THE LEGEND OF BOGGY CREEK

BOC's Boggy Creek facility is home to a unique flooded CO_2 cascade system.

An installation on the west coast of Victoria is using a CO_2 cascade refrigeration system to recondense CO_2 vapour that would otherwise be lost to atmosphere. Sound complicated? Sean McGowan takes a look at this one-of-a-kind solution and why it is about to be implemented elsewhere.

While the world looks to reduce its CO_2 emissions in a bid to thwart climate change, the food, beverage and industrial markets can't get enough of the stuff.

That's not to say these industries are not doing their bit to reduce their carbon footprint. Rather, they need CO_2 to produce the products we enjoy on a daily basis.

For example, whenever you buy a carbonated drink you are also likely buying a couple of grams of CO_2. And when you consider there are 1.7 billion servings of Coca-Cola a day worldwide, a lot of CO_2 is required to give Coca-Cola its familiar fizz.

In Australia, CO_2 for the food, beverage and industrial markets is sourced from multiple sources and sites around the country. One of the largest lies beneath the fertile dairy farms of western Victoria, not far from the iconic Great Ocean Road.

BOC's Boggy Creek facility (part of The Linde Group) pipes transcritical CO_2 gas from a gas-field located about one kilometre below the surface.

The CO_2 vapour is separated from other elements at ground level, before being purified and condensed into CO_2 liquid. This liquid is then stored on site in two storage vessels, ready for transport.

However, when tankers attend the site to fill up, they increase the standing pressure in the storage vessels, which results in a controlled release of CO_2 vapour.

To eliminate this release to atmosphere, the industry has long had a practice of re-condensing the CO_2 vapour in the storage vessels by using refrigeration as a means of keeping the standing pressure down.

In doing so, a significant amount of money in lost product and revenue has been saved.

WHEN AGEING EQUIPMENT IS A PROBLEM

In 2013, with ageing existing equipment at the site and a looming replacement required for R22, the company sought a new refrigeration package to replace the existing system (which was operating on R22).

"The brief was simply to supply a condensing package capable of meeting the design flows of our plant," says Peter McManus, project manager for BOC.

"BOC has a very strong safety culture that is incorporated into everything we do, so there were stringent safety requirements that needed to be met in the technical specifications."

Adelaide-based design and construct firm Amertec has many years of experience in the design of industrial refrigeration applications, including previous systems design for BOC. They showed interest in the opportunity for the application of natural refrigerant for the Boggy Creek project and began to look at a number of options.

The design concepts put forward by Amertec, which had previously engaged Julian Hudson, M.AIRAH, of JCH Refrigeration Consulting, led to Hudson being appointed as the project manager on the Boggy Creek project.

"We had to determine the most suitable refrigerant and machine type to condense CO_2 vapour at -25.5°C," say Amertec's directors, Jeff Treadwell, M.AIRAH, and Rocky Moyes.

The limited water supply at the site provided the opportunity to design a system that had little reliance on water resources and conventional cooling towers, or condensers that require chemicals for Legionella and water treatment.

A NOVEL APPROACH

Full engineering and system comparisons were completed for a flooded ammonia system, as well as an air-cooled R404A system.

The R404A option was the first to be discarded due to the system's co-efficient of performance (COP) of less than one, as well as the increased cost of R404A at the time due to the introduction of the HFC refrigerant levy.

The ammonia option, however, did progress to the quoting stage before being turned down by BOC.

> "Testament to the project's success is that BOC is currently installing a number of these units at several of its CO_2 facilities across Australia"

"Even though the Boggy Creek site had a large ammonia plant operating on the existing CO_2 plant, BOC made a company-wide decision to move away from the use of hazardous materials where possible, prompting the search for an alternative to ammonia in this application," says Amertec.

This led to the examination of a CO_2 cascade system incorporating R134a and glycol.

A novel approach, given CO_2 would essentially be recondensing CO_2, this system offered a number of advantages, including operating efficiency and a reduction in the required HFC charge.

But doubts remained because there was no documented evidence of a flooded CO_2 system ever being used to condense CO_2.

"We were wary at first because Amertec had not installed this type of system for such an application before," says McManus. "However, after a detailed review of their design they convinced us it was a good option."

Following a competitive tender process, Amertec was awarded the project under a design and construct contract.

CO_2 CONDENSES CO_2

Although CO_2 had not been used in a flooded evaporator system before, and certainly not to condense CO_2, the project team's experience with CO_2, led by Hudson, gave Amertec the confidence that such a system would work.

Hudson's experience as an engineering manager at Bitzer Australia during the infancy of the design implementation of CO_2 systems in Australia, New Zealand and China proved invaluable, as did his work on some of the first transcritical CO_2 projects in Australia.

Yet the system design was significantly more than just taking a standard R134a/CO cascade system and using it in a different application.

"It required some significant design changes," Hudson says.

At a glance – how it works

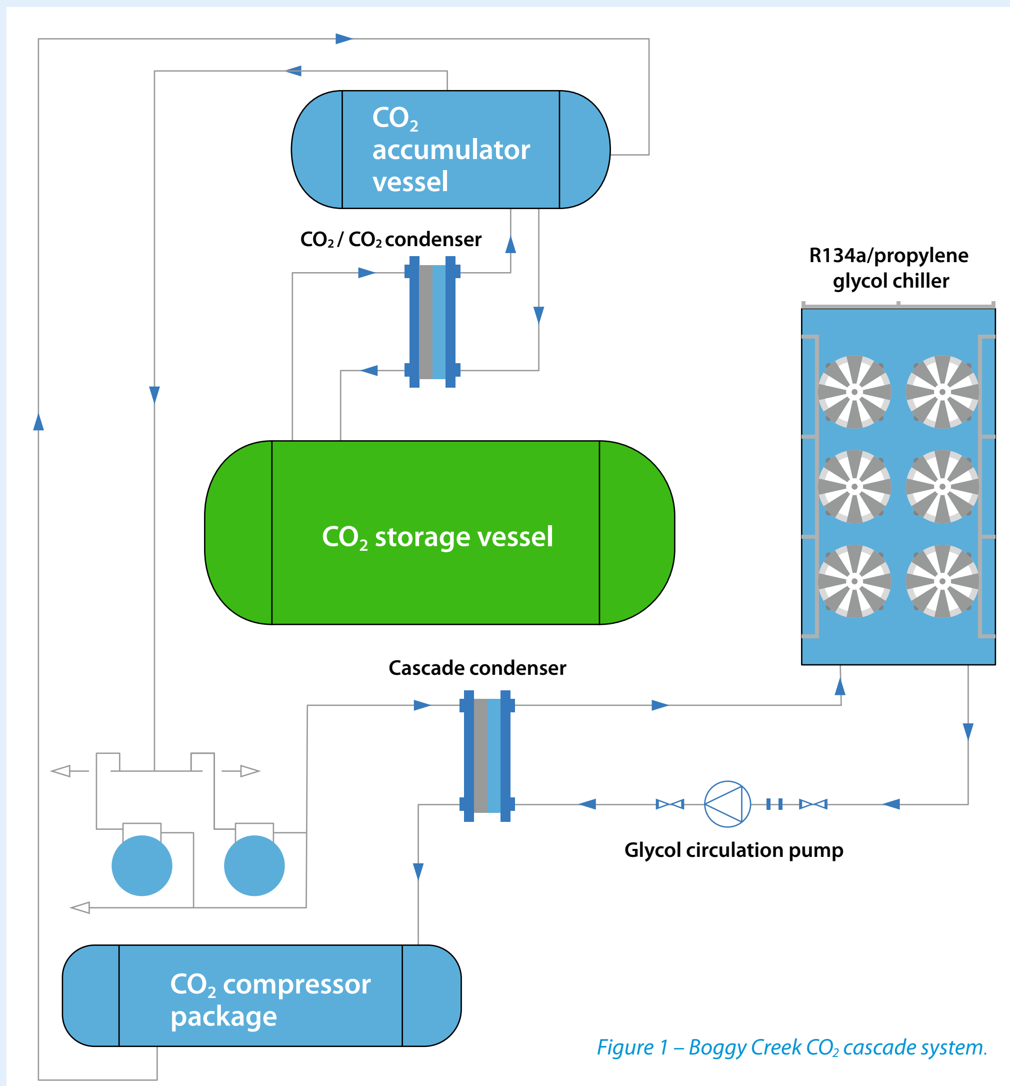

Figure 1 – Boggy Creek CO_2 cascade system.

Figure 1 shows the basic system layout used at BOC Boggy Creek.

-25.5°C CO_2 vapour from the storage vessels is condensed in the CO_2/CO_2 BHPE condenser situated above the vessels.

This is achieved by evaporating -31°C CO_2 liquid from the accumulator vessel on the other side of the BPHE condenser, by means of a thermosyphon effect.

The CO_2 liquid in the accumulator is kept at -31°C via two CO_2 compressors. These compressors compress the vapour component from the accumulator vessel.

The compressed vapour is then condensed in a cascade condenser by a propylene glycol – the glycol further cooled by an R134a air-cooled screw chiller.

Lessons from the project

"When developing new systems, it is essential that all parties involved buy into the concept and understand that new product development is not always a smooth ride. This means working together in a partnership, rather than the traditional consultant/contractor/end-user model."
– Julian Hudson, JCH Refrigeration Consulting.

"With some tweaking to the design philosophy, we learned it is possible to apply what are commonly 'commercial' refrigeration solutions in an 'industrial' application."
– Peter McManus, BOC.

"The HFC refrigerant levy was a real game-changer for the Australian refrigeration industry. End-users of refrigeration forced the industry to look for innovative ways of making things cold, and to reassess our reliance and overuse of synthetic greenhouse gases. Although the levy has been removed, the industry should continue the push forward to deliver innovative designs for applications that highlight the industry's ability to adapt."
– Jeff Treadwell, M.AIRAH, and Rocky Moyes, Amertec.

He says that the standard evaporation method used in CO_2 cascade systems in Australia is predominantly DX, apart from some pumped CO_2 volatile secondary systems used in supermarkets.

This system was neither – instead, it used a thermosyphon principle to condense the CO_2.

"A huge amount of work went into the design – in particular the accumulator vessel, the BPHE condenser/evaporator and oil recovery system design," Hudson says.

"Standard R134a/CO_2 cascade systems generally use DX R134a on the cascade BPHE to condense the CO_2 discharge vapour. This was the first of its kind to use a closed-loop glycol system to condense the CO_2."

> "One of the major challenges of the design was the integration of the system controls, including control logic and PLC software, to ensure the system components ran in equilibrium"

The package designed by Amertec consisted of four different systems – a flooded CO_2 accumulator condenser/evaporator, a low-temperature (LT) CO_2 rack, closed-loop glycol system, and an R134a screw chiller package.

The system utilises sub-critical CO_2 compressors capable of condensing up to 15°C. This allows the SST of the R134a system to be raised from -7°C to -4°C, with closed-loop glycol operating at 0°C to condense CO_2 at 5°C – normally the HP cut-out of most CO_2 cascade systems.

This design delivers good COP at the extreme operating conditions of -31°C SST 51°C SCT. It is also offers stable operation due to the use of glycol to condense the CO_2, and reduces the risk of cracking the cascade condenser.

"Using DX R134a to condense CO_2 directly is not a good cascade combination, and has led to BPHEs failing prematurely in the past," Hudson says.

The reduced HFC charge also limited exposure to the HFC refrigerant levy and helped to future-proof the system regarding restrictions of HFC use in the future.

One of the major challenges of the design was the integration of the system controls, including control logic and PLC software, to ensure the system components ran in equilibrium.

"We also found that during commissioning, the standard oil system being used on CO_2 cascade racks would not work in this application, requiring a redesign."

FROM NOVEL TO NORMAL

Close collaboration between BOC and the Amertec team proved critical to the successful delivery of the Boggy Creek project.

Amertec's directors say it is important that all parties are comfortable with using a new and untested design, but also the inevitable hurdles that need to be overcome collectively.

> "The brief was simply to supply a condensing package capable of meeting the design flows of our plant"

Not only did it require a leap of faith by BOC, but the project was also the first flooded CO_2 cascade system installation for Amertec.

As BOC had previously recondensed CO_2 at the site, very little infrastructure work was required to accommodate the new system. The package's compact footprint meant a concrete slab with a lean-to roof was the only requirement, as well as some minor support steelwork and an access ladder to the accumulator package.

There were the usual wet-weather delays (no prizes for guessing where the name Boggy Creek comes from), and some OEM component issues. Still, the system was installed over three weeks in mid-2014, with little disruption to BOC's operations.

> "Not only did it require a leap of faith by BOC, but the project was also the first flooded CO_2 cascade system installation for Amertec."

The unit was designed and manufactured to be "plug and play". The only additional site work was the interconnecting liquid and dry suction lines, plus the installation of a multi-core cable between the accumulator package and the main package.

Now, more than six months since commissioning, the system has reportedly operated efficiently, and exceeded the design performance criteria originally specified by BOC.

"The unit has performed very well," says McManus. "There have been some teething issues, but this is to be expected when you're commissioning a new plant and doing something a little outside the square."

Testament to the project's success is that BOC is currently installing a number of these units at several of its CO_2 facilities across Australia.

For Amertec, the Boggy Creek project highlights the opportunity for innovation across the refrigeration industry.

The major lesson to be learned from the project?

"Never be afraid to take an educated risk." ▲

PROJECT SPECS

WHO

Client: BOC

D&C contractor: Amertec and JCH Refrigeration Consulting

Controls: BJ Electrical and Automation

WHAT

Air-cooled condenser: Bitzer

CO_2 rack glycol chiller: Bitzer

Condenser: Buffalo Trident

Common skid: Amertec

Controls: Schneider with an Alan Bradley PLC

Pumps: Grundfos

Stainless steel vessels: Britannia Jahco