10 Airside Economizer Application Primer

10.1 Summary

- Economizer operation is complementary to Demand Control Ventilation, providing optimal energy savings when the right outside air conditions exist.
- The number of free cooling hours is not only affected by weather conditions, but is also very much dependent on the latent and sensible heat loads within a building. Of these, moisture from occupants, kitchen areas, bathrooms, and other sources can affect a significant rise in return air moisture levels over supply air conditions.
- It's important to account for "wet-coil" and "dry-coil" conditions when implementing economizer switchover logic. Conventional economizer controls do not do this, primarily because of sensing limitations. This often leads to poor performance. OptiNet® overcomes these limitations to provide a cost effective solution with excellent performance.
- Traditional differential drybulb and even differential enthalpy economizer approaches do not always provide an adequate measure of whether the return air or outside air requires more cooling energy and this results in errors in economizer operation and reduced energy efficiency. Such errors are very likely to occur with differential drybulb economizers during "wet coil" conditions. To protect against this, drybulb economizers are configured to lock out at relatively low outside air temperatures (typically about 70°F) which, in turn, greatly limits the amount of savings that is possible with this approach. Likewise, certain "dry coil" conditions can result in efficiency issues with differential enthalpy economizers, even though they have the potential of saving much more energy over the differential drybulb approach. However, the inaccuracy and drift issues with conventional discrete sensors used with enthalpy economizers can render them ineffective. OptiNet overcomes these limitations to provide a cost effective solution with excellent performance using the Differential Energy™ approach that's based upon cooling load calculations which are performed on both the return air and outside air. This logic is bundled within the configuration of the OptiNet system.
- Required OptiNet Equipment:
  - Sensors:
    - Precision dewpoint temperature measurement via C2D3 (fully density compensated hygrometer).
    - Drybulb temperature via duct probe (DPB200)
  - Critical Parameters: Enthalpy, Drybulb Temperature, Dewpoint Temperature or Humidity Ratio.
  - Measurement Locations: Outside Air and Return Air locations. It is generally recommended that supply air be monitored as well. Although this is not critical for the economizer logic, supply air dewpoint and CO2 levels can be used to verify economizer and general AHU performance. CO2 measurement capabilities are also included with the C2D3 sensor required for economizer applications.
- Outside air may be monitored for other parameters such as TVOCs, Particles, and CO to create an additional switchover function to prevent economizer or DCV modes when levels of these parameters are excessive.

10.2 Basic Economizer Operation

Regardless of geographic location, most commercial buildings require cooling during each season, due to the large heat gains realized within a typical facility, and this cooling requirement can have a significant impact on operating costs. In many locations, however, especially during the cooler or more temperate months of the year, some, or in certain cases, a large fraction of these cooling needs can be offset by way of an airside economizer. An airside economizer is a system that typically incorporates a linked damper assembly (tying together the outside, return, and building exhaust dampers common to an air handler), a means of sensing the "heat" or energy level present in the outside air and return air, and control logic that when conditions are right, determines the amount of outside air to introduce in order to reduce mechanical cooling needs. If done properly, the result can

rev 01-2014

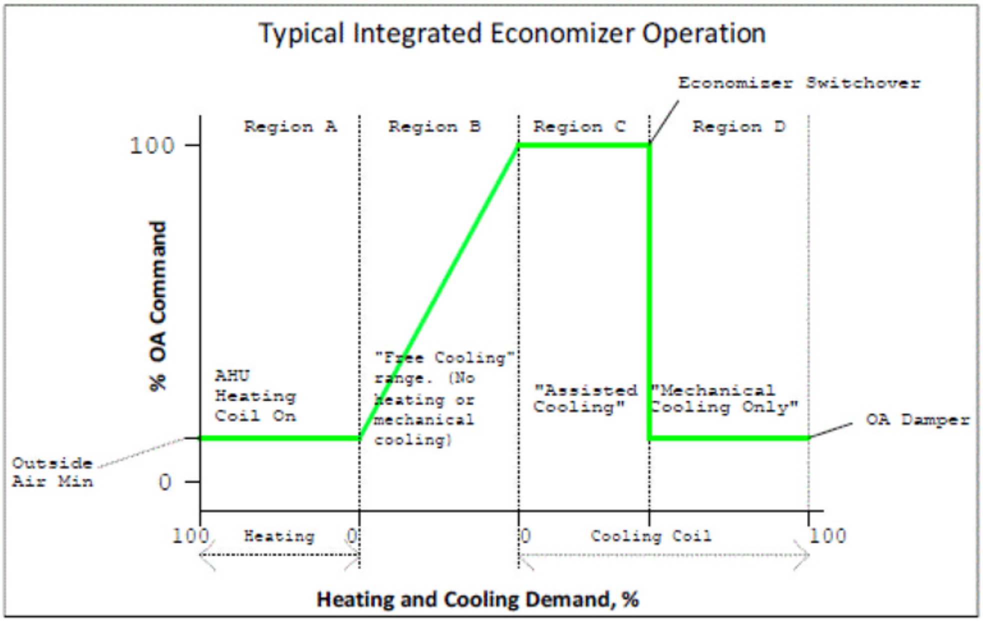


Figure 10-1. Typical Integrated Economizer Operation

lead to substantial energy savings.

When a system is equipped with an economizer, savings can be realized on the cooling costs associated with the load posed by return air, because the economizer acts by increasing the outdoor air percentage to the building when it is more economical to condition the outdoor air in lieu of the return air. In essence, an economizer incorporates a damper system that controls outside air and return air in an inverse fashion; so that as the outside air volume is increased the return air volume is decreased. The objective, theoretically, is to proportion the two so that their total volume stays the same.

Figure 10-1 illustrates the heating and cooling operation of a typical AHU with an integrated economizer which generally involves 4 functional modes that are dependent on the thermal demand for heating or cooling and the suitability of using outside air for cooling purposes.

In region "A" the outdoor air temperature is below a point where, for the minimum setting of the outdoor air damper the resultant air mixture at the intake of the Air Handler Unit (AHU) has to be heated in order to realize the desired AHU discharge air temperature (typically 55°F). The operating state of the system in this region, generally involves an active heating coil at the AHU. The boundary between Region A and Region B is the pivot point temperature of the building, and is the normal point at which the outdoor air temperature is sufficiently low to require heat to be added at the AHU. This is the case whether there is an economizer or not. Notice that if the outdoor air percentage is reduced it will increase the operative free cooling range, which can add to the energy savings. There is a practical limit to this, however, as many buildings are designed with an outdoor air preheat system that will turn on when outdoor air temperatures are below freezing. With such systems the economizer will be shut off under these conditions. When preheat is applied, significant energy savings can be realized by lowering the outdoor air percentage, since it will directly reduce the load on the preheat coil.

Note: There is a contribution of "free cooling" due to outdoor air even with systems that do not have an economizer and modulating outdoor air damper.

In region "B" the outdoor air damper is automatically adjusted to provide the correct mixture with return airflow to satisfy all of the cooling demand imposed by the return air. Because of this, this is referred to as "free cooling", since the AHUs cooling coil will be off in that mode. (Note: There is a contribution of "free cooling" due to outdoor air even with systems that do not have an economizer and modulating outdoor air damper.)

Region "C" of Figure 10-1 signifies the range where mechanical cooling is applied and the system is operating at 100% outdoor air. This is also known as the assisted cooling range, where energy savings is realized, even though mechanical cooling is applied, because in this range less cooling is required to condition outdoor air than that for return air.

The boundary between region C and region D is the point at which assisted cooling with outdoor air becomes non-economical due in many cases to the latent energy realized at these higher temperatures. With a dry bulb economizer this boundary is typically taken to be 65°F to 70°F, conditional on geographic location, but can be lower based on the expected return air conditions. However, variations in both return air latent energy, as well as that of outside air often makes economizers based only on dry bulb or differential dry bulb ineffective, often realizing only a fraction of the potential savings as well as being potential wasters of energy. In order to be effective, the economizer control function needs to account for latent heat; and this can be done using OptiNet's dewpoint and enthalpy measurement capabilities.

Note: ASHRAE Standard 90.1-2010 lists the airside economizer as a conditional requirement (when a waterside economizer is not used) for systems having a capacity of 54,000 BTU/h or more.

10.3 Differential Enthalpy Economizer Approach

In order to more effectively gage when it is appropriate to activate the economizer, instead of implementing a simple drybulb temperature measurement (differential or fixed drybulb) to compare return air conditions against outside air conditions, a very common method has been to utilize enthalpy measurements of each air source (return and outside air) to account for both latent and sensible load. If performed correctly, this differential enthalpy approach can result in improved energy savings over fixed or differential drybulb economizer performance, by increasing the number of operational economizer hours and decreasing the number of "incorrect" economizer hours that would otherwise lead to wasted energy. Incorrect economizer hours is simply the amount of time that the economizer is erroneously activated, and it can be significantly influenced by the means used to sense which air source requires more energy to cool. For example, these incorrect economizer hours can result when the switchover point in a drybulb economizer (regions C and D of Figure 10-1) occurs at high drybulb temperatures, where latent cooling loads become a factor. This can be an issue in climates having temperate to moderate humidity levels, but the performance is also influenced by a building's internal latent load as seen by the moisture levels in the AHU return air.

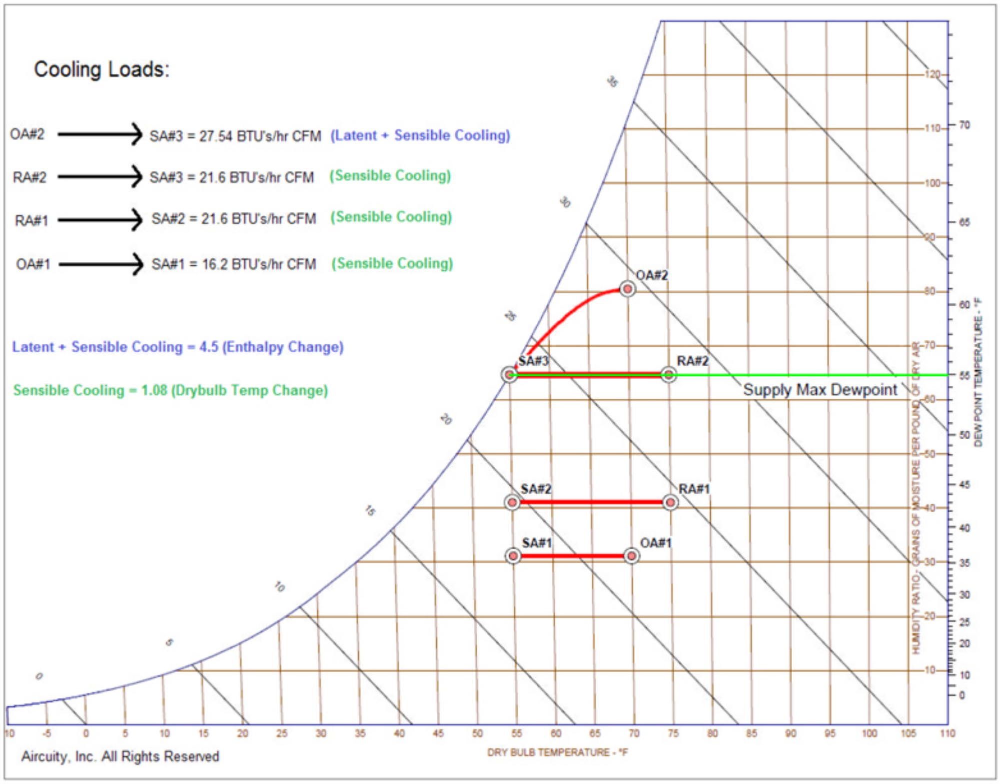


Figure 10-2. Differential Drybulb Approach Resulting in Erroneous Economizer Hours

For a better understanding of how the differential drybulb economizer can yield erroneous economizer hours, consider the conditions depicted in Figure 10-2. Shown here are two sets of outside air and return air conditions (OA#1, RA#1 and OA#2, RA#2). Although the drybulb temperature for the return and outside air conditions does not vary, the actual cooling load imposed by each state is significantly different, given the higher levels of moisture that exists especially in OA#2. However, a differential drybulb economizer would treat both states as being equivalent and, in both cases would enable the economizer based on the fact that in both cases the outside air is at a lower drybulb temperature (70°F) than the return air (75°F). However, because OA#2 has a dewpoint temperature of 61°F, a moisture removal process will occur as this air source is conditioned to the supply air state SA#3, causing the cooling process of OA#2 (resulting in a cooling load of 27.54 BTUs/hour per CFM) to be significantly greater than that of RA#2 (presenting a sensible cooling load of 21.6 BTUs/hour per CFM). With the application of the differential drybulb economizer, this would result in energy waste, as OA#2 would be selected over RA#2.

For the more common conditions such as those depicted within Figure 10-2, the differential enthalpy economizer will provide superior performance, given that it will enable the economizer when the return air exists at a higher enthalpy level. In the case of Figure 10-2, RA#1 has a higher enthalpy value than OA#1, so the differential enthalpy economizer would enable the economizer function for the conditions of OA#1 and RA#1. Conversely, the differential enthalpy economizer will correctly lockout the economizer function for the conditions of RA#2 and OA#2, given that in this case the outside air enthalpy value is higher than that of the return air.

10.3.1Enthalpy Economizers Based on Discrete Sensors Do Not Work Well And Can Waste A Lot of Energy

Although the differential enthalpy approach can yield superior energy savings over a differential drybulb approach, historically, enthalpy economizers have had major issues with the sensing technology used, which can lead to poor performance and energy inefficiency. The poor accuracy of most commercial sensors used to provide an enthalpy measurement can result in errors in the economizer logic, causing the economizer to be enabled under inappropriate conditions as well as not being enabled when it would be beneficial. For example, commonly used discrete enthalpy sensors are notorious for exhibiting poor stability due to the stability of hygroscopic materials, such as nylon that have been used to form these sensors. Even with the more recent introduction of solid state humidity sensors, significant tolerance stacking errors are introduced, given the pair of sensors required in order to separately monitor outside and return air conditions. These errors are exacerbated as the sensors age and drift over time.

Note: Visit http://www.iowaenergycenter.org/ to view "Product Testing Report Supplement: Duct-Mounted Relative Humidity Transmitters", which was published in 2005 by the National Building Controls Information Program.

For more information on the reliability of commercially available discrete humidity sensors, refer to a report entitled ***"Product Testing Report Supplement: Duct-Mounted Relative Humidity Transmitters",*** which was published in 2005 by the National Building Controls Information Program. This report, which can be found on the Iowa Energy Center website, discusses in great detail how, after a 12 month test, almost every sensor evaluated performed far outside its tolerance specification, and many of which ceased to operate.

In contrast, OptiNet provides the moisture sensing performance on which a reliable economizer control application can be built. Central to this is our infrared based hygrometer (SEN-C2D-3), providing unequaled accuracy of less than 1°F (dewpoint). Along with this, OptiNet's multiplexed sensing architecture eliminates the common tolerance stacking errors that exist when using discrete sensors. In addition to this, OptiNet Assurance Services (OAS) ensure that these sensors are calibrated and maintained on 6 month intervals. Further, proactive monitoring services that are included with OAS, provide remote verification to guard against issues that may interfere with proper system operation.

10.3.2 Under Certain Conditions Differential Enthalpy Logic Can Erroneously Enable or Disable the Economizer

Note: ASHRAE Standard 90.1-2010 lists the airside economizer as a conditional requirement (when a waterside economizer is not used) for systems having a capacity of 54,000 BTU/h or more.

Just as drybulb economizer logic can be wrong for certain wet coil conditions, differential enthalpy logic can sometimes misjudge dry coil conditions. [Again, a dry coil condition is one where the air source (return or outside air) does not have a high enough dewpoint temperature to result in condensation on the AHUs cooling coil, as the air source is cooled.] Figure 10-3, helps to illustrate just such a condition. Referring to the states of OA#2 (outside air), RA#2 (return air), and supply conditions SA#2 and SA#3, shown in Figure 10-3; a differential enthalpy economizer would misjudge the outside air and return air states and disable the economizer, because OA#2's enthalpy is higher than that of RA#2. The reason why this would be incorrect is that, in this case, the actual cooling load is less for OA#2 than it is for RA#2 because only a sensible cooling process applies to each, meaning that the cooling amount is a function of the drybulb temperature drop across the coil only (1.08ΔT). The Differential Energy logic available via OptiNet addresses the errors common to differential enthalpy and differential drybulb approaches.

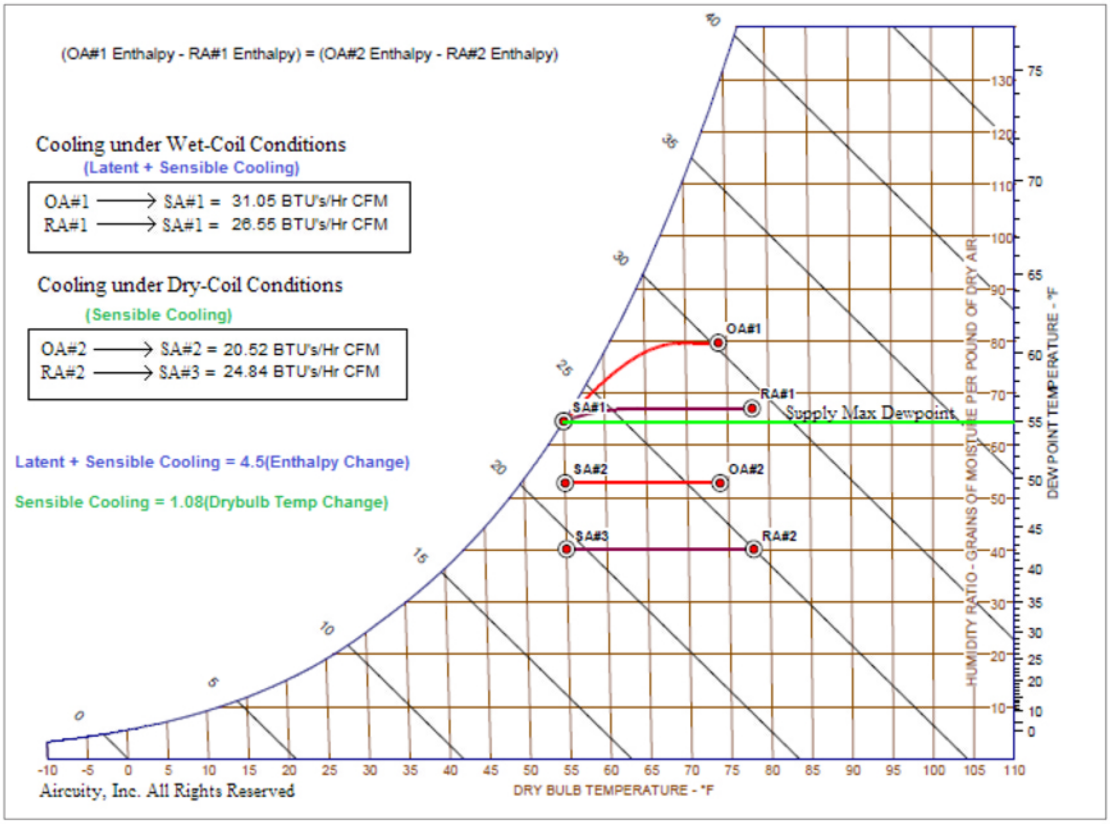


Figure 10-3. Psychrometric Chart Showing Outside Air and Return Air Conditions

10.4 An Improved Economizer Lockout Function Using Differential Energy™ Logic Implemented Through OptiNet

OptiNet's Differential Energy economizer logic is a patent pending approach that provides a superior level of economizer lockout functionality without the estimation errors that can occur with fixed or differential drybulb or even enthalpy approaches. The key to this method is that OptiNet's application logic continuously performs cooling load calculations on the return air and outside air sources, based on actual sensed dewpoint and drybulb temperature values, which allows us to accommodate calculations for both sensible and latent loads. These calculations include AHU supply air conditions and the calculated values are available as data points within the OptiNet system. The lockout function enables the economizer only when the cooling load estimate for the outside air is less than that of the return air, and all of the logic necessary to perform the cooling load calculations, to make the comparison, and to generate a lockout signal is processed by software within the OptiNet system. This makes it easy to implement a reliable economizer lockout signal in the field. The signal can be communicated to the BAS or other system that is performing the actual economizer control via a BACnet® binary point or more directly via an analog signal.

10.4.1 Wet/Dry Coil Active Sensing

The cooling load calculations which are at the heart of Aircuity's Differential Energy economizer logic account for both sensible and latent cooling loads by estimating if condensation will occur on the AHU cooling coil as return or outside air is conditioned. This is accomplished by comparing the measured dewpoint temperature of the air source (return or outside air) to the saturation temperature of the supply air. If the air source's dewpoint exceeds the supply air saturation temperature, then condensation will take place and the process will involve both sensible and latent cooling. In this analysis, the supply air saturation temperature is estimated by recognizing that the dewpoint value cannot exceed the supply air discharge drybulb temperature, thus the value of supply air drybulb temperature is used by OptiNet in these calculations.

Example 1:

As an example of how these calculations are performed by the Differential Energy logic assume the following conditions for an AHUs air components:

- Supply Air (SA1)
  - SA1 Drybulb Discharge Air Temperature = 55°F
  - SA1 Enthalpy at Saturation = 23.18 BTU/lb
- Return Air (RA1)
  - RA1 Drybulb Temperature = 72°F
  - RA1 Dewpoint Temperature = 63°F DPT
  - RA1 Enthalpy = 30.72 BTU/lb
- Outside Air (OA1)
  - OA1 Drybulb Temperature = 82°F
  - OA1 Dewpoint Temperature = 53°F DPT
  - OA1 Enthalpy = 29.05 BTU/lb

From this information, the cooling load per CFM of return air and outside air are determined as follows:

- **Outside Air Cooling Load ($OA1_{CL}$):**

  Because of the observed drybulb temperature of the supply air, the saturation temperature of the supply air is assumed to be 55°F DPT. Based on this, the outside air dewpoint temperature (53°F DPT) is less than that of the supply, which means no condensation will result (Dry Coil) as the outside air is cooled. As such, the outside air cooling process will involve sensible cooling only, and the cooling load estimate for the outside air is as follows:

  Outside Air Cooling Load = $OA1_{CL} = 1.08(\Delta T)$

  $= 1.08\ (82°F–55°F)$

  $OA1_{CL}$ = 29.16 BTUs per hour per CFM

- **Return Air Cooling Load ($RA1_{CL}$):**

  Based on the above, the return air cooling process will result in a wet coil because the return air's dewpoint temperature (63°F DPT) exceeds the saturation temperature of the supply air (55°F DPT). As a result, the cooling load of RA1 is calculated as follows:

  Return Air Cooling Load = $RA1_{CL}$ = 4.5(Enthalpy Change)

  =4.5(30.72BTU/lb – 23.18BTU/lb)

  $RA1_{CL}$ = 33.93 BTUs per hour per CFM

- **Outcome of Differential Energy Logic:**

  Because in this example the outside air cooling load is less than that of the return air, OptiNet's logic output would enable the economizer, since it would be more economic to utilize outside air, rather than the return air. Note that in this case, the integrated economizer would have to operate in mechanical assist mode, as sensible cooling would be required to reduce the outside air from a drybulb temperature of 82°F to 55°F. Also, observe that in this case an enthalpy economizer logic would have generated the correct result (enabling the economizer), given the fact the outside air enthalpy is less than that of the return air. However, differential drybulb economizer logic would have misinterpreted the condition and would have locked out the economizer, due to the higher drybulb temperature of the outside air, as well as the fact that most drybulb economizer will automatically lockout at such high outside temperatures.

Example 2:

As another example of how these calculations are performed by the Differential Energy logic assume the following conditions for an AHUs air components:

- Supply Air (SA2)
  - o SA2 Drybulb Discharge Air Temperature = 55°F
  - o SA2 Enthalpy at Saturation = 23.18 BTU/lb
- Return Air (RA2)
  - o RA2 Drybulb Temperature = 70°F
  - o RA2 Dewpoint Temperature = 59°F DPT
  - o RA2 Enthalpy = 28.43 BTU/lb
- Outside Air (OA2)
  - o OA2 Drybulb Temperature = 82°F
  - o OA2 Dewpoint Temperature = 49°F DPT
  - o OA2 Enthalpy = 27.74 BTU/lb

From this information, the cooling load per CFM of return air and outside air are determined as follows:

- **Outside Air Cooling Load ($OA2_{CL}$):**

  The outside air cooling process will result in a dry coil because the outside air's dewpoint temperature (49°F DPT) is less than the saturation temperature of the supply air (55°F DPT). As a result, the cooling load of OA2 is calculated as follows:

  Outside Air Cooling Load = $OA2_{CL}$ = 1.08(ΔT)

  =1.08(82°F – 55°F)

  $OA2_{CL}$ = 29.16 BTUs per hour per CFM

- **Return Air Cooling Load ($RA2_{CL}$):**

  The return air cooling process will result in a wet coil because the return air's dewpoint temperature (59°F DPT) exceeds the saturation temperature of the supply air (55°F DPT). As a result, the cooling load of RA2 is calculated as follows:

  Return Air Cooling Load = $RA2_{CL}$ = 4.5(enthalpy change)

  = 4.5(28.43BTU/lb – 23.18BTU/lb)

  $RA2_{CL}$ = 23.63 BTUs per hour per CFM

- **Outcome of Differential Energy Logic:**

  With these conditions, the outcome from the OptiNet Differential Energy logic will be to disable the economizer because the outside air cooling load will be greater than that of the return air. This is the case, even though the outside air enthalpy is lower than that of the return air enthalpy. Therefore, in this case, an enthalpy economizer would have misjudged the condition.

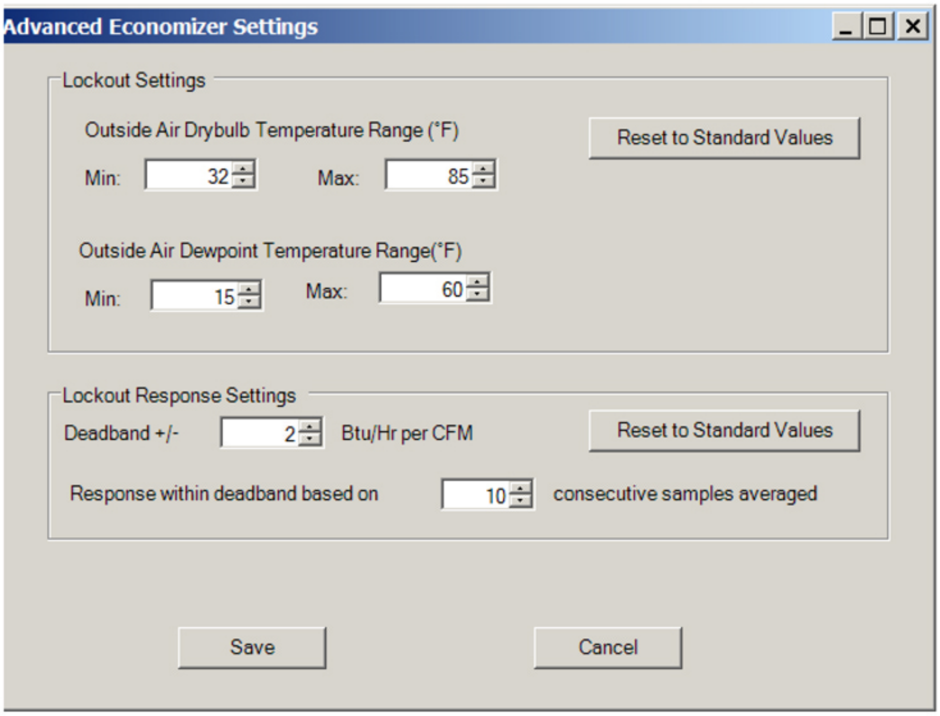
10.4.2 Other Lockout Settings

In addition to the Differential Energy logic, the OptiNet application provides other settings to ensure that a "lock-out" state will be commanded if outside air conditions go beyond a specified range. For example, the drybulb temperature limits can be useful to guard against a condition where preheat would be applied to outside air when outside air temperatures go below a specified value. Also, a dewpoint lockout setting can be useful to guard against running the economizer under conditions that would require a humidifier to be activated. Flexibility is provided with these settings to allow the user to provide a level of customization according to the design requirements of their system.

10.4.2.1 Economizer Module Deadband Settings

The energy calculations for sensible or sensible-plus-latent cooling result in a quantity that is in BTUs/Hour per CFM. During routine operation, it is not be uncommon to have the calculated return air values be close in magnitude to that of the outside air values. When this is the case, instability in the conveyed lockout signal could arise due to subtle alternating temperature variations or event variations in moisture levels between return air and outside air. In the worst case scenario, where outside air conditions require assisted mechanical cooling as the economizer is enabled; this would result in unnecessary wear and tear on the damper assemblies and related linkages as, under these conditions, each time the economizer function is enabled the outside air damper would modulate to its full open position.

To guard against this instability, both a deadband and an averaging setting is provided which will not allow the lockout function to toggle for small differences in cooling energy estimates between return and outside air unless the condition persists for a predetermined number of samples. If the difference exceeds the deadband value, any change of state will take place immediately. The default settings for the deadband is 2 BTUs/hour per CFM, and the persistence setting is 10 samples. With these settings, for example, if the outside air cooling estimate is 1 BTU/hour per CFM greater than the return air cooling estimate, this condition will not result in a change of state to lockout the economizer until a box car average of 10 samples is observed where the outside air energy level is greater than that of the return air. That is, the average out of ten samples must be positive. If, however the difference of any of the samples exceeds the 2 BTUs/hour per CFM deadband, the average count will start over and the lockout signal state will immediately assume the instantaneous value. So, if in this case the outside air cooling estimate jumps to 3 BTUs/hour per CFM greater than that of the return air, the lockout signal's state will immediately be asserted as "lockout". If this value then drops to -1BTUs/hour per CFM the lockout condition will continue to persist until an average (based on 10 samples) is registered which is negative.



Advanced Economizer Settings

Lockout Settings

Outside Air Drybulb Temperature Range (°F)
Min: 32 Max: 85

Outside Air Dewpoint Temperature Range(°F)
Min: 15 Max: 60

Lockout Response Settings

Deadband +/- 2 Btu/Hr per CFM

Response within deadband based on 10 consecutive samples averaged

Figure 10-4. Added Lockout Settings Provided Through OptiNet®

10.4.3 Summary Sequence

The following is the summary sequence describing the OptiNet Differential Energy™ lockout function:

- The BAS or other system used to sequence the economizer, including outside and return air dampers, chilled water valve, and other applicable system components will operate in economizer mode, based upon the state of the economizer lockout signal from the OptiNet system. This may include an analog 0–10V or 0–20mA signal, or it may be communicated to the economizer controls via a BACnet binary point. For this purpose, it is assumed that the economizer control strategy accommodates not just free cooling, but the mechanical assist cooling mode of operation as well; which means that the economizer will be capable of using outside air that needs to be additionally cooled by the AHU to achieve the desired supply discharge air conditions.
- For each AHU economizer, the OptiNet system will at least measure the dewpoint temperature and drybulb temperature of the outside and return air supplied to the AHU and will additionally use either an estimate or an actual measurement of the supply discharge air temperature (also performed by the OptiNet system) as part of the economizer lockout calculations.
- Energy calculations will be performed by the OptiNet system to estimate the cooling load presented to the AHU by each air source. The energy calculation for each air source (return or outside air) will be adjusted for sensible and latent cooling estimates when the cooling process is expected to result in a wet coil (condensation), or just sensible cooling if only a dry coil is predicted. To test for a wet coil condition, the measured dewpoint temperature of the air source will be compared to the supply air saturation temperature. If the dewpoint of the air source exceeds the supply air saturation temperature, a wet coil will be expected.
- The estimated cooling load presented by the return air will be compared to the estimated cooling load presented by the outside air. When the estimated outside air cooling load is less than that of the return air, the economizer will be enabled, as long as other lockout parameters are not exceeded. These added lockout settings include a maximum and minimum outside air drybulb temperature setting, a maximum and minimum outside air dewpoint temperature setting, and a cooling load energy deadband setting.