AirTest™
Sensors That Make Buildings Smart!

Economizer Control Design Guide a White Paper

1. Overview

The key components to an energy wise and green outdoor air strategy involves knowing if your building is operating properly. This is often called continuous commissioning. It can result directly from monitoring the operation of equipment and sensors to ensure all components of the building system are operating as intended and not wasting energy unnecessarily. Outdoor air delivery to the building to meet code required ventilation rates and to support economizer control strategies, can have a major energy impact on a building if they are not working as intended. Yet these components of a building operation are seldom measured. And what you do not measure, you cannot control. Such is the state of outside air ventilation in most buildings today. Either it is not measured, or in the case of economizer control not it is not measured properly resulting in significant energy waste.

A companion paper to this document discusses the problems with providing outside ventilation air for buildings and how CO2 sensors can provide a good feed-back control mechanism to ensure ventilation rates always meet occupancy requirements and the the building is never over ventilated which can result in excessive energy costs, comfort issues and potential moisture problems. For further details on how CO_2 can reduce ventilation based on occupancy and reduce the over ventilation inherent in most buildings, read the AirTest white paper: Using CO_2 Feed-back Control To Stop Costly Over Ventilation (Link: www.airtest.ca/support/reference/CO2&OverVentilation.pdf).

This paper specifically addresses the use and applicability of outdoor air economizers used for free cooling of buildings. This technique is intended to use outdoor air for a first stage of free cooling when outdoor air meets certain target conditions. Today, approximately 60% of buildings utilize economizers in the US. This paper discusses three methods of economizer control.

1. Temperature Control
2. Enthalpy Control (Single point and dual enthalpy)
3. Dew Point and Temperature Control

The first two approaches have historically been most common in buildings. The use of dew point and temperature has recently been suggested as a superior method of economizer control in the “ASHRAE Humidity Control Design Guide” published in 2002. This paper looks at the three approaches and documents the severe draw backs related to the historical methods used for economizer control. As will be discussed later, AirTest has also developed an energy analysis program that can determine the differences between these techniques for specific climates and how CO2 control can provide savings to buildings when economizers are not in use.

2. Indoor Design Conditions

Air conditioning and heating systems are designed to meet specific conditions in a building where comfort needs will be met, energy costs will be reasonable and the structure itself will be free from excessive moisture levels that can cause condensation or mold growth. These design conditions are based on maintaining two parameters within the building.

1. The sensible energy or dry bulb temperature (e.g. 68ºF for heating and 74ºF for cooling).

2. The latent energy or moisture component in air. This is typically expressed as a specific humidity at the design temperature (e.g. 60% humidity at 72ºF). A humidity level alone cannot be used because humidity levels will change with temperature. For example a 1ºF decrease in the temperature of air will increase RH by 2%.

   Increasingly, a measure called dew point is being used to define the indoor air conditions because it considers only the moisture content of air. The 50% humidity at 74ºF conditions would equal a dew point of 55ºF. This represents the temperature at which moisture would condense out of air, and is typical of the moisture conditions delivered by an air conditioning cooling coil when it is operating. The advantage of dew point measurement is that it will be the same at any temperature.

The chart to the right summarizes the parameters that are used to measure the temperature and moisture characteristics of air. Most buildings today use either enthalpy or temperature to determine if outside air can be used for free cooling. For reasons that will be discussed below there are some problems with using the two above approaches and many building operators have begun to use temperature and dew point as an economizer control strategy to ensure that outside conditions more closely reflect the conditions delivered by the cooling system when in economizer mode.

Parameter	Definition	Economizer Control Issue
% RH	Ability of air to hold moisture at a specific temperature. Generally a 1ºF change in temperature will result in a 2% RH change.	• Temperature dependence of RH makes it useless for economizer control. • Can be used with temperature to calculate enthalpy or dew point.
Temperature	Dry bulb temperature relates to sensible energy in air. This measurement does not detect moisture in the air.	• Does not consider moisture in air (latent energy). Will result in moisture levels over design conditions. • Any moisture introduced must ultimately be air conditioned out of the space. • Most common control today.
Enthalpy	Measure of total energy in air (sensible and latent). Most often used to calculate delivered conditions by active AC.	• Most sensors have no rated accuracy and poor long term performance. • Will result in moisture levels over design conditions.
Dew Point & Temperature	Dew point is a good measure/latent energy of moisture in the air. It predicts the temperature at which condensation will occur.	• Recommended by ASHRAE Humidity Design Guide for economizer control. • When used with temperature can ensure outside air never exceeds design/cooling conditions.

3. Why Moisture Is Now A Greater Concern In Buildings...

Control of moisture in buildings has become a real concern, even in climates like California that are considered relatively dry. This may sound implausible, but the widespread use of energy conservation measures is the reason why moisture is more of a concern. Think about the typical upgrades that have occurred to buildings over the past 20 to 30 years:

- Higher insulation in walls and ceilings;
- Installation of low E window films to reduce solar gain and loss of cooling energy;
- Installation of more energy efficient lighting that effectively reduces the heat given off by lighting;
- The development of more energy efficient computers, office equipment and appliances that also produce much less heat.
- Use of higher efficiency (SEER) air conditioning equipment.

Each of these initiatives has saved tremendous energy by reducing the temperature load in the space and therefore the dry bulb or sensible energy demand. As a result air conditioning systems are running much less and using much less energy. The problem is that none of these initiatives reduce the moisture load in the space. Moisture comes from people in the space and from outside air. So the cooling demand has been reduced while moisture loads remain the same. The problem is that moisture is only removed when it can pass through a cooling coil where a portion of the moisture in the air can be condensed out. If the air conditioner runs less, more moisture is left in the space.

Our ability to control moisture is further aggravated by the fact that if the air conditioner runs less, less moisture can be removed from the space. A study by ASHRAE conducted in 2003 found that a typical cooling coil must operate for at least 15 minutes before moisture condensing on the coil runs off the coil. If the coil runs for less than 15 minutes the air may be cooled but all the moisture collected on the coil will re evaporate into the space. The result is that no moisture removal will take place.

It is important to note that moisture is just not resident in the air. Building materials and furnishings will absorb moisture to equilibrate with the concentration in the air. That means that if an air conditioner makes the air drier, it will draw out more moisture from the building components to replace the moisture that has been removed. The building, acts as a massive moisture reservoir that must be dried or dehumidified before significant reduction in moisture levels can be achieved. At some point moisture levels in the air and in building materials can be high enough that they enable the growth of mold that can be a threat to both the structural integrity of the building and to occupant health.

4. Moisture Is Ignored In Temperature And Enthalpy Based Control

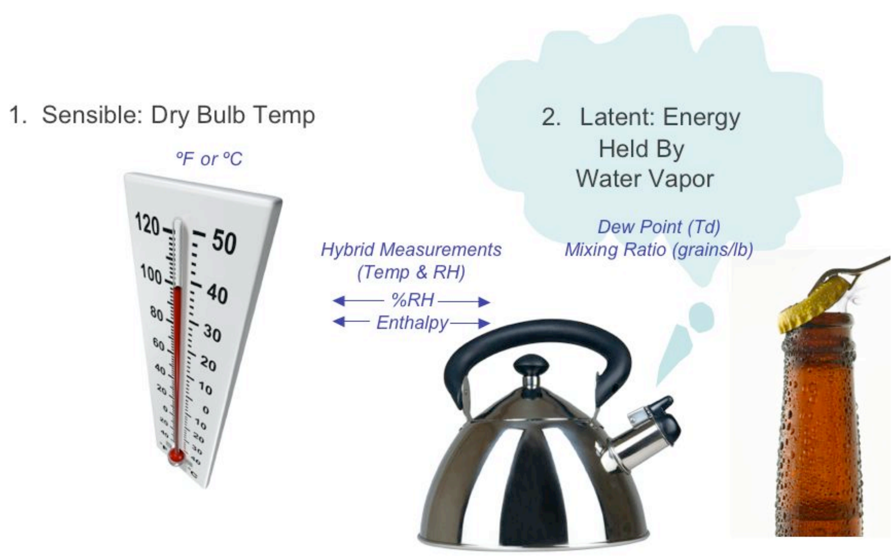
All this discussion about moisture is important because many economizer approaches do not consider the moisture they are bringing in to a building. Both temperature based and enthalpy based economizer control, because they do not specifically consider the latent content in air, can bring excessive moisture into the space. In these cases, free cooling becomes a deferred dehumidification requirement when moisture introduced to the building is above cooling design conditions. As a result, any moisture that is introduced during the economizer cycle will be removed later by the air conditioning system, which in many cases will negate any savings for "free cooling" that might of originally been anticipated. This is why in the recently published ASHRAE Humidity Design Guide it is recommended that economizer operation be controlled using temperature and dew point.[1] By using dew point as the moisture control parameter it is possible to ensure that outside air moisture content used as part of an economizer cycle will not exceed the conditions that would be delivered by the air conditioner or that meet design conditions. If conditions are not the same it is definitely not "free" cooling.

5. What is Enthalpy?

Is enthalpy really a valid measure of whether outside air can be used for free cooling? Before answering that question lets explore what exactly enthalpy is. Enthalpy is actually a measure of the total energy held in air by two components:

1. Sensible Energy, measured by dry bulb temperature.

2. Latent Energy, which is the heat retained in water vapor that allows it to remain as vapor. When this heat is removed through a process such a condensation the water vapor is converted to water and the heat is released as sensible energy. Latent heat is created when enough heat is added to water to cause it to becomes a vapor. Latent energy is typically measured by dew point or mixing ratio which specifically only measures the moisture content of air. Values of enthalpy or humidity are hybrid measurements that consider both temperature and moisture and cannot be used to directly determine the latent content of air.



For individuals designing cooling systems or cooling coils, enthalpy is a useful measure that can help determine the moisture levels and temperatures that will occur after air has passed through a cooling coil of a certain temperature. It allows the determination of how much temperature drop will occur and how much moisture will condense out of the air as a result of being cooled.

6. Is Enthalpy Appropriate For Economizer Control?

Enthalpy is inappropriate as an indicator of economizer control because there is no moisture phase change or dehumidification that takes place when outside air is introduced into the space using an economizer. The sensible and latent energy proportions of the outside air do not change once they are introduced to the building. To be truly free cooling, the conditions delivered by the outside air should be the same as the conditions delivered by a cooling coil. This information cannot be determined from an enthalpy measurement. Since there is no moisture phase change involved in economizer operation, the only suitable method of determining if outside air can provide free cooling is to separately measure the sensible and latent components and to ensure they match what the cooling system would provide. A single enthalpy measurement could mean that temperature is high and moisture is low or that temperature is low and air moisture content is high. There is absolutely no way to determine if the temperature/humidity mix is appropriate to provide free cooling.

Since no phase change of moisture takes place during a economizer strategy, it is impossible to determine if a particular enthalpy would meet the design conditions of a space. As a result, enthalpy is the wrong measure for an economizer control strategy.

A serious consideration about enthalpy sensors is what their accuracy is. Most inexpensive in-unit enthalpy sensors have no stated accuracy in their literature. In many cases their stated performance does not even follow a specific enthalpy value, instead offering a custom performance curve that is neither a consistent enthalpy or other type of psychometric value. Energy savings from these devices is directly related to the accuracy of sensing. If the manufacturer does not state sensor accuracy it is probably not worth considering it as a control device.

A final issue related to enthalpy is that it cannot be accurately calculated without knowing the local barometric pressure or elevation. The fact that most enthalpy sensors do not consider elevation means that poor accuracy and quality are further affected by imprecise calculation of the enthalpy value which can add 2% error per 1,000 feet of elevation. Calculation of enthalpy from humidity and temperature is also a highly complex formula that involves calculation of exponent and logarithmic values that need can only be handled by computers of high end microprocessors. In contrast, while dew point also requires a sophisticated calculation capability, pressure or elevation is not required for its accurate calculation.

Many buildings have attempted to use a "dual enthalpy" economizer approach where outside air is used for free cooling if the enthalpy is outside air is less than return air. In theory this is a solid approach. However, in practice, using two sensors of unknown accuracy, with imprecise calculation methods will just double what is already a undetermined and unacceptable measurement error.

7. Summary

There are a number of conclusions that can be drawn from the information presented in this paper.

1. Enthalpy is inappropriate for economizer control because it is a measure of the total energy in air. Since it cannot differentiate the sensible and latent components of air, and since outside air in economizer mode does not go through a condensation process, enthalpy measurements cannot assure that outdoor air will meet indoor design conditions. It is also important to note that most enthalpy sensors do not even state their accuracy or correct their output for elevation. Most devices that claim to measure enthalpy based on temperature and humidity also do not have the microprocessor capability to accurately calculate the complex equation to determine this value. Ironically millions of buildings today are attempting to control economizers with enthalpy, which in many cases may mean significant wasted energy use for cooling. No wonder there is significant migration by most buildings from enthalpy to temperature control.

2. Temperature based economizer control can be effective in very dry climates. However, for most climates, while outdoor temperatures may be below design dry bulb conditions, the latent content of air can be above design conditions. This added moisture, over design conditions, will remain in the building until it is ultimately removed by the air conditioning system. This can significantly diminish expected energy savings and in some cases may impose an energy penalty on the building.

3. Dew point and temperature measurement is the only measurement parameter that can ensure that design conditions are met when using economizers for free cooling. If an economizer introduces air above design conditions (i.e. Higher latent content), this additional load will have to be removed later when the air conditioning system is activated.

4. When dew point and temperature control is used for economizer control, one sensor can be used to serve multiple air handling units. Owner investment is focused on having a single, durable, weather station quality dew point and temperature sensor designed to provide accurate control input for 10 to 15 years. This is in contrast to investing in a number of low cost, low performing in-unit sensors of unknown accuracy that cannot deliver the performance necessary to optimally harvest economizer energy savings opportunities.

Indoor Design Conditions & Dewpoint

Temperature (ºF)	%RH	Target Dew Point (ºF)
75	60% 50%	60.2 55.1
74	60% 50%	59.3 54.2
73	60% 50%	58.3 53.3
72	60% 50%	57.4 52.4
71	60% 50%	56.4 51.5
70	60% 50%	55.5 50.5

5. When calculating the energy impact of an economizer strategy, any evaluation strategy should discount savings by the additional energy necessary to remove any moisture in the air that is above design conditions.

AirTest Solutions

AirTest has a number of weather station quality sensor solutions that can be used to provide the appropriate control for dew point economizers. All sensors are intended for outside mounting and are designed to operate at temperature to -40ºF. It is recommended that all sensors be used with a radiation shield option that is a proven approach for shielding a sensor against solar, wind and snow effects. Shielding of the sensor element is as critical to good economizer control as the accuracy of the sensor is. Sensors should be mounted away from exhaust air-streams or other physical components of the building and equipment that may distort outdoor environmental measurements. All of these sensors can be used as a universal sensor input to control multiple economizer devices.

EE23: Dew Point (Td) And Temperature Sensor (T)

This is a durable, weather station quality temperature and RH sensor, designed for outdoor operation that calculates and provides very accurate dew point and temperature outputs. This unit can be integrated into existing building control systems.

Enclosure: NEMA 4, Metal Or Plastic Housing
RH Accuracy: ±1.3 +(0.003 x measured value)= 1.5%@60% RH
Temp Accuracy: ± 3.6ºF@ 70ºF
Calculated Dew Point Accuracy: ± 0.8ºF Td (50-75ºF, 60% RH)
Outputs: 0-1V, 0-5V, 0-10V, 4-20 mA (2 outputs: T, Td)
Accessories/Options:
- Radiation Shield & Mounting Bracket (HA010504)
- LonWorks communication module (coming soon)

Product Link: http://www.airtest.ca/support/datasheet/EE23.pdf

EE21-FTA21 High Accuracy Temperature And Humidity Sensor (For External System Dew Point Calculation)

This is a durable, weather station quality temperature and RH sensor, designed for outdoor operation that calculates and provides an accurate, RH and temperature output. This product would be used for economizer control if a building control system can take the analog output of the sensor to accurately calculate dew point. Contact AirTest for an accurate formula for calculating dew point (floating point calculations required).

Enclosure: NEMA 4, Plastic Housing
RH Accuracy: ±2% RH 0-90% RH
Temp Accuracy: ± 3.6ºF@ 70ºF
Calculated Dew Point Accuracy: ± 0.8ºF Td (50-75ºF, 60% RH)
Outputs: 0-10V, 4-20 mA (2 outputs: T, %RH)
Accessories/Options:
- Radiation Shield & Mounting Bracket (HA010501)
- Passive Temperature output option
- LonWorks communication module (coming soon)

Link: http://www.airtest.ca/support/datasheet/EE21.pdf

EE08 Weather Station Sensor For Temperature And RH (For External System Dew Point Calculation)

This is a small compact probe that is design as a replacement part for weather stations but can also be a very cost effective outdoor sensor for economizer control if a building control system is available to calculate dew point. All calibration information and analog circuitry is in the probe body. Available with cable attached (3 to 16 ft) or with screw in connection with cable (6 ft or 16 ft). Contact AirTest for an accurate formula for calculating dew point (floating point calculations required).

Enclosure: NEMA 4, Plastic Housing
RH Accuracy: ±2% RH 0-90% RH
Temp Accuracy: ± 3.6ºF@ 70ºF
Calculated Dew Point Accuracy: ± 1ºF Td (50-75ºF, 60% RH)
Outputs: 0-1V, 0-2.5V, 0-5V, Two Wire Serial (E2 Protocol)
Accessories/Options:
- Attached 8 wire (Model E) or screw-in 8 pin cable connection (Model D)
- Radiation Shield & Mounting Bracket (HA010506) (Model D Required with Radiation Shield)
- Passive Temperature output option
- LonWorks communication module (coming soon)

Link: http://www.airtest.ca/support/datasheet/EE08.pdf

AirTest Energy Analysis Program For Economizers And CO_2 Control

AirTest has developed an energy analysis program that uses local climatic data and building information to estimate potential savings that will result from a outdoor air strategy that uses a combination of CO2 and economizer control. The program will provide an evaluation of savings possible from the economizer strategies examined in this paper. The AirTest Ventilation Optimization Energy Analysis Program (VOEP) is available at no cost for to AirTest customers and distribution partners. Call AirTest for more information.

For Further Information: AirTest Technologies Inc. Web: http:www.AirTestTechnologies.net
Email: info@airtest.ca Phone: 888 855-8880, 604 517-3888

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[1] L. Harriman, G.Brundrett, R. Kitter, Humidity Control Design Guide for Commercial and Institutional Buildings, Published by ASHRAE, 2001. Available form the ASHRAE Bookstore www.ashrae.org