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Engineers Newsletter

volume 45–2

waterside economizers

Keeping the "Free" In Free-Cooling

This EN revisits the topic of a 2008 newsletter and provides additional discussion about applying and controlling a waterside economizer.

There are six basic steps to designing and operating a waterside economizer:

- Identify the right application
- Select and size
- Determine control points
- Protect chiller and tower
- Predict value of integrated mode
- Deliver energy savings

In order to deliver energy savings, the system must be designed and controlled properly.

Identify the Right Applications

The critical first step for a successful waterside economizer cannot be overlooked: identifying the right applications. Waterside economizers are usually less effective at saving energy than airside economizers. There are simply more heat exchangers between the source of the free cooling and the cooling load. Each heat exchanger "loses" a few degrees of cooling, the approach temperature. Each transfer of cooling requires energy-consuming equipment, such as condenser fans, condenser-water pumps and chilled-water pumps.

Therefore, it's critical that we select the right applications, and intelligently control the system to deliver energy savings.

There are several reasons for designing a system to use a waterside economizer.

Sometimes airside economizers are impractical. In most dedicated outdoor air systems, the airflow rate is sized for the minimum, code-required ventilation rate. Therefore, even if the outdoor air is suitable for cooling, the system is not capable of delivering "100% of the design supply air quantity as outdoor air for cooling," as required for airside economizing by ASHRAE Standard 90.1.

Another constraint could be due to central mechanical system architectural issues or preferences.

What if my preferred system can't use either type of economizer?

Energy standards and model codes do not have blanket exceptions for these systems. However, there are a number of exceptions to consider. For small terminals <54,000 Btu/h, no economizer is required by ASHRAE Standard 90.1-2013.

Systems with condenser heat recovery may qualify for an exception. Air-cooled chillers serving central equipment can use the efficiency trade off for equipment (Table 1), condenser heat recovery or desuperheaters, or add a free cooling circuit.

Equipment efficiency trade off method

ASHRAE Standard 90.1-2010 and later provides a new exception for the economizer requirement. The standard back-calculated an IPLV or IEER improvement by climate zone that would provide equivalent energy savings (Table 1).

Table 1. ASHRAE Standard 90.1-2013, 6.5.1-3

Climate zone	Part load efficiency improvement
2A	17%
2B	21%
3A	27%
3B	32%
3C	65%
4A	42%
4B	49%
4C	64%
5A	49%
5B	59%
5C	74%
6A	56%
6B	65%
7	72%
8	77%

Sometimes airside economizers are undesirable. Airside economizer applications that bring in dry air may use more energy if humidification is required. ASHRAE Standard 90.1 requires that if spaces are humidified to above 35°F dewpoint, the systems serving them must use a water economizer when an economizer is required.

Designers of process cooling applications such as data centers may have concerns about the attributes of the air in airside economizer mode, or about outdoor air dampers malfunctioning.

Sometimes condenser heat recovery is impractical. Systems with condenser heat recovery of sufficient capacity are given an exception to economizing. Shedding mechanical cooling when the outdoor temperature is cool reduces the hours of simultaneous heating and cooling—conditions that are key to making heat recovery systems work. The heat rejected by the cooling system offsets the heating required in another system. The best system would be one that uses the economizer to offset only the portion of the cooling load that is not needed for satisfying the heating load, commonly called a load-shedding economizer.

Does a water economizer make sense for my application? Carefully consider the expected load profile. Offices and hospitals are two applications where prototypical load profiles use chilled-water systems and are available across multiple climates. These profiles can be found in Trane's myPLV™ or by exporting TRACE hourly load and weather information to a spreadsheet application.

Using this data, it is possible to plot cooling load against the wet-bulb temperature (WB), the driving force for the water economizer cycle. Figure 1 illustrates the different opportunities for the waterside economizer cycle. The graphs compare data plots for a hospital and an office in climate 4A. The area under the black line to the left of, say, 50°F WB represents the ton-hours that might be served or at least partially served by a waterside economizer cycle. The office is unoccupied during many of the hours below 50°F WB, reducing the waterside economizer savings opportunity. On the other hand, the hospital requires more ventilation, so its system already brings in more outdoor air for a partial airside economizing effect during these cooler hours of operation.

The airside economizer opportunity for the hospital and office load profiles is summarized in Table 2. This is the free cooling sacrificed when an airside economizer is *not* used.

Figure 1. Hospital and office cooling and operating hour distribution in zone 4A

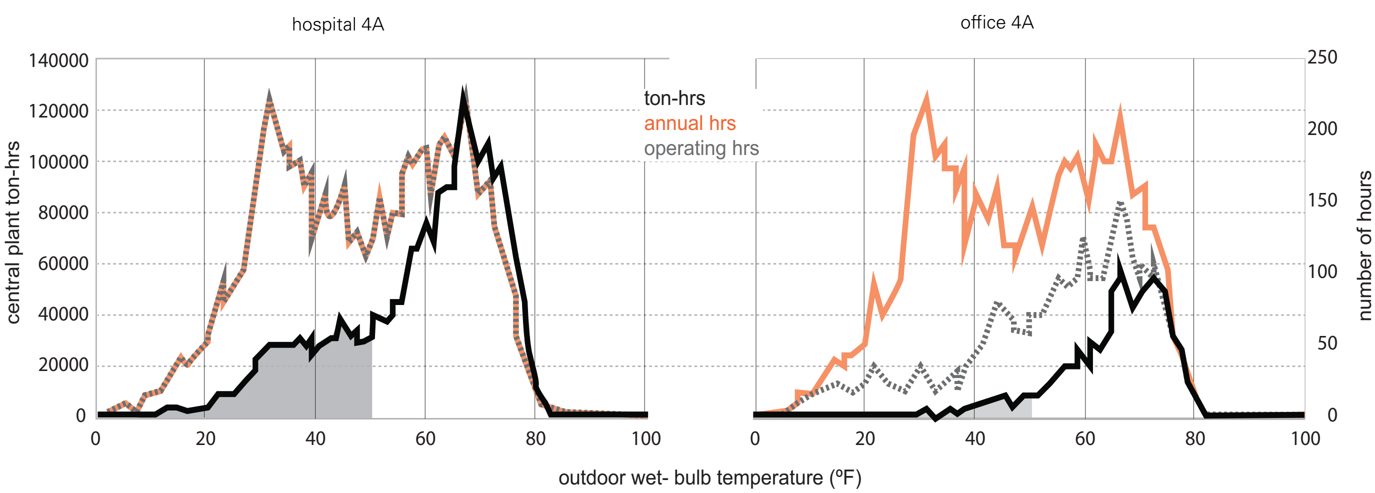


Table 2. Summary of operation and load displaced by airside economizer

climate zone	building type	chiller plant load without economizer (ton-hrs)	plant annual operating hours	cooling load offset by airside economizer (ton-hrs)	airside economizer ton-hrs (%)	economizer operating hours	plant hours displaced with airside econ (%)
1A	office	2,681,687	5,806	2,601	0.1	55	0.9
2A	office	2,020,071	5,022	9,546	0.5	225	4.5
3A	office	1,414,396	4,240	12,386	0.9	358	8.4
4A	**office**	**1,123,020**	**4,033**	**75,286**	**6.7**	**995**	**24.7**
5A	office	918,012	3,935	97,335	10.6	1,352	34.4
1A	hospital	5,547,962	8,760	20,207	0.4	86	1.0
2A	hospital	4,628,842	8,759	253,285	5.5	1,412	16.1
3A	hospital	3,667,161	8,758	516,296	14.1	2,605	29.7
4A	**hospital**	**3,109,749**	**8,729**	**683,872**	**22.0**	**3,769**	**43.2**
5A	hospital	2,635,926	8,596	722,553	27.4	4,426	51.5

The summary clearly shows that some building types are more conducive than others to either style of economizing, most likely as a function of how the ventilation loads and operational hours for the building coincide with outdoor conditions that are suitable.

Select and Size

Several styles of waterside economizers are common. The 2008 EN compared and contrasted different technologies, system layouts, and control methods for waterside economizers. Its conclusions may be summarized as:

1. Sidecar position benefits include preferential loading of the economizer and downstream temperature control with chillers, plus potentially less disruptive transition into and out of waterside economizer free cooling mode, as the chiller downstream will unload or load to meet setpoint.
2. A dedicated free-cooling heat exchanger has about a 1.5°F closer approach to wet bulb than the integrated thermosiphon chiller. On the other hand, the thermosiphon has lower maintenance, lower first cost and likely lower pressure drop due to the shell-and-tube heat exchanger.
3. Exiting or terminating free cooling waterside economizer mode requires decisions to be made about the usefulness of the cycle. (More on that later in this newsletter.)

How much capacity does my waterside economizer need?
Table 3 displays a pivot table for the hospital in climate 4A. Extracting the hourly loads and weather into a spreadsheet is useful for summarizing and visualizing how much load can be expected at a given wet bulb, and for how many hours. In this example, there were

- No hours with loads below 10 percent at 34°F WB, or below 15 percent at 42°F WB or higher
- No hours with loads above 25 percent at 37°F WB or lower
- No hours with loads above 30 percent at 45°F WB or lower

These observations will be helpful when evaluating potential control points for the system.

Meet the prescriptive requirements in the energy code. Unless exempted, the minimum capacity of the water economizer is determined by the expected cooling load at a given outdoor dry bulb (DB) and WB condition. For comfort cooling applications these conditions are 50°F DB/45°WB.

Expected load at 50°F DB/45°F WB.
To meet this requirement, a predicted load profile for the year is necessary. The example hospital data gave 39 hours at 45°F WB with 50°F DB or less, with no more than 25 percent load at these conditions. This is the minimum waterside economizer size for meeting code.

Integrate with mechanical cooling.
Section 6.5.1.3 *Integrated Economizer Control* of ASHRAE 90.1 states,

> "Economizer systems shall be integrated…and be capable of providing partial cooling even when additional mechanical cooling is required to meet the remainder of the cooling load"

There is no definition of how the integration must happen. Blending two temperatures of water (a slightly warmer temperature from the waterside economizer with colder water from the mechanical cooling chiller) is acceptable though not typically intentionally practiced.

The value of this mode is uncertain. Energy simulation software rarely shows a significant difference between integrated and non-integrated economizer operation. Regardless of its value, the current model codes require integration. We'll revisit this topic later in this newsletter.

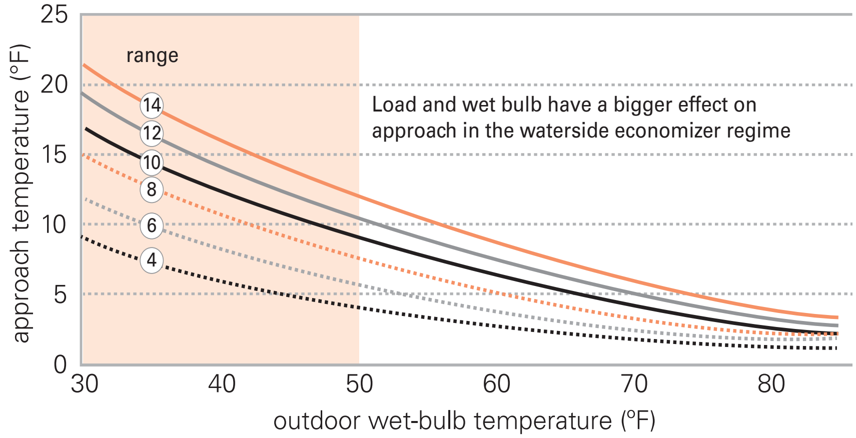
Determine maximum chilled-water temperature. The amount of cooling that can be accomplished by the waterside economizer is dependent on the desired chilled-water temperature. Is it the normal chilled-water setpoint? Or could the system tolerate warmer water? If so, how much warmer?

Table 3. Number of hours by expected load and wet-bulb temperature

cooling load (%)	outdoor wet bulb temperature																								total hrs
	27	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	
5	30	16	16	14	10	6	1																		**93**
10	68	93	124	158	138	152	120	58	61	21	16	15	10	4	2										**1040**
15		9	12	27	60	62	76	103	103	117	114	105	99	54	70	68	35	33	22	6	2	3			**1180**
20						2	5	20	25	28	40	30	47	45	60	53	58	47	61	45	57	44	48	42	**757**
25										4	8	7	12	13	18	30	29	34	**39**	21	26	24	27	47	**339**
30													3	2	2	4	14	31	40	41	44	36	30	26	**273**
40																				2	1	4	7	7	**21**
total hrs	**98**	**118**	**152**	**199**	**208**	**222**	**202**	**181**	**189**	**170**	**178**	**157**	**171**	**118**	**152**	**155**	**136**	**145**	**162**	**115**	**130**	**111**	**112**	**122**	**3703**

Some systems that use waterside economizers also use sensible only equipment such as chilled-beams or radiant cooling. These devices use fairly warm water for cooling to keep the surface temperature above the space dewpoint to avoid unintended condensation. Conventional systems can also tolerate warmer chilled water, especially when loads are low, and when outdoor air is less humid—conditions normally expected when the water economizer mode is active.

Figure 2. Effect of load (cooling tower ΔT or range) and wet bulb on tower approach



Determine Control Points

Predicting if the system can meet the current day's cooling load with the waterside economizer is roughly two parts experience and one part alchemy.

Most chilled-water systems with an experienced hand at the helm "know" when it will work and when it probably won't. Distilling tribal knowledge into a control algorithm can be a difficult task. The goal is to predict what temperature you can get out of the cooling tower before driving the tower fans to full speed and overriding your optimal temperature control algorithm for mechanical cooling.

Tower performance. To determine if the towers can make the water cold enough, without always driving the tower as cold as possible at the expense of fan energy, we must predict tower performance. Many people erroneously believe that the tower can or will make a constant approach to wet bulb. This is simply not true.

At lower wet-bulb temperatures, ambient air entering the tower doesn't absorb moisture as well. Unless the load is quite low (and it very well may be), the tower leaving temperature is, counterintuitively, incapable of getting as close to the lower wet-bulb temperature (Figure 2).

A tower solver spreadsheet tool tuned for a given combination of tower and flow turndown capability can be helpful for determining control points.

Number of tower cells to operate. The number of tower cells that may operate is a relevant variable in tower performance predictions. One method for preventing high tower fan energy in economizer mode is by flowing through more tower cells. The tower fans are run to the same (hopefully low) speed, and the tower is designed for lower flow.

However:

- If water flow rates are too low the tower may ice or scale, suggesting it would be better to turn off a tower cell. However, no flow through isolated tower cell(s) may lead to icing.
- Balance condenser-pump energy when tower fans are at minimum speed. If too many cells run at minimum fan speed, the increased condenser pump energy necessary to achieve sufficient cell water flow limits the energy savings from tower fans.
- Know the maximum flow of the heat exchanger(s) and the minimum flow of the towers and modify the sequence accordingly.

Example control points. Table 4 overlays potential control points on the load profile from Table 3. The loads cluster into three regimes based on wet-bulb temperature. A tower solver was used to estimate performance and determine the number of cells to operate at the highest expected load for a given wet bulb.

Table 4. Hospital expected load at each wet-bulb temperature

cooling load (%)	outdoor wet-bulb temperature (°F)																								total hrs
	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	
5	30	16	16	14	10	6	1																		93
10	68	93	124	158	[illegible]	[illegible]	[illegible]	[illegible]	61	21	16	15	10	[illegible]	[illegible]	[illegible]	[illegible]								1040
15		9	12	27	[illegible]	[illegible]	[illegible]	[illegible]	103	117	114	105	99	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1180
20					[illegible]	[illegible]	[illegible]	[illegible]	25	28	40	30	47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	61	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	757
25					[illegible]	[illegible]	[illegible]	[illegible]		4	8	7	12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	**39**	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	339
30													3	2	2	4	14	31	40	41	44	36	30	26	273
40																				2	1	4	7	7	21
total hrs	98	118	152	199	208	222	202	181	189	170	178	157	171	118	152	155	136	145	162	115	130	111	112	122	3703

regime 1: all chillers off, 1 tower cell, 45°F tower setpoint

regime 2: all chillers off, 2 tower cells, 47°F tower setpoint

regime 3: integrated mode, one chiller on, 3 tower cells, 47°F tower setpoint

The number of cells operating was considered suitable if, for a given wet bulb and maximum expected load, the tower fan was below 100 percent speed, and the leaving water temperature was below the maximum leaving chilled-water temperature setpoint, minus 2-3 degrees of heat-exchanger approach.

Regime 1: All chillers are off, one tower cell is on and set for 45°F leaving-water temperature, waterside economizer is enabled

Regime 2: All chillers are off, two tower cells are on and set for 47°F leaving-water temperature, waterside economizer is enabled

Regime 3: Lead mechanical cooling chiller is on, three tower cells are open and set for 47°F leaving-water temperature, waterside economizer is enabled, chiller head pressure control as necessary. Once you start the lead chiller, it's possible to add another tower cell. The chiller adds a heat exchanger to the system, so condenser flow rises enough to support another tower cell's flow. Alternatively, consider a dedicated tower for the lead chiller or an air-cooled lead chiller.

Protect Chiller and Tower

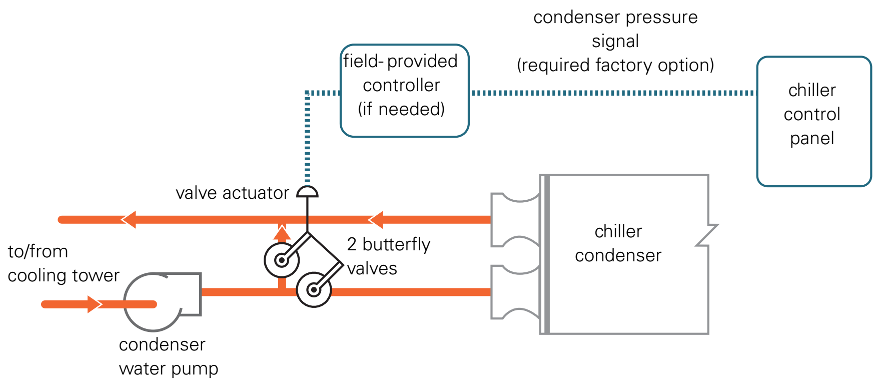
Plan for cold towers. The waterside economizer requires a winterized cooling tower in many climates. Since the tower is expected to operate when it's cold outside, it cannot be seasonally drained.

Use chiller bypass for chiller head pressure control so that the tower flow rate can be higher than the condenser flow rate when needed, for freeze protection and proper fill coverage.

Carefully consider the outdoor parts of the system that are off or isolated from the building load:

- Use a dry or indoor sump, or use heat trace and sump heaters
- Install heat trace on the make-up water system
- If using tower bypass, throttling valves, or variable-speed condenser pumps for chiller head pressure control, ensure that the minimum tower flow rate is always met to avoid freezing.
- Condenser bypass is preferred, see next section.

Figure 3. Head pressure control method for integrated waterside economizer



Plan for chiller head pressure control. Operating the chiller compressor while continuing to drive the cooling tower to a colder temperature requires a plan for chiller head pressure control. While it's not unique to this application, applications without waterside economizing may have fewer hours expected for operation in this condition.

Careful coordination between the chiller and the system controls is critical (watch for scope gap). Many newer chillers have the ability to directly control their own head pressure device—this is preferred. Newer chillers also may selectively ignore the condenser flow switch during head pressure control mode. And, chillers must be capable of performing an inverted start, defined as having the condenser at a lower pressure than the evaporator.

The controls contractor should be alerted to the time permitted to achieve the required differential pressure, as not all chiller types have the same requirements. For example, achieving differential pressure in a helical rotary (screw) chiller must happen in two minutes. In this type of chiller, oil is used for creating the compression seal. Centrifugal chillers are more tolerant of low differential pressures for longer periods of time (20 minutes is typically acceptable).

There are five methods of head pressure control for water-cooled chillers; some are more suitable for systems with waterside economizers. Figure 1 shows the preferred method; other methods are described and illustrated in several Trane Engineering Bulletins. Some methods have drawbacks when used for head pressure control during integrated waterside economizer mode.

Condenser bypass is the preferred method for waterside economizer mode, as it allows the tower flow rate to remain high, which provides adequate fill coverage to prevent icing or deicing, with fast-acting head pressure control at the chiller (Figure 3).

Tower fan speed, leaving temperature setpoint control simply resets the tower leaving-water temperature setpoint higher when requested by the chiller controller. This is slow acting and will be at odds with the waterside economizer control points. Use this method for entering and exiting economizer mode, but not for head pressure control.

Tower bypass may be problematic for waterside economizer mode, as its ability to manage chiller head pressure will be constrained by the minimum required flow rate of the tower. When systems are expected to operate for more than transient periods of time in head pressure mode, tower bypass is less desirable, though fast acting. Another problem with this method is that it is typical to share a common tower bypass across all devices, and one or more of the waterside economizer devices may require higher tower flow than the others.

Throttling valve or variable flow condenser pump, when available per chiller, can have a similar effect as condenser bypass, but may make it difficult to adequately flow the preferred number of tower cells while continuing to meet the head pressure requirements.

For all these reasons, condenser bypass and tower speed control are preferred for waterside economizers.

Value of Integrated Economizer Mode

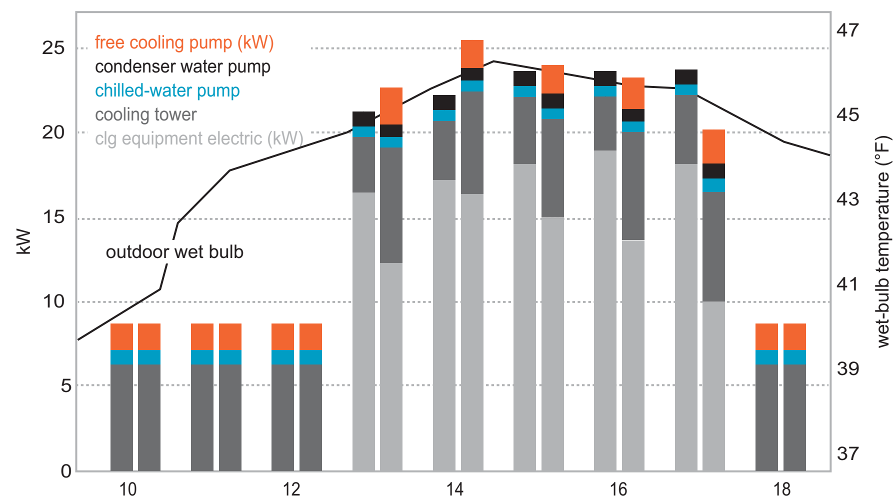
Whether or not to stop waterside economizer if it's not meeting the entire cooling load. One of the biggest debates that has raged for many years is whether integrated economizer mode actually provides value. The two positions can be summarized as:

- Integrate free and mechanical cooling. Code requires it (so it must be the right thing to do), plus it's easy enough to initiate and terminate if the chiller is in series with the waterside economizer device.
- Energy models and other calculations suggest the opposite. Integrated free cooling doesn't usually save much energy, and it complicates the controls on the lead chiller. Either it meets all of the load or it's discontinued.

Based on the model energy codes, integrated has won the debate. But should it have? All rules should be re-evaluated occasionally, and we must not assume that all applications react the same way. Data center loads are fairly constant year-round—office loads are not.

The key is to know the likely system efficiency of mechanical (only) cooling when the waterside economizer can no longer meet the entire load. This can be tough to pin down as a control point, but our building models offer guidance. Because tower fans, condenser-water pumps and chillers would be at a different operating point than they would have been, we can't just look at the chiller-only energy prediction.

Figure 4. Integrated free cooling in November



Consider a fall day while operating in free-cooling mode (Figure 4). For each hour, the right column is the series or integrated free cooling alternative. The left column is the parallel, all-or-nothing, non-integrated free cooling alternative.

Once the economizer cycle can no longer meet the entire load (five out of the nine hours when the plant is operating), remaining in economizer mode after starting the chiller actually uses *more* energy than mechanical-only cooling. How can this be?

While chiller energy is reduced in the integrated mode, tower and pump energy increase more than the chiller energy decreases, overwhelming any potential savings. The cooling tower fans, economizer pump and condenser-water pump were higher in the integrated alternative.

Even if the need for an economizer pump were designed out of the system, the integrated mode would still use more energy overall than the non-integrated alternative. This particular example used a fixed-speed lead chiller. The non-integrated mode wins more dramatically with a variable-speed lead chiller.

In addition, the waterside economizer "steals" load from the chiller and drives the chiller into a less efficient operating point. When load is low, chiller kW/ton is relatively high—that is, not very efficient—even when using a variable-speed compressor. This is because a portion of the chiller energy is constant. The less work (tons) that it does, the lower the efficiency. Having tower fans operate at high speed to continue the cycle, while the condenser pump and chilled-water pump speeds are also high, creates the classic example of chasing your tail.

This is why integrated and non-integrated economizer mode comparisons defy the engineer and energy modeler's expectations and result in very similar system annual energy consumption.

Deliver Energy Savings

This brings us to a few final thoughts for terminating waterside economizer mode. What amount of free cooling is worth it? Rather than assume that supressing the return water temperature a couple of degrees is sufficient, understand how the entire system performs in economizer mode, and identify the alternative system performance in mechanical-cooling mode.

Table 5. Chiller plant performance (chiller, tower, all pumps)

	with chilled-water reset	without chilled-water reset
Energy @ 20% plant load	CHWSP 49°F, LCWT ~64°F	CHWSP 45°F, LCWT ~61°F
fixed-speed chiller and condenser-water pump, variable-speed tower and chilled-water pumps	0.758 kW/ton	0.745 kW/ton
variable-speed chiller, tower and chilled-water pumps, fixed-speed condenser-water pump	0.451kW/ton	0.440 kW/ton

A variable-speed lead chiller and its condenser pump and tower fan(s) operating at slow speed might use 0.36 kW/ton. Determine this number and use it as a yardstick to decide if free cooling is "free" after all.

Chilled-water reset. By encouraging extending the economizer mode, the system effects of chilled-water reset, at some point, limit the potential energy savings. Chilled-water reset is a waterside economizer's friend, until it isn't. That point occurs when the chiller is started and operated in head pressure control mode.

Release or reduce chilled-water reset during head pressure control. When a chiller is in head pressure control mode, an excessively warm chilled-water setpoint perpetuates the need for head pressure control. Releasing or reducing chilled-water reset may even *save* energy, see Table 5. Delivering colder water allows for a reduced chilled-water flow rate and therefore reduced chilled-water pump energy. Due to coil dynamics, variable flow systems with two-way valves (that are operating properly) should return the same or warmer water to the free-cooling heat exchanger, not the other way around.

Consider putting a variable-frequency drive on the lead mechanical chiller but do not let low chiller loading in integrated economizer mode trigger hot-gas bypass installation or operation. This is *false loading* and absolutely not the way to go when trying to save energy.

If the goal is to prevent the chiller from cycling on low load, instead of hot-gas bypass, add more load to the chiller by reducing the load performed by the waterside economizer. If you're also concerned about the low efficiency at low chiller loads in the integrated mode, consider installing thermal storage instead as a first stage of supplemental cooling.

Summary

Designers must evaluate the proper application of waterside economizers and plan for cold towers, as well as cold start-up and operation of chillers.

Warmer climates have fewer hours conducive to waterside economizing. The load profile should be considered when deciding if enough ton-hours and operating hours exist at attractive wet-bulb temperatures. The equipment efficiency trade off may be a better option in some cases.

Series arrangement is easier to control without disrupting cooling, but beware of extending the economizer cycle too long.

Once the chiller starts, integrated free and mechanical cooling may have marginal value when mechanical cooling is controlled optimally. Release chilled-water reset in integrated mode. If the lead mechanical cooling chiller is variable-speed and/or high efficiency, terminate economizer mode sooner.

By Susanna Hanson, applications engineer, and Jeanne Harshaw, program manager,Trane. You can find this and previous issues of the Engineers Newsletter at www.trane.com/EN. To comment, send e-mail to ENL@trane.com.

References

[1] Hanson, S., "Free Cooling with Waterside Economizers," *Engineers Newsletter*, 2008, Trane.

[2] Hanson, S., "ASHRAE Standard 90.1-2010: Updates to Mechanical System Mandatory and Prescriptive Requirements," *Engineers Newsletter*, 39-3, 2010, Trane.

[3] Hanson, S., "ASHRAE Standard 90.1-2013 HVAC and Power Section Highlights," *Engineers Newsletter*, 44-1, 2010, Trane.

[4] Lindahl, P., "Cold Weather Operation of Cooling Towers," ASHRAE Journal, March 2014.

[5] Schwedler, M., "Effect of Heat Rejection Load and Wet Bulb on Cooling Tower Performance." ASHRAE Journal, 2014.

[6] Sullivan, B., "Chiller Selection Made Easier with myPLV™," *Engineers Newsletter*, 44-4, Trane 2015.

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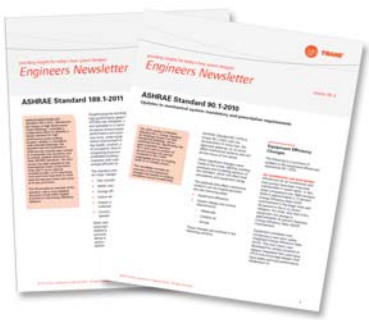

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TRACE 700 v6.3.3 Now Available

The latest release of TRACE™ 700 focuses on updating and adding to the standard libraries included in the program.

ASHRAE Standard 90.1-2013 libraries. Previously the TRACE library included equipment and constructions for 90.1–2004, 2007, and 2010. This has now been expanded to include 90.1-2013 equipment and constructions to support the LEED v5.

CVHS Library Trane Series S CenTraVac™ chiller is now available as cooling equipment library in the program. This can be found in the water-cooled chiller category. Remember, you can still import Trane equipment selections from TOPSS® into TRACE.

Visit **www.Trane.com/TRACE** to view version details or download a free 30-day trial.

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For more information, contact your local Trane office or e-mail us at comfort@trane.com