Parilla Thermal Storage Project

Case Study

May 2014

BACKGROUND

Parilla Premium Potatoes is a large refrigerated storage facility (Figure 1) located in South Australia; the facility consists of five individual refrigerated storage rooms.

Figure 1 Parilla Premium Potatoes SA Facility

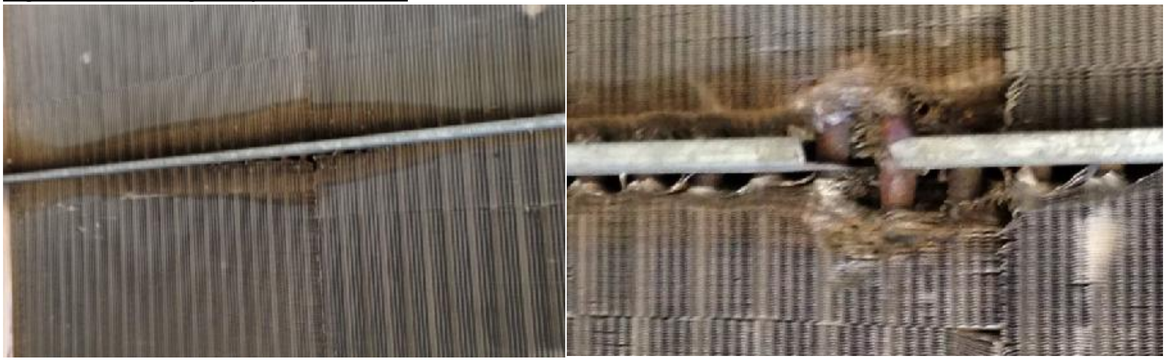
Figures 2 below shows the old refrigeration parallel rack with 3 x DWM Copeland suction gas cooled semi hermetic compressors model D6DJ 400X operating on Refrigerant R22. The rack capacity is estimated at 190.5kW at–10°C Saturated Suction Temperature (SST), 47°C Saturated Condensing Temperature (SCT).

The estimated total heat of rejection (THR) of the rack is 271.2kW. Condensing is achieved by a Kirby KNRC 3990V air cooled condenser with an estimated capacity of 39.9 kW per K TD. Operating TD is 6.79K.

Figure 2 R22 Parallel Rack

The old refrigeration plant required replacing due to ongoing refrigerant leaks and equipment failure, Figure 3 shows leaks on the evaporator coils.

Figure 3 Leaking Evaporator Coils



As the price of R22 increased dramatically and the reliability of the existing decreased, Parilla Potatoes made the decision to replace the old refrigeration plant and equipment.
Two design options were considered with an emphasis on power consumption, running cost environmental impact and exposure to the HFC Levy.

OPTION.1 DX R134a Economised Screw Compressors Plant, with Glycol Secondary Plant
Air cooled Direct Expansion (DX) R134a is currently the industry standard refrigerant used in large commercial Medium Temperature (MT) applications of this type, mainly due to lower initial capital expenditure. However since the introduction of the HFC Levy in July 2012, the list price of R134a refrigerant has risen to approximately $182 per Kg.
In order to reduce the R134a charge the cooling in the cool rooms is a achieved by circulating R1270 (Propylene Glycol 30%).
This proposed system would consist of
2x BITZER HSK 7471-70 Economised Semi Hermetic Screw Compressors
Capacity 196kW @ -10°C SST 49°C SCT

OPTION.2 R717 Primary Dynalene Secondary + Phase Change Material (PCM) Plant
This type of system is still in its infancy in the refrigeration industry but similar systems using ice slurries are being employed successfully in a variety of applications due to their low operating cost.
The system consists of a central R717 plant. The central R717 plant only operates during the evening using off peak electricity, during this period Dynalene is cooled to a lower temperature; the Dynalene in turn freezes a (PCM). During the day the R717 plant is cycled off and the Dynalene is cooled by the phase change in the PCM.

The proposed system consist of
2x BITZER OSNA 7461-K Open Drive Screw Compressors
Capacity 200kW @ -18°C SST 35°C SCT

The two options listed above were analysed In order to quantify which option would give the lowest power consumption, running cost environmental impact and exposure to the HFC Levy.

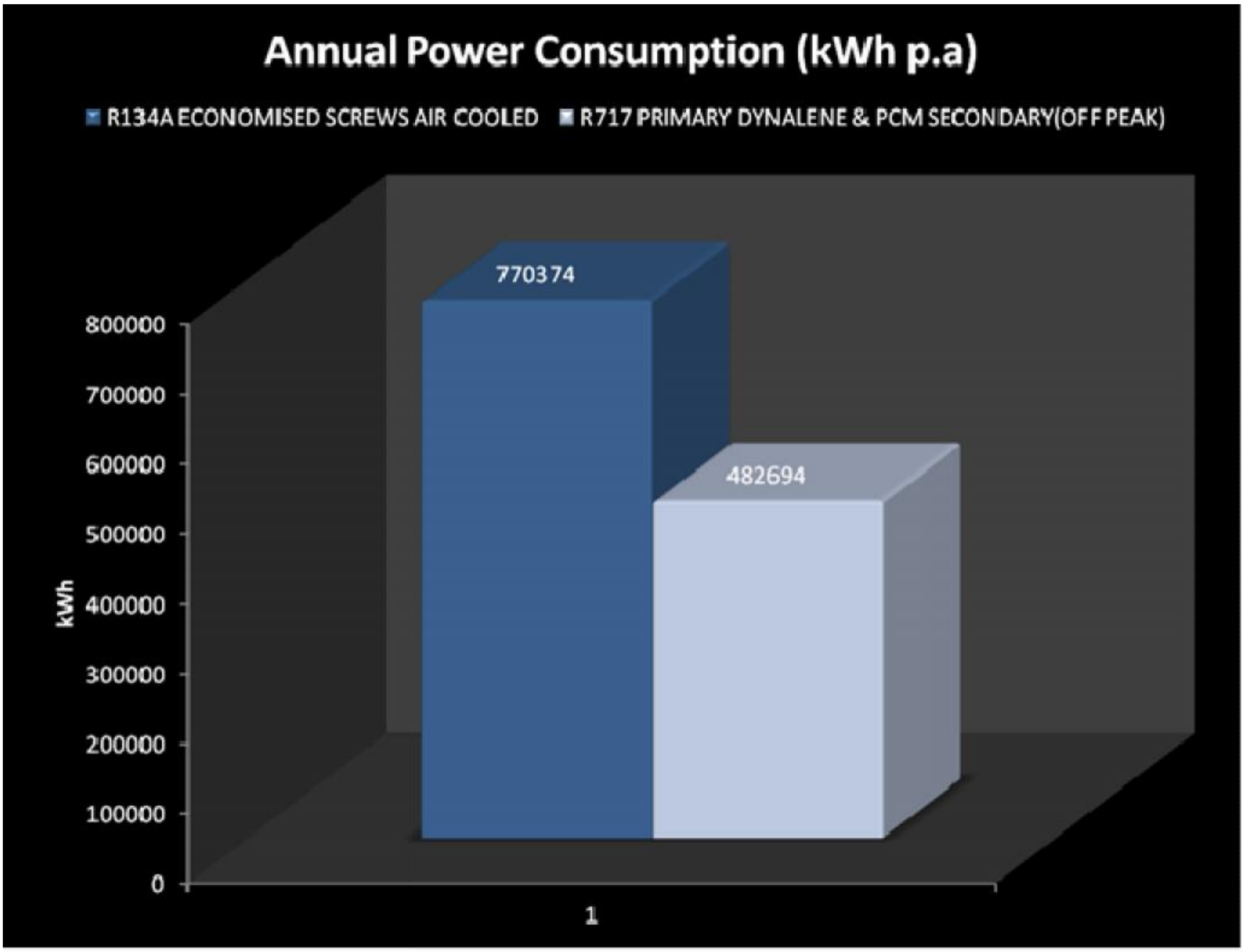
The analysis was carried out in accordance with the Australian Institute of Refrigeration Air Conditioning and Heating (AIRAH) Methods of Calculating TEWI 2012 Best Practise Guidelines.

Annual Power Consumption

Figure.1 below shows a graphical representation of the power consumption data, it can be seen that Option 1 (R134a Economised Screws) will consume the most power. Option 2 (R717/Dynalene + PCM off peak) consumes 37% leas power even though it is operating at a lower Saturated Suction Temperature (SST).

The R717 plant will only operate approximately 12 hours a day using off peak electricity to freeze a PCM, during on peak hours, refrigeration would be done by the thermal energy stored in the PCM, thus drastically reducing the power consumption.

Figure.1 Estimated, Annual Power Consumption Comparison



Annual Running Cost

Figure.2 below shows a graphical representation of the annual running cost data. An on/off peak electricity tariff of $0.23 and $0.11 respectively has been used based on information provided Parilla Potatoes.
Option 1 (R134a Economised Screws) has the highest running cost.

Option 2 (R717/Dynalene + PCM off peak) has a lower operating cost as it only operates using off peak electricity. The reduction in annual running cost between Option 2 (R717/Dynalene + PCM off peak) and Option 1(R134a Economised Screws) is 70%

Figure.2 Estimated, Annual Running Cost Comparison

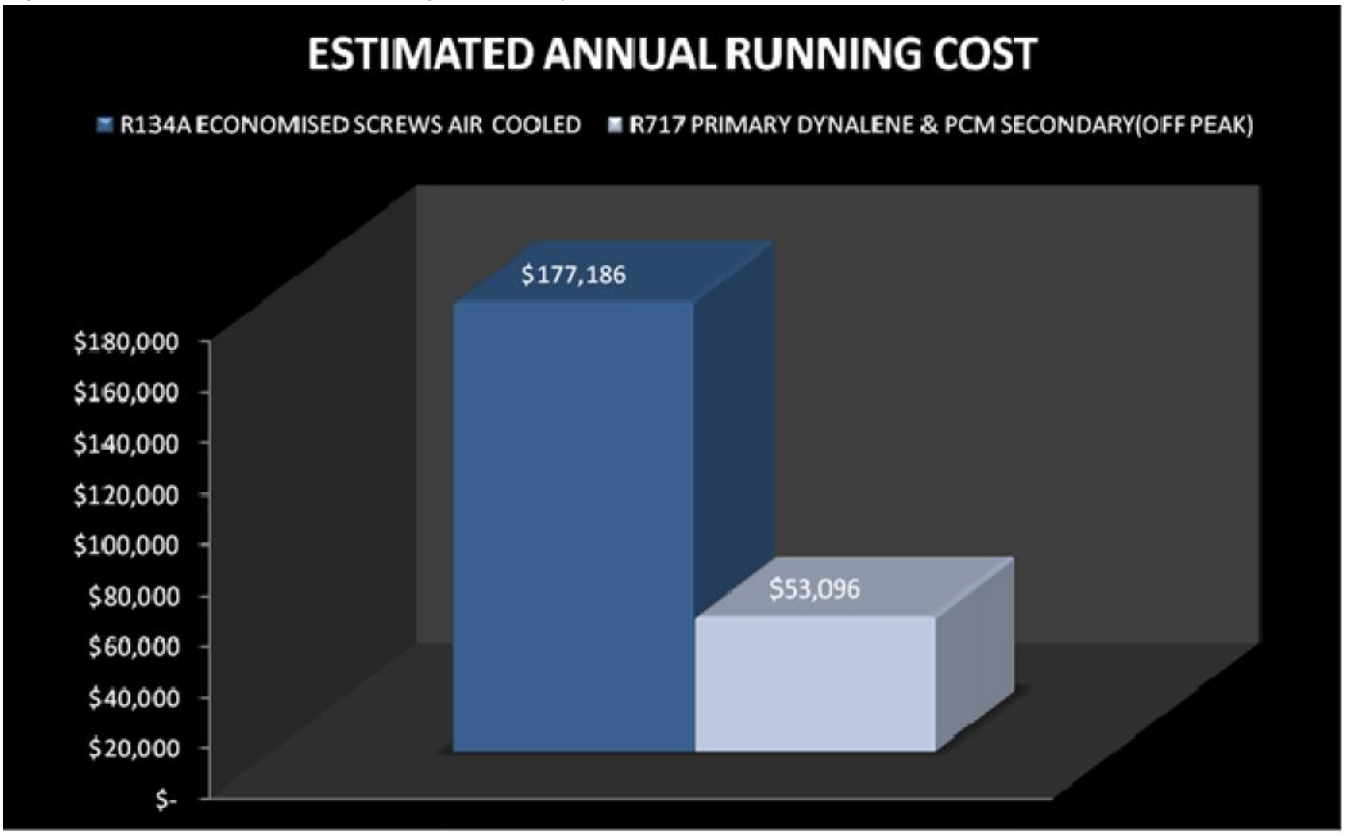
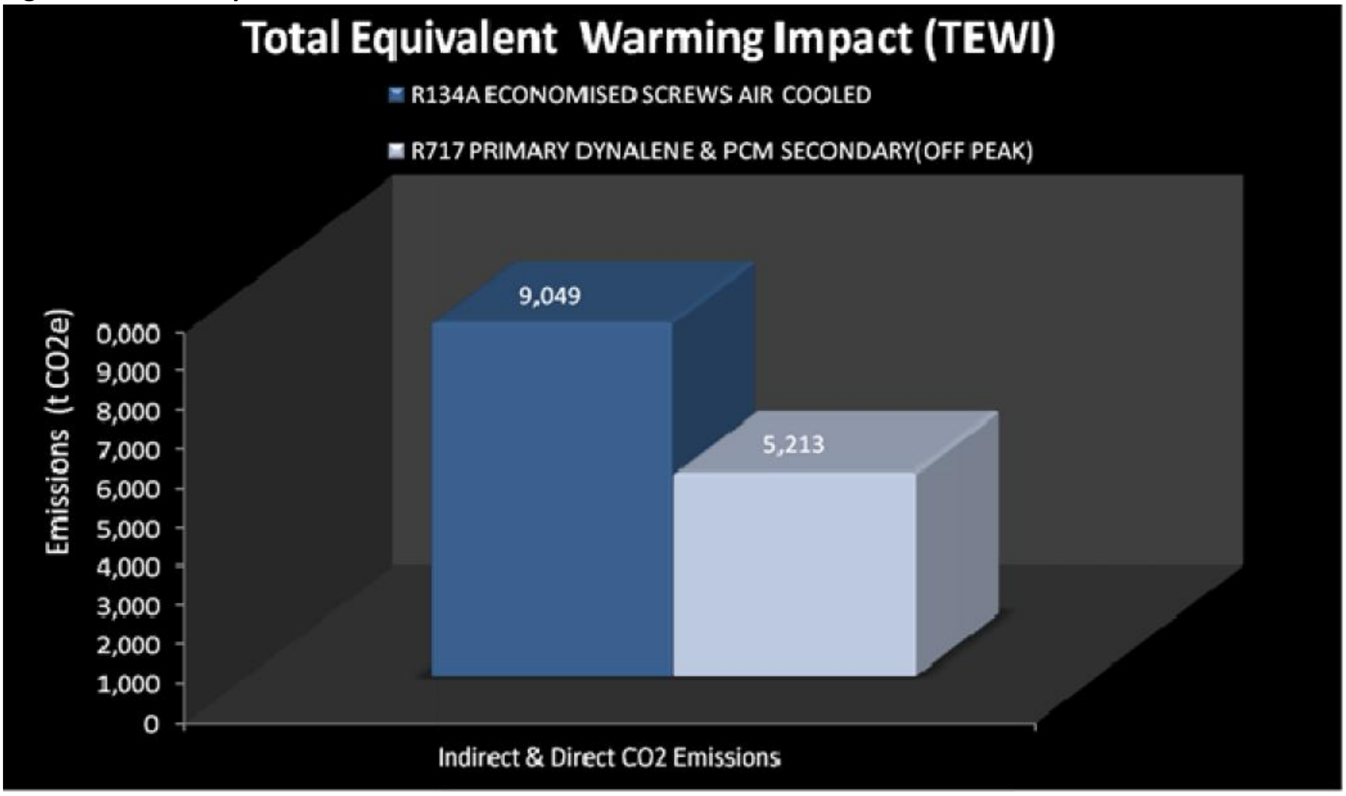


Figure.3 TEWI Comparison



Total Equivalent Warming Impact (TEWI)
Figure.3 above shows a graphical representation of each the options TEWI, over the 15 year lifecycle for each refrigeration plant.

Option 1 (R134a Economised Screws) has a higher TEWI than Option 1 Option 4 (R717/Dynalene + PCM off peak).

The reduction in TEWI between Option2 (R717/Dynalene + PCM off peak) Option 1 (R134a Economised Screws) is 42%

Based on the above analysis it was clear that Option 2 (R717/Dynalene + PCM off peak) was the best option as it showed significant reductions in power consumption running cost and environmental impact in comparison to the other option 1. The key factor in its performance is the ability to only operate the central R717 plant during the night only using off peak electricity.

Option 1 also had the added disadvantage in using refrigerant R134a, as R134a is an HFC refrigerant and is therefore subject to the Australian Federal Government HFC Levy and has a current list price of around $182 per Kg.
Figure 1 TEWI calculation predicts the total operational leakage over 15 years to be 561Kg, this would equate to an additional $102,102 in refrigerant cost at current prices over the plants life averaging out to around $6,806 per annum.

The above analysis formed the basis on which the project was sold, although the initial capital investment for the PCM option was 51% more for Parilla Potatoes the pay back period on based energy consumption was less than 3 years.

System design

The Parilla project installed by Alltech Refrigeration is the first refrigeration system of its kind in the in Southern hemisphere (if not the world), although thermal storage systems are not new, the various innovation's used on this project make it truly unique.
Figure 9 (attached to this document) shows overall system schematic; the following pages highlight the main features

R717 Chiller (Critically Charged Ammonia Chiller 0.25Kg/kW charge ratio)
The ammonia chiller (Figure 10) used on this project was specified by JCH Refrigeration Consulting and built by BITZER Australia.
The primary function of the R717 system is to cool the secondary refrigerant Dynalene HC30 which in turn provides thermal energy to the PCM. The Dynalene is cooled by the ammonia through a flooded Alfa Laval Plate Heat Exchanger (PHE); the system only requires enough ammonia to form a liquid seal in the accumulator vessel and to flood to PHE, with liquid. The minimum level in the accumulator is maintained using a pressure differential (PD) sensor (Figure 11), the PD sensor sensors the change in pressure as the liquid level the in the accumulator fluctuates and sends a 4-20ma signal to the PLC, the PLC then outputs a 4-20ma to a Danfoss ICF6 valve assembly (Figure 12) which injects liquid into the accumulator at the exact rate that is required.

Figure.4 200kWr BITZER R717 Chiller

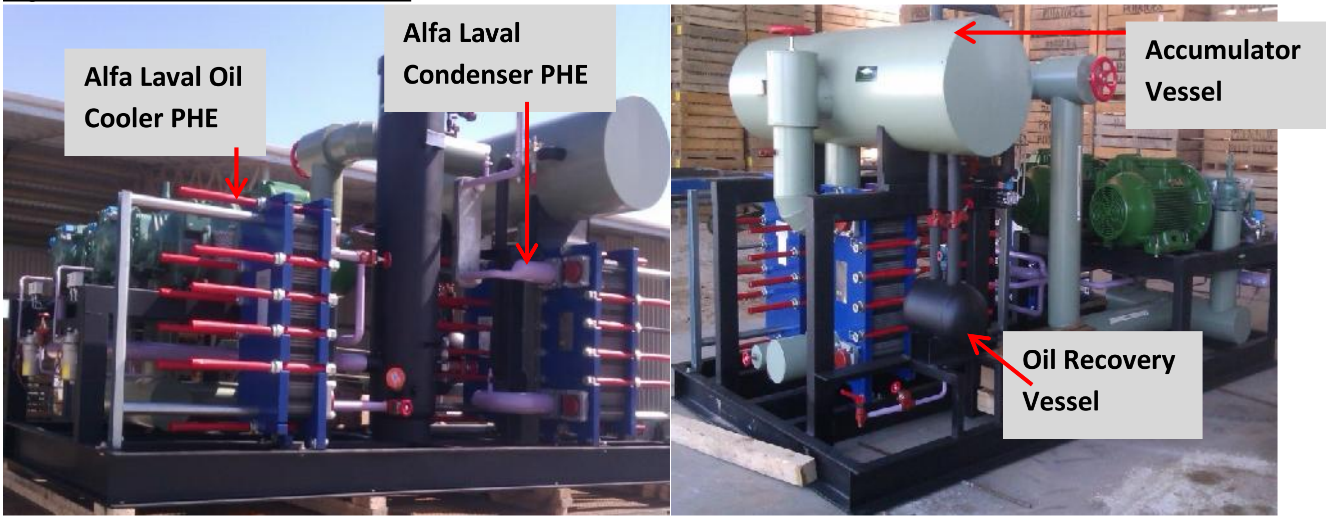


Figure.5 PD Sensor

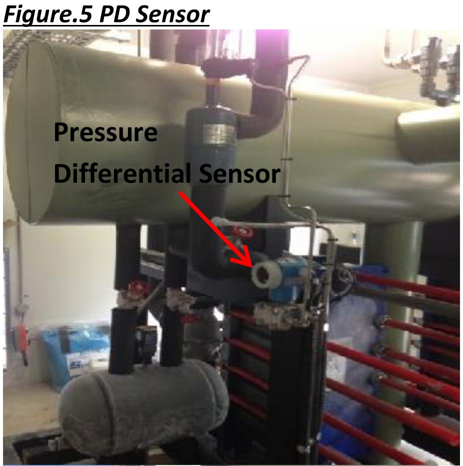


Figure.6 ICF 6 Make up valve

Figure.7 BAC Closed Loop Fluid Cooler

In order to keep the ammonia charge of the package to a minimum Alfa Laval PHE are used for condensers and oil cooling (Figure 10), water is circulated through a close loop through a BAC fluid cooler (Figure 13) and pumped through both PHE's.
This drastically decreases the amount of ammonia in the ammonia chiller, which has an operating charge of 50Kg of R717, this equates to a Kg/Kw ratio of 0.25Kg/kWr

The chiller is installed in an air tight plantroom complete with explosive proof extraction fan, motorised dampers, the plantroom is air conditioned using a Dynalene evaporator piped to the main system.

Secondary Refrigerant Dynalene HC30 (Low viscosity high thermal performance)

Various secondary refrigerants were considered for this project, the one chosen was Dynalene HC30, Dynalene is a water-based heat transfer fluid engineered to deliver high performance throughout its temperature range. The main driving factor for choosing Dynalene over a glycol based solution was Dynalene's low viscosity, for example Propylene glycol with a freezing temperature of -30°C would have a viscosity 157cSt compared to 4.5cSt of Dynalene HC30.

This drastically reduces the amount pump power required too circulate the secondary refrigerant therefore reducing running and installation cost.

The purpose of the Dynalene HC30 in this system is to freeze (charge) the PCM during the night using off peak electricity and then use the energy stored in the PCM during the day time. Figure 14 below shows the main parts of the secondary system.

Figure.8 Secondary Refrigerant Tanks & Pumps

During the charging cycle Dynalene is pumped from the warm glycol tank through the flooded ammonia PHE where it is cooled down to -15°C and then through to the PCM tanks where it freezers the PCM tanks, from here it flow back to the cold Dynalene tank.

During the discharge cycle the ammonia chiller is turned off and the Dynalene PHE on the chiller is bypassed with a 3 way valve (Figure 15), the Dynalene circulates through the PCM using the latent heat stored in the PCM for cooling the process

Figure.9 3 Way Motorised Bypass Valves

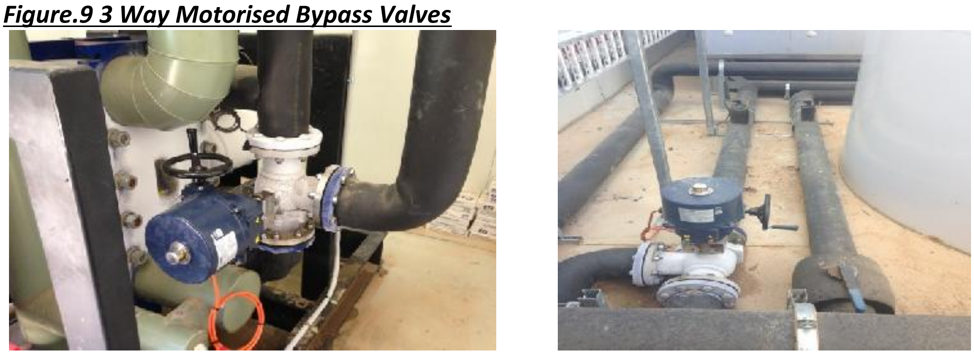


Figure.10 Dynalene Circulating Pumps

Figure 16 shows the Dynalene circulating and process pumps. Each room has it own Dynalene process pump, -6°C Dynalene is pumped to each of the room evaporators, from there it returns back to the warm Dynalene tank.

Phase Change Material (Low temperature thermal storage material)

One of the major factors that make the Parilla project unique is the PCM. The most commonly used PCM is ice which has excellent thermal storage characteristics, however secondary refrigerant temperatures of around 1°C to 2°C are only possible as the melting point of water is 0°C

The PCM used at Parilla is a specialised product developed by the Barbara Hardy Institute at the University of South Australia and Alltech Refrigeration Services and is able to give secondary refrigerant temperatures of around -6°C to -8°C; this makes it ideal for food storage that requires room temperatures of around -1°C to 3°C.

Figure 17 shows the PCM tanks installed at Parilla, there are four PCM tanks in total each with a capacity 720kWh, giving a total thermal storage capacity of 2,880kWh.

The tanks were designed and manufactured by Quikcool Australia; the tank body is constructed out of stainless and insulated with 50mm urethane, each tank has over 4.6Km of stainless steel coil inside.

Figure.11 PCM Tanks

Storage Rooms (No electric heaters Glycol Defrost)
There are five refrigerated rooms at Parilla each designed to the following

Rooms 1 -3

Size:	Each room 16m wide x 16m deep x 6.3m high.	
Product:	Potatoes / Onions	
	Total product per room:	400,000 kg
	Product entering per day:	50,000 kg
	Entering temp:	Ambient Temp (approx. 20°c)
	Pull down time per room:	Approximately 3 - 6 weeks

Room temperature Onions / Potatoes:	0.0°c / 3.5°c
Room humidity Onions / spuds	70 % / 90 %
Refrigeration capacity per room	51 Kw

Rooms 4&5

Size:	Each room 23m wide x 18m deep x 9.25m high.	
Product:	Potatoes / Onions	
	Total product per room:	600,000 kg
	Product entering per day:	100,000 kg
	Entering temp:	Ambient Temp (approx. 20°c)
	Pull down time per room:	Approximately 3 - 6 weeks

Room temperature Onions / Potatoes:	0.0°c / 3.5°c
Room humidity Onions / spuds	70 % / 90 %
Refrigeration capacity per room	73 Kw

The evaporators for each room were designed and manufactured by Quikcool Australia. One of the unique features of these evaporators is a separate closed loop circuit that uses warm Dynalene for defrost. The Dynalene is heated by an Alfa Nova Brazed Plate Heat Exchanger (BPHE) fitted to the discharge of the Ammonia Chiller
The warm glycol is stored in an insulated tank (Figure 14) and pumped to each evaporator as required.
Not having any defrost heaters fitted to the evaporators drastically reduces the energy consumption of the evaporators and significantly increases the overall running cost of the system.

Figure.12 Quikcool Evaporators

Figure.13 Warm Dynalene BPHE

Electrical (State of the art control & monitoring system)

The refrigeration system as a whole is controlled by a Schneider PLC, the electrical installation and control panels were installed and built by Electric Solutions Pty Ltd.

The system has over 150 analogues input measuring points installed and some very complex site specific software routines that ensure the smooth interface of all the various refrigeration components.

A SCADA monitoring package logs & records all data points and allows for full remote web based access there is also a Schneider Power Logic EGX300 monitoring system installed, which measures the mains supply coming into main distribution board for the refrigeration plant and all relevant sub boards. All data can be accessed via web based software

All compressors and pumps (except warm glycol) have VSD fitted thus further enhancing the overall efficiency of the plant, all VSD are also networked back Power Logic EGX300 System so individual motor energy usage is recorded.

Figure.49 Electrical Panels

As part of Clean Technology Innovation grant all running parameterts are being logged and the data will be independantly verified by Univesity SA