



Donald L. Beaty

Airside Economizers In Data Centers

BY DONALD L. BEATY, P.E., FELLOW ASHRAE; AND DAVID QUIRK, P.E., MEMBER ASHRAE

Over the last several years, energy consumption by data centers worldwide has become a topic of intense discussion beyond the data center industry itself. One of the more comprehensive studies was that by the U.S. Congress in Public Law 109-431 in which the EPA was mandated to quantify the electricity usage by U.S. data centers. The EPA published its findings in an official Report to Congress on Server and Data Center Energy Efficiency Public Law 109-431, 2007. The key finding of this study indicated that in 2006, U.S. data centers consumed 1.5% of *all* electricity used in the U.S. and that according to historical trends, this consumption was set to rise exponentially in the future.

This report effectively laid down the gauntlet for data center designers to increase their focus on energy efficiency to ensure that this exponential rise was not being compounded by the overdesign of data centers, (and especially their cooling systems) and ultimately became the catalyst for introducing cooling economization into data centers.

This column presents some of the history and the current day challenges surrounding airside economizers in data centers.

Traditional Data Center Cooling Systems

Traditional data center cooling systems were often referred to as “Precision Cooling;” a reflection of their tight management, tolerances and controls. Similar to the cleanrooms of the pharmaceutical industry, data centers only introduced the bare minimum quantity of outdoor air into the data center space (often through a separate independent system from the actual cooling system).

With a near 100% recirculation cooling system and low-temperature operation of the data center rooms themselves, it was very common for the power requirements for the cooling system to approach that of the power to the computer equipment. *Figure 1* indicates a typical breakdown of the total power requirements in traditional data center designs.

Pursuit of Lower PUE

The 2:1 ratio of total power to computer power indicated in *Figure 1* was known and accepted throughout the industry. However, in 2007 The Green Grid, a conglomerate of industry stakeholders dedicated to the efficient operation of data centers, published several white papers introducing the Power Utilization Efficiency (PUE) Metric. This new industry metric quickly became widely adopted and resulted in a heightened awareness of the importance of energy consumption in data centers (something that was instrumental with advancing aggressive industry measures to reduce it).

One of the primary methods to improve PUE was the adoption and deployment of economizers in data centers, including airside economizers. This was further enabled by the expansion of the *ASHRAE Thermal Guidelines* environmental envelopes (discussed later).

Airside economizers have a lengthy history of application within commercial buildings, but the initial reaction in the “ultra-conservative and risk adverse” data center industry has been very controversial. There was initial opposition to the inclusion of data centers within ASHRAE Standard 90.1 and most recently even more controversy as the result of many deployment problems across the industry.

Donald L. Beaty, P.E., is president and David Quirk is VP and principal at DLB Associates Consulting Engineers, in Eatontown, N.J. Beaty is publications chair and Quirk is chair of ASHRAE TC 9.9.

By 2010, ASHRAE approved a significant change in the Title, Purpose, and Scope of Standard 90.1 to include data centers (computer rooms). In doing so, they introduced prescriptive requirements for economizers, including airside economizers, despite fierce opposition from the data center industry members.

Despite the opposition towards prescriptive mandates, economizers continue to be viewed as the “low hanging fruit” opportunity for improving PUE and have been deployed in dozens of data centers.

Economizer Considerations

The choice of whether or not to use an economizer, and if so, what type to use, depends on a variety of factors including:

- Stated mission of the facility, especially those classified as mission critical;
- The total cost of ownership evaluation;
- Geographic locations;
- Existing building constraints on available space;
- Limitations on reliable water supplies;
- Poor air quality;
- Expected life of the facility;
- Technology refresh rates; and
- Freeze protection considerations.

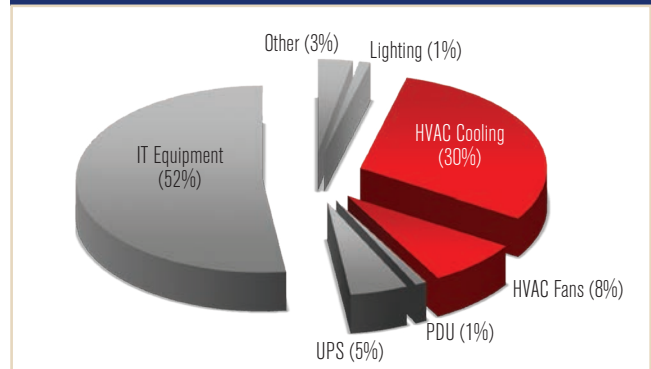
Data center economizers are not the same old commercial building economizer applications. This is where many owners and engineers have gotten themselves into trouble.

Some important factors to consider with data center economizers are as follows:

1. Economizer Options. There are many types of economizer options available, each with their own benefits and pitfalls, which must be evaluated for a specific application. Note, under the prescriptive requirements of ANSI/ASHRAE/IESNA Standard 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, many of these options are prohibited or have limitations placed on them, such as the use of refrigerant based economizers.

2. Economizer Economics. The economics of data center economizers is very complicated. While the 24/7 operation and year-round high loads of data center facilities offers greater savings potential, the higher reliability & redundancy, often tighter environmental controls, unpredictable load growth, sometimes non-constant IT loads, and much larger overall loads can drive up both initial capital costs as well as ongoing op-

FIGURE 1 An example of a traditional data center design power allocation.



erational costs which may make the economics unfavorable in many applications.

3. Mission Critical Operations. Many data center facilities have a critical mission and depend on long-standing, tried and true forms of HVAC cooling to ensure reliable, predictable, and highly available operations. In support of these goals, mission critical facilities often rely on high system and component redundancies to ensure availability of cooling. In many cases, economizers can compromise those redundancies as well as the tried and true forms of HVAC cooling. Economizers may not be the optimal solution to energy savings for all data centers facilities.

Airside Economizer Options and Overview

Airside economizers are generally categorized in a couple forms as follows:

- **Direct exchange.** Where outdoor air is directly introduced into the data center facility; this would also include adiabatic type air coolers.
- **Indirect exchange.** Where air-to-air heat exchangers are used to isolate the cooler outdoor air from the interior airflow, such that outdoor air is not directly introduced into the data center facility.

Airside economizers can be supplemented with a wet-bulb or adiabatic cooler creating what is known as an adiabatic economizer. This design features wetted media or spray type that uses adiabatic cooling to cool the air directly before going into the data center. This type of economizer can be beneficial in areas of high wet-bulb depression, such as desert regions. This design also adds humidity to the air as well as serves as a filter (air washing) medium, both of which can be useful in data center applications.

Geographic Considerations

Economizers are most commonly used in cooler climate zones, such as Zones 5 and higher per older versions of the energy code. More recent changes to the energy code push for economizers in all climate zones except Zone 1A.

Hypothetically, the expanded range of the Thermal Guidelines permits economizer mode in any climate zone, but only if the data center is operating in the allowable ranges or with higher class ratings of the installed hardware.

In terms of potential energy savings, the airside economizers with direct exchange of outdoor air will often offer the greatest potential energy savings from a thermodynamic standpoint, assuming there is not an indoor humidity requirement or contamination concern. This can be seen in the chart of annual mechanical refrigeration (chiller) hours in several global locations in ASHRAE's *Thermal Guidelines* publication (Figure 2). The relatively low number of chiller hours indicates the operation of airside economization for the majority of hours throughout the year.

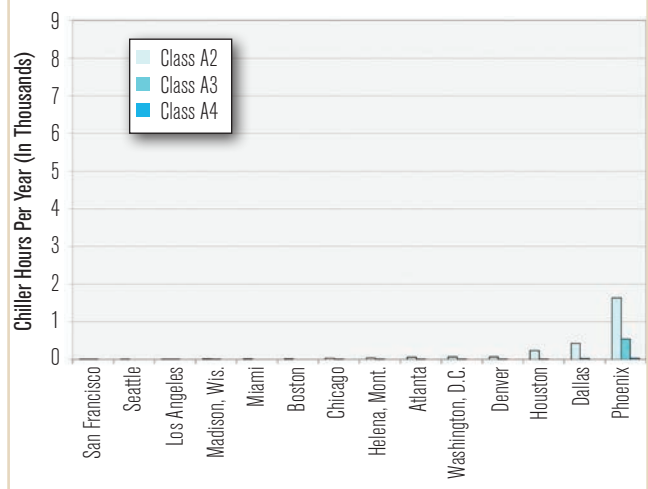
Thermal Guidelines

Equally important as the geographical environmental conditions, the internal environmental conditions of a data center play a significant role in the decision for economizers. If higher inlet temperatures and wider humidity conditions are deemed acceptable, the opportunities for savings can greatly increase. At the extreme, chillers can be eliminated from select designs.

The third edition of ASHRAE's *Thermal Guidelines for Data Processing Environments* introduced wider allowable entering air envelopes (Figure 3).

Energy efficient operation, through expanded allowable environmental envelopes, was previously tempered by unknown impact that higher temperatures would have

FIGURE 2 Number of hours per year of chiller operation required for air-side economizer for selected U.S. cities.



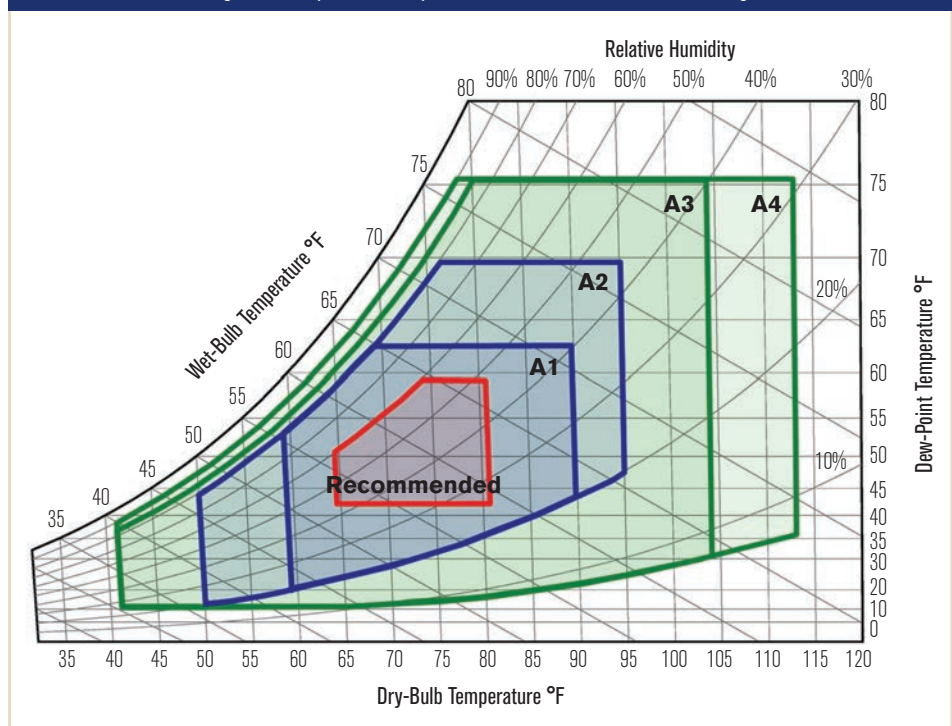
on the failure rates of the IT equipment as discussed in November's column ("X-Factor Explained").

Airborne and Gaseous Contamination Considerations

With direct exchange airside economizers (the most common application), airborne particulate and gaseous contamination need to be considered.

Recent changes to the manufacturing of electronics brought about by RoHS (discussed in December's

FIGURE 3 ASHRAE thermal guidelines expanded envelopes for recommended and allowable entering air conditions.



SOURCE: ASHRAE. MODIFIED BY DLB

ASHRAE Journal column entitled “Creating A Perfect Storm”) have created a condition where increased corrosion rates can occur on electronic hardware in select environments.

In short, there are real risks due to the improper control and introduction of outdoor particulate and gaseous contamination that can lead to premature failures in select data centers.

The publication from TC 9.9, Particulate and Gaseous Contamination in Datacom Environments, should be referenced for more details on the topic.

Controls

Airside economizer control is a more challenging topic to address in data centers. Part of this problem is brought about by several facts:

- There is no rating standard for the performance of economizers;
- Economizers have to operate at higher internal load conditions in data centers than in commercial buildings;
- Data centers have internal environmental control

limits 24/7 that must be met, including humidity and temperature limitations;

- Dynamic large plug load conditions, combined with multi-variable controls for pressure, temperature, and humidity; and
- Weather effects on the performance of economizers, including high winds, driving rains, and blowing snow conditions.

Airside economizers can be integrated or non-integrated control type. In the integrated type, the compressors can operate simultaneously with the economizer function. In the non-integrated type, the compressors shutoff when the economizer operates.

Both of these control strategies present unique challenges in the data center as follows:

- **Integrated type.** Extreme part-load conditions on compressors when operating in the integrated mode since compressors are already in a part-load condition in many data centers.
- **Non-integrated type.** Sudden changes in the system cooling method and system stability (compressors shutoff).

Advertisement formerly in this space.

Restart condition and issues with compressors (short-cycle timers, cold temperature restart conditions, etc.).

The economizer function is typically operated by what is known as the high-limit control. There are several commercially available options for economizer high-limit control as follows:

- Fixed dry-bulb;
- Differential dry-bulb;
- Fixed enthalpy;
- Differential enthalpy;
- Differential enthalpy + fixed dry bulb;
- Differential enthalpy + differential dry bulb;
- Fixed enthalpy + fixed dry bulb; and
- Dew point + fixed dry bulb.

In dry climates, such as found in the U.S. Southwest, dry-bulb only sensors may be sufficient to control the economizer cycle for commercial office space. In most climates however, the switchover from chiller operation to air-side economizer mode for data centers should be based on enthalpy controls, not on dry-bulb temperature alone.

Advertisement formerly in this space.

Standards and Codes

Standard 90.1 was amended to include data centers (computer rooms) within the scope of the 2010 edition. Additional addenda have subsequently been approved, which establish some specific criteria for data centers, including some key exemptions for economizers.

This change prompted a reaction from the industry, including TC 9.9, to sponsor a new ASHRAE Standard specific to data centers. In 2012, ASHRAE approved a new committee to produce a new Standard 90.4, *Energy Standard for Data Centers and Telecommunications Buildings*.

This standard takes a performance based approach in recognition of all the variables in data center applications including:

- The many options for cooling available in the data center industry;
- Rapid change and innovation in technology in the data center industry;
- The various risk considerations for different types of data center applications; and
- There is no industry rating standards on performance of economizers and it's largely not researched yet.

The first publication public review draft of this Standard was recently released for industry comment.

Closing Comments

Airside economizers offer a tremendous opportunity for energy savings and lower PUE's, particularly when combined with the wider thermal envelopes published in the third edition of *Thermal Guidelines*.

The application of economizers in data centers has pushed the engineering boundary conditions of economizers and introduced new unintended consequences. Airside economizers applied to data centers have proven much more difficult than originally thought by many.

There are a number of additional design considerations that require a careful review and thorough understanding prior to implementation. The industry is currently void of the appropriate research and rating standards for the performance of airside economizers within data center applications.

Airside economizers offer a sustainable promise for future data centers, but only once the problems with the application are ironed out and these voids are filled. In the meantime, careful application and engineering will be necessary to ensure their success. ■