Free Cooling: Don't Let Savings Slip Away

Understanding what goes wrong with airside economizers can help facility managers ensure the systems operate at optimum effectiveness

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Airside economizers are simple, effective systems that significantly reduce cooling energy usage and improve indoor air quality. They increase the energy efficiency of the HVAC system so much that most energy codes require them for most commercial applications. Yet these systems are often neglected and, over time, can degrade to the point that they don't operate correctly, resulting in energy waste. A little periodic maintenance can help keep them operating correctly.

Sometimes referred to as "free cooling," an airside economizer system consists of a set of outside and return air dampers that operate together to reduce the load on the mechanical cooling system. When outside air conditions are cool enough, the mechanical cooling can be shut off completely and the system can use outside air to cool the building, thus reducing the overall energy use of a facility. Indoor air quality is increased during airside economizer operation. That's because a greater amount of ventilation air is provided to the occupied spaces than during minimum outside air mode.

Airside economizers come in various different forms (e.g., temperature-based or enthalpy-based); they're typically more cost-effective for larger buildings with a greater percentage of internal zones; and they may not make much sense in some climates, especially hot, humid climates. These design considerations are important and have to be addressed, but design is only one side of the question of making airside economizers effective. If you already have an airside economizer system, how can you maintain it to keep energy costs down and indoor air quality high? The principles involved apply to small packaged HVAC systems as well as larger built-up air handling systems.

Airside economizers operate behind the scenes, meaning that most occupants and sometimes operators do not sense whether an economizer system is working correctly or not. If it's not working correctly, the main consequence is higher-than-necessary energy bills.

> A recent PECI study showed that optimizing the performance of airside economizer systems is one of the most common and most cost-effective measures implemented as part of an existing building commissioning process, usually with a simple payback of less than one year. For more information, go to www.peci.org/documents/annex_report.pdf

How do airside economizers typically fail? What are the aspects that contribute to sub-optimal operation, and what can building operators do to address these issues and maintain proper performance? There are a wide variety of methods of maintaining performance, from periodic testing to trend data analysis. Here are some of the key issues to consider when it comes to airside economizer performance and maintenance.

Dealing with Design and Construction Problems

Some airside economizer systems are essentially doomed from the start, whether from sub-optimal design or improper construction. This is especially common for buildings that were not initially commissioned during construction. Common issues and their related fixes include:

- *Improper sensor type.* In theory, enthalpy-based control of airside economizers is more energy efficient than temperature-based since enthalpy controls account for humidity. In practice, enthalpy sensors are especially prone to drift out of calibration — assuming they were ever calibrated properly to begin with — which can result in energy waste. Recent studies have shown that it may be more cost-effective to use temperature-based control when operation costs, maintenance costs and sensor error are considered along with energy benefits. If your system uses enthalpy sensors, evaluate the energy benefits against the added operation and maintenance costs of maintaining the calibration of these sensors.

- *Oversized return air dampers.* For proper control, return air dampers need adequate air velocity across them. This is especially true for systems that use return fans instead of relief fans. Measure the air velocity across the return air damper during minimum outside air mode, when the return air dampers are 100 percent open. If it's much less than 1,500 fpm (a rule of thumb), consider blanking off some of the return air dampers to increase performance (see Figure 1).

Figure 1. Return air dampers too big? Blanking them off may improve performance.

- *Inadequate building pressure relief.* During economizer operation, adequate pressure relief must be available to avoid building over-pressurization issues such as doors standing open and reduced supply airflow. Measure the difference between the indoor and outdoor pressure during economizer operation. If the difference is much greater than a tenth of an inch, investigate the relief air system to see if it has an adequate airflow path and that it's controlling properly.

- *Poor sensor placement.* Temperature and enthalpy sensor placement is crucial for proper economizer operation. Verify that the outside air sensor is in a good, representative location (i.e., never in direct sun, not too close to air outlets), and make sure the mixed air sensors are located correctly as well (e.g., in a place with good mixing). Averaging sensors are the best choice for mixed air temperature.

Maintenance Issues and Fixes

According to a PECI study on existing building commissioning, air handlers typically have more performance issues than any other type of equipment. There are many aspects to maintain on an air handler, and this maintenance can easily be overlooked or deferred. The Building Owner and Managers Association's (BOMA's) recently updated preventive maintenance guide, "Preventive Maintenance: Best Practices to Maintain Efficient and Sustainable Buildings," suggests preventive maintenance tasks for air handlers, which include quarterly and semiannual preventive maintenance tasks for maintaining the performance of airside economizer systems. Here are some common maintenance-related issues and periodic tests that can be done to address and avoid performance problems with air-handling units:

- *Stuck dampers or broken linkages.* Economizer dampers, especially outside air dampers, can seize in place due to entrained debris and humid conditions. This is especially an issue for salty, corrosive marine environments. Also, the linkages, which connect the actuator to the damper, can fail. Cycle your dampers open and closed periodically, and verify that they operate as intended. This often requires one person at the control system's operator workstation, and another person observing damper operation. When the damper is commanded open, does it actually open? Don't just rely on the output signal from the operator workstation as the final word in how a system is actually working (see Figure 2).

Figure 2. Control can be challenging to non-existent if the actuator isn't tight to the linkage. The top set of outside air dampers should be open, based on the command signal.

- *Actuators not adjusted for full closure.* A slight opening in the "closed" return air dampers during integrated economizer and mechanical cooling mode (100 percent outside air) can significantly reduce the efficiency of the system due to increased mechanical cooling load, because the system is operating at less than 100 percent outside air. The pressure characteristics are typically such that a slight opening in the return air damper translates to a significant amount of airflow. Command your return dampers closed, and verify that they close completely by feeling for leakage (see Figure 3). If they're not closed completely, adjust the actuator/linkage connection. When closing the return dampers, be sure the outside air dampers are open, to prevent the plenum walls from collapsing inward.

Figure 3. Are those return air dampers completely closed? The answer in this case: no. There's a slight gap, which lets a lot of air through and reduces the efficiency of the system.

- *Worn blade and jamb seals.* Blade and jamb seals help reduce damper leakage when the damper is closed. With no seals, leakage can be as much as 10 percent of rated damper airflow. Inspect your blade and jamb seals for leaks by feeling around the damper blades when they're closed, and if your dampers don't have seals, consider installing them as a way to increase the efficiency of your system through reduced return damper leakage during 100 percent outside air mode.

- *Sensors out of calibration.* Temperature and enthalpy sensors are prone to drift out of calibration, especially enthalpy sensors. It's important to keep the outside air and return air sensors calibrated, as these are typically the sensors that make the determination for the economizer operating mode. Developing and implementing a sensor calibration program can help keep these sensors calibrated and maintain the overall performance of the system. This is good to do for other HVAC sensors too, especially those used as inputs to control sequences, such as measuring chilled water flow for a chiller staging sequence.

Tackling Control Issues

Airside economizer damper control requires close coordination and integration with the system's heating and cooling systems to maximize the energy efficiency of the system. Common controls-related issues, and their corresponding fixes, include:

- *The economizer is not integrated with mechanical cooling.* It's beneficial to operate the system in full economizer mode (100 percent outdoor air) when the outside air conditions are just a bit cooler than inside conditions and the system is asking for mechanical cooling. This helps reduce the mechanical cooling load by keeping the cooling coil's inlet air (mixed air) temperature as low as possible. Take a look at your air handler control sequences, and observe system operation during these cool outside air conditions (e.g., 55°F to 65°F outside air, depending on the control sequence) to verify you're getting the full benefit of airside economizer operation.

- *Economizer control disabled.* Some buildings have disabled their airside economizers in reaction to a performance issue where the economizers weren't the main culprit or due to a lack of understanding of the system's benefits and performance. If you've disabled your airside economizers, consider re-enabling them, but also address any outstanding performance issues.

- *Reduced economizer effectiveness.* Past existing building commissioning projects have uncovered many control strategies that reduce the efficiency of the system. Two examples: a 30 percent minimum return air damper setpoint rather than a zero percent setpoint, and a low economizer changeover setpoint (the point at which the system changes from economizer mode to non-economizer mode, usually around 70 F outside air temperature). Review your control sequences to see if there are any opportunities for increased energy efficiency.

In general, first determine the intended operation of the airside economizer system. Review the original construction documents and consult with your operating staff to see how the system is currently programmed to operate. Investigate and implement optimization opportunities based on this exercise. Then, periodically test the system to determine if it's performing as intended and take corrective action when it's not. When testing the control sequences, be sure to test them in all operating modes (heating, economizer cooling, integrated economizer and mechanical cooling, and mechanical cooling with minimum outside air).

Most airside economizer damper systems are intended to operate similar to this:

When outside air conditions are very cold: The unit is in the heating mode. Mechanical cooling is off, economizer dampers are at minimum outside air position, and the heating coil operates to maintain supply air temperature setpoint.

When outside air conditions are cold: The unit is in economizer cooling mode. The heating coil is off, mechanical cooling is off, and economizer dampers modulate to maintain supply air temperature setpoint.

When outside air conditions are cool: The unit is in "integrated economizer" and mechanical cooling mode. Heating coil is off, economizer dampers are at 100 percent outside air position, and mechanical cooling operates to maintain supply air temperature setpoint.

When outside air conditions are hot: The unit is in mechanical cooling mode. The heating coil is off, economizer dampers are at minimum outside air position, and mechanical cooling operates to maintain supply air temperature setpoint.

This general description applies to most systems. The specific type of system, climate and control sequence will dictate how a system is intended to perform for actual installations.

Your BAS Can Help

Your building automation system (BAS) can be a powerful tool to help monitor the performance of the economizer system. Periodically collecting and analyzing BAS trend data can be a good way of viewing system performance. X-Y scatter plots are often more telling than time-series plots, which can be confusing. See Figure 4 and Figure 5, which present the same data but in different formats. The chart in Figure 5 clearly shows that the system has performance issues – the trend data points (pink dots) fall far from the ideal operation (blue dashed line). The dampers are stuck at 48% open.

Note that neither method will show what problem exists, only that there is a problem requiring investigation. Be sure to filter the data to show "fan on" operation only, and also be sure that your BAS temperature and enthalpy sensors are calibrated.

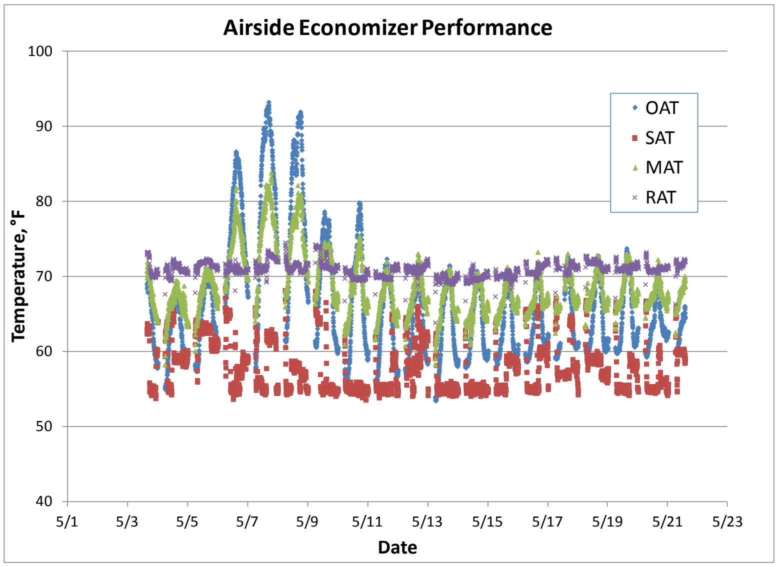

Figure 4. Time-series charts of BAS trend data can be confusing.

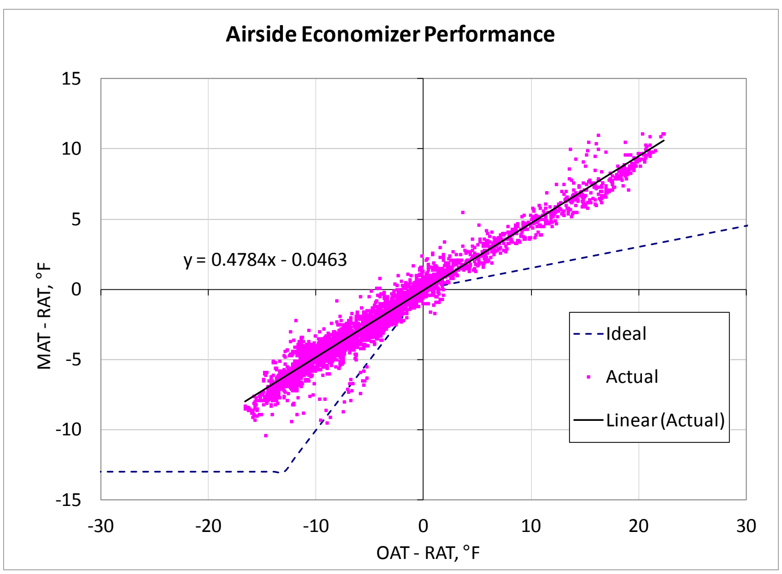

Figure 5. X-Y scatter charts can be more revealing.

Airside economizers can save a significant amount of energy, but they need to be maintained for their "free cooling" energy benefits to be realized. For more information on airside economizer fundamentals, methods of control, and test procedures, consult the Functional Testing and Design Guides at www.peci.org/ftguide. Always consider the effects on other systems and include necessary precautions in any test procedures.

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