False Economy: An Analysis of Packaged Equipment Economizer Systems

Summary

Economizers don't work very well, especially in competitively-priced packaged HVAC units. This is important, because these types of units are applied in a majority of the commercial applications that exist in the USA and beyond. They are promised as an investment in energy savings, but they usually just serve to increase first cost to the owner, while failing to deliver savings to the tenant. Recently, their use has been codified (regulated) to a point that a design engineer is required to use them, even in scenarios that don't make sense, or could harm the public. This paper explores how an economizer is supposed to work, and two of the ways that they do not work. Future papers will explore code and other issues that surround this topic.

Background and History

An air-conditioning unit is equipped to provide the area it serves with cold air for space cooling. Cold air is generally produced using a refrigeration cycle that cools air flowing across a coil before it is supplied to the space. However, during the winter, or other mild seasons, the outside air may actually be at a temperature lower than the unit supply air temperature. One might imagine that it would be preferable to utilize this outside air, as it could be "free" cooling, without the need to use refrigerated air, which comes at the cost of operating an electrical compressor. This free-cooling concept has come to be known as "economizing," and the mechanism used to utilize free cooling on an air-conditioning unit is know as an "economizer."

Economizers are not really a neatly-boxed accessory that can simply be bolted on to a unit. Instead, they are an alternative concept of air dampers and control devices that allow the unit to choose between drawing its supply airflow from air returning from the space or from the outside. When the outside air is at a condition where it can be utilized for cooling, the outside air damper is opened, and the return air damper is closed. If a relief air path is provided, then that damper must be controlled as well, in unison with the other dampers.

Seems pretty simple, right? Along with the proper damper setup, electronic controls are provided that open dampers based on outside conditions. Various control schemes exist to do this, and a full understanding of them is available elsewhere. However, it is useful to understand that the economizer dampers are often at positions somewhere between fully open and fully closed. In theory, this functions as planned and offers a reduction in electric use when the economizer cycle is activated.

Economizers are inherently complex, difficult to understand, and difficult to implement.

If you don't find this explanation "simple," you are not alone. Economizers are inherently complex. If they cannot be explained easily, how can they be expected to operate simply and reliably? The real-life answer is that they don't deliver on their promise. Let's look at some of the reasons why.

Relief Air

If one is to introduce cool, fresh air into the space, then there must be a path of relief. Think of blowing into a balloon. One can blow air into it, but none will come out the other end. The balloon will pressurize and expand but not allow air to move through it. It may ultimately pop, but then the air will simply disperse. An economizer works in a similar manner. It may open and allow fresh air to enter a space, but if the air has no path to travel through, then no air actually moves through the space. No cooling will occur.

A relief air path can take many forms. One might be to install an air outlet separate from the unit. In an open space, this can function well and is know as "barometric relief." It is usually provided in the form of a roof hood or wall damper that must also be controlled. All of this comes at a cost. As spaces become more complex, with many rooms, then return ductwork becomes necessary. At this point barometric relief is no longer reasonable, because the pressure drop in the return ductwork is too much for the unit to push air through it. The solution to this is a fan, either a relief or exhaust fan. This may be provided separate from the unit, but only with additional equipment and controls. A properly sized relief fan can draw the same amount of air that is being supplied through the economizer through the return duct and out of the building. Under this condition, an economizer cycle can work well.

Both of the previous forms of relief air require additional equipment and cost beyond a typical packaged unit. That equipment can be expensive to install and control, and one might ask - isn't a packaged unit supposed to be a single package? Of course it is! There are many, many more applications that need relief than those that do not.

Most manufacturer relief fans are inadequate for the service they must provide.

Now, some units do have available accessories that include a relief fan. Going back some years, these were known as 50% exhaust fans. Early in my career, I asked where the option for a 100% relief fan was; I did not know of many projects where I needed just 50%. I never really got a good answer, usually it was something like "well, the building is going to leak quite a bit anyway, so 50% usually works just fine." In fact, today, these fans are no longer called 50% fans because they really don't even relieve a true 50%. One wonders why they are even offered!

Today, an energy-code compliant building does not leak in any significant manner. Energy codes prescribe a leakage rate that is associated with prescribed building materials and methods. It is a very small rate and will not even begin to support air relief from an economizer system. One building official that I have talked with, who had experience with building pressure leak tests, told me that of most tests that failed, they failed by leakage through the HVAC unit dampers!

The owner has paid for an expensive accessory, and will not realize any significant savings from it.

So, what happens when an economizer is utilized without a relief path, or with a grossly undersized relief fan? The building becomes pressurized, just like the balloon, and no fresh air moves through it. Unlike the balloon, the building will not pop. So, the compressors continue to run, and little to no benefit is realized from the economizer cycle. The owner has paid for an expensive unit accessory, and will not realize any significant savings from it. In addition, it is much more likely that the economizer will fail in some manner, sooner than later, and it will result in additional service charges over and above what a simple unit would have experienced. If a building energy model has been developed based on it working correctly, then any projected savings will not result. If actual savings are claimed, then they came from another source. Finally, if the economizer malfunctions in a manner that causes excessive fresh air to be drawn into the building during cold or hot weather, heating and cooling energy can actually increase dramatically over a simple unit. Often, the tenant has no idea what has happened!

So, do all packaged units have relief air problems? No, not all. There are units on the market that solve this problem adequately. However, they are usually of the "applied" category of equipment. A simple way to describe applied equipment is that it is not the low cost solution. It is usually set up to be customized to some degree, and it usually offers a higher quality level in most every feature of the unit. It is in the "competitive" category of equipment that the problem exists. This category is designed to offer a lowest first cost to buyers, often to developers who will rarely have to pay the utility bills for the space.

Unitary equipment is the largest and most significant market segment. It should be addressed as a priority!

Packaged equipment accounts for about 70% of all air-conditioned space in the USA. The lion's share of this is from the competitive category of providers, because first cost usually governs. Today's energy codes require 100% relief air as a part of the system, if not the unit itself. With packaged equipment having the market share that it does, it makes sense that these units should work efficiently as a package and certainly not malfunction from the day they are installed. We should be giving this sector of the market our utmost attention, as this is where savings potential exists.

Dampers

Most engineers perceive a damper as having sheet metal blades, formed in a traditional manner (V-bends), rotating on axles and bearings in a reasonably precise manner. Figure 1 shows a small damper that meets these expectations.

Figure 1 - A usual and customary air control damper.

There is a definitive industry standard for how a quality damper should be constructed.

This damper has reinforced blades (3V-style), rigid axles, and a rigid frame for the blades to operate within. The damper blades will interlock for a reasonable air seal. For certain applications, rubber blade seals and stainless-steel edge seals can be included (they are not on this damper). When they are, the damper can be certified as an AMCA Class 1 damper. Current energy codes require Class 1 dampers for all economizer dampers (outdoor air, relief air, and return air).

Unfortunately, most competitive packaged units don't utilize dampers that approach the quality of a Class I damper.

Figure 2 shows a competitive unit mixing box with both an outside air damper and a return damper, if one chooses to describe it that way. The outside air damper is a flat piece of sheet metal with 90-degree bends at each edge. One can notice the visible gap at each edge. This is an air leakage path. If the fresh air filter had been removed, one would see daylight through this gap.

Considering the competitive nature of the HVAC industry, one might understand, even accept a compromise in damper quality here. However, the train jumps the tracks when one considers the return damper.

This is a completely inadequate solution for an economizer application!

Figure 2 - View of Economizer Mixing Box

Figure 2 also shows a warped slab of plastic - this attempts to function as a return damper. I'll describe it as a "flapper." It is mechanically interlocked with the fresh air damper, although in just one location, at the side. Because of this, the flapper flexes, especially with air flowing around it to cause additional warp. It is quite difficult to visualize this combination of damper and flapper working in any type of accurate manner.

If one is to incorporate a quality economizer cycle into a packaged unit, then great attention is to be paid to air control dampers. First, an appropriately sized, air-tight fresh air damper must be provided. Second, a similarly sized relief air damper must be provided, with a 100% capable relief fan. There must be a path for both air streams to flow through. Finally, a damper must be provided to balance airflow between the supply air path and relief air path during partial economizing, otherwise known as an "integrated economizer." These dampers must be controlled in unison, or the resulting air flow imbalances will decrease the efficiency of the cycle.

Energy codes now require Class 1 dampers to be utilized for economizer service. This is a most reasonable requirement! To date, we have not seen a sincere attempt by competitive manufacturers to comply.

Conclusion

Economizers cost more to purchase, probably more to operate, and more to service.

Economizers, when correctly implemented, will save 9-12% of annual cooling energy. We reach these conclusions from our own energy models. Data from manufacturer presentations seem to confirm these values. However, when one understands that these savings will probably not be realized, an investment in the accessory seems pointless. Further, economizers that malfunction (most of them) can cause much greater energy usage than would normally occur. One would be much better served by investing in a higher-efficiency unit and keeping its operation simple.

Implementation of partial relief fans and ill-designed dampers render competitive packaged unit economizers as junk. Our field observations are that the cycle is usually disabled by the contractor in the field, often at startup. In fact, economizer controllers offer the ability to do so with relative ease. However, the owner has paid a handsome price for the accessory, and the tenant will never realize the cost savings that was paid for at startup.

This paper accomplishes a goal of explaining "simple" economizer accessories and their limitations. A separate paper will address past and current energy code requirements and implementation, advising how they have evolved over time. For the present though, one cannot reasonably claim code compliance for many, if not most of today's competitive packaged air-conditioning units.

applied
engineering

405 Erin Drive
Knoxville, TN 37919
www.appeng.com

For more information:

Contact: Jack Hopkins, P.E. Principal

Copyright 2018 Applied Engineering of East Tennessee, Inc. All Rights Reserved.