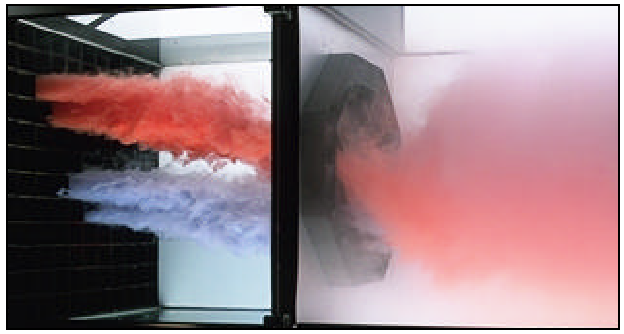
Blender Products, Inc.

HVAC MIXING UPDATE



Mixing and Sensor Errors: Temperature Stratification

Historically the use of an Air Blender® mixer in an air handling unit has been viewed strictly as a protective measure against freeze stat trips and frozen coils. However, there are additional benefits, and the purpose of this article is to increase awareness of the problematic nature of sensor errors on air handling systems. For those not familiar, sensor errors are defined as the potential for stratified air streams to impact a mixed air temperature sensor's accuracy, therefore affecting the DDC system's ability to efficiently control an air handling unit. However, unlike a problematic freeze stat trip, which physically stops the air handling unit from operating, the negative effects of sensor error are more difficult to quantify. The goal of this article is to evaluate costs associated with sensor error and discuss the energy savings associated with using the Air Blender mixer.

Understanding the Problem of Sensor Errors

Unlike the problem of the freeze stat tripping on a cold, winter day, sensor error is a factor whenever the unit is introducing outside and return air steams together, even during the summer. The two figures below show stratification patterns that were measured in an operating air handling unit. The temperatures listed were measured at the face of the filter, the same location the mixed air temperature sensor is typically located. Figure 1 represents stratification data that was measured on a cold day with the air handling unit operating in economizer mode, showing there was very little mixing occurring in the air handling unit. The potential sensor error is equivalent to the range from Tmax = 76°F to Tmin = 36°F and can be stated as +/- 20°F.

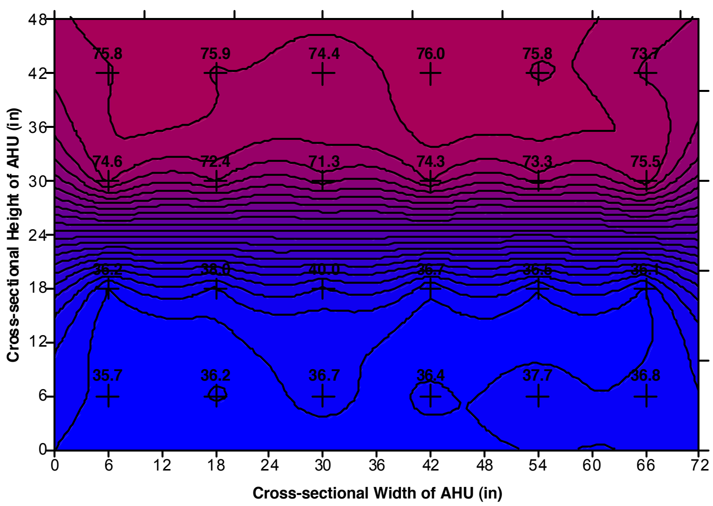


Figure 1: Winter stratification pattern

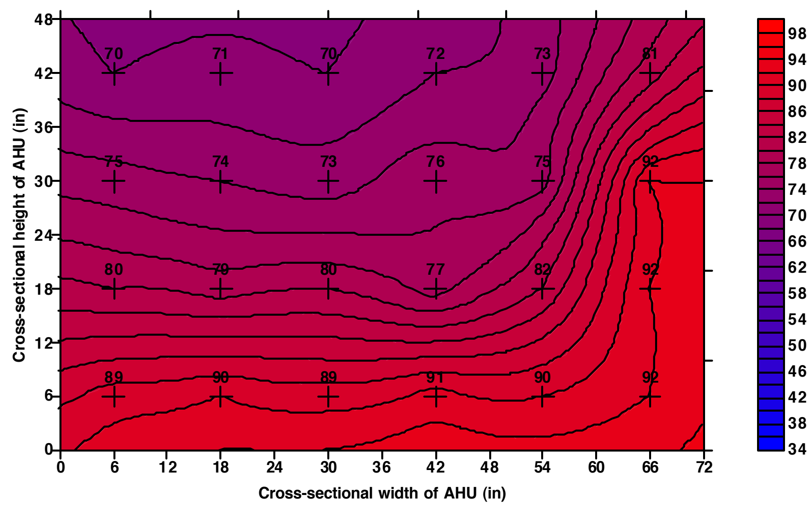


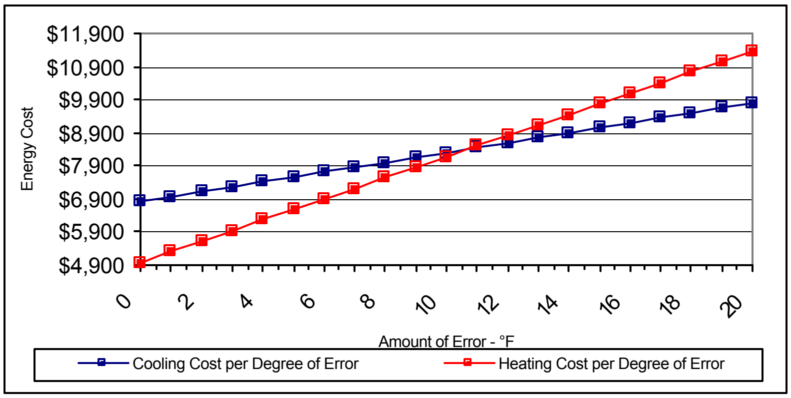
Figure 2: Summer stratification pattern

Figure 2 represents stratification data measured in the same air handling unit while running minimum OA during the summer time. The potential sensor error in Figure 2 is +/- 11°F. Note that the pattern of stratification can be symmetrical or varied depending on the outdoor and return air inlet conditions, the difference in velocities of the streams, and the geometry of the unit. One reason stratification presents a problem is because the pattern is difficult to predict and often changes as the outdoor and return air dampers modulate. As a result, there are no guarantees that the Mixed Air Temperature sensor will consistently be exposed to any or all of the range of temperatures at the measuring point. These dynamic factors compound to make sensor error a complicated issue. If the information received by the DDC computer is not accurate then the changes the system makes in damper and valve position to maintain the desired supply air temperature may be unnecessary, thereby increasing the chance of wasted energy. Even with an averaging sensor installed in the plenum, the stratification pattern can still skew the reading. In addition, differences in the velocities of the air streams prevent the averaging sensor from recording the true mass weighted average, which will contribute to the error.

Sensor Error Energy Study

Because of the difficulty in quantifying the impact of sensor errors, the issue has not been studied in great detail. One of the better studies appeared in the January 1985 ASHRAE Journal. In the article "Sensor Errors", author James Kao used a computer simulation program to determine the potential energy waste resulting from sensor error on a 10 story building, 10,000 sq ft of space per floor, located in Washington D.C. A VAV system was used in the simulation to examine the impact of that sensor error during both heating and cooling. The article states, for an ideal system without sensor errors the annual heating required for the building is 759 MMBTU and the annual cooling required is 1356 MMBTU. Kao then ran several trails of the same simulation at varying the levels of sensor error. The results showed a waste in heating energy of 6.4% per degree of error and a waste of cooling energy of 2.2% per degree of error. Using these percentages the potential heating and cooling costs can be estimated at varying sensor errors.

The potential heating cost can be estimated by assuming the current cost of natural gas, $6.57/MMBTU. At that price, the yearly cost for heating under ideal circumstances (759 MMBTU) is $4,986.63. As stated before, each additional degree of error is an additional 6.4% of energy wasted. The red line on Graph 1 shows the heating cost of the system at each degree of error up to 20 degrees.



Graph 1: Annual Heating and Cooling Costs at Varying Sensor Errors

Similarly, the potential cooling cost can be estimated by assuming the current cost of electricity, $0.06 per kwH. As stated before, each additional degree of error is an additional 2.2% of energy wasted. The blue line on Graph shows the cooling cost of the system at each degree of error up to 20 degrees.

As can be seen from the stratification data in Figure 1 and Figure 2, the opportunity of sensor error to be in the double-digit degree range is possible. Therefore, engineers should carefully consider the potential impact of sensor errors. Significant energy savings can be realized by simply reducing the sensor error by a single degree.

Conclusion — The Air Blender® Solution

The most effective way to minimize sensor error is to create a single mixed air stream of uniform temperature and velocity. The Series IV Air Blender mixer is the most effective product available for providing temperature and velocity uniformity. Testing has shown installing a Series IV Air Blender with a single diameter of downstream distance available limits the sensor error to +/- 6 degrees temperature range, even in the most extreme cases. When compared to the possibilities shown above, that is a pretty nice "worst case scenario". Depending on the size and capacity of the system, the reduction in wasted energy alone will often offset the cost of the Air Blender mixer during the first year of operation.

The Air Blender mixer provides the design engineer with a way to address critical issues that air handling units face year round. The Air Blender mixer is recognized as an important system component in cold climates because of system shut down due to freeze stat trips or frozen coils is unacceptable. However, because the Air Blender mixer is so effective in minimizing sensor errors, the application of these mixers should not be limited to cold weather climates. By minimizing sensor errors, systems operating in both warm and cold climates can realize significant cost savings by inclusion of the Air Blender mixer.

Footnotes:

[1]There are several tools available to calculate how much mixing is required to achieve varying levels of sensor error. The Blender Products Mixing Effectiveness Design Guide contains a performance chart and our Air Blender selection software will calculate the effectiveness depending on the design conditions entered. Both are available on our website – www.airblender.com.

[2]Contact Blender Products if you are interested in receiving a copy of "Sensor Errors", authored by James Kao (ASHRAE Journal, Jan., 1985)

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