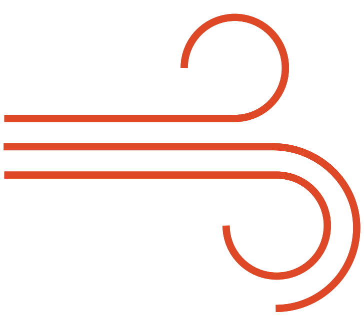
IoT REVOLUTIONIZES ROOFTOP ECONOMIZERS

Deep Thoughts by Deepinder Singh: Part 4

A series on the future of cloud computing, big data and buildings

An economizer is a device designed to make a package rooftop unit (RTU) more energy efficient. The economizer controls the outside air damper of a rooftop unit (RTU) and brings in fresh outside air which can provide free cooling when conditions are right. It also helps meet indoor air quality (IAQ) requirements. While few RTU economizers today are utilizing the Internet of Things (IoT), its inception enables intelligent companies to make smarter, more efficient decisions that increase savings and decrease our impact on the planet.

Based on the maximum occupancy of a building, IAQ standards require a certain amount of air exchanges every hour with fresh air from the RTU's outside air damper. There are two types of air exchanges. The first is when an RTU simply moves the air in a room by recirculating the air in the building and the second type freshens a room with outside air. When fresh air comes in, the same amount of air must also be exhausted out. Without smart controls, an outside air damper will typically be set to open a minimum of 20-30% to provide enough fresh air to meet the IAQ standards. The precise percentage opening of the damper is determined by factors such as how many Cubic Feet per Minute (CFM) is blowing, the size of the outside air damper relative to the ductwork and the size of the spaces being served.



Demand control ventilation (DCV) is a control strategy in which we only open the outside air damper when IAQ demands it, based on CO_2 levels measured in the return air system. The outside air damper is kept nearly closed (well below the minimum of 20-30% outlined above) most of the time. Only if the CO_2 levels rise is the outside air damper opened to reduce them. If CO_2 levels are low (say because the building is only partially occupied), DCV can save a lot of energy when it's freezing outside and we don't have to heat that outside air up to 72°F. The same principle enables DCV to also save energy in hot, humid weather.

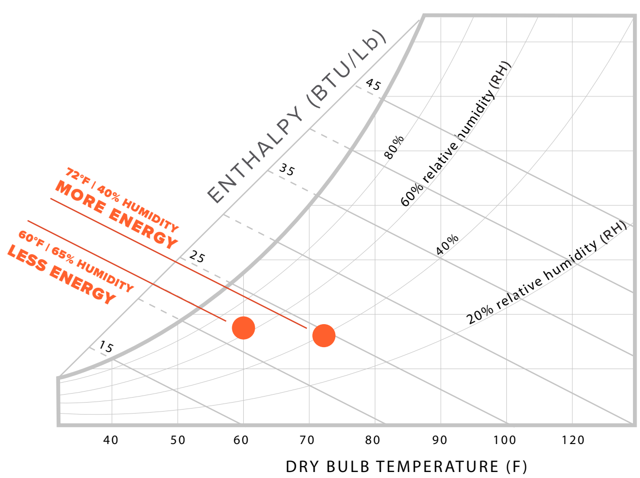
That same fresh outside air can provide free cooling when conditions are right. For example, if it were 72°F inside and 55°F outside, fresh air coming in at 55°F would help cool down the building. Free cooling through the economizer frequently works out nicely in the spring and fall and the outside air damper can be opened up well past the minimum. It's just like opening up a window on a spring day instead of turning on the A/C, which helps save energy.

There are different strategies to determine when to bring in outside air and IoT is changing the game. One could just look at the outside air temperature alone and make the decision based on that, which is called "dry bulb." But the total amount of energy in the air (and therefore the amount of cooling power needed to remove it) is determined by both temperature and humidity. This is where it gets interesting and enthalpy comes into play. Typical economizer controls will have either a dry bulb or comparative enthalpy control. Comparative enthalpy controls measure the outside air enthalpy based on the temperature and humidity and compare it with the indoor enthalpy, to determine how much outside air to bring in.

HOW IS THE ENERGY OF AIR RELATED TO HUMIDITY?

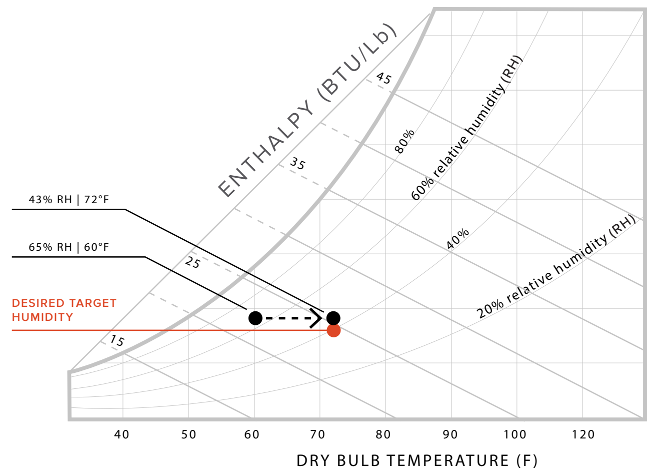
If you take water and let it evaporate, the water will convert into water vapor. During this time, the water left behind is actually cooled. If you've ever walked through a greenhouse that had water misters stationed within, you may have noticed you felt cooler inside. The reason behind this is mist will eventually evaporate and as it does, it cools the air around it. The water vapor in the air stores a huge amount of energy.

Enthalpy determines the total amount of energy in the air and is based on both humidity and temperature. While there is no simple math to determine enthalpy, we use a psychometric chart to discover how much energy the air has. This graphical representation calculates thermodynamic properties like dry bulb temperature, wet bulb temperature, humidity, enthalpy and air density. Let's take an example of a building that has an inside temperature of 72°F with 40% humidity, while the air outside is cooler at 60°F with 65% humidity. In the chart below we plot the enthalpy as downward sloping diagonal lines from left to right. We can see that 60°F with 65% humidity has less enthalpy than 72°F air with 40% humidity. So according to the graph, the outdoor enthalpy is less than the indoor enthalpy, so bringing in fresh air to cool the building (instead of mechanical cooling) makes sense.



This psychometric chart indicates that air which is 72°F with 40% humidity, has more energy than 60°F with 65% humidity.

However, enthalpy alone is not a good metric to determine when to use free cooling, since it does not account for what bringing in the outside air would do to the indoor building humidity. Even when the enthalpy is favorable, the humidity might still increase beyond what is comfortable for humans and good for the building (mold growth due to high humidity is a big concern). Using the psychometric chart, we can see that 60°F air with 65% humidity will end up at 43% humidity when it heats up to 72°F.



This psychometric chart indicates that air which is at 60°F with 65% humidity, will end up with 43% humidity when heated to 72°F.

75F measures the indoor humidity and also gets a 'desired target humidity' for each building it automates. Now if that building's desired target humidity was 40%, we'd see that bringing in the outside air would make the building more humid, so we'd pass on getting that outside air even though it's tempting just looking at the enthalpy.

The comparative enthalpy method works most of the time, except when there are high humidity levels inside the building (restaurants with steam cooking lines and high occupancy offices are notorious for this), which cause the enthalpy comparison method to break down. At 75F we take into account not just enthalpy, but also what bringing in the outside air will do to the building's indoor humidity.

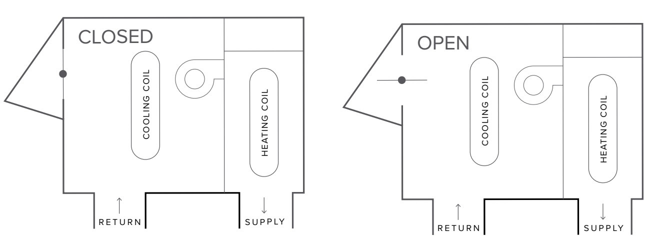
WHAT HAPPENS TO AN RTU IN A RESTAURANT SETTING, WHEN YOU HAVE HOODS CONTINUOUSLY EXHAUSTING AIR OUT?

When it comes to restaurants, you have an RTU, a makeup air unit and exhaust hoods. The amount of air that gets pulled into the RTU through its outside air damper increases the air inside the restaurant. With outside air coming in and exhaust hoods expelling air out, the building pressure is dynamic and always shifting. So as pressure within the restaurant grows, there's a hinged relief flap built into the RTU that enables excess air (positive pressure) to flow back outside. This exists to help balance the building's pressure and prevent doors from flying open. The problem with these flaps is they're not very accurate, they tend to stick and generally don't work.

Economizers have no concept of what's going on in the building. They only turn on when the thermostat calls for cooling. Let's say the desired indoor temperature is 72°F and the actual temperature is 73°F. In a normal scenario, your thermostat requests cooling and that signal travels to the RTU, which holds the economizer. It would interpret the signal coming in from the thermostat as a request for cooling, even if the outside air is 60°F and ideal for free cooling.

Based on the enthalpy, the system would calculate that it would be less expensive to bring in free cooling, so the damper opens 100%. It would open a full 100% because typical economizers have no concept of how much cooling is required, they are simply fully open or fully closed as long as the mixed air temperature is above a minimum (typically 55°F). The economizer is now fully open and there's a whole lot of outside air flowing in. So let's hope that hinged flap functions properly, or you'll be left with excess positive pressure, forcing your doors to swing open.

TRADITIONAL DAMPER



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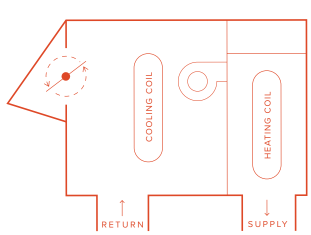
75F SMART MODULATING DAMPER



Even when the flap does operate, there's always going to be a fair amount of excess pressure built in, which is the same amount of pressure it takes to open that flap. Then as soon as the indoor temperature goes back to 72°F, the economizer will turn off. As described, typical economizers are 100% open, then 100% closed, all the time. So you end up having a huge amount of pressure in the building and then a sudden drop. This is how they work especially with mixed air temperatures of 55°F temperatures and above. If the mixed air temperature is below 55°F, some of them will modulate so that the air slowly comes to be 55°F. This would typically happen only when the outside air is around 35°F. However, if the outside temperature drops below 35°F, there's a good chance you don't need the free cooling anyway. Buildings mostly use free cooling when the outside air is 55-70°F.

In the case of 75F, we understand the building loads and we mix the indoor and outdoor air together to exactly satisfy the load, resulting in a space that is more consistent and comfortable. Instead of saying let's fully open the damper and then fully close it, 75F takes the overall average open percentage and simply opens the damper that percentage. For example, if an economizer is needed to be on for 10 minutes and then off for 15 minutes, that would mean it would be in use 40% of the time. So 75F opens the damper 40% for the full 25 minutes, alleviating the yoyo pressure scenario we ran into earlier. Now, a lot of outside air isn't rushing in all at once. This leaves you with a system that is more stable.

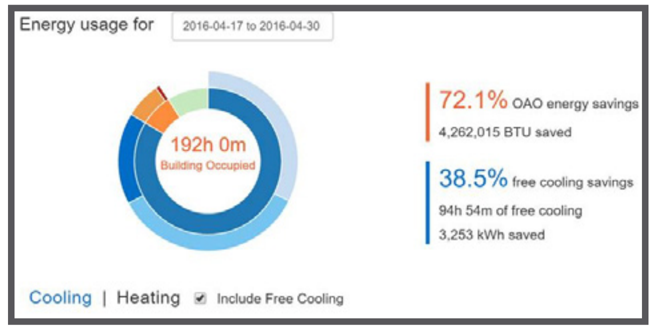
Restaurants in particular, must be mindful of pressure as their exhaust hoods expel a lot of gas, requiring new air to come in. That air has traditionally been replaced by a makeup air unit, which is a dedicated outdoor air system (DOAS). The problem is that these units are quite expensive, the installation is rather costly and they run 24/7. You've now got an RTU which is running for regular operations and a makeup air unit which runs solely for the purpose of tying back to the exhaust hoods. Finally, people said why not use an RTU as a makeup air unit and just keep its outside air damper open about 50% to compensate for the exhausted air? There is a problem with this theory however. Having the hood on constantly is not economical, because first thing in the morning, it's turned on at one fixed speed and then it expels a set amount of CFM all the time. The fryers are not yet turned on, cooling is unnecessary as there are no guests and now you're wasting a lot of energy. So restaurant owners started installing temperature sensors and infrared smoke sensors in exhaust hoods.

These sensors assess the exhausted air temperature to determine the size of the actual cooking load. As the cooking load increases, the exhaust speed ramps up to increase the amount of air being pushed out. The unfortunate part is that the RTU is never informed. So as this cooking load increases, the RTU has a fixed percentage opening and you end up going back to the same scenario of having negative pressure.

IS THERE A WAY TO CORRECT RESTAURANT PRESSURE IMBALANCE?

To correct this issue of excess pressure, 75F monitors indoor and outdoor pressure before opening the outside air damper the perfect percentage, to ensure pressure is forever maintained. This allows the hood to run independently. Even more importantly, the facility manager no longer needs to arbitrarily set the outside air damper to minimum value based on expected exhaust loads. When it comes to the cool air brought in by the 75F economizer, we can limit it based on pressure if needed. However, limiting free cooling would be extremely rare since we generally don't need to open the outside damper fully (see previous note on our modulation). This prevents positive pressure, which would result in the doors blowing open. In a restaurant, the pressurization piece is used both for positive and negative pressure.

IoT for verification. One of the most difficult things with standard economizers is verifying the operation of the units. Economizers are notorious for not being maintained and having dampers that stick, sensors that go bad or actuator motors that fail. One of the really cool things that 75F does, is it uses its sensors to actually verify that the economizing action is happening. This can be done by looking at the outside air temperature, the indoor air temperature and the mixed air temperature (the temperature of the inside air once it has been mixed with the cool air from outside). Not only do we use this to make sure that the economizer is working, we can actually calculate just how much energy we save, in real time!



The 75F system verifies the operation of economizer equipment and provides real time energy usage graphics, depicting just how much energy (BTU & kWh) is saved.

Lastly, enthalpy sensors go bad quite frequently. This occurs especially when they are exposed to outside air (especially hot, humid air), which they need to be to function. So 75F uses live weather feeds from reliable sources such as meteorological stations and airports instead. This IoT innovation eliminates one of the most common points of failure to the traditional economizers operation and allows the 75F solution to perform more reliably, delivering essential energy savings and superior IAQ.

In summary, for an economizer to be effective, it's got to factor in a building's temperature, humidity, pressure, air quality, thermal envelope and forecast weather. Today 75F has the most advanced outside and inside air optimization system in the world. IoT and cloud computing allows us to track these factors and use them for making proactive, smart decisions that heighten comfort and productivity. All the while, this smart solution lowers energy consumption and our carbon footprint.

ABOUT THE AUTHOR

Deepinder Singh founded 75F in 2012 after he designed some of the world's fastest core networks for Tier 1 service providers like AT&T, NTT and Verizon. With almost 25 years experience in electronics and computing, he's brought a wealth of embedded products to the market. His key goal in every endeavor is to simplify operational complexity and make products intuitive.

That's why he created 75F, an intelligent building solution that utilizes the Internet of Things and the latest in cloud computing to create systems that predict, monitor and manage the HVAC needs of light commercial buildings.