HVAC HESS

PEOPLE

PRACTICES

SYSTEMS

Factsheet

Chiller Efficiency

The HVAC and common area lighting systems of a 45 year old 5,400m[2] commercial office building in Canberra (Figure 1) were upgraded in 2010, resulting in a NABERS Energy Rating improvement from 2 to 4.5 stars. This resulted in a reduction in annual energy usage saving $120,000, a 70% reduction in annual greenhouse gas emissions, and an increase in occupant comfort. One facet of the retrofit included an upgrade of the Chillers; other components of the retrofit are detailed in companion factsheets.

Figure 1: Street view of 4 Mort Street, Canberra

Chillers

HVAC systems typically consume around 70% of a base building's energy usage, with 25-35% of energy consumed by chillers producing chilled water for air-conditioning. Therefore, the efficiency of chillers and the optimisation of their performance within the HVAC systems they operate are important in achieving high performance.

Most chillers work on the vapour compression cycle, where a compressor circulates refrigerant through heat exchangers to produce chilled water, and a condenser where heat is rejected.

Chillers can be air or water cooled, depending how the heat is rejected. Water cooled chillers are more compact, less noisy, have longer operating lives and are more energy efficient than air cooled chillers.

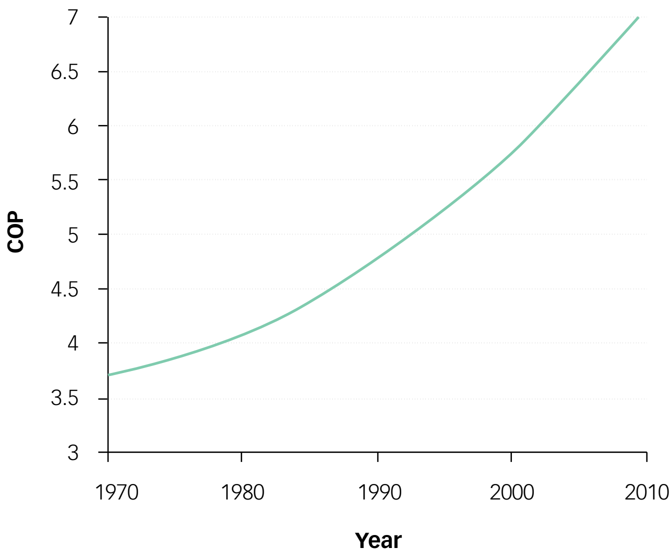
As a general guide, chillers older than 15 years, typically contain ozone depleting refrigerants[1] and are best replaced with more efficient modern units which use refrigerants with zero ozone depleting potential and lower global warming potential.

Chiller Efficiency

When engineers and controls specialists focus on improving chiller efficiency, it is often at the detriment of the energy consumption of associated equipment such as cooling towers, air distribution fans, chilled water and condenser water pumps. Sometimes the net result is an increase in total energy consumption. It is important that a more holistic systems type approach is used when looking to improve chiller efficiency.

The cooling efficiency of a chiller is expressed as its coefficient of performance (COP) or energy efficiency ratio (EER) which is the refrigeration capacity at full load (in watts)/electrical input power (in watts). Chiller efficiency has steadily increased mainly due to improvements in compressor and heat exchanger technology, along with better controls. Figure 2 shows improvement in chiller efficiency from 1970 to 2010.

Figure 2: Chiller efficiency gains (source GHD)



Given that chillers used in HVAC systems rarely operate under full load conditions, a better index for the assessment of chiller efficiencies is the integrated part load value (IPLV)[2] The IPLV takes into account the COPs of a chiller at loadings of 25, 50, 75 and 100% at different operating conditions, and is more representative of the performance of a chiller over a typical cooling season. Figure 3 shows that the chiller demand is low in typical office type buildings for most of the year and, hence, demonstrates the importance of assessing the chiller efficiency at part load under prevailing ambient conditions rather than at full load, as per traditional practice.

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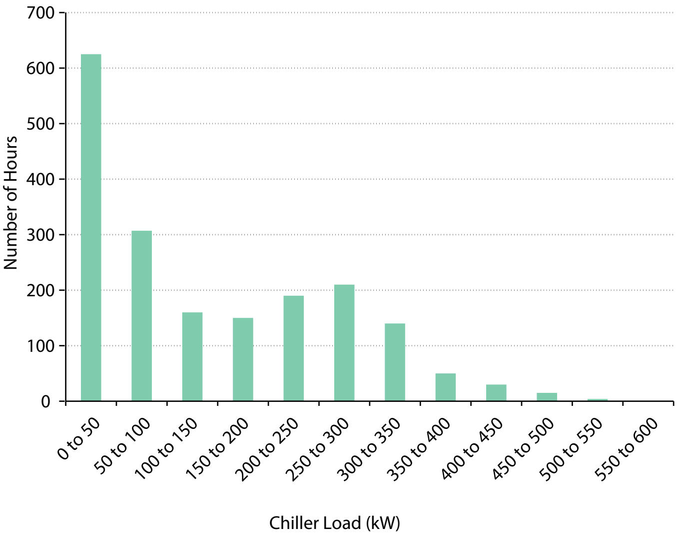
[1] Such refrigerants include R11, R22 and R123, which are either banned from production and import or are being phased out. For more information see www.environment.gov.au/atmosphere/ozone/index.html

[2] Which was developed by the Air-Conditioning Heating and Refrigeration Institute (AHRI) USA and standardised as ANSI/AHRI 551/591(SI).

To optimise chiller selection for high performance buildings, the most accurate method is to carry out a thermal simulation of a building to determine the annual cooling load profile under different ambient conditions. For existing buildings, the cooling load profile may be determined using data from the Building Management System (BMS) where there is sufficient thermal and energy metering and monitoring.

Figure 3: GHD building simulation showing Chiller Demand



Efficiency Regulations

As of December 2012 Chillers with capacities greater than 350kW sold in Australia must comply with the minimum energy performance standards (MEPS) regulations. Table 1 shows the efficiency ratings that chillers must achieve, when tested in accordance with AS/NZS 4776. Chillers with capacities less than 350kW are covered by the National Construction Code (formerly the Building Code of Australia). For water cooled chillers, the minimum COP is 4.2 and the minimum IPLV is 5.2; for air cooled chillers the minimum COP is 2.5 and the minimum IPLV is 3.4.

Table 1: MEPS Ratings

Capacity (kW)	Minimum COP		Minimum IPLV	
	Air cooled	Water cooled	Air cooled	Water cooled
350-499	2.70	5.00	3.70	5.50
500-699	2.70	5.10	3.70	6.00
700-999	2.70	5.50	4.10	6.20
1,000-1,499	2.70	5.80	4.10	6.50
>1,500	2.70	6.00	4.10	6.50

Factors to Consider

Water Cooled vs Air Cooled Chillers

In general, water cooled chillers are more compact, less noisy, have longer operating lives and are more energy efficient than air cooled chillers. However, whole of lifecycle costs must be taken into account. The final chiller selection will depend on a number of factors such as climatic region, operating hours, cooling load profile, system redundancy requirements, space availability, capital and operating costs, energy efficiency, water consumption and water treatment costs. For example, in cooler climatic regions, especially for buildings that operate overnight when ambient temperatures are low, the energy savings from water cooled chillers can be minimal. Water cooled chillers tend to have lower life cycle costs in warmer climatic regions, in buildings where chillers are operated for long hours and where chiller capacity is typically larger than 1.5MW. Water efficiency is a key operational consideration where water cooled chillers are installed.

An option available for smaller systems is the use of an air cooled system with the addition of adiabatic type pads. Adiabatic pads are evaporative pre-cooler pads that are fitted in front of the heat exchanger and allow the precooling of air by passing it through the adiabatic wetted pads prior to entering the heat exchanger.

Condenser Water and Chilled Water Reset

Chiller efficiency improves significantly, especially when variable speed type compressors are installed, when the condensing (heat rejection) temperature is lowered and/or the evaporating (chilled water) temperature is raised. Energy consumption can be reduced by 1.5-2.5%/°C depending on the type of chiller.

Traditionally, cooling towers have been set to maintain the temperature of the water entering the chiller at a constant 29°C. In modern chillers the condenser water temperature can be as low as 15°C when suitable ambient conditions prevail. Similarly, during periods of low cooling demand, the chilled water temperature, which has traditionally been set at 6°C, can be reset upwards, resulting in efficiency gains.

It is important, however, for designers to ensure that chiller efficiency gains are not outweighed by increased energy consumption associated with powering cooling tower fans and air handling unit fans required in order to maintain the same level of occupant comfort at the higher air temperature.

Variable Pumping

In a large building, the energy associated with circulating the chilled water can be a significant proportion of the energy consumed by the chilled water system. Designers should consider the options available for variable flow chilled water pumping which can be achieved either through a primary or a primary/secondary system.

Pumping energy will also be reduced by having lower chilled water flow rates, albeit at a lower chiller efficiency. Traditionally chillers have been sensitive to lowering of water flow rates. Modern chillers, however, are far more flexible, providing the rate of change is maintained within acceptable limits.

Manufacturers are now offering options including the connection of chillers in series with chilled water and condenser water in counterflow through the chillers. Although these and other options have the potential to deliver significant efficiency gains, it is important for designers to consult manufacturers and gain a thorough understanding of the systems and issues in order to avoid potential pitfalls.

Maintenance and Monitoring

Good maintenance is essential to keep a chilled water plant in peak operational efficiency. Considerations such as calibration of control sensors and keeping heat exchangers clean have a significant impact on energy efficiency. When open circuit cooling towers are used, chiller condensers must be monitored for fouling. A 0.6mm layer of fouling (including dust, dirt, pollen, moisture, etc.) on the finned coils (responsible for heat exchange) is estimated to increase chiller power consumption by 20%.

BMS play a key role in monitoring chiller energy consumption and COP, and can be programmed to produce automatic exception reports when key performance indicators stray beyond acceptable limits.

4 Mort St Retrofit

The chiller installed at 4 Mort Street, Canberra City (Figure 4) has 420kW capacity, with twin Turbocor type centrifugal compressors, incorporating oil free magnetic bearings and variable speed drives. Its COP is 4.03 and IPLV 7.1. Due to the relatively small size of chiller, the chiller is an air cooled unit incorporating adiabatic type pads rather than a water cooled machine connected to a cooling tower. This option reduced annual water treatment and consumption costs by around $3,000. The system essentially functions as an air cooled unit, with the adiabatic pre-cooling pads used during high ambient conditions.

Due to the relatively low water content of the chilled water system, a 1m³ buffer vessel was installed to improve chiller control. The buffer vessel incorporates temperature sensors at low and high level to sense its state of charge and extra thick thermal insulation to reduce heat losses.

The chilled water pumping system consists of constant flow primary only, with minimum system flow regulated through three port valves. Due to the compact nature of the chilled water system a primary/secondary type arrangement was not installed. To maintain controls simplicity, the system was configured for constant flow, however, the necessary hardware has been installed (chiller high level interface, chilled water flow meter, temperature sensors and differential pressure sensors) to further optimise by configuring for variable flow.

Figure 4: Chiller installed at 4 Mort Street, Canberra

HVAC HESS

The Heating, Ventilation and Air-Conditioning High Efficiency Systems Strategy (HVAC HESS) is a ten year strategy under the National Strategy on Energy Efficiency that aims to drive long term improvements in energy efficiency of HVAC systems Australia wide. Under the Energy Efficiency Working Group (E2WG), the Commercial Buildings Committee (CBC) manages the implementation of the HVAC Strategy. The CBC is comprised of representatives from Australian, State and Territory Governments.

The Strategy takes a whole of life perspective in targeting HVAC efficiency improvement, encompassing the design, manufacture, installation, commissioning, operation and maintenance stages of the HVAC lifecycle. The Strategy consists of a number of complementary measures that fall under the three broad initiatives - People, Practices and Systems. This Chiller Efficiency factsheet specifically relates to Systems. It is one of a suite of factsheets developed to provide a quick overview and reference to inform, educate, and encourage energy efficiency in the HVAC industry.

Acknowledgements

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This and other HVAC HESS factsheets can be found on the Department of Climate Change and Energy Efficiency website at:

www.climatechange.gov.au/government/initiatives/hvac-hess