AN INNOVATIVE APPROACH TO ECONOMIZERS IN DATACENTERS

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ABSTRACT

Datacenters are the backbone of a modern society, facilitating mission critical functions such as communications, commerce, scientific research, and national defense. Along with these benefits, datacenters have grown in size, scope, and numbers to the point where they consume a relatively high percentage of the electrical energy used in the United States. This has become a national concern on many levels. Power Usage Effectiveness, or PUE [1], has become an accepted industry metric for evaluating the ratio of the total power consumed by the facility to the amount of power required to run the IT equipment. The lower the PUE, the more efficient the datacenter is judged to be. One of the most efficient methods to reduce the overall PUE of the datacenter is to reject the heat directly to the environment without the need for mechanical refrigeration using economizers.

This paper discusses an innovative approach to the use of economizers in order to mitigate some of the common concerns associated with the use of either airside or waterside economizers. Closed circuit cooling towers coupled with air-cooled chillers will be explored as a means to minimize energy usage, improve reliability, minimize first costs, and alleviate common concerns associated with the use of economizers. A background on airside and waterside economizers will first be presented and then the advantages of a closed circuit cooling tower based waterside economizer will be examined.

THE ROLE OF ECONOMIZERS

Datacenters typically have cooling loads 24 hours per day, seven days a week, for every week of the year. In most climates, datacenter cooling needs can be satisfied during part of the year using cooler outdoor ambient temperatures to either supplement or replace the use of mechanical cooling. This process is known as an “economizer” or “free cooling” because the higher energy mechanical equipment can be shut-off or operated at reduced loads. Cooling can instead be provided by taking advantage of outdoor ambient conditions at significantly lower energy consumption.

The potential benefits of economizers in datacenter applications fall into the following two broad categories:

1. Environmental or “Green”
   a. Potential for reduced energy consumption resulting in lower greenhouse gas and other pollutant emissions.

2. Operational
   a. Potential for additional disaster recovery approaches (two independent, yet complementary cooling sources).
   b. Reduced life cycle costs through lower overall energy use and increased service life of mechanical equipment.
   c. Maintenance – Two independent cooling systems provide additional downtime options for routine maintenance while ensuring continuous operation.

TYPES OF ECONOMIZERS

Economizers fall into two broad categories – airside and waterside. Airside designs bring cool outside air directly into the center to cool the IT equipment. Waterside economizers cool the chilled water loop in the datacenter using a heat rejection device, such as a cooling tower or dry cooler.

For the purposes of datacenter applications, the following additional sub-categories are defined:

1. Airside
   a. Direct exchange – where outside air is directly introduced into the datacenter facility; this category would also include direct adiabatic type air coolers
   b. Indirect exchange – where air-to-air heat exchangers are used to isolate the cooler outside air from the interior airflow, such that outside air is not directly introduced into the datacenter facility; this option would also include indirect adiabatic designs.

2. Waterside
   a. Direct exchange – where condenser water is supplied directly to the cooling coils. This approach is rarely used in modern datacenters.
   b. Indirect exchange – where a heat exchanger is used to separate the economizer and chilled water loops.

AIRSIDE ECONOMIZERS

In simplest terms, direct airside economizers bring outside air into the conditioned space to provide equipment cooling whenever the outdoor air is sufficiently cool. A properly sized air intake damper system, fan, filter bank, connecting ductwork, and controls are the primary components of an airside economizer subsystem.

Indirect airside economizers use a dual ductwork system with an isolating heat exchanger, such as a run-around loop with dual finned coils in the opposing ductwork or a heat wheel to isolate the two airstreams. Although this arrangement introduces heat transfer inefficiencies, the chance of outside air contamination is reduced significantly.

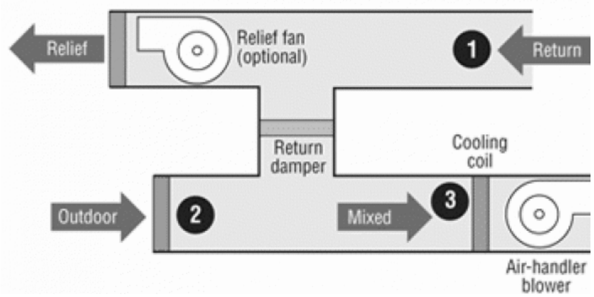

FIGURE 1: AIRSIDE ECONOMIZER [2]

Airside economizers fit in well on systems with central station air handlers rather than individual computer room air conditioning (CRAC) units because the air-moving system can more easily access outside air by being located close to outside air sources such as exterior walls and roofs. [3] Retrofitting of existing datacenter facilities with airside economizers can be expensive and problematic due to the need for large ductwork, outside air louvers, motorized dampers, and controls.

Another type of airside economizer is known as the wet-bulb or adiabatic economizer. This design features wetted media that utilize adiabatic cooling to cool the air directly before going into the datacenter. Adiabatic designs expose the incoming airflow directly to water, which is absorbed into the airstream, using the heat energy of the airstream itself to evaporate the water and in turn cool the airstream. These units can be spray (atomizing) type or wetted pad. This type of economizer can be beneficial in areas of high wet-bulb depression, such as desert regions. Areas of high “wet-bulb depression,” which is the difference between the dry-bulb and the wet-bulb temperature of the entering air, offers the potential for increased hours of economizer operation. 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 datacenter applications. Adiabatic economizers do require an appropriate source of water as well as a water treatment program. Furthermore, the impact of a failure of the water system must be considered in the design of the infrastructure so as not to affect the datacenter operation.

Airside economizers can operate in both partial (integrated) or full economizer mode. In the former case they help to reduce the load on the primary cooling system; and in the latter case, they completely replace the operation of the primary cooling system. Transitions into an out of economization must be handled properly to avoid interruptions to cooling of the datacenter.

WATERSIDE ECONOMIZERS

Waterside economizers typically consist of a liquid-to-liquid heat exchanger, a cooling coil and an outdoor heat rejection device, such as a cooling tower. The cooling tower produces cold water for cooling whenever the outdoor wet-bulb temperature or, in the case of a dry cooler, whenever the outdoor dry-bulb temperature is sufficiently low enough to provide meaningful cooling.

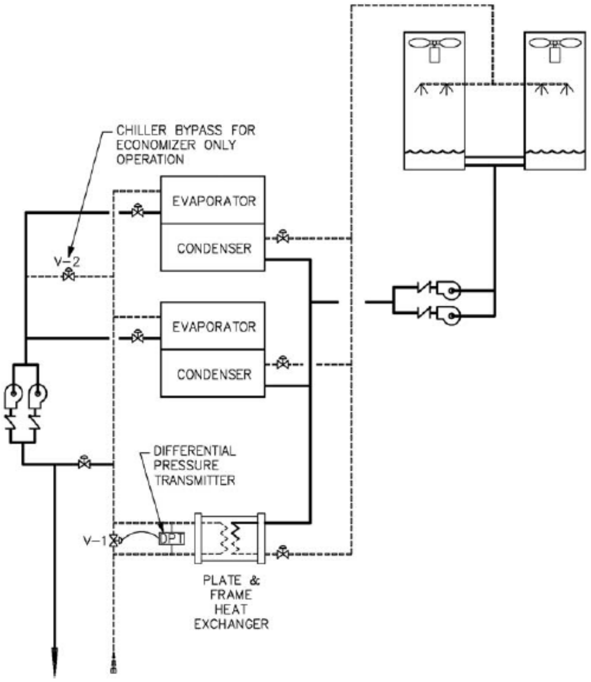

FIGURE 2: TYPICAL HEAT EXCHANGER BASED WATER ECONOMIZER [4]

The cooling coil in an air handling unit provides datacenter cooling by using the chilled fluid cooled by the outdoor heat rejection device supplementing or replacing the cooling by the chiller. In the case of a liquid-to-liquid heat exchanger, the fluid cooled by the outdoor device is used to indirectly cool the chilled water loop, which continues to be distributed to the datacenter air management system to cool the datacenter. As with the airside economizer, the waterside economizer can either operate in a partial (integrated) or full economizer mode. Like airside economization, transitions into and out of economization must be handled properly.

Because only relatively small amounts of outside air are required for ventilation purposes in datacenters, the use of waterside economizers can limit the risk from sources of outside contamination and provides better humidity control. This is due to the majority of the datacenter cooling being provided through a closed loop fluid stream which is not exposed to the datacenter’s environment, so there is little chance of contamination. The outside ventilation air volume is relatively small compared with that required for an airside economizer and is comparatively easy to monitor, filter, and control.

Waterside economizers are utilized where the combination of load profile, climate, and application requirements provides the energy savings and operational advantages to justify any additional equipment cost required. Waterside economizers are particularly attractive in areas of high wet-bulb depression, such as desert areas. The low wet-bulb allows for more economizer hours per year and can reduce the need for humidity control. Datacenters with high heat load densities benefit from the elimination of large ductwork, which provides more usable space within the facility.

ECONOMIZER DESIGN CONSIDERATIONS

Several critical issues come into play when selecting economizers for the datacenter environment. Issues such as high levels of guaranteed uptime and reliability, control of the rate of change of both temperature and humidity, and the availability of adequate cooling in response to sudden changes in the exterior environment must be addressed. This, in turn, makes the choice of both the system type and the specific system design critical, primarily involving areas such as contaminant and humidity control. These and other factors can play a key role in the type of economizer system selected.

Some of the common challenges encountered with the datacenter mechanical systems are highlighted below.

Outside Air Humidity

Even though the allowable range as listed in ASHRAE's Thermal Guidelines for Data Processing Environments is wide, moisture control is still critical in most datacenters. Although airside economizers are attractive in terms of energy savings and simplicity, large and varying amounts of outside air are brought into the datacenter. As such, humidity control must be factored into the control algorithms in order to allow only outside air into the center when humidity conditions are acceptable. High humidity can result in circuit board failures due to condensed moisture while low humidity can result in damage to the electronics from electrostatic discharge (ESD). Humidification and/or dehumidification can be integrated into the system if required, although the operating cost of the humidity control system can offset much of the savings of airside economizer operation while increasing operational risk. Algorithms that shut down an airside economizer when the humidity is out of bounds reduce the potential hours of economization, which need to be taken into account in any economic and energy analysis.

Proper placement of outside air intake louvers is essential to guard against the entrainment of contaminants, such as warm, corrosive boiler exhaust or cooling tower discharge which can contain warm, moist air as well as contaminants. The intake louvers must be rain proof and avoid moisture ingress from heavy fog that can penetrate louvers even when they have been properly sized and selected to minimize rain penetration. The large outside air louvers, both intake and exhaust, must also be rain (and snow) tight and self-closing in the event of a failure.

Note that the impact of economizer operation on humidity is less critical with waterside economizers, as little moisture is created in a datacenter and the quantity of outside air is based solely on ventilation requirements, which are generally low.

Outside Contaminants

Contaminants must be kept out of datacenters to prevent damage to the electronic equipment and avoid operational issues. Waterside economizers do not require outside air to be brought into the datacenter beyond that required for normal ventilation for the operators and to prevent the buildup of internally generated contaminants. The datacenter cooling loop is typically a closed system, which avoids the potential for contamination from sources such as condenser water.

Direct airside economizers, on the other hand, bring in large and constantly varying amounts of outside air. This allows the potential for contamination to enter the datacenter, including both particulate and gaseous contamination. Steps must be taken to properly design the system, maintain adequate filtration, provide the appropriate contamination sensors and locate them properly in the ductwork, and guard against the induction of contaminants from multiple potential sources.

Access to Outside Air

Airside economizers must have access to cool, fresh outside air as well as a means to exhaust the heated air. This can be accomplished using louvers on the walls or roof of the datacenter facility, which can present architectural and retrofit challenges on many facilities. Due to increasing energy densities, the airflow volumes required become quite large, in turn, requiring large duct work which takes up space within the datacenter. In addition, datacenter operators may not allow roof penetrations over the server and electrical distribution support areas due to the risk of water infiltration.

Rooftop central air handling units with integrated roof intakes or sidewall louvers can also be utilized. Distributed down-flow CRAC units are also available that offer airside economizers, but these units can limit future layout changes and the multiple outside air inlets complicate maintenance. The multiple intake and exhaust louvers must be located so as to prevent re-entrainment of the waste heat as well as avoid other potential sources of contamination, as mentioned earlier.

Filtration Requirements

Datacenter facilities using airside economizers require a high level of filtration for outside air introduced into the electronic equipment area over and above that normally required for human occupancy areas. Dust and other contaminants can result in operational problems with sensitive electronic equipment. For datacenters with higher gaseous contamination levels, gas-phase filtration of the inlet air and the air in the datacenter is highly recommended to maintain high reliability of the IT equipment, avoid the cost of hardware replacement, and comply with the stated mission of the facility.

Filtration requirements are typically higher if the air intakes are located close to the potential sources of contamination such as exhausts from other buildings, loading dock and employee parking areas, dust / exhaust from heavily traveled roads, nearby construction sites and factories, power plants, sources of pollen, cottonwood trees, farming areas, exhaust from cooling towers, generator exhaust, etc. Caution must also be exercised against unanticipated, infrequent but highly plausible events, such as a brush fire in an adjacent field or a sandstorm in a nearby desert area.

The higher level of filtration required by datacenters increases the airside pressure drop, resulting in increased fan energy to move the required amounts of air. The additional fan energy required for the filters and mixing sections are a necessary part of airside economization.

Filters also need to be serviced on a regular basis to both maintain their effectiveness and minimize unnecessary fan energy use. The maintenance costs associated with filter inspection and filter changes, along with periodic cleaning of outdoor air intakes should be taken into account when designing an airside economizer system as well as in any economic evaluation.

Security

In today's world, security concerns also must be taken into consideration. The air intakes for a critical datacenter facility can be a prime target for a terrorist attack. While special sensors can be installed in high-security datacenter facilities to shut down the air intakes, it is virtually impossible to guard against all possible threats of this nature. As such, the large air intakes and exhausts must be in a protected location behind the security perimeter. Rooftop intakes can offer advantages from a security perspective, but may suffer from the heat island effect of the building. Warning sensors for high security installations can be placed in the ductwork to shut down the intake louvers should a problem be detected, including the entrance of unauthorized personnel. In any case, the louvers must be able to be quickly shut, either automatically or by operational personnel in the event of an emergency, and the cooling switched over to the mechanical cooling system. Lastly, the louvers and ductwork must be located and designed such that they do not allow the entrance of birds and vermin from the surrounding area.

Operational and Maintenance Challenges

Airside economizer louvers and ductwork present additional challenges associated with louver maintenance. The louvers must also have the ability to open and close reliably as well as be designed to be "fail safe" in the closed position to protect the datacenter facility. Louvers must also have the proper wind ratings for the specific location. The dampers must be properly controlled and sequenced to ensure proper economization is accomplished as well as avoid issues such as over-pressurization of the building. Note that additional return and relief fans and additional humidification equipment with its associated maintenance are also not typically required for waterside economizer systems.

As stated earlier, outside air intakes should also not be placed near external heat sources. Any elevation of intake air temperature over the ambient will reduce the effectiveness of the airside economizer system, requiring the mechanical cooling system to work harder and longer to maintain the desired interior conditions, as well as challenge the control system to maintain the proper set points in the datacenter facility. Minimizing such recirculation on larger datacenter facilities can be difficult due to the large volume of intake air coupled with the large amount of heat that is discharged.

The air intake louvers must be high quality, corrosion resistant, and rain tight, especially in areas prone to storms such as near coastlines. Depending on the location of the outside air filter, carryover snow could accumulate at the filter and block the airflow. The melted snow, along with organic particulates on the filter provides an environment for mold growth, which can threaten indoor air quality. [5] Regular maintenance checks of the filter banks should be made during heavy snowstorms. Water-side economizers, although less prone to these issues, still require adequate freeze protection and effective water treatment to allow proper operation of the economizer system in colder climates.

Space Considerations

As mentioned elsewhere, large ductwork and intake and exhaust air openings are required for airside economizers. Waterside economizers require space for heat exchangers, cooling towers, pumps, etc. Retrofitting an existing datacenter with an airside economizer can be difficult because of the challenges and contamination risks involved with creating air openings. In contrast, water side economizers can be retrofitted into an existing system given the availability of space for the economizer equipment and availability of isolation valves for integrating an economizer into the existing mechanical system, as shown in Figure 2 and Figure 5.

Make-up water Availability

According the latest Tier level requirements [6], onsite make-up water storage is required for Tier III and Tier IV sites using water-cooled chillers and evaporative cooling equipment such as cooling towers. The make-up water system must be concurrently maintainable to the point of delivery for a minimum duration of 12 hours. As cooling towers can consume large amounts of make-up water, the availability of water especially in drought-prone areas, the size of the make-up water storage systems, etc. should all be taken into account when designing the mechanical system for a datacenters. The use of alternate water sources, such as reclaimed water and rainwater harvesting, is growing for this reason.

Water use in a cooling tower is tied to three factors: the heat rejection load, the blow-down rate, which is the amount of water that is discharged to prevent the accumulation of solids in the cooling water, and the entering air temperature and humidity. In general, the colder the ambient air, the less water is consumed by evaporative heat rejection equipment versus design, as can be seen in Figure 3. Because of this factor is often neglected, water use by cooling towers is often overestimated.

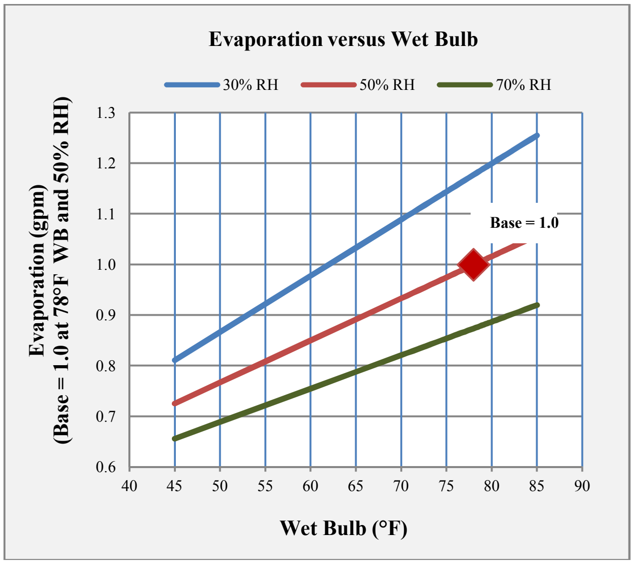

FIGURE 3: EVAPORATION VERSUS WET BULB TEMPERATURE [7]

The blow-down rate determines the water chemistry, or cycles of concentration (or number of times the solids in a volume are concentrated), of the recirculating water, and can vary depending on makeup water quality, the treatment program, and the tower's materials of construction. The higher the cycles of concentration at which the cooling towers can be operated at, the lower the amount of water that must be bled from the system, leading to reductions in water use. However, the risk of scaling, corrosion, and microbiological growth increases with higher cycles, which must be taken into account in the design of the water treatment program.

In general, closed circuit cooling towers have less stringent water treatment requirements since the process fluid is isolated from the environment and the external recirculating loop volume is relatively small. This allows closed circuit cooling towers to typically operate with a lower blow-down rate, thereby reducing the make-up water requirement when compared to open circuit cooling towers. Additionally, when the back-up cooling is provided by an air-cooled chiller, which does not use water on site, the need for backup water sources to maintain the datacenter's Tier rating is greatly reduced or eliminated.

EXPLORING ECONOMIZER ALTERNATIVES

Like airside economizers, waterside economizers rely on cool ambient temperatures to replace mechanical cooling to save energy. In a typical waterside economizer arrangement, a cooling tower or a dry cooler utilizes the ambient air to cool the fluid, typically water or an aqueous glycol solution. The cooling energy is transported in the liquid rather than the air as in the case of an airside economizer system. While it may at first seem inefficient to use an indirect heat transfer medium as opposed to a direct air economizer system, water and other heat transfer fluids can move pound-for-pound nearly 42 times the amount of heat as compared to air. Looking at this another way, over 3,700 times more air volume is required to transport the same amount of heat as is contained in the equivalent volume of water.

All heat transfer processes introduce some inefficiencies due to the required temperature difference across the heat exchanger, be it a cooling tower, plate-and-frame heat exchanger, or a dry cooler. This temperature difference is referred to as the "approach temperature." In general, the closer the specified approach is, the larger the heat exchanger but the more hours of economization are possible. Typical design approach temperatures for various heat transfer devices are shown in Table 1 below.

TABLE 1: TYPICAL APPROACH TEMPERATURES FOR HEAT EXCHANGERS

Type of Heat Exchanger	Comparison Temperature	Typical Design Approach Temperature* (°F)
Open-Circuit Cooling Tower	Entering Wet-Bulb	5 to 7
Closed circuit Cooling Tower	Entering Wet-Bulb	7 to 12
Finned Dry Cooler	Entering Wet-Bulb	15 to 20
Adiabatic Finned Dry Cooler	Entering Wet-Bulb	10 to 15
Plate and Frame Heat Exchanger	Process Fluid	3 to 5
Direct Evaporative Cooler	Entering Wet-Bulb	10 to 15

*Approach = Comparison Temperature minus the Leaving Fluid Temperature

Datacenter facilities equipped with water-cooled chillers will typically have cooling towers that can be used for waterside economization. On the other hand, air-cooled mechanical systems typically do not have economizers or utilize airside economizers. Designers select air-cooled mechanical systems, such as air-cooled chillers, for reasons of simplicity, low first cost, when only a relatively short datacenter design life is specified, and / or water costs and availability, which may offset the energy penalty of such systems on certain datacenters. However, when there is a concern over energy use, humidity control, contamination from outside air, and / or a lack of space inside the datacenter, the efficiency of an air-cooled chiller plant can be improved significantly through the use of waterside economization using either an open circuit cooling tower / heat exchanger combination or a closed circuit cooling tower.

Closed circuit cooling towers, also sometimes referred to as "fluid coolers," operate on the same basic principle of evaporative cooling as do open-circuit cooling towers, except that the process fluid to be cooled is kept isolated from the open loop spray water in a clean, closed loop. The heat load to be rejected is transferred from the process fluid (the fluid being cooled) to the ambient air and the spray water through a heat exchange coil. The coil serves to isolate the process fluid from the outside air, keeping it clean and contaminate free in a closed loop. This creates two separate fluid circuits: (1) an external circuit, in which spray water circulates over the coil and mixes with the outside air, and (2) an internal circuit, in which the process fluid circulates inside the coil. During operation, heat is transferred from the internal circuit, through the coil to the spray water, and then to the atmosphere as a portion of the water evaporates.

There are two main types of closed circuit cooling towers – coil only and coil / fill towers, as illustrated in Figure 4. The coil only cooling towers (bottom figure) are counter-flow in nature with air moved by axial or centrifugal fans in a forced draft or induced draft manner (induced draft axial fan configuration shown). Coil / fill versions (top figure) utilize cooling tower fill to boost the performance of the closed loop coil significantly. This is accomplished by using the fill to sub-cool the spray water before it flows over the coil surface, thereby increasing the unit capacity as well as the heat transfer efficiency, resulting in lower unit fan energy. Additionally, because most of the evaporation occurs in the fill section, the coil surface tends to stay cleaner and thus perform at a higher level over time. The lower spray water temperature as compared to coil only closed circuit cooling towers also tends to reduce scaling tendencies and hence are more preferable for the datacenter applications. Closed circuit cooling towers are typically equipped with an integral spray pump to recirculate the open-circuit water over the heat transfer surfaces.

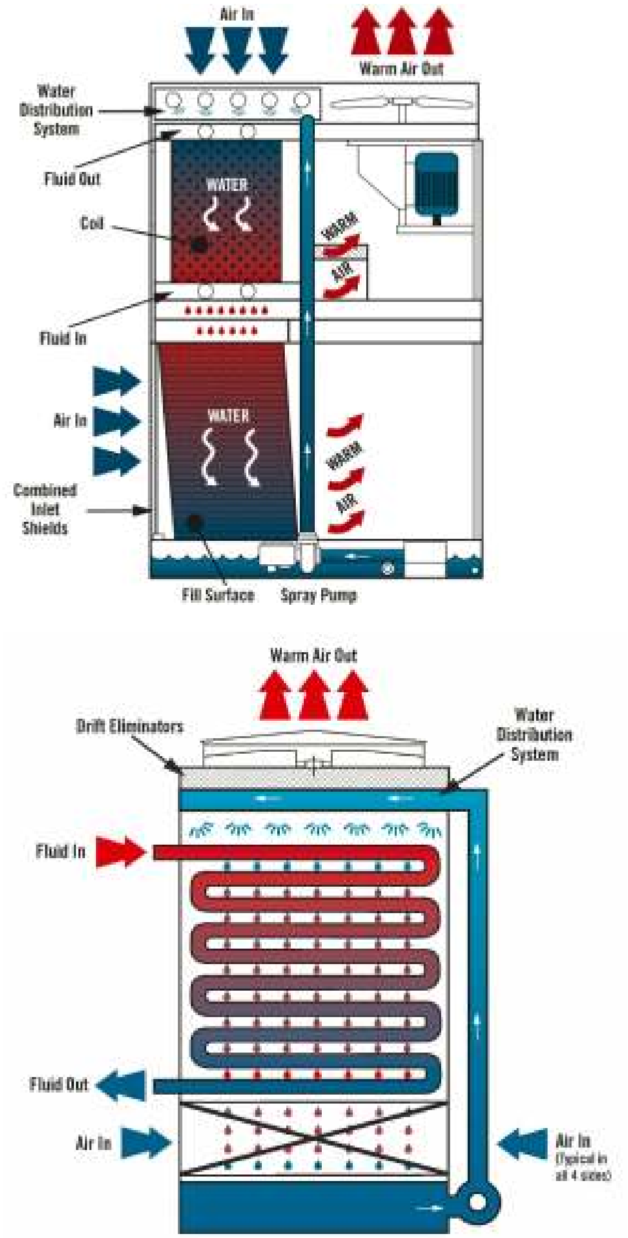

FIGURE 4: CLOSED CIRCUIT COOLING TOWERS [8]

A chiller plant waterside economizer using closed circuit cooling towers can be integrated, meaning the economizer can meet all or some of the load while the chiller meets the rest of the load, or non-integrated, meaning the economizer can only operate when it can meet the entire load. [4] To have the possibility of an integrated waterside economizer operation - the closed circuit cooling tower must have the capability to be piped in series with the chillers. [9]

Figure 5 shows an integrated waterside economizer in a variable primary chiller plant with two chillers in an N+1 redundancy configuration. The closed circuit cooling tower is in series with the chillers on the chilled water return side. The economizer is designed to operate in conjunction with the mechanical cooling system to help shave part of the compressor load. Such arrangement can provide a significant number of hours of either partial or full economization. This can be especially beneficial compared to running the less efficient air-cooled chiller for supporting datacenter cooling needs.

When the outdoor air wet-bulb temperature is low, the closed circuit cooling tower fans are run at high speed to produce the desired chilled water temperature set-point. If the economizer cannot bring the chilled water temperature down to the supply temperature set-point, then the chiller(s) pick up the remaining load and bring the water leaving the chilled water plant down to a desired set-point.

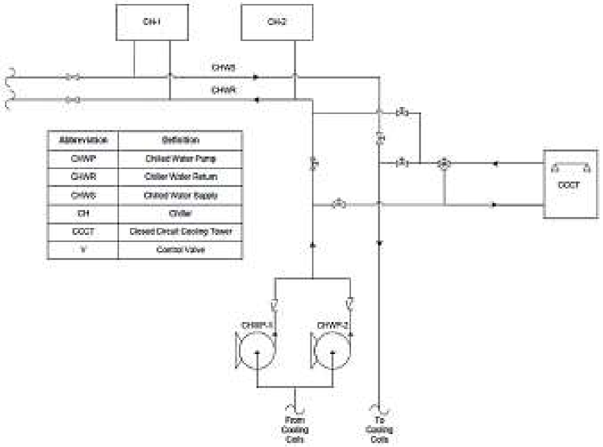

FIGURE 5: INTEGRATED WATERSIDE ECONOMIZER USING CLOSED CIRCUIT COOLING TOWERS

The closed circuit cooling tower should have the “capability” to be piped in series with the chiller. Capability refers to the integration of motorized valves and bypass piping. The valves can be actuated in a manner that redirects the flow between the closed circuit cooling tower and chillers, routing fluid through the closed circuit cooling tower first and then on to the chillers (i.e. series configuration). For partial free cooling, the CHWR from the datacenter cooling coils is routed to the closed circuit cooling tower first and then to the chillers. For full free cooling, the CHWR from the datacenter cooling coils is routed to the closed circuit cooling tower and the chillers are bypassed completely. In some cases, for simplicity in piping and especially when pressure drop through the chillers are minimal; the chilled water is allowed to flow through the chillers even when operating in 100% free cooling mode.

ADVANTAGES OF CLOSED CIRCUIT COOLING TOWER BASED WATERSIDE ECONOMIZERS

Closed circuit cooling towers permit operation without refrigeration well above the usual ambient dry-bulb temperature limits of airside economizers or systems using dry-coolers for waterside economizer in most climate zones. A closed loop system protects the quality of the process fluid, reduces system maintenance, and provides operational flexibility. Closed circuit cooling towers come at a comparable initial cost compared to an open-circuit cooling tower/heat exchanger combination. Both types of cooling towers should be CTI certified and the plate and frame heat exchanger should be AHRI-400 certified to assure an apples-to-apples comparison. Note also that the approach temperature is similar between the two alternatives. From Table 1, the combination of the 5°F to 7°F approach of an open circuit cooling tower with the 3°F to 5°F approach of a certified plate and frame heat exchanger compares favorably with the typical 7°F to 12°F approach for a closed circuit cooling tower.

Closed circuit cooling towers can be chosen over open-circuit towers for datacenter facilities for three primary reasons. First, the reliability and lower maintenance of the clean, closed loop is an operational advantage. Second, closed circuit cooling towers do not require the use of an isolating heat exchanger for economizer duty when cooling water. This saves the maintenance of having to break down and clean plate and frame heat exchangers, which can be expensive and time consuming. With closed circuit cooling towers, any scaling that occurs on the outside surface of the tube can be handled through the water treatment program and the inside of the tube only sees the clean closed loop fluid. Third, closed circuit cooling towers have the ability to run dry in colder temperatures. This can be advantageous for sites that are concerned with water cost and availability, plume in colder climates, or the potential for icing of the cooling tower in cold weather. The coils can also be finned to increase the hours of dry operation.

In freezing climates, there is a risk of the coil in the closed circuit cooling tower freezing when the unit is idle. In datacenter applications, heat loads are typically high and constant, reducing (but certainly not eliminating) this threat. If coil freezing is a concern, the use of aqueous glycol solution and / or the use of a positive closure damper (PCD) hood are recommended. PCD hoods help to hold the heat in the coil during shutdowns. In addition, when using water as the process fluid a minimum flow should be maintained through the coil along with a small auxiliary heat load when the unit is idle to maintain a fluid temperature of approximately 45°F leaving the coil anytime the ambient temperature has a chance of falling below 32°F.

FIGURE 6: TYPICAL CLOSED CIRCUIT COOLING TOWER WITH PCD HOOD TO REDUCE HEAT LOSS IN COLD WEATHER [10]

Using closed circuit cooling towers with air-cooled chillers for economization offer advantages in terms of reduced system complexity, improved reliability, and better controllability. The addition of a closed circuit cooling tower, spray pump, control valves, and associated piping is all that is required in terms of additional equipment. The requirements for outside air and the associated risk of humidity control and potential contamination is substantially reduced. Transitions into and out of economization, one of the greatest operational risks to most economizer based systems, are more easily controlled.

Waterside economization with a closed circuit cooling tower is useful whenever the combination of wet-bulb temperature plus the closed circuit cooling tower approach is lower than the temperature of chilled water returning from the load. The wet-bulb temperature is always equal to, or lower than the dry-bulb of the air, which provides an advantage for evaporative cooling.

The air-cooled chillers are sized to handle the entire cooling load for when the closed circuit cooling towers cannot contribute to the cooling duty due to high wet bulb temperatures. Because of this, the challenges associated with maintaining make-up water storage and the concurrent maintainability of make-up water distribution are substantially resolved. Conversely, the closed circuit cooling tower serves as a back-up to the air-cooled chiller, even on a design day, where it can allow the system to continue operating, albeit at some combination of reduced load and / or higher datacenter temperature.

Air-cooled chillers have lower efficiencies at both peak and off-peak loads than comparable water-cooled chillers. However, recent advancements in air-cooled chiller technology and the introduction of VSD compressors and magnetic bearings have reduced the absolute difference between the two technologies, especially for non-design day ambient conditions and at part loads. Therefore, for this strategy to be fully effective, variable speed, high efficiency air-cooled chillers must be utilized. Even with their use, the effect of a high summer peak when economization is not possible should be evaluated relative to their influence on auxiliary systems such as generator set sizing and the impact of electrical utility demand charges on operating expense.

The overall energy efficiency of an air-cooled chilled water plant can be improved and the sound emissions can be reduced when using closed circuit cooling towers as opposed to airside economization or the use of dry coolers for waterside economization. Installing or retrofitting a closed circuit cooling tower is often less expensive than the first cost of large architectural louvers, dampers, ductwork, filters, and two sets of fans required for retrofitting an airside economizer in an existing, non-economized datacenter. If the primary cooling system is based on chilled water or glycol, the same cooling coils can be utilized for both mechanical and free cooling cycles. Note that many air-cooled chiller systems in colder climates utilize an aqueous glycol solution for freeze protection as the chillers are located external to the facility, which simplifies freeze protection for the closed circuit cooling towers.

CASE STUDY

The purpose of this section is to evaluate chiller plant performance for a typical datacenter application at a specific operating point to demonstrate how a closed circuit cooling tower based waterside economizer can reduce energy usage compared to a conventional air-cooled chiller plant with no economizer. The project includes 1,200 kW of IT load with an approximate cooling load of 1,354 kW (386 tons). The datacenter consists of a 10,000 ft^2 (IT Load: 120 W/ft^2) space with a Tier III topology for the mechanical system. The cooling load is met by one air-cooled chiller with variable speed compressors and fans. A closed circuit cooling tower was added in series with the air-cooled chillers to provide waterside economization. The efficiency of the air-cooled chiller and closed circuit cooling tower at varying ambient and load conditions is based on the performance plots obtained from the respective manufacturers. For simplicity, a constant 60°F chilled water supply temperature with a 70°F chilled water return temperature is assumed for the load. The energy usage from the cooling plant was evaluated for different regions across the country and the results of the energy analysis are shown in terms of electrical energy used (kWh) by the chilled water plant and in terms of the mechanical PUE of the datacenter.

A summary of project parameters is shown below.

IT Load: 1,200 kW (constant)
Cooling Load: 386 Tons
CHWS: 60°F
CHWR: 70°F

Nominal Chiller Capacity: 405 Tons
Nominal Closed Circuit Cooling Tower Capacity: 428 Tons (at 95°F / 85°F / 78°F nominal conditions)
Pumping Scheme: Variable Primary Chilled Water Distribution

For free cooling conditions, the energy use of the closed circuit cooling tower and any pressure drop across it is taken into account. This additional energy must be offset by the reduction in chiller compressor power. An engineering analysis was performed to determine the switchover temperature that will result in an economical reduction in overall chiller plant energy usage, especially when using a variable speed chiller. The chiller VSD reduces compressor energy consumption at lower loads, reducing the energy input required by the air-cooled chiller when operating in the integrated economization mode.

To emphasize the impact of a closed circuit cooling tower based economizer on energy efficiency of datacenters, bin data was used to evaluate the chilled water plant energy usage for various ASHRAE Standard 90.1 climate zones as shown below:

TABLE 2: CLIMATE ZONES FOR DIFFERENT CITIES

City	Climate	Climate Zone
San Francisco, CA	Warm-Marine	3C
Dallas, TX	Warm-Humid	3A
Denver, CO	Cool-Dry	5B
New York, NY	Mixed-Humid	4A
Chicago, IL	Cool-Humid	5A
Portland, OR	Mixed-Marine	4C
Phoenix, AZ	Hot-Dry	2B

Figure 7 compares energy usage for an air-cooled chiller plant based mechanical system with and without closed circuit cooling tower based economizer. The difference between the two cases in the figure is the HVAC energy (including pumps, compressors, indoor air handling units, tower, etc.) that was saved through the use of a closed circuit cooling tower based waterside economizer.

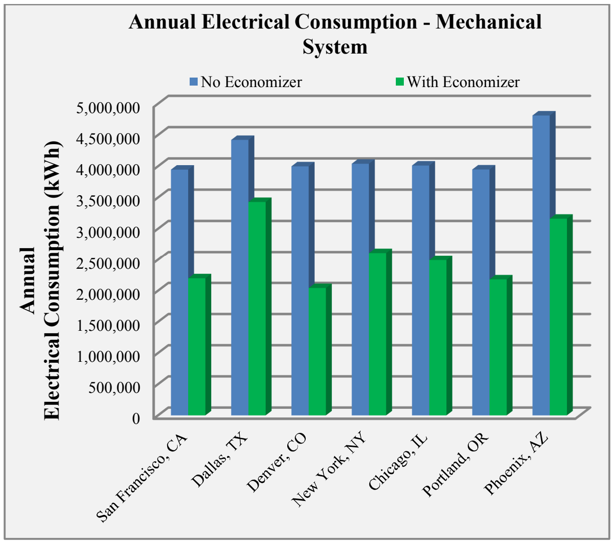

FIGURE 7: ANNUAL ELECTRICAL SAVINGS WITH ECONOMIZER

As shown in Figure 8, the economizers saved between 22% and 49% of the HVAC energy, depending on the climate zone. The largest savings were in Climate Zone 5B (cool-dry) and Zones 3C and 4C (marine), and the smallest savings were in Climate Zone 3A (warm-humid). Examination of Figure 8 shows the impact of the wet-bulb and dry-bulb temperature on the chilled water plant energy usage. The air-cooled chiller efficiency is affected by the ambient dry-bulb temperature, whereas the closed circuit cooling tower performance is a function of the wet-bulb temperature.

For example, looking at the climate of Phoenix, AZ (hot and dry), the closed circuit cooling tower offers excellent potential for economization; but in the time of non-economizer operation, the efficiency of the chilled water plant suffers because of the high dry-bulb conditions and associated lower air-cooled chiller efficiencies during those conditions.

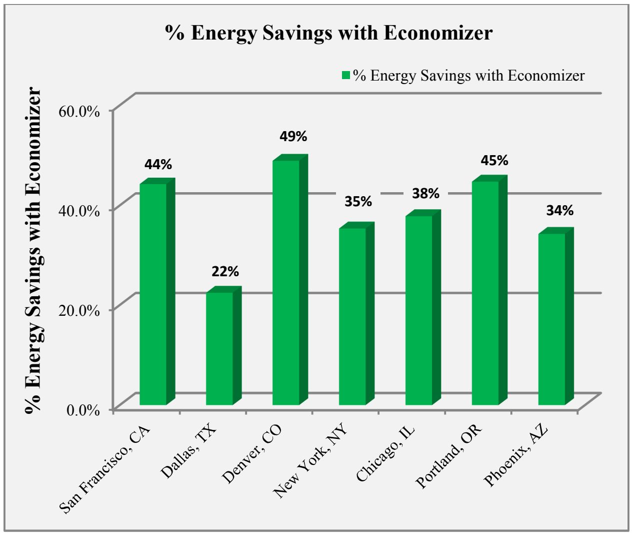

FIGURE 8: ENERGY SAVINGS WITH ECONOMIZER

The greater savings for Climate Zones 5B, 3C and 4C are due to the higher number of wet-bulb bin hours below 70°F, which translates into more economization hours. Waterside economizers using evaporative cooling are most favorable in regions of high wet-bulb depression and in moderate to cold or dry climates, where the wet-bulb temperature often falls below 50°F.

Figure 9 and Figure 10 show the annual operating hours for a chilled water plant serving a datacenter in diverse climates, divided into three modes – no free cooling, partial economization, and full economization. Even in a relatively warm and humid climate like Dallas, Texas, a waterside economizer using a closed circuit cooling tower can operate in economization mode almost 80% of the year.

The number of economization hours available is determined by the chilled water supply and return temperatures. The chilled water supply temperature governs the number of 100% free cooling hours available, whereas the partial free cooling hours is governed by the chilled water return temperature. The number of economization hours can be significantly increased by raising the chilled water supply and return temperatures to the maximum permitted by the IT equipment manufacturer and the air-cooled chiller supplier while still meeting the datacenter operational requirements.

The impact of chilled water supply and return temperatures on economization hours available is illustrated by Figure 9 and Figure 10 below. It can be seen in Case B that there are many hours where economization is not possible due to the low chiller water supply design temperature (45°F) specified. In Case A, however, the higher chilled water supply design temperature (60°F) significantly increases the number of hours of economization in all climate zones studied. Locating a datacenter in the proper climate zone while increasing the allowed internal design temperature within the center can enable “chillerless” datacenters which only rely on economizers for cooling.

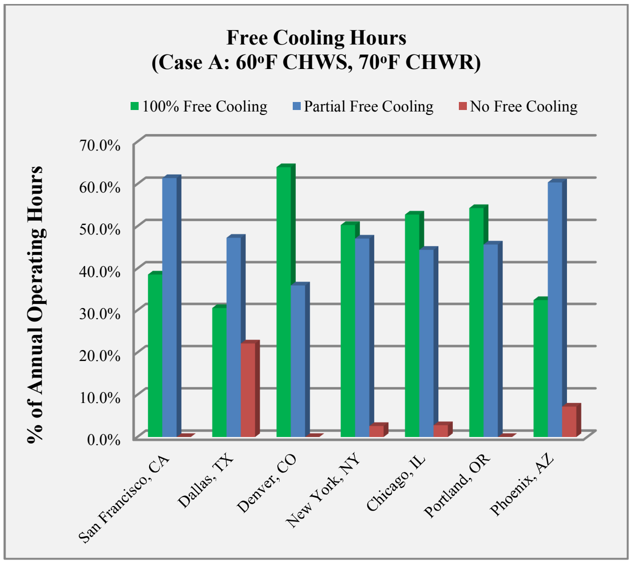

FIGURE 9: FREE COOLING HOURS AVAILABLE WITH ECONOMIZER – CASE A

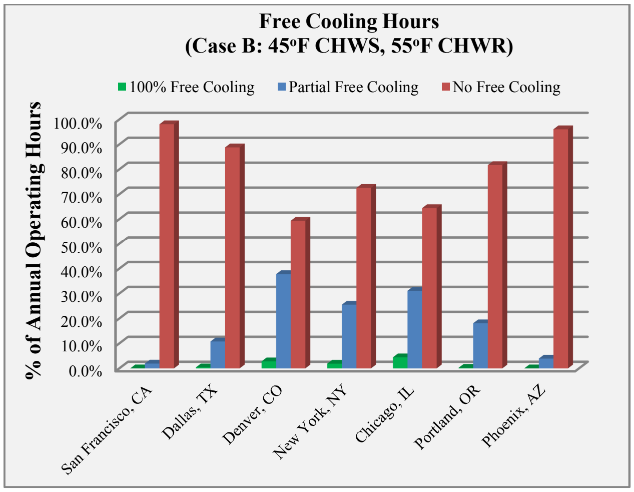

FIGURE 10: FREE COOLING HOURS AVAILABLE WITH ECONOMIZER – CASE B

Datacenter operators quantify their HVAC energy usage in terms of mechanical PUE. Mechanical PUE (mPUE) is defined as the ratio of total facilities mechanical energy usage to IT equipment energy usage. The mPUE for different climate zones with closed circuit cooling tower based economization in this case study is shown in Figure 11 below. In all cases, the reduction in mPUE is substantial. Note that the mechanical PUE (mPUE) for an air-cooled chiller only system would be 7% to 15% higher for the climate zones evaluated in this study, but the mPUE does not tell the complete story - see Figure 8 for more details on energy savings associated with the addition of a closed circuit cooling tower based economizer.

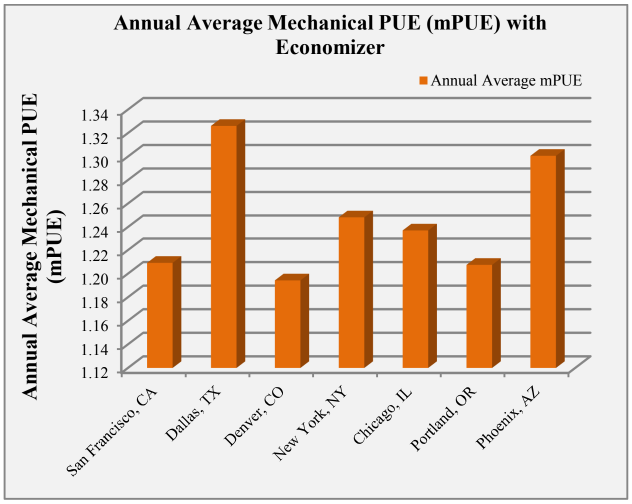

FIGURE 11: TYPICAL MECHANICAL PUE (mPUE) WITH ECONOMIZER

System energy savings can be further increased by selecting a closed circuit cooling tower with a closer approach, which would increase the hours of economization but also increase first cost. A closed circuit cooling tower with more coil surface and / or fill surface can also be selected to reduce the connected fan horsepower, which would reduce the energy use of the closed circuit cooling tower. This would be especially advantageous on systems with high hours of economization. Additionally, the temperature in the datacenter can be increased per ASHRAE guidelines to increase the hours of economization as mentioned earlier.

ECONOMIZER CONTROLS FOR A CLOSED CIRCUIT COOLING TOWER BASED ECONOMIZER SYSTEM

The control system for the economizer cycle is critical, especially in a datacenter facility environment, where tightly controlled temperature and humidity conditions are required. The waterside economizer is enabled whenever the fluid temperature from the heat rejection device, in this case the closed circuit cooling tower, is below the chilled water return temperature, plus some dead band to prevent short cycling between modes. The use of temperature dead bands is recommended to prevent the building automation system (BMS) from switching into and out of different operational modes rapidly [5]. The BMS sends the signal to open or close a series of control valves to allow switching from economizer to non-economizer mode and vice-versa.

The mechanical system can be controlled off the fluid temperature, though ambient wet-bulb sensors can also be utilized to assist in the control process. The wet-bulb sensor itself is required to alert the system when to begin and end economization. The use of good quality sensors as well as proper sensor placement is critical. The control sequence should confirm that waterside economization is possible by checking the leaving water temperature from the tower heat exchanger. The economizer is enabled based on the predicted closed circuit cooling tower leaving temperature based on the ambient wet-bulb temperature and the closed circuit cooling tower approach obtained from the closed circuit cooling tower performance data. The predicted closed circuit cooling tower leaving fluid temperature is the ambient wet-bulb temperature plus the closed circuit cooling tower approach.

The mechanical cooling system must be shut down when the waterside economizer can handle the entire cooling load, using the appropriate dead band to prevent short cycling the chillers. When mechanical cooling is again required due to the combination of load and outside wet-bulb temperature, the chillers should be brought back on in an optimized sequence for the site. Care must be taken to be sure that the chilled water temperature is not too low, which can cause the chiller to trip. The use of variable speed chillers along with chiller staging and chiller controls can help in this regard by following the load more closely.

The fan speed on the closed circuit cooling tower is controlled to maintain the desired chilled water supply temperature set-point. The tower fan speed can modulate between 100% down to the minimum recommended by the closed circuit cooling tower manufacturer, which is typically around 10% of design for units equipped with belt-driven fans. The tower fans will run at 100% fan speed as long as the chilled water temperature leaving the tower plus the dead-band is less than the CHWR. Similarly, the tower fans will modulate fan speed as long as the chilled water temperature leaving the tower minus the dead-band is less than the CHWS. A bypass arrangement is typically used to bypass the chiller or the closed circuit cooling tower if needed to ensure reliable operation and maintain the desired chilled water temperature set-points. The chilled water will bypass the chiller completely and the chiller will be turned off if the closed circuit cooling tower can meet the cooling requirement. With VSDs on the tower fans, however, the last bit of tower speed (from 90% to 100% speed) does little to lower the chilled water temperature but increases tower fan energy significantly [5]. This factor should be taken into account in the control algorithms to minimize the overall energy usage of the chilled water plant. The chilled water temperature set-point can also be gradually reset for different economizer modes and allow smooth transition from an economizer to non-economizer mode and vice-versa.

The first step in determining if an economizer is a feasible option is to examine the bin weather data for the site, focusing on the annual ambient temperatures and how they relate to the closed circuit cooling tower and chiller performance. Similar to when determining the amount of hours that waterside economizer operation will occur, the designer should account for the "partial free cooling hours". Partial free cooling and full free cooling hours refer to the hours of the year when chilled water temperature falls within the ranges below:

Partial Free-Cooling Condition:

$$T_{wb} + T_{CCTapp} + 1.5 < T_{CHWR}$$

Full Free-Cooling Condition:

$$T_{wb} + T_{CCTapp} - 1.5 < T_{CHWS}$$

where:

T_{wb} = Wet-Bulb Temperature (°F)
T_{CCTapp} = Closed circuit Cooling Tower Approach (°F)
T_{CHWR} = Chilled Water Return Temperature (°F)
T_{CHWS} = Chilled Water Supply Temperature (°F)
Dead-band: 1.5°F (typical)

This relationship is better understood with actual numbers. Consider a system with 60°F CHWS temperature and 70°F CHWS with a variable primary chilled water distribution to the computer room air handling units (CRAHs). As long as the temperature at the exit of the closed circuit cooling tower is below 61.5°F, or 1.5°F degree more than the desired CHWS, the plant is allowed to operate in a full economizer mode. This may result in a transient condition where the datacenter temperature may rise 1°F or 2°F. Most chillers require a minimum of 15% to 20% load or the chiller may trip off line (here is where a variable speed chiller is advantageous). Therefore, it is beneficial to have a minimum of 15% load for the chiller before switching from full economizer to partial economizer mode. This will allow the chiller to operate in a stable manner when the partial mechanical cooling is turned on. Similar to the dead-band on a thermostat control, the system should continue to operate in a partial economizer mode, as long as the temperature at the exit of the closed circuit cooling tower is within 1.5°F of the desired CHWR. This will allow a minimum of 15% load on the closed circuit cooling tower and help maintain stable operation. Although the chiller power reduction is attractive for energy savings, the operator should never risk dropping the critical load due to transitioning between various economizer modes [9].

Unscheduled and frequent changes of operational modes are considered risks to continuous datacenter availability. Operator vigilance, especially during these transition modes, is required. The default is normally to revert to the mechanical cooling system in the event of an economizer fault. This transition region is critical to the reliability of the datacenter cooling system, which ties into the mission of the datacenter.

A variable speed drive on the closed circuit cooling tower fan system is highly recommended for energy saving and control reasons, both of which are critical to successful datacenter operations. As the outside temperature becomes colder and / or the load is reduced, less airflow is required to maintain the desired leaving water temperature. Note that fan cycling alone, even if multi-speed motors are utilized; is not recommended as a means of capacity control on evaporative chilling systems, especially for datacenter facilities. Fan cycling will not provide the close temperature control required in a datacenter and can potentially lead to tower icing in colder climates. Operators must also ensure that the motors are not driven below minimum speed, per the cooling tower manufacturer's requirements. Belt drive fans can typically operate at as low as 10% of full speed, which will permit an adequate amount of motor cooling.

Waterside economizers have unique operational and maintenance characteristics that must be evaluated in light of the annual climatic conditions for the datacenter's location, the abilities and preferences of the operational personnel, resource availability, and regulatory requirement. Other than normal air-cooled chiller maintenance, closed circuit cooling towers add little to the annual maintenance requirements in a well-designed and maintained system.

COLD WEATHER OPERATION

Cold weather operation of closed circuit cooling towers can be a concern for some operators, primarily centered on icing and coil freeze-up. However, when the appropriate measures are taken during the initial design, layout, installation, and operation of the system, these concerns easily can be alleviated. Datacenter applications are actually ideal for cold weather operation, thanks to the constant high loading on the HVAC system.

Whenever the wet-bulb is below 32°F, there is a possibility of ice formation on the tower. Note that the wet-bulb temperature can be below freezing even when the dry-bulb temperature is several degrees above freezing. For the water in an idle coil to freeze, the dry bulb temperature must be below 32°F, usually for a sustained period of time.

The tower should be operated at the highest possible leaving water temperature that will be consistent with efficient system operation. The warmer the design water temperature, the less chance of external ice formation. Low temperature alarms should be set through the BMS to alert the operator of any upset conditions, such as if the leaving water temperature off the tower falls to 43°F or below. Sensors must also be located properly to read the true leaving fluid temperatures. The recommended minimum leaving chilled water temperature from the coil is typically around 50°F for closed circuit cooling towers not using glycol and 45°F for closed circuit cooling towers using an aqueous glycol mixture. Keep in mind that the external spray water over the coil will be several degrees lower than the leaving fluid from the coil. Too low a chilled water temperature can lead to icing of the external recirculating water.

It is also preferable to operate the closed circuit cooling tower with constant water flow over the tower but variable air volume through the tower during cold weather. Constant, as opposed to variable spray water flow, helps to assure that all areas of the fill are properly wetted. When starting the towers in cold weather, the water should be pumped over the tower first before the fans are started. This is because cooling towers have a relatively high capacity in cold weather due to the natural draft effect. The warm water heats the air in the tower, which rises and induces airflow through the tower, further increasing the capacity.

The most common cause of tower freeze-ups is "too little load" being handled by "too much tower." First, the constant high loading on datacenter applications makes icing control easier. Second, the VSD can be used to match the capacity of the tower with the load and entering wet-bulb at any given point. To ensure this happens, two key points must be noted. First, the placement of the leaving water temperature sensor is critical and must sense a true average leaving water temperature from all the towers assigned to that load. Second, all towers in that grouping should be controlled to the same fan speed so that one tower is not overcooling and another undercooling the fluid. The tower that is overcooling will have the greatest potential for ice formation. For instance, in a four-cell installation with only one tower controlled by a VSD and the rest using on/off control, the towers that are "on" will have to overcool the fluid as the cells that are "off" will have a higher leaving water temperature. This greatly increases the incidence and severity of icing on these operating cells.

The next most common cause of ice formation in and around cooling towers involves water management. Closed circuit cooling towers are equipped with air inlet louvers to prevent "splash out," which can freeze on the louvers as well as the surrounding area. Drift eliminators minimize the loss of the recirculating water from the tower that can be carried along by the airflow through the unit. To avoid icing from both these sources, the inlet louvers and drift eliminators must be inspected regularly, properly oriented, and well maintained. Leaks from the tower, such as from a basin or casing seam, can also be the source of icing on the surrounding area, including the steel supports and roof deck. Such ice formations can, in turn, lead to leaks in the roofing membrane, potentially threatening the electronic equipment inside the facility.

Proper tower layout, including accounting for the prevailing wind direction, is important to avoid recirculation and interference of the moist discharge air into the tower inlets. The tower discharge, often called plume when visible in cold weather, can freeze on cold tower surfaces and surrounding buildings or walkways. Left unchecked, the frost can build up to the point that it can create maintenance access and safety issues due to slippery surfaces or frozen access panels. The high year-round datacenter load helps in this regard by heating the air. This helps the air to rise up and away into the atmosphere, where it dissipates harmlessly.

Freeze protection must be used for the cooling tower's cold water basin as well as the process and make-up piping. A variety of heating methods can be used for the cold water basin, such as electric heaters and steam injectors to keep the basin from freezing during idle periods. All external piping should be heat traced and insulated, especially the make-up line. For many datacenter facilities, the use of a remote sump, especially one located indoors in a heated space, is ideal for freeze protection of the recirculating water.

Should ice formation reach an unacceptable level, the fans on induced draft towers can be reversed for approximately 10 minutes every half-hour at no more than half-speed (otherwise the recirculating water can be blown out of the air inlet louvers). In this method, the air is heated as it passes through the fill. The warm air will then defrost the air inlet faces as it leaves the tower. Another technique is to allow the water temperatures to climb temporarily, which will help to melt any ice that has formed. The control system also will have to be designed to handle the swings in temperature during these de-icing periods. If icing continues, the operators must review the control sequencing, as well as the other recommendations in this section, to correct the situation.

In very cold weather areas, closed circuit cooling towers can be selected to operate dry to eliminate the potential for icing. As mentioned earlier, fins can be added to the coils or a separate dry cooling section added to the unit. However, the use of dry operation will generally lead to higher fan energy as the dry capability will be much less energy efficient than the evaporative (wet) mode of operation.

ECONOMIZER SELECTION GUIDELINES

There isn't necessarily a right way to select a waterside economizer with closed circuit cooling tower. The larger the closed circuit cooling tower, the greater the energy savings; but there is obviously a diminishing return on investment[8]. Additional coil and / or fill surface can be advantageous for datacenter facilities as the colder water temperatures produced by a more capable tower reduces the chiller energy consumption at peak loads. The main defining variables with a closed circuit cooling tower are the approach and the capacity. The approach is the difference between the leaving chilled water temperature from the closed circuit cooling tower and the entering wet-bulb temperature.

$$T_{CCCTapp} = T_{CCCT\ Leaving} - T_{wet\text{-}bulb}$$

where:
$T_{CCCTapp}$ = closed circuit cooling tower approach temperature
$T_{CCCT\ Leaving}$ = leaving chilled water temperature from the closed circuit cooling tower
$T_{wet\text{-}bulb}$ = entering wet-bulb temperature

The smaller the approach, the larger the closed circuit cooling tower becomes. The closer the closed circuit cooling tower can bring the temperature of the chilled water to the entering ambient wet-bulb temperature, the more efficient the economizer becomes. The temperatures, specifically the approach, that the heat transfer process occurs at is the real measure of the closed circuit cooling tower performance. A closed circuit cooling tower with the lowest approach temperature would allow the waterside economizer to begin operation at a higher ambient web-bulb temperature. However, the size (and associated cost) of the closed circuit cooling tower increases as the approach decreases.

The following procedure is one way to select an optimized closed circuit cooling tower:

1. Select the highest allowable datacenter operating temperature allowable for the site, based on ASHRAE guidelines while meeting the datacenter operational needs.
2. Obtain design chilled water flow from the chiller selection. Use aqueous glycol mixture if desired for freeze protection.
3. Obtain design chilled water supply and temperatures from the chiller selection.
4. Select a closed circuit cooling tower for economizer duty using design chilled water flow and temperature conditions. Assume an approach of 7°F to 12°F for the closed circuit cooling tower selection. Ensure that the selected closed circuit cooling tower can produce the design chilled water supply temperature at the design cooling load. The design capacity of the cooling tower will be same as the design capacity of the chiller.
5. Limit the chilled water pressure drop through the closed circuit cooling tower; 10 psi to 12 psig at design flow is a typical target limit.
6. Cross plot closed circuit cooling tower cost versus energy cost savings for various tower approaches and datacenter design temperatures to establish the optimum selection.
7. Ensure that the chiller can run at the non-economizer and economizer conditions. It is also important that the entire chilled water system be designed and operated to utilize high chilled water return temperatures to maximize economization hours.

For all of these options, the lowest Total Cost of Ownership (TCO), which takes into consideration first cost, operating costs, and maintenance costs over the life of the system, can also be used to help establish an optimum system configuration for a specific facility.

Once the base closed circuit cooling tower is chosen, alternate selections with larger coils and / or additional fill surface area can be run, as these models will have lower fan horsepower requirements for the same thermal duty. For a nominal increase in first cost, a significant reduction in circuit cooling tower fan horsepower is possible. The smaller fan motors also reduce the required VSD size and wiring costs, offsetting part of the additional cost, while lowering the sound generated by the closed circuit cooling tower.

ECONOMIZER PUMP AND PIPING CONSIDERATIONS

For systems using primary/secondary chilled water distribution, the closed circuit cooling tower should be located on the secondary side so as to maximize the economization hours. The primary pumps can be turned off when the system is operating in 100% free cooling mode. As mentioned earlier, the chilled water return temperature governs the number of partial free cooling hours available; and hence the warmer the chilled water return temperature, the more economization hours will be available.

Chilled water pump selection should follow traditional design practice and be selected with VSDs and account for the head differences between the economizer and non-economizer modes. One caveat when selecting the pumps to operate in an economizer mode is to make certain that the pump's working pressure compensates for the pressure drop through the closed circuit cooling tower, along with the additional piping and valves. The pumps will only experience this increased pressure drop when the system is in the economizer mode of operation. When the conditions for the economizer are unfavorable and when 100% mechanical cooling is required, the system should have measures to bypass the closed circuit cooling tower and avoid the additional pressure drop [9] as well as any unnecessary heat gain. Likewise, the chiller bundles can be valved out during full economization for the same reason. If existing chilled water pumps cannot support the economizer operation like in the case of retrofitting an economizer to an existing chilled water system, a dedicated pump can be added to overcome pressure drop through the economizer loop

Pumps and pumping system design should take into account energy efficiency, reliability, and redundancy. The hydrostatic path through the chiller and the closed circuit cooling tower generate the highest pressure drop on the chilled water loop. To minimize the impact of the closed circuit cooling tower on the system pumping head, the closed circuit cooling tower should be selected for the lowest economical pressure drop while still meeting the thermal requirements.

The primary chilled water pump must be sized according to the highest pressure drop that will be encountered, which can then mean that it will be oversized for other operational modes. variable speed drives (VSD) can be utilized for the primary chilled water pump. With VSD control, the pump can be balanced to operate at different speeds for the different operational modes. However, the inefficiency of the VSD (typically around a 3% loss) must also be taken into account during the analysis. Note that the chilled water flow through the coil(s) of the closed circuit cooling tower, unlike open circuit cooling towers, has virtually unlimited turndown capability.

SUMMARY

Waterside economizers with closed circuit cooling towers, coupled with air-cooled chillers offer significant operating energy savings compared to air-cooled chillers alone, while simplifying the control of humidity and contaminants in datacenter facilities. Waterside designs are highly compatible with most datacenter missions, which focus on reliability and uptime availability. On existing datacenters with air-cooled chillers, waterside economizers can be easily justified and implemented using closed circuit cooling towers on a retrofit basis.

The key to a successful waterside economizer installation is commissioning. This includes regularly calibrating the wet-bulb sensors, functionally testing all control sequences, and reviewing trend graphs of all HVAC systems to insure the controls are stable and operating as expected. The mechanical system must also be thoroughly commissioned after the implementation of a waterside economizer. In particular the transitions into and out of economization must be verified and parameters, such as temperature differentials, adjusted as needed.

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