COVER FEATURE

Western Australia accounts for more than 90 per cent of Australia's fresh carrot export market.

Energy carrot

Just as sustainable building design has taken notice of phase-change materials, so too are industrial and manufacturing processes recognising the energy cost savings these systems offer. Sean McGowan reports on the successful retrofit of the technology at a farm north of Perth.

Due to its natural advantages of a mild climate, suitable soils and access to underground irrigation sources, Western Australia boasts one of the country's strongest carrot industries, accounting for over 90 per cent of the nation's total fresh carrot export market.

Indeed, strong demand for the state's high-quality carrots from Malaysia, Singapore, the Middle East and the Maldives has seen annual export quantities from the region reach in excess of 65,000 tonnes in recent years.

Many of these carrots are grown around the agricultural towns of Gingin and Lancelin, about 100km north of Perth, where cereal crops, olives and oranges also flourish in the sandy soils of the region. Such is the climate here that carrots can be seeded and harvested all year round, and given this area's proximity to Fremantle, produce can be harvested, packed and transported to ships ready for export within 24 hours.

However, the packing of carrots for overseas export is no simple task, requiring careful chilling of the carrot core to maintain as-picked quality and ensure a longer shelf life. This requires process-cooling equipment that can be both high-energy-consuming and susceptible to failure during the heat of summer.

It was for these reasons that a 405 hectare carrot farm in Gingin turned to phase-change materials (PCMs) to improve the efficiency and capacity of its processing operations while reducing energy costs by $80,000 per year.

According to Gavin Colbourne, technical manager of Phase Change Products, which supplied the PCM system in this project, the farm had been using four chillers to cool glycol. This in turn cooled water inside a hydro-cooler, but had suffered power supply issues while also experiencing increased demand from buyers.

"They required increased cooling capacity but couldn't add on more chillers

as the power to the site was at maximum capacity," he explains.

"We were contacted by someone familiar with the problem the farm faced, and suggested the problems could be resolved by retrofitting a PCM thermal storage system that would utilise the existing cooling infrastructure at night to increase overall cooling capacity and therefore production."

CONTROLS CRITICAL

According to Colbourne, the retrofitting of the PCM system was a relatively straight-forward process, but the control of the entire system was critical.

After assessing the existing infrastructure on site, the four chillers were deemed fit to be used in the farm's new PCM system provided a complete overhaul of their controls was conducted.

"It is understood that the units were bespoke and built in New Zealand as one-offs," says John Hill of Advanced Building Controls. "The existing controls were very basic, and the chillers basically all started and stopped at the same time based on the glycol tank temperature, set at a fixed -11°C."

"All four chillers were controlled via a central signal from the process plant temperature controller, so they were either all started or all stopped at the same time. They were also shutdown on pump-down sequence because the compressors had equalisation lines fitted for oil return."

> 'Staff can access the system from their desk using their own PC, or an engineer can access the system via a laptop with wireless connection, meaning it can generally be dealt with before processing is affected'

He says this meant that even when the plant was off, the chillers constantly cycled on and off, for a few seconds at a time, to keep pumping them down, also an enormous waste of energy.

Where a chiller should trip or fail, this was not noticed until the temperature began to rise, by which time it would be too late to recover. On occasion, and particularly in summer months, this would result in the processing facility being shut down.

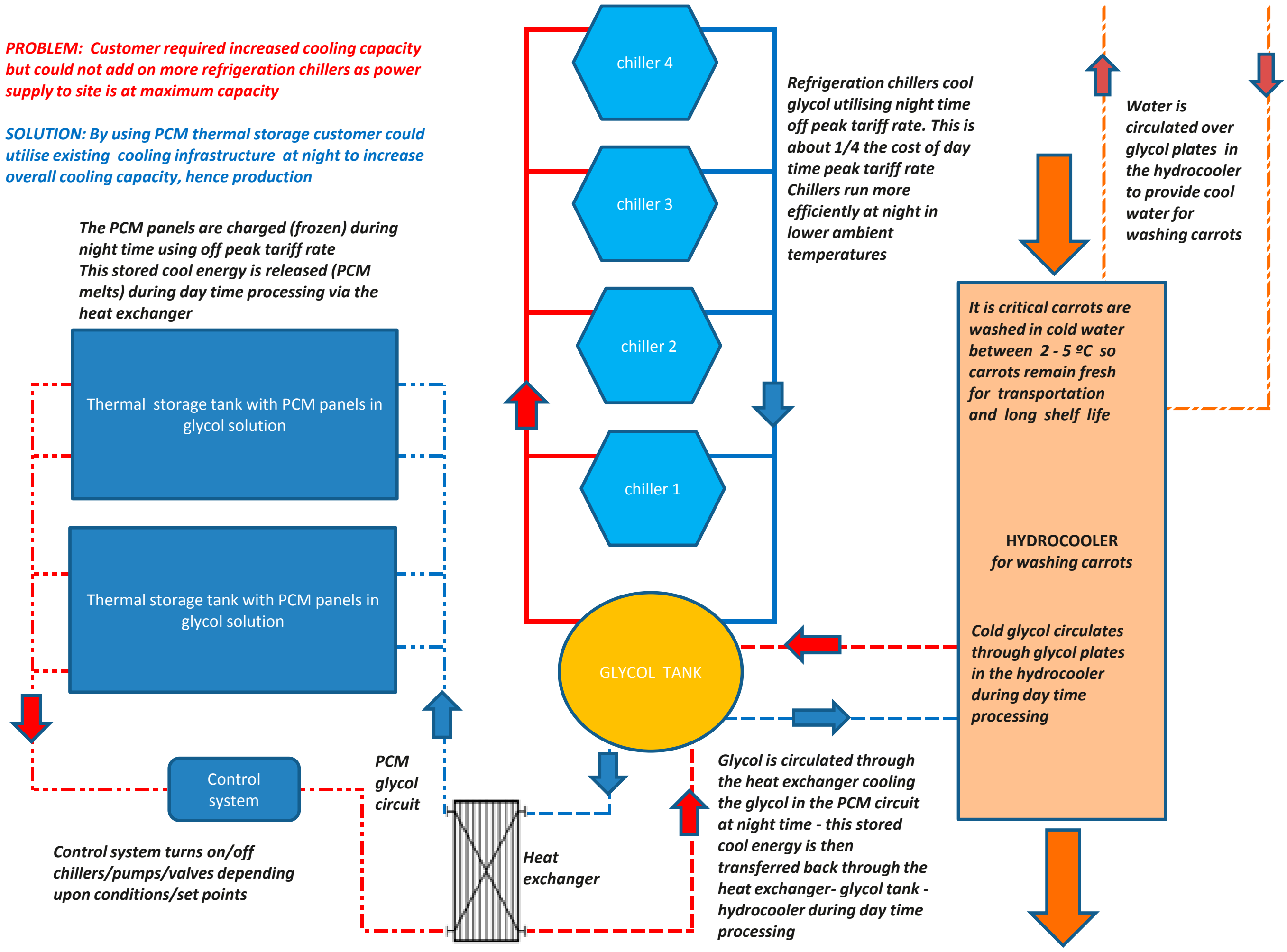
Following a mechanical overhaul, each chiller was retrofitted with a completely new control system. A 6" monochrome touch screen was also fitted to each chiller allowing full local access, and a 6" full-colour screen fitted to the PCM.

An open system controller was selected – a programmable multiprotocol display data channel (DDC) controller and integrated webserver – and fitted to each unit with a completely new application program written for chiller control.

The same controller was also used for the PCM control, with the entire system connected together via ethernet TCP/IP LAN. Graphical web pages were generated within each webserver, allowing the user to log directly into any controller, download logs, view graphs and data, alter set-points and set up time schedules and change modes.

Once logged in, users can jump from device to device seamlessly.

Phase-change material increased the farm's cooling capacity without the need for extra chillers.



The PCM thermal storage layout.

Chillers - thermal storage tank.

According to Hill, as this project used multiple protocols including Modbus for the touch screens and VSD communication, SNMP to the expanded IO and its own integrated TCP/IP data packets for inter controller communication, it was important that the controller be multi-protocol.

Another advantage of this system is that no special or third-party HMI software is required, making access simple from any standard PC connected either directly to the network or via wireless connection with a web browser.

“The DDC controls were made off-site on a new back panel, allowing for each chiller to be modified in a single weekend, avoiding any downtime in the farm’s processing,” he says. “Programming of the controls was done via a free programming tool using a functional block-type environment with all the standard DDC control functions and algorithms.”

PCM panel installation day.

With DDC controllers fitted, the operation and efficiency of the chillers was improved immediately.

"Now the system can provide an immediate indication that there is a problem, via SMS text alerts, as well as providing an audio visual alert on the factory floor," Hill says. "Staff can access the system from their desk using their own PC, or an engineer can access the system via a laptop with wireless connection, meaning it can generally be dealt with before processing is affected."

RETROFITTING PCM

With no information or wiring schematics available, it was calculated that each chiller produced around 70kW/hr, for a total of 280kW/hr. Following an energy audit, it was realised that this fell well short of the 420kW/hr of cooling the farm's processing plant actually required.

This was the equivalent of adding another two chillers of the same capacity.

With power to the site already at maximum capacity, Colbourne proposed to retrofit a 1600kW/hr thermal storage system that would be charged at night utilising the customer's off-peak power tariff that was 25 per cent the price of the peak tariff.

This solution also provided a secondary benefit of having the chillers operate more efficiently at night due to the lower ambient temperature.

"The idea was to draw the energy from the chilled glycol, via a heat exchanger, to charge phase-change material, and during the day supplement the energy back into the system as required," explains Colbourne.

> "Imagine a building that has eight hours of additional cooling or heating stored ready for use, and that has been acquired overnight using electricity at a fraction of the peak rate"

Following the chiller upgrade, two large, insulated concrete thermal storage tanks were connected to the existing system via a plate heat exchanger. These hold the selected PCM – a mix of non-hazardous inorganic hydrated salts encapsulated in HDPE plastic panels – that offers a temperature differential of 5°C from target to allow for the heat exchanger.

A variable speed pump was installed on the PCM tank side and a constant flow pump on the glycol tank side. As the PCM and chiller controls are connected via a common LAN, the PCM system is able to command or stage the chillers as well as adjust their set-points between a charging set point of -15°C and a cooling set point of -4°C.

PCM panels in frames.

EFFICIENCY IN OPERATION

As the installation of the PCM system did not disrupt processing, the retrofit was both straightforward and efficient.

The system operates by charging the PCM tanks overnight through the operation of the chillers. With the variable speed pump running at a constant speed, the chilled glycol is circulated from the glycol tank, through the plate heat exchanger. The glycol on the thermal storage tank side is then used to cool the PCM panels in the tanks to temperature, with phase change occurring at around -6°C and latent energy stored.

The temperature of the PCM panels continues to fall down to around -11°C, at which time the tanks are considered to be fully charged and the whole system switches off. During summer, this process can take up to seven hours; however, in winter this is reduced to five hours.

During daytime processing hours, harvested carrots are cleaned and chilled by the hydrocooler, which features glycol plates through which cold glycol is circulated. Heat transfer takes place with water circulated over them, which is cooled and maintained at between 3°C and 5°C.

Maintaining this temperature range is achieved through normal chiller operation at a set point of -4°C, which maintains a leaving glycol temperature from the hydrocooler of lower than 2°C and is critical in ensuring the carrots remain fresh for transportation.

"During the day, when return glycol from the hydrocooler reaches 2°C, the PCM system is automatically initiated," Colbourne says.

"Pump 1 starts and pumps glycol through the heat exchanger from the glycol tank, which sets a constant speed to calculate the kilowatts generated by using the temperature differential between the glycol entering and leaving."

Pump 2 then starts and circulates glycol through the PCM storage tanks at the lowest speed, controlled by the VSD. Temperature sensors on the flow and return of the plate heat exchanger on the glycol tank side are used to calculate the differential temperature, with the variable speed pump modulated to maintain this differential at around 1.6°C, based on the calculated flow rate.

"The control system has a temperature differential that has to be maintained in the heat exchanger. For example, 1.5°C equals 150kW. If the temperature differential drops below this the pump is slowly ramped up to maintain the differential, Colbourne says."

As the latent energy from the PCM tanks is released, eight to 10 hours of additional cooling is provided, dependant upon through-put and the load of the factory.

PCM panels in glycol

Colbourne says that when the system first starts, just 4kW of pump power is used to generate 200kW of cooling, resulting in an energy efficiency ratio (EER) of 50.

"During this operation, if the return glycol from the hydrocooler drops to 0.5°C, it switches off the system. In this way, we are able to regulate energy when required."

Once the leaving glycol from the thermal storage tanks reaches 1°C, it is considered discharged and the system is switched off.

During winter months, Colbourne says the chillers have been able to be staged on and off during the day because the PCM is keeping up with demand, saving even more energy.

AN ENERGY CARROT

At a project cost of $330,000, the PCM retrofit and upgrade of controls on the system has delivered annual energy cost savings of about $80,000. Cooling and production has also increased significantly, reported to be over 40 per cent better during summer months.

Now with the ability to process over 500 tonnes of freshly harvested carrots during a five-day working week, the farm is better positioned to take advantage of increased demand from overseas customers.

Having worked in the UK on ice storage systems for many years, Hill is adamant that they do not provide the capacity or control that a PCM thermal storage system such as this offers, and believes such a system could work just as effectively in buildings as it does for process cooling.

"I see no reason why such a system couldn't be easily adapted for use in a standard building HVAC application," says Hill.

"Imagine a building that has eight hours of additional cooling or heating stored ready for use, and that has been acquired overnight using electricity at a fraction of the peak rate."

Whether we see PCM become a common design element of future commercial buildings remains to be seen, but the results from this project alone show that the technology has a greater role to play in reducing the energy consumption in process cooling.

PROJECT AT A GLANCE

The professionals

PCM System:
Phase Change Products Pty Ltd

Controls: Advanced Building Controls Pty Ltd

The equipment

PCM: PC-4 (hydrated ammonium bicarbonates and chlorides (min. 90%))

DCC: Intelli-Web V3 multiprotocol freely programmable controller/ webserver

VSD pumps: Pump 1: Grundfos 4kW; Pump 2: Grundfos 11kW both with VSDs

Heat exchanger:
400kW plate heat exchanger