water, if applicable, is at the design hot water temperature setpoint (typically 160°F to 180°F). Low discharge air temperatures (<80°F) while at full heat command is also indicative of excess primary airflow. Supply fan VFDs that consistently operate at high speeds or maxed out are another indicator. However, direct measurement of the TU airflows yields the most definitive results. These tests will provide solid information that can be used to make informed decisions on the appropriate level of effort. The calibration work can be implemented in-house if you have a calibrated airflow capture hood, trained staff, and access to the TU program settings. A local TAB firm can also be contracted to perform this work.



Photograph 4 – Evergreen Telemetry Capture Hood

Conclusion

Calibrating the TU airflow indications recovers the energy that is unnecessarily wasted because of erroneous airflow readings. In addition, it improves comfort by minimizing overcooling and by improving space heating performance. If the air-handling unit and its associated TUs have been operating for more than five years without calibration, they are typically good candidates for this ECM. TU airflow calibration generates triple energy savings (cooling, heating, and fan). First, the excess cooling airflow is eliminated because the airflow indication has been calibrated. If the correct amount of airflow is delivered by the TU, it will then reheat the correct amount of airflow. In addition, if the correct amount of airflow is delivered to each space, the supply air fan that delivers the primary air to the TUs operates at lower fan speeds producing fan energy savings. If the air-handling unit and TUs utilize chilled-water and hot-water, the energy savings would also extend to the central plant. Airflow calibration ensures that 500 CFM indicated airflow is equal to 500 CFM of delivered airflow. Sensors and transmitters require periodic calibration and the airflow readings of TU controllers are no exception.