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CHILLER OPTIMIZATION AND ENERGY-EFFICIENT CHILLERS

INTRODUCTION

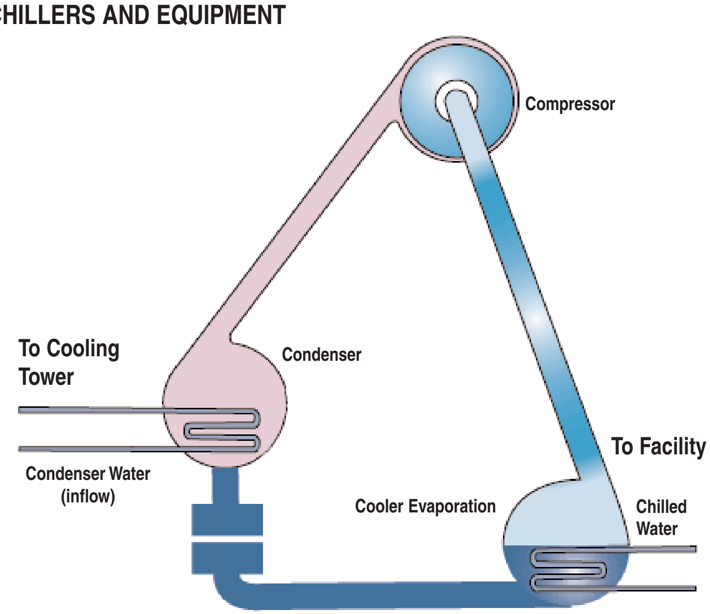
Over 24 percent of the energy in commercial buildings is used for Heating, Ventilation and Cooling (HVAC). Of this energy, more than half goes to building cooling. In larger buildings, chillers are often used for cooling. Chillers are a type of cooling equipment that produces chilled water to cool air. Making your cooling systems as efficient as possible is an important component of reducing building operating costs. This article addresses energy saving opportunities in chillers.

There are significant efficiency improvements that can only be cost justified at the time of purchase. If a poor purchase decision is made, you may be saddled with high operating costs for many years to come. Pay particular attention to the first section on Purchasing Energy-Efficient Chillers and Equipment if you have a chiller greater than 10 years old, if you have a heavily used air-cooled chiller over 100 tons, if your chiller has insufficient capacity, if it is experiencing frequent problems or if you are considering the purchase of a chiller for expansion or redundancy.

If your chilled water system is less than 10 years old and not in need of imminent upgrade or replacement, it is unlikely that you will be able to cost justify replacing the chiller based on energy efficiency savings alone. In this case, you should review the section on Optimizing Existing Chilled Water Systems to evaluate ways to make your existing chiller system more efficient.

PURCHASING ENERGY-EFFICIENT CHILLERS AND EQUIPMENT

First, you should understand the terminology of chiller efficiency. Chiller efficiency is generally expressed in terms of kW per ton (kW/ton.) A kW is a kilowatt of electrical input. A ton of cooling is equivalent to 12,000 BTU of cooling per hour. More efficient chillers will have lower kW/ton ratings indicating that they use less electricity to deliver the same amount of cooling.



You should also realize that chillers may have a Full-Load (FL) rating and an Integrated Part Load Value (IPLV) rating. The IPLV is a weighted average of efficiency measurements at various part-load conditions. It is a standardized way of comparing chillers at conditions more representative of field conditions. IPLV is preferred for situations with variable loads. However, buyers may wish to put more emphasis on full-load performance in installations with staged chillers.

New chiller efficiency (IPLV) can vary widely from as low as 1.25 kW/ton (standard efficiency air-cooled screw compressor) to as high as 0.38 kW/ton (high efficiency water cooled centrifugal compressor.) In other words, energy operating cost can be more than 2½ times as high for the lower efficiency chiller. For each 100 tons of chiller capacity, this can lead to savings of more than $104,000 over 10 years.

To estimate savings for higher efficiency chillers, use the following formula:

(kW/ton saved) x (number of tons) x $/kWh saved = $ per year saved

Equivalent Full-Load Hours			Electric Rate		$/kWh Saved
One-Shift Operation	1,500 hours	X	$.06	=	$90
Two-Shift Operation	2,250 hours				$135
Three-Shift Operation	3,000 hours				$180

As an example, a two-shift operation using a 300 ton chiller and selecting a model with an IPLV of 0.55 compared to one with an IPLV of 0.7 would save:

(0.7 - 0.55) kW/ton x 300 tons x $135 / year = $6,075 per year saved

In other words, to achieve a two-year payback, you could pay as much as $12,150 more for this higher efficiency chiller.

The tables below show efficiency recommendations for various types of chillers. The columns list the recommended level (based on Standard 550/590-98 of the American Refrigeration Institute) and the best available IPLV for that chiller type. Values are based on standard rating conditions specified in ARI Standard 550/590-98. Only packaged chillers (i.e., none with remote condensers) are covered.

Efficiency Recommendations – Air Cooled Chillers		
Compressor Type and Capacity	Part Load Optimized Chillers	
	Recommended[a] IPLV (kW/ton)	Best Available[a] IPLV (kW/ton)
Scroll (30 - 60 tons)	0.86 or less	0.83
Reciprocating (30 - 150 tons)	0.90 or less	0.80
Screw (70 - 200 tons)	0.98 or less	0.83
Compressor Type and Capacity	Full Load Optimized Chillers	
	Recommended Full Load (kW/ton)	Best Available Full Load (kW/ton)
Scroll (30 - 60 tons)	1.23 or less	1.10
Reciprocating (30 - 150 tons)	1.23 or less	1.00
Screw (70 - 200 tons)	1.23 or less	0.94

Efficiency Recommendations – Water Cooled Chillers		
Compressor Type and Capacity	Part Load Optimized Chillers	
	Recommended[a] IPLV (kW/ton)	Best Available[a] IPLV (kW/ton)
Centrifugal (150 - 299 tons)	0.52 or less	0.47
Centrifugal (300 - 2,000 tons)	0.45 or less	0.38
Rotary Screw >= 150 tons	0.49 or less	0.46
Compressor Type and Capacity	Full Load Optimized Chillers	
	Recommended Full Load[d] (kW/ton)	Best Available Full-Load[d] (kW/ton)
Centrifugal (150 - 299 tons)	0.59 or less	0.50
Centrifugal (300 - 2,000 tons)	0.56 or less	0.47
Rotary Screw >= 150 tons	0.64 or less	0.58

BUYING TIPS

- Buyers must decide between air-cooled or water-cooled chillers. Air-cooled systems eliminate the need for a cooling tower which reduces installation and O&M costs. However, as you can see from the tables above, air-cooled chillers are significantly less efficient. Decisions must be made on a case-by-case basis.

- When selecting a chiller, pay careful attention to sizing. Oversized chillers are not only more expensive to purchase, they may waste energy due to poor low-load efficiency.

- When replacing chillers, consider other energy retrofits that may reduce cooling load such as improved window glazing or lighting improvements. The lower cooling load may allow a smaller chiller that may tip the scales in favor of justifying the other improvements.

- For more precise energy cost calculations consult the following websites for air-cooled and water-cooled chillers:
  www.eere.energy.gov/femp/technologies/eep_ac_chillers_calc.cfm
  www.eere.energy.gov/femp/technologies/eep_wc_chillers_calc.cfm

- Consider multiple compressor chiller systems for redundancy and to allow staging compressors. Staged compressors are automatically sequenced to keep compressors near full-load.

- Variable speed centrifugal chillers allow chillers to operate at *increased* efficiency at part-load. If chillers can be staged, consider using a centrifugal chiller as a lead chiller to take care of the variable load and conventional chillers as backup operating at near full-load whenever they come on.

- Remember that there are also savings to be realized in high efficiency pumps and motors and in efficient cooling towers (two-speed or variable speed fans).

- Chilled water pumping systems may involve “primary” and “secondary” loops and can be quite complex. Conventional primary\secondary pumping systems are starting to lose favor as strategies to save energy (www.ari.org/pr/2004/05-04-ARTIrpt.html). Ensure that your system designer has evaluated the pros and cons of alternative chilled water pumping strategies.

OPTIMIZING EXISTING CHILLED WATER SYSTEMS

If you have a reasonably new chiller and can't justify outright replacement, don't give up. There are a number of things you can do to reduce the operating cost of your existing system. The following well-known strategies can be used in many modern systems and, used together, they may save from 5 to 25 percent of your cooling energy. Be sure to consult your chiller applications manual or chiller manufacturer before dramatically changing chilled water or condenser water set-points. Many of these capabilities are built into existing chiller control modules.

Chilled Water Supply Temperature Control

For years, chillers were controlled to supply constant temperature water to the building regardless of cooling load. However, modern chillers can vary the Chilled Water Supply Temperature as the cooling load decreases. By allowing the water temperature to float up during low cooling load periods, savings of about one percent per degree temperature rise are typical. In other words, raising Chilled Water Supply Temperature by an average of 5º F will save about 5 percent in chiller energy.

To do this, the chiller must somehow sense when there is reduced load. Sometimes Chilled Water Return Temperature is used as an indicator (higher return temperatures indicate fewer cooling BTUs are being taken out of the loop, i.e. reduced load). More sophisticated systems will monitor the worst zone — the one with the most open cooling water valve. When the temperature of that zone starts to rise, chilled water temperature is lowered.

For more information on Chilled Water Reset strategies, visit www.energybooks.com/pdf/264266.pdf.

Condenser Water Temperature Set-Point Control

This approach can be applied to systems, such as those using cooling towers, where the Condenser Water Temperature can be varied. Typical cooling tower control schemes maintain a constant Condenser Water Temperature (usually at 85ºF) by varying the flow rate of air. As the outdoor wet-bulb temperature decreases, the Condenser Water Temperature can be decreased. The result is less work for the compressor and a savings of about 0.5 percent for each 1ºF decrease in Condenser Water Temperature. In other words, lowering Condenser Water Temperature by an average of 5ºF will save about 2.5 percent in chiller energy. There are limits to how low you can go — check with your chiller manufacturer. Most chillers can handle temperatures of 70ºF or below.

Chiller Sequencing

Conventional chillers exhibit a decrease in efficiency when operated at reduced loads. Chiller sequencing in multi-chiller systems ensures that the most efficient combination of chillers is operating to ensure that the system is operating at or near maximum efficiency. Often chiller control systems already have the capability to handle this function.

Chiller Maintenance

Pay attention to set-point calibration, proper water treatment and periodic tube cleaning to improve heat exchanger efficiency. For more discussion of various Chiller System Energy Saving Strategies, visit the following website: www.eere.energy.gov/femp/pdfs/ccg08_ch6.pdf.

ADDITIONAL INFORMATION

For additional help, contact your Progress Energy representative, your local contractor or Advanced Energy (919-857-9000).

American Council for an Energy-Efficient Economy (ACEEE) publishes the *Guide to Energy-Efficient Commercial Equipment*, which includes a chapter on HVAC systems, as well as a listing of chiller models that meet this recommendation.
Website: www.aceee.org
Phone: 202-429-0063

ASHRAE publishes the *Cooling and Heating Load Calculation Manual*.
Website: www.ashrae.org
Phone: 800-527-4723

E Source publishes the *Electric Chillers Buyer's Guide*.
Website: www.esource.com
Phone: 720-548-5000