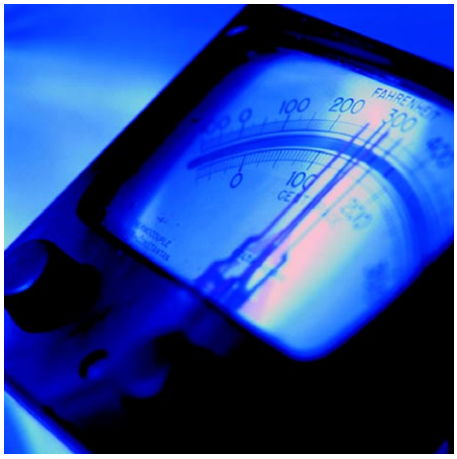
ASHRAE Journal

Do Averaging Sensors Average?



By Gil Avery, P.E., Fellow/Life Member ASHRAE

An averaging temperature sensor (ATS) is used to maintain the design mixed air temperature of an airside economizer system. These devices have sensing elements from 5 to 50 ft (1.5 to 15 m) long. To provide acceptable performance, they must be installed so that they sense the average ambient air temperature *and* the average temperature of the mass flow of air. Because sensing the average temperature of the mass flow of air is the criterion for satisfactory control, the installation of the sensor is critical. However, design documents rarely detail the sensor installation.

To limit the scope of this article, all references to stratification assume that there is no mixing in the air chambers unless otherwise noted.

Airside economizer systems may be configured using factory supplied mixing boxes or with custom designed assemblies incorporating multiple outdoor and return dampers. This article discusses sensing the mass flow average temperature associated with mixing boxes. It also provides enough information so that engineers can correctly specify the installation of ATS to detect the true mass flow mixed air temperature in more complex airside economizer systems (systems that may have more than one outdoor or return air damper).

Horizontal Stratification

A common application of an ATS is shown in the side view in *Figure 1* where the air is stratifying in horizontal planes through the unit. Section A-A (*Figure 1A*) shows how the sensing element often is installed. Operating conditions are 25°F (–4°C) outdoors, 75°F (24°C) return, and a design supply air temperature of 50°F (10°C). When the air-handling unit is off, the outdoor air damper will be closed and the return air open. The ambient temperature in the mixed air plenum where the ATS element is located may be 75°F (24°C).

With the fan off, there is no flow difference across the ATS. When the air handler is started the outdoor air damper will go wide open and the return will close to reduce the mixed air temperature to 50°F (10°C). The velocity (mass flow) of air across the lower half of the element will be much higher than the upper half of the element. The upper half of the sensor will be in ambient air at 75°F (24°C) and the lower in ambient air at 25°F (–4°C). The average ambient temperature is 50°F (10°C), but the mass flow mixed (supply) air temperature will be much less than 50°F (10°C) — possibly in the 30°F to 35°F (–1°C to –1.6°C) range.

The airstreams will not mix sufficiently to prevent stratification even when parallel blade dampers are installed so that the outdoor and return airstreams are directed toward each other. Unless the freeze stat shuts the unit off, the water coil might freeze. The warm and cold airstreams in *Figure 1* will move up and down depending on the

About the Author

Gil Avery, P.E., is director of systems research with The Kele Companies in Memphis, Tenn.

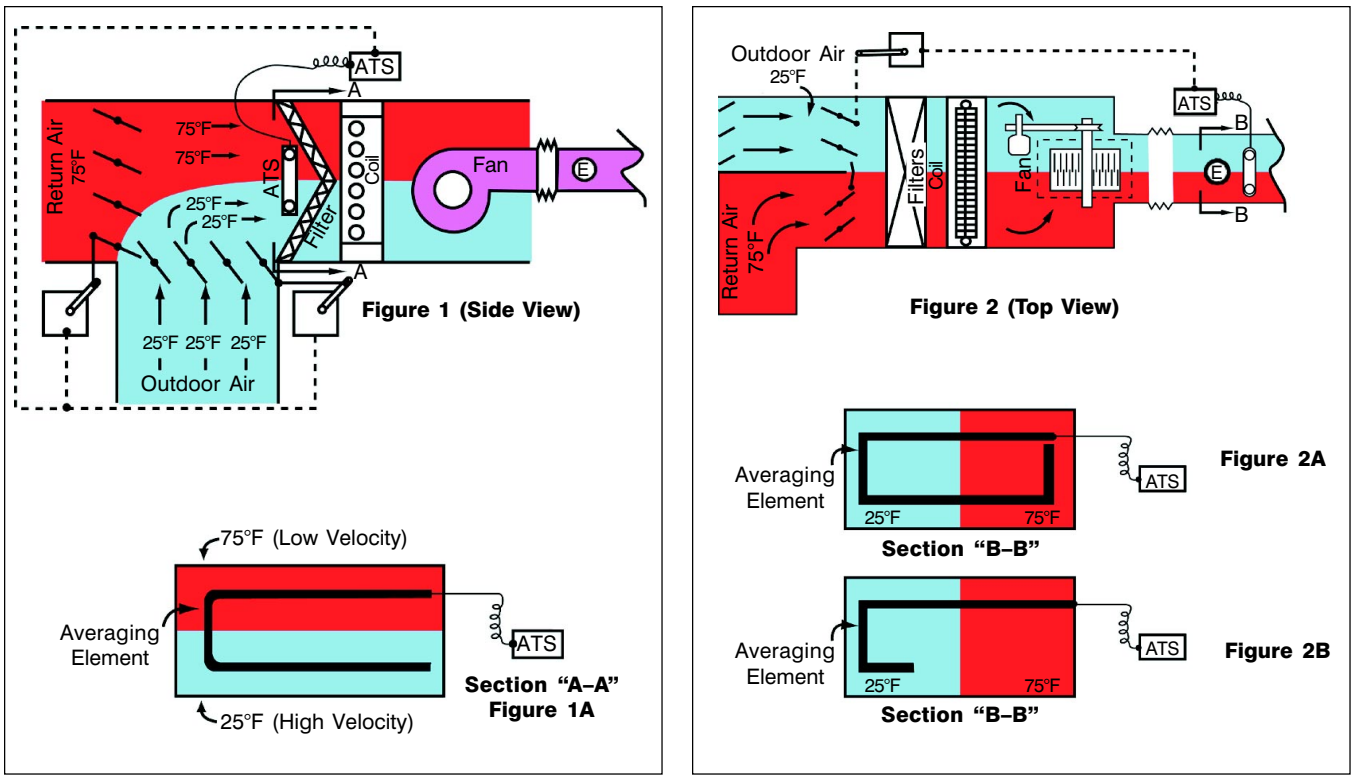


Figure 1 (left): ATS with air stratifying in horizontal planes. Figure 2 (right): ATS with air stratifying in vertical planes.

position of the outdoor and return air dampers. As the return air damper opens and the outdoor closes, the 75°F (24°C) warm airstream will move down in the air handler. As the outdoor air damper opens and the return closes, the 25°F (–4°C) cold airstream will move up in the air handler. This makes sensing the mass flow mixed air temperature even more difficult. Moving the sensing element to the other side of the filters would help to equalize the velocity (mass flow) over the element but the freeze and shifting airstream problems are still present.

A preferable location for the sensor is Location E in the supply air duct. If the economizer dampers are installed as shown in *Figure 1,* the air should mix in double inlet supply fans so that a conventional non-averaging, duct sensor can be installed in any position in the supply duct as far downstream from the fan discharge as possible. It is possible for air to remain stratified through the supply fan, particularly with axial fans, but the stratification downstream of the fan will always be less than stratification in the mixed air position upstream of the fan.

Vertical Stratification

Stratification will still be a problem if the outdoor and return air enters the mixing box so that the air stratifies in vertical planes through the unit as shown in the top view in *Figure 2*. The velocity (mass flow) across the supply duct is relatively constant so that the ATS elements can be installed as shown in *Figure 2A*. The element should be installed as far downstream from the fan discharge as possible to take advantage of the mixing that occurs in the supply duct and where the stratified airstream velocities are more uniform. The ATS element should not be installed so that more of the sensing element is installed in the left side (25°F [–4°C]) of the stratified airstream than in the right side (75°F [24°C]) of the stratified airstream as shown in *Figure 2B*.

Conclusion

An improperly installed ATS used to control mixing dampers can cause three problems:

1. In cold weather, coils may freeze.
2. Mixed air temperature measurement error may cause the supply air temperature to be lower than desired. This can waste energy by increasing reheat energy at the zone level and can cause overcooling in spaces that do not have reheat coils.
3. Mixed air temperature measurement error may cause the supply air temperature to be higher than desired. This can result in undercooled spaces.

The design engineer must specify the location and the method of installation. It may be necessary to mount the ATS element on a sheet of expanded or perforated metal so that the element is properly supported and correctly positioned to sense the true average mass flow mixed air temperature.