Purdy's Wharf

Plumbing the depths

The use of seawater in HVAC heat rejection offers substantial energy savings and carbon reductions, as well as a host of secondary benefits. Yet as **Sean McGowan** reports, such advantages need to be weighed against higher capital costs and the potential impact on marine life.

For many decades engineers in the northern hemisphere have designed cooling systems to take advantage of the naturally occurring sub-surface temperatures of freshwater lakes. But it was not until the turn of the millennium that technology was significantly advanced to allow for large-scale projects.

Among the first was the implementation of a $US57 million ($57,744,000) centralised lake cooling system at New York State's Cornell University, which draws very cold water from nearby Cayuga Lake to help cool the university's buildings and a local high school.

The city of Toronto followed soon after with the world's largest deepwater cooling project to date.

Hawaii's Honolulu has been planning a massive district cooling system for its downtown commercial sector. The system will take advantage of the cold seawater found deep offshore.

Similar, albeit smaller, systems have also been implemented in Stockholm, Sweden, taking advantage of the frigid waters of the Baltic Sea, and in certain regions of Canada. Large systems are now also being proposed in the Middle East.

COOL WATER DOWN UNDER

In Australia, the obvious advantages of seawater cooling have not gone unnoticed, with such systems now being given serious consideration over traditional cooling tower solutions.

In Sydney, where the natural harbour offers an obvious source of cool water, a handful of projects have already been completed with seawater cooling systems employed. Workplace6, Sydney's first 6 Star As Built Green Star building, and the winner of the 2009 AIRAH Award for Sustainability, is a high-profile example.

The use of harbour water allows water-cooled equipment including the base-building electric chillers and tenant-installed packaged units, to use less compressor energy in the refrigeration cycle, while also reducing associated pump power.

According to Scott Brown, M.AIRAH, director of mechanical services and sustainability with the Waterman Group, which completed ESD and mechanical services for Workplace6, the major benefit of seawater cooling is the energy efficiency of a water-cooled system, without the potential downsides of cooling towers. These can include issues such as water consumption, rooftop or external plant footprint and of course *Legionella* risk and control management.

Sydney leads the way in Australia for the adoption of seawater cooling, with the Sydney Opera House, Star City Casino, AMP Cove, Woolloomooloo Wharf, King Street Wharf and the Sydney Harbour Convention Centre all examples of installations.

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Brisbane's river and nearby Moreton Bay have also proved capable of sustaining seawater cooling systems.

Brown says the capital cost and ongoing maintenance can be higher than traditional cooling tower solutions, with all system components from pipework to the heat exchanger required to be corrosion resistant. Most water-cooled HVAC and refrigeration equipment and system types are suitable.

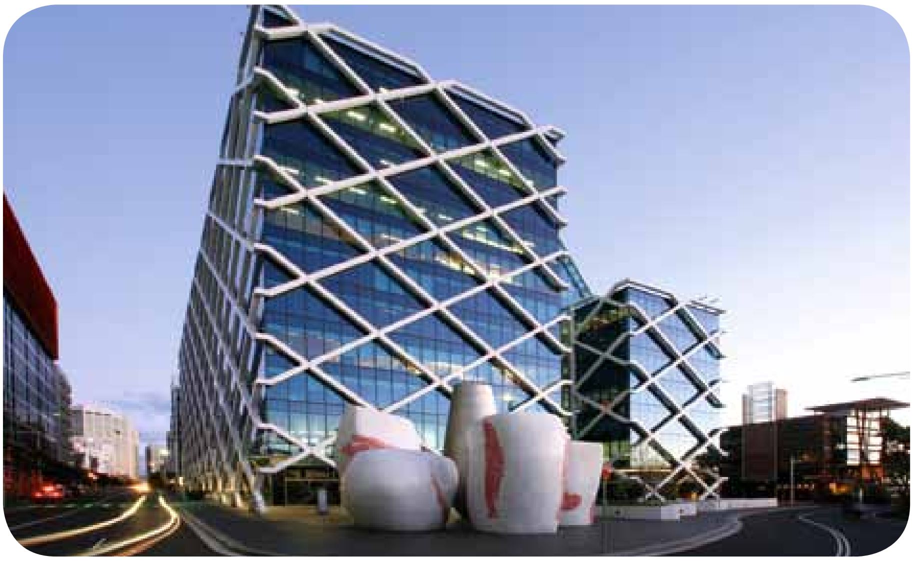
"There is no preference for HVAC system type because the end result is condenser water at roughly similar temperatures to cooling tower systems," he says.

OPEN OR CLOSED?

One of the major decisions for designers investigating seawater cooling is the selection of open-loop or closed-loop systems, each with their own pros and cons.

Open-loop systems are more commonly used, and while the capital cost remains greater than traditional HVAC solutions, they remain significantly less expensive than the closed-loop variation, albeit with the ongoing maintenance costs associated with corrosion and control of marine biology growth.

Open systems, as the description suggests, draw water directly from the harbour or ocean into a high-grade heat exchanger, typically made of titanium to combat the corrosion incurred from the seawater. Filters are also required to be installed on the intake side of the heat exchanger to remove biological particles.



King St Wharf

Once heat is exchanged with the condenser water, the warmer seawater is returned to the habour or ocean under strict environmental guidelines that determine the temperature and chemical makeup of the discharged water.

According to Brown, to maintain a healthy marine environment, government guidelines preclude increasing the surrounding seawater by more than 2°C in an hour.

"To simplify this, most recent open-loop systems in Sydney have been designed to add no more than 2°C to the harbour water inlet temperature," he says. "This is considered to provide compliance and not to affect the local marine ecosystems."

However, concerns remain regarding the impact on marine ecology from chemicals used in open-loop systems to prevent fouling.

In response, a study by researchers from the University of Sydney is looking at the types and volume and of marine creatures living near discharge pipes, compared with the biodiversity found at three similar harbour locations.

This research is expected to reveal the real impact of seawater cooling, and could play a role in the development of more stringent guidelines should a negative impact be proven.

In contrast to open-loop systems, a closed-loop system passes condenser water through a loop or series of loops of HDPE pipework, which are submerged under the water surface in custom-built baskets or frames.

The heat from the condenser water is simply "exchanged" to the surrounding seawater through the wall of the pipework, with the resultant cooled condenser water looping back to the system.

Brown says this system is not as commonly employed due to the relatively poor heat exchange ability of the plastic pipe, meaning that larger quantities of pipework are required, taking up a significantly larger sub-surface area. Although the initial capital costs are more expensive, closed-loop systems require less ongoing maintenance than open systems.

DEEP AND MEANINGFUL

Brett Beeson, mechanical and ESD Engineer with Cundall in Brisbane, is another to have had significant experience in the field of seawater cooling, including designing a closed-loop system for a two-storey commercial office building located at Manly Harbour, just a few kilometres east of Brisbane's CBD.

At the time, it was the only closed-loop system of its type in Brisbane, and among the first nationwide. In this installation, Beeson combined the energy efficiency of seawater cooling with a mixed-mode HVAC design, further reducing the building's energy consumption.

Yet he cites the expense of such a system as one that limits its deployment to building sites located "very close" to the sea.

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"In my experience, it is substantially more expensive than a traditional system," says Beeson, who addressed the topic at AIRAH's recent Achieving the Green Dream conference. "However, if more systems are installed the risk premium will reduce.

"These systems are generally quite simple, so an effective design in the right situation might get close to cost-neutral. Larger systems are much more economically viable."

One of the keys to a successful seawater cooling installation is the depth of the water intake pipe in open systems, or the depth of the submerged pipework in closed systems, which varies greatly according to the heat exchange ability of the body of water.

According to Beeson, the heat rejected into the body of the water can be removed by bulk water flow, such as tides, open sea or river flow, or local effects of evaporation and mixing.

"Slow rivers and lakes are often not suitable, or at least are higher risk, as the bulk water movement is reduced. Local temperature increases in the water temperature can also render a system unviable," Beeson explains.

"A seawater temperature of less than 25°C is also required [and] this means Brisbane is probably at the limit for surface applications. Seawater at lower depths is colder, so can be used in tropical areas."

Another factor that dictates the depth of intake pipes or submerged loops is the low-tide height, or the minimum lake or river depth, so that any seasonal changes that result in a warmer surface layer of water is avoided.

In contrast, the discharge depth of an open-loop system is not as critical, so long as regulations for discharge temperature are met and there is reasonable separation between the discharge and intake pipes to reduce any effect of short cycling.

In some instances, such as Hawaii's district seawater cooling project, the intake pipe of the open-loop system has reportedly been designed at a depth of some 700m, where the water is constantly in the range of approximately 5-7°C. This will see the pipe stretch several kilometres offshore, while the discharge pipe will run to a depth of 40m.

Brown says a basic understanding of the water environment is required by designers so as to adequately make engineering decisions on equipment.

"Depth, temperatures, flows, tides, salinity, water cleanliness and biology in terms of likely fouling, filtering and cleaning are all important factors for consideration," he says. "Appropriate system materials are then selected to suit."

PERFORMANCE AROUND THE WORLD

Though the use of seawater cooling systems remains in its infancy here compared to other countries in the northern hemisphere, where data is available, energy efficiency and performance in Australian projects has proved positive.

In the case of Workplace[6], the open-loop seawater cooling system and use of water-cooled chillers offered designers a significantly higher COP compared to similar sized air-cooled chillers. The lower water temperatures sourced from the harbour allows equipment, including packaged units, to operate more efficiently.

The system also saved the site eight million litres of water annually by removing the need for cooling towers, contributing significantly to the building achieving its 6 Star Green Star rating.

In Halifax, Canada, where seawater cooling has been used at the city's Purdy's Wharf Office and Commercial Complex, an open-loop system has delivered effective cooling for almost 11 months of the year.

Drawing cold seawater from the adjacent harbour, the system is used to cool the building's cooling water, which is then pumped to each floor and circulated through a coil system to cool the warmer internal air.

At a cost of CA$200,000 ($200,605) it has reportedly delivered a simple payback of two years by reducing electricity use and maintenance costs, resulting in a net annual saving of CA$104,000 ($104,344).

Whether savings like these are possible in the Australian climate is a matter of conjecture. Yet given our propensity for waterside development, district seawater cooling schemes like those being developed in Hawaii and the Middle East must surely offer significant advantages that should be investigated in greater detail.