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Ecolibrium

Cool runnings

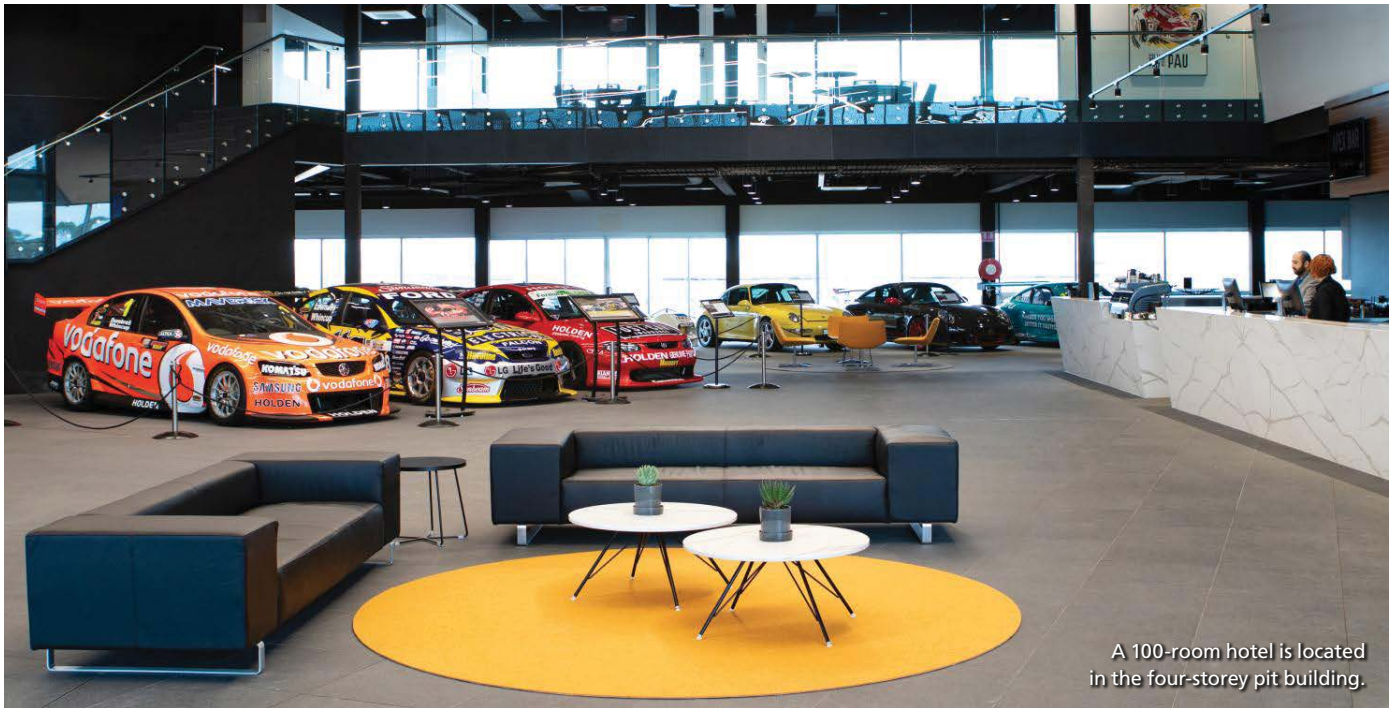
Refrigeration innovation at SA's purpose-built motorsport park.

AIRAH

The fast and

the curious

A new, purpose-built motorsport park in South Australia has not only consolidated the state's long-held involvement in the sport, but is also home to the first commercial trial of an innovative CO_2 refrigeration solution, as **Sean McGowan** reports.



A 100-room hotel is located in the four-storey pit building.

Considered one of the most significant developments in Australian motorsport history, The Bend Motorsport Park at Tailem Bend – an hour's drive south-east of Adelaide – is a state-of-the-art, purpose-built facility catering for all motorsport disciplines.

As well as hosting a second Australian Supercar Championship event on the world-class motor racing circuit this month, The Bend also features circuits for drift, karting, rallycross, drag racing, rally/off-road racing, 4WD adventure and driver training.

The on-track facilities at The Bend are complemented by a central Welcome Centre and 100-room hotel located in the four-storey pit building, as well as a caravan and camping tourist park.

An airstrip suitable for light aircraft and helipads for fast commuting between Adelaide and the park are also being built.

Developed and primarily funded by the Peregrine Corporation, the main motor-racing circuit was completed in April 2018, with other precincts following suit in the months since.

The Peregrine Corporation is South Australia's largest privately owned company, with annual revenue of more than $2 billion. A key part of the group is its On The Run (OTR) convenience store operations, with over 135 sites across South Australia.

Combined with the group's other retail and property interests, Peregrine's operations consume a large amount of electricity. Many of the sites' refrigeration systems are also exposed to the HFC phase-down.

AN ALTERNATIVE PLATFORM

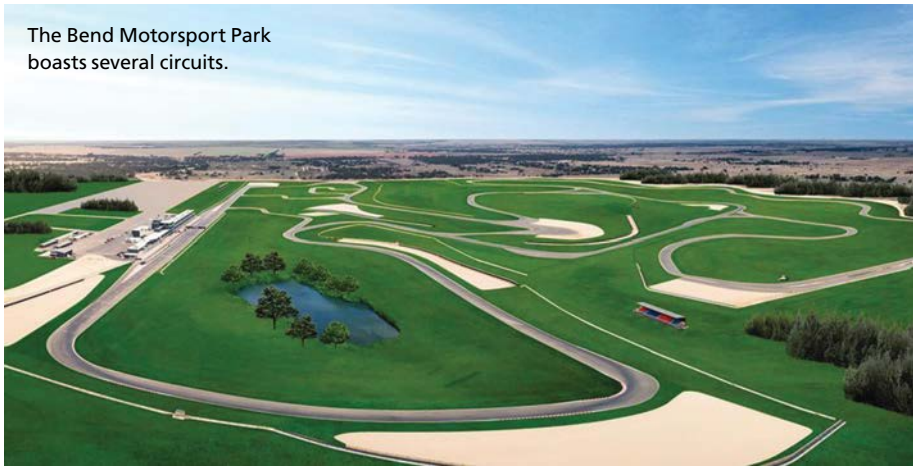
In 2016, Glaciem Cooling Technologies – a senior industry partner of UniSA – approached Peregrine to explore an alternative refrigeration platform for the OTR sites.

"Due to the significant increase in the price of energy in South Australia, more and more businesses are turning to renewable energy as a way of controlling their energy cost," says Glaciem's managing director, Julian Hudson, M.AIRAH.

"Peregrine's commitment to sustainability meant the corporation had already begun an internal process aimed at reducing overall energy costs across its OTR operations. And as Glaciem has a proven track record of providing innovative, energy-efficient cooling solutions – as well as being SA-based – it seemed a natural fit."

Hudson says the original brief was to dramatically reduce onsite electricity consumption, future-proof against changes to the use of synthetic refrigerants, and offer redundancy in the event of power outages.

But it was during these discussions that Peregrine's latest venture,


The Bend Motorsport Park boasts several circuits.

The facility was identified as an ideal candidate for a trial of DP-CO_2 refrigeration.

The Bend Motorsport Park, was identified as an ideal candidate for a commercial trial of Glaciem's new refrigeration platform, Dew-Point Carbon Dioxide-only (DP-CO_2) refrigeration.

"We were looking for an opportunity to install this newly developed technology platform on a large, greenfield site," Hudson says. "And The Bend – being under construction at the time – ticked these boxes."

The system was designed to be installed within the pit building to serve the 10m² freezer and cool rooms used by the commercial kitchen, dining rooms and hotel.

For Peregrine, the ability of the proposed system to meet the group's sustainability objectives while addressing life-cycle costs and mitigate environmental risks were key to the project proceeding.

THREE ALGORITHMS

There are three algorithms used to operate the refrigeration system at The Bend.

DEW-POINT MODE

Based on R&D carried out, the most efficient modes for operating the dew-point cooling were identified. The software takes into account the humidity ratio and dry-bulb temperature of the air, and proceeds to select the operating mode for the medium-temperature system.

CONDENSING TEMPERATURE CONTROL

A floating condenser temperature algorithm was also developed as part of the R&D.

"For any given ambient temperature there exists a highest efficiency point between the COP (coefficient of performance) of the compressor, and the amount of fan power required," says Julian Hudson, M.AIRAH.

Based on the mode selected, the CO_2 condensing temperature is automatically adjusted to this point.

"This algorithm can be used on any refrigeration system," he says, "and is not site-specific."

ADVANCED CONTROL FORECASTING ALGORITHM (ACFA)

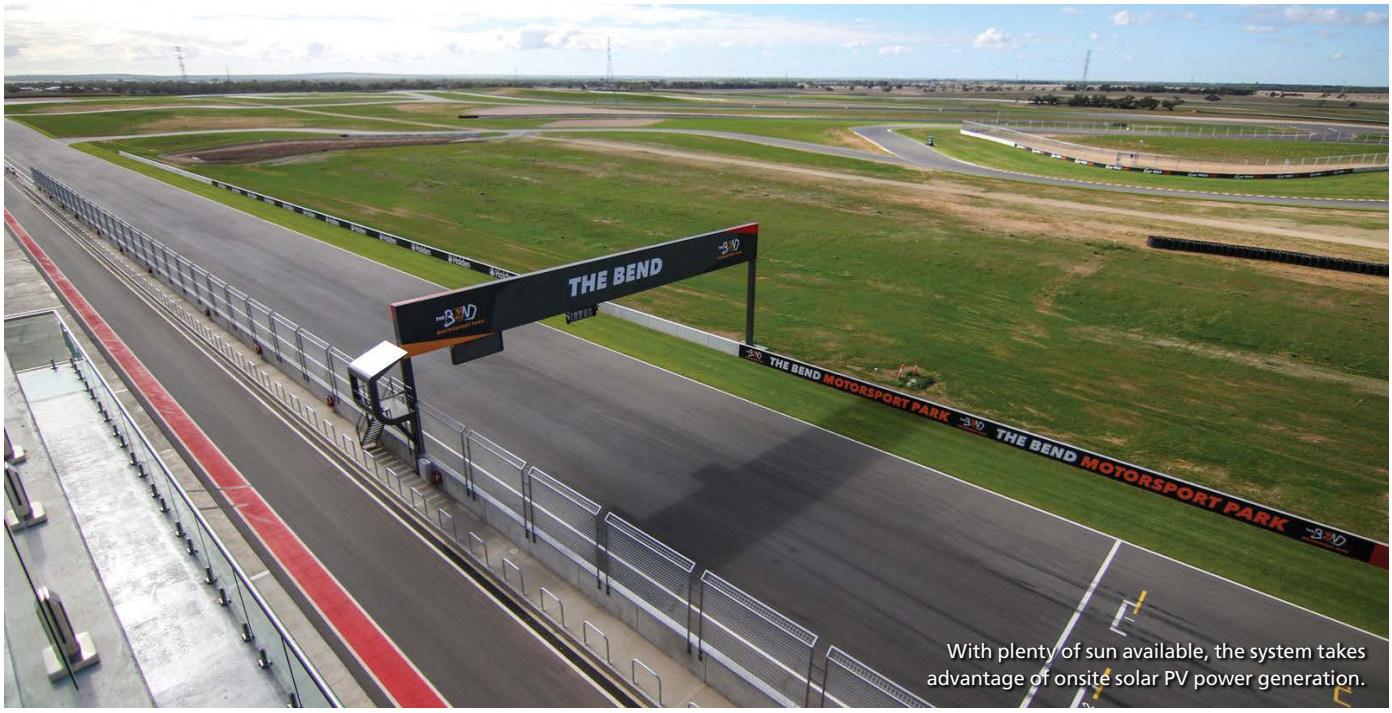
This algorithm was developed under Glaciem's research and development project with ARENA. The algorithm takes into account variables from a range of live data feeds including:

- National Energy Market (NEM) price
- PV generation
- PV forecast
- Site electrical loads
- Thermal load
- Compressor COP.

Control of the PCM TES (phase-change material thermal energy storage) is enacted based on the combination of expected load, expected renewable energy generation, and most importantly, the expected cost for imported energy as compared to the expected price paid for any exported energy.

"The ACFA compares the price of energy and then 'suggests' a sequence of optimal control modes for each 30-minute interval," says Hudson.

"ACFA is not site-specific, and can be used in any situation where you have renewable energy and TES."



With plenty of sun available, the system takes advantage of onsite solar PV power generation.

RESEARCH DELIVERS

As a senior industry partner of UniSA, Glaciem has conducted research and development targeted towards the HVAC&R sector over many years.

Among its more recent projects have been the maximisation of solar PV with phase-change material and thermal energy storage (PCM TES) in conjunction with ARENA, and a project with the Australia-India Strategic Research Fund that seeks to enhance the shelf life of dairy milk using PCM TES and renewable energy.

The system installed at The Bend integrates two key Glaciem technologies: the aforementioned DP-CO_2 refrigeration system, and PCM TES, which provides end users with highly efficient energy storage.

"Each component, on its own, represents a significant technical advancement for the industry," says Hudson.

"But when coupled together, they are well placed to leave a measurable and long-lasting legacy as they de-risk end-users of refrigeration from two of the key issues facing the industry – the HFC phase-down and Australia's commitments under the Paris Climate Agreement."

The combined DP-CO_2 and PCM TES refrigeration system deployed at The Bend operates entirely on natural refrigerants. R744 (CO_2) is used as the primary refrigerant for the medium-temperature system, which cools a heat-transfer liquid, HC30.

"CO_2 was selected to demonstrate the advantages of using dew-point (or indirect evaporative) cooling in high ambient conditions," says Hudson. "This is particularly salient given summer daytime temperatures in Tailem Bend regularly exceed 45°C."

The low-temperature (LT) side of the system is a CO_2 cascade system, and the medium-temperature (MT) side is "more or less" a standard CO_2-only system.

Hudson says the difference between the two sides of the system is that a heat-transfer fluid (HTF) is circulated between the two LT and MT loops to enable the CO_2 systems to exchange heat with the thermal energy store (TES).

The HTF performs several functions.

When the TES requires charging, the MT CO_2 system cools the HTF to -9°C, which in turn freezes the -6°C phase-change material (PCM). But when the TES is required to discharge, the MT system is cycled off, and the energy stored in the TES is used to cool the cool room and to condense the LT CO_2 cascade system. Peak power consumption is therefore dramatically reduced.

The system also takes advantages of onsite solar PV power generation, with algorithms developed that optimise the generation of this renewable energy. This offers a "hedge" to users exposed to spot market electricity pricing fluctuations.

But to enable the MT system to operate sub-critical, even in ambient temperatures above 45°C, it has been designed with the addition of indirect evaporative cooling installed in series with its main condenser.

CLOSE COLLABORATION

One of the UniSA researchers involved in The Bend Motorsport Park project, Professor Frank Bruno, M.AIRAH, from the Future Industries Institute, says the partnership between UniSA and Glaciem was key to making the new cooling system possible.

"The first commercial system is a result of close collaboration between UniSA and Glaciem," Professor Bruno says.

"The system uses technology developed at UniSA over the past 10 years, and our capability in refrigeration, air conditioning and solar, to deliver the world's most efficient, air-cooled CO_2 refrigeration system for hot climates."

The Park caters for a variety of motoring activities, including hot laps in high-performance vehicles.

COMPLEX CHALLENGES

Identifying a cost-effective refrigerant with high efficiency to charge the PCM store proved challenging to the research team. Synthetic refrigerants were ruled out due to their environmental impact and long-term sustainability performance.

This left natural refrigerants only, with CO_2 adopted, Hudson says, due to non-toxic and non-flammable properties.

But because CO_2 systems have low efficiencies in ambient temperatures above 25°C, the solution considered by Glaciem and UniSA was to integrate indirect cooling technology. This allows the system to operate in high ambient conditions.

"To achieve this, the incoming air is indirectly cooled close to the dew-point temperature of the air," says Hudson.

"Tests show that with ambient dry-bulb air temperatures above 40°C, condenser air inlet temperatures of below 20°C could be achieved, thereby allowing the CO_2 to condensate at 25°C."

LESSONS FROM THE REFRIGERATION ENGINEER

Julian Hudson, M.AIRAH, managing director of Glaciem Cooling Technologies, shares some of the lessons from the installation of this leading-edge refrigeration technology at The Bend Motorsport Park.

Collaborative research between universities and industry leads to real outcomes that benefit industry.

Having partners like Peregrine Corporation that are fully invested in new technology, and assistance from state and commonwealth governments, is key to getting industry to accept new technologies.

Minimising the amount of work that needs to be done onsite by prefabricating offsite is extremely beneficial.

The indirect evaporative cooling uses existing technology – found in commercial systems – which has been integrated in series with the main condenser coil.

"This integration turned out to be quite complex – particularly around the balance between low condensing temperature and fan power," says Hudson.

To allow the system to operate at sub-critical, an automatic bypass valve is installed around the high-pressure expansion valve, thereby simplifying the cooling cycle. Hudson says from a pressure enthalpy diagram perspective, it is identical to a standard HFC DX cycle.

During its inaugural summer season, The Bend did not have a single call-out for refrigeration work.

The application of this technology was developed with the assistance of Tech in SA – a South Australian government funding program. Research and development was carried out at UniSA Mawson Lakes over an 18-month period.

It has resulted in a worldwide patent, as well as the creation of a new control algorithm.

PHASE CHANGE

Although water in the form of ice has been used in the HVAC&R industry for many years to provide chilled water at 6°C, the fact that ice melts at 0°C has seen its use in refrigeration applications limited.

"A lot of research has taken place into chloride-based salt solutions for refrigeration applications, but due to the corrosive nature of chlorides the PCM is usually encapsulated within a ball," says Hudson. "This encapsulation brings several prohibitive aspects – namely cost and poor heat-transfer characteristics."

Although researchers at UniSA had already overcome these issues by developing a -11°C PCM suitable for -6°C process cooling, it was only suitable for use with an ammonia or R404A system.

"We identified the need for a new PCM with a higher freezing point because R404A has no real longevity due to its high GWP," Hudson says. "And not everyone is comfortable using ammonia either."

This led to the development of the -6°C PCM by the Barbara Hardy Institute at UniSA – as part of the ARENA research and development project. A low-cost, non-chloride based salt solution, it enables ice to be built up directly on coils, thus eliminating the need for encapsulation, and reducing the overall cost of the TES tank.

When used in the system installed at The Bend, this new coil and dynamic melt design increases the efficiency of the TES system by allowing more of the latent heat to be extracted, and thereby reducing the installed footprint.

THE CHEQUERED FLAG

Over a year since its installation, the DP-CO_2 refrigeration system at The Bend is considered a resounding success. It breaks new ground for the performance of CO_2 systems operating in warm climates.

"The performance of the DP-CO_2 system and control algorithms has met expectations," says Hudson. "In fact, the design and nature of the system has proven to be extremely reliable."

Such was the reliability of the system during the summer season that The Bend was the only one of Peregrine's sites not to have a call-out for refrigeration during the period.

"There have only been a couple of service calls," Hudson says, "and these have all been able to be reset through our remote access software."

As well as now offering the Peregrine Corporation with a tried-and-tested platform to roll out across the OTR convenience stores in line with its sustainability strategy, the project has also attracted interest from a supermarket group and national hotel chain.

In this way, the collaboration between Glaciem and UniSA is achieving its objectives.

"These kinds of partnerships targeted at finding important solutions for real problems are part of what makes UniSA Australia's university of enterprise," says UniSA deputy vice chancellor of research and innovation, Professor Tanya Monro.

"We want to deliver research that makes an impact, that meets industry at the coalface, and helps them to deliver great outcomes for the environment, for society and for business."

The Bend refrigeration project won the 2018 AIRAH Excellence in Refrigeration Award, and the 2017 Carbon Neutral Adelaide Award for Applied Innovation.

PROJECT AT A GLANCE

The personnel

- Builder: **Romaldi**
- Client: **Peregrine Corporation**
- Data analytics: **UniSA Ventures**
- Funding (in part): **Tech in SA Early Commercialisation Grant**
- Refrigeration contractor: **Glaciem Cooling Technologies** (sub-contractors)
- Refrigeration engineer: **Glaciem Cooling Technologies**

The equipment

- Compressors: **Bitzer**
- Controls: **Schneider**
- Electrical panel PLC program: **Electric Solutions**
- Indirect evaporative cooler: **Seeley**
- Integrated cooling system: **Glaciem Cooling Technology**
- PCMs: **Barbara Hardy Institute, UniSA**
- PCM tank: **Glaciem, AR Industrial**
- Pumps: **Grundfos**
- Sensors: **IFM Effector**
- Thermal energy storage (TES): **Glaciem, Sinobaron**

Source: Glaciem Cooling Technologies