ATMOsphere ASIA
technology & innovation
natural refrigerants
3 - 5 February 2014 in Tokyo

THE FORTUITOUS REPLACEMENT OF AN AIR COOLED DX R22 PROPYLENE GLYCOL COOLING SYSTEM WITH A FLOODED AMMONIA SYSTEM WITH AN EVAPORATIVE CONDENSER

By KLAAS VISSER
Hon M.IIR, M. Inst. R, M.IIAR, M.ARA, M.KNVvK, Meurammon
PRINCIPAL
KAV CONSULTING Pty. Ltd
P.O. BOX 1146,
KANGAROO FLAT, Vic 3555
AUSTRALIA
Tel:- +61 3 54 479 436
Fax:- +61 3 54 479 805
Email: - kavconsult@bigpond.com

KAV CONSULTING PTY LTD
Advisers to the Refrigerated Food Industries

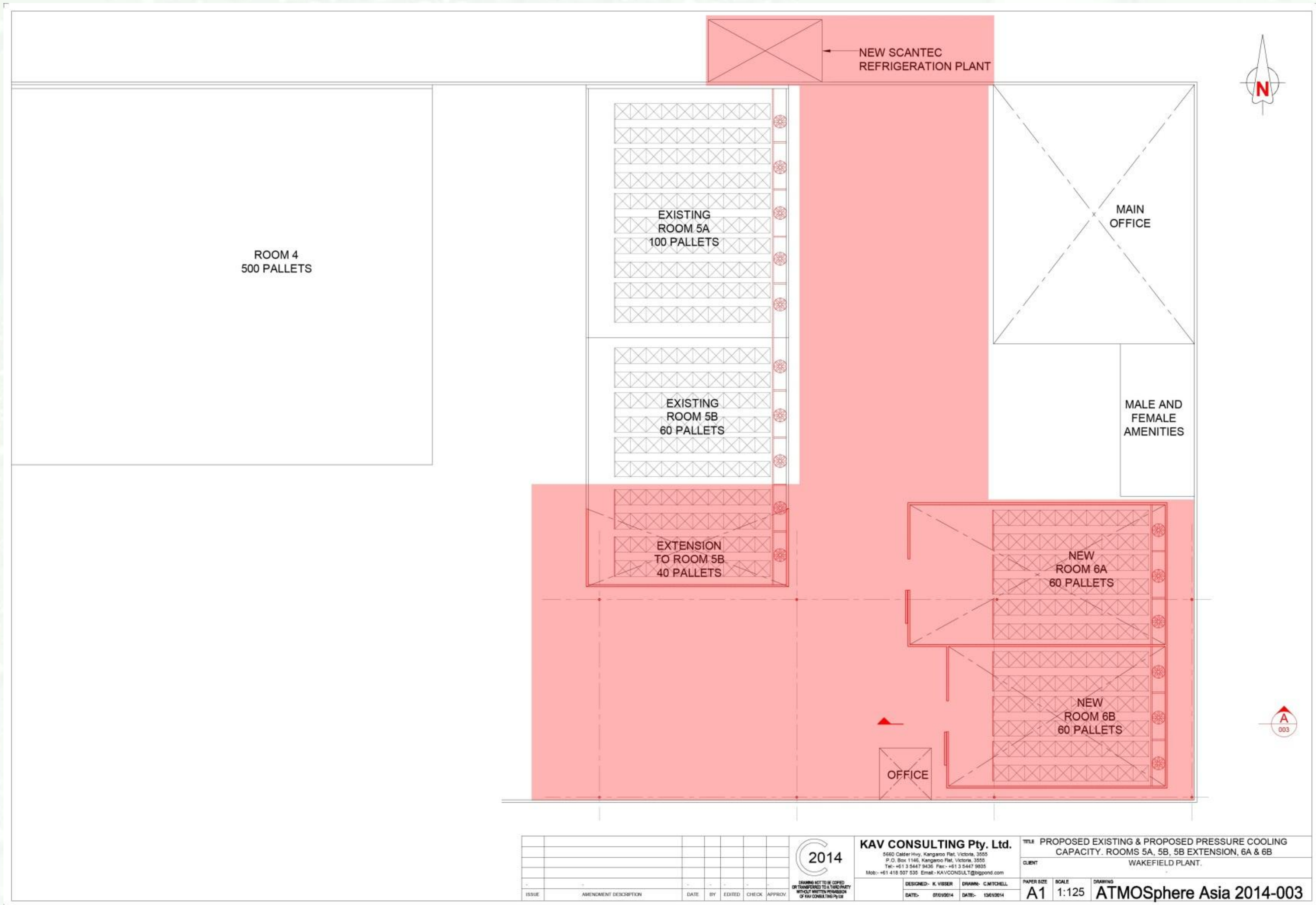
Introduction

Following a recommendation from a mutual business partner Mr. Bruno Moras, the CEO of Wakefield Transport Group, Mr. Ken Wakefield sought my advice on Refrigeration Design & Construct proposals to augment cold sterilization capacity for export oranges. Our investigation revealed the following:

- Both proposals were for air cooled R134a systems to cool 84 tonnes/day in two coolers with a cooling time of 36 hours – 60 pallets @ 1400 kg each.
- Both proposals required an increase in the electrical power supply capacity to the plant.
- The existing air cooled DX R22 carrier system generating propylene glycol for existing cold sterilization and cold storage would be retained.

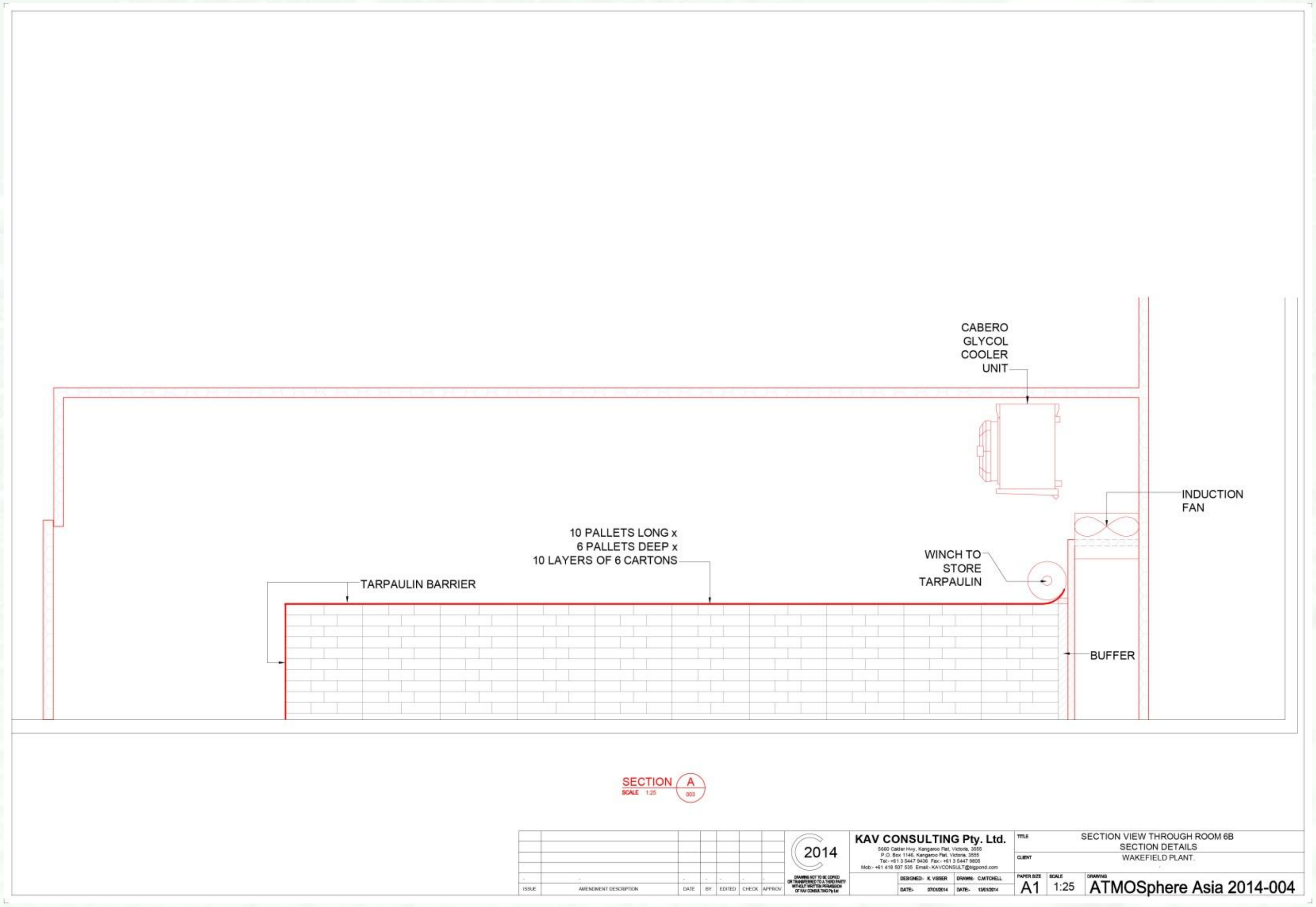
ATMOsphere ASIA technology & innovation natural refrigerants

Existing Pressure Cooling Capacity
320 Pallets on the Floor.
36 Hours Cooling.



KAV CONSULTING PTY LTD
Advisers to the Refrigerated Food Industries

Pressure Cooling Operation Schematic



Refrigeration Capacity Determination

ATMOsphere ASIA technology & innovation natural refrigerants

- We examined the past production profile and established a refrigeration system load factor of **69%** when cooling 112 tonnes/day (80 pallets) and storing 700 tonnes (500 pallets).
  This led to the following picture:

Parameter		System Capacities	
No.	**Description**	**Existing**	**Augmented**
1	Cold Sterilization Capacity 1. No of pallets in cold sterilization room 2. No of pallets chilled/day 3. Weight sterilized/day, tonnes	 160 80 112	 320 160 224
2	Entering Fruit Temp, °C	13 – 25	13 – 25
3	Final Fruit Temp, °C	1	1
4	Temperature Reduction Range, °C	12 – 24	12 – 24
5	Product Cooling Load, kW - 18 hours cooling	80 – 160	160 – 320
6	Add Base Load; Fans, Insul^{n}, Infilt^{n}, etc. kW	50 – 50	80 – 80
7	Add Storage Cool Room Load, kW	60 – 100	60 – 100
8	Design Refrigeration Loads (Q), kW	190 – 310	300 – 500
9	New Compressor Design Capacity at **85%** diversity *(assumed)*		**425kW**

KAV CONSULTING PTY LTD
Advisers to the Refrigerated Food Industries

ATMOsphere ASIA technology & innovation natural refrigerants

Required Power Supply Analysis

Consumer		Name Plate Rating		
No.	Description	Existing	New	New Total
1	Existing Water Cooled R22 System	152.0	-	152.0
2	Existing Air Cooled Carrier R22 System *Including Glycol Pump.*	95	-	Replaced
3	18 Induction & Glycol Cooler Fans In Rooms 5A & 5B	20.0	-	20.0
4	2 or 3 Ammonia Compressors	-	135 – 150	135 – 150
5	1 New Evaporative Condenser Fan & Pump	-	7	4
6	Glycol Circulating Pump	-	15.0	15.0
7	2 Cabero Glycol Coolers each with 2 off 1kW ECM Fans	-	4	4
8	Office Equipment, AC, Lights	30	-	30
9	**Total Connected Load, kW**	**297**	**161 – 176**	**363 – 378**
10	**Increase in Connected Load, kW**	**-**	**-**	**66 – 81**
11	**Increase in Connected Load, %**			**22.2 – 27.3**

KAV CONSULTING PTY LTD
Advisers to the Refrigerated Food Industries

Discussion

- Depending on initial fruit temperature, the required refrigeration capacity increases by 110 – 190 kWR, i.e. 58 – 61%.
- The maximum power supply capacity increase available was 9.5% from 388 kW MD to 425 kW MD at 0.85 Power Factor (500kVA transformer).
- The projected increase connected load amounted to 66 – 81kW, i.e. 22.2 – 27.3%
- It was decided to proceed doubling the cooling capacity without expensive and time consuming power supply and emergency generator augmentations for the following reasons.
- Having regard to the local climate, it would be quite rare that the maximum refrigeration capacity would be required during the six to seven month orange export season from April to October. (i.e. Autumn, Winter, and early Spring)

Considerations Influencing the Recommendation to proceed without Augmenting the power supply capacity.

- Having regard to the seasonal local climate, it was safe to specify a 30°C Saturated Condensing Temperature (SCT) during the peak season of orange harvesting running from May to October.

- At – 8SST/+30°C SCT a COP of at least 4.0 was expected for reciprocating NH_3 compressors. This gave an expected demand of 108 BkW for the compressors, this is only 80% of the name plate rating, to deliver 432kWR, 7kWR more than the required capacity of 425kWR at 85% diversity. An MD of 450 – 460 kW from the same power supply would be possible if the power factor were to be improved from 0.85 to 0.9–0.92.

- We specified high efficiency electric motors for the compressors and the propylene glycol circulating pump.

- We elected a high efficiency PGC pump to reduce the electrical energy consumption and the resulting refrigeration loads.

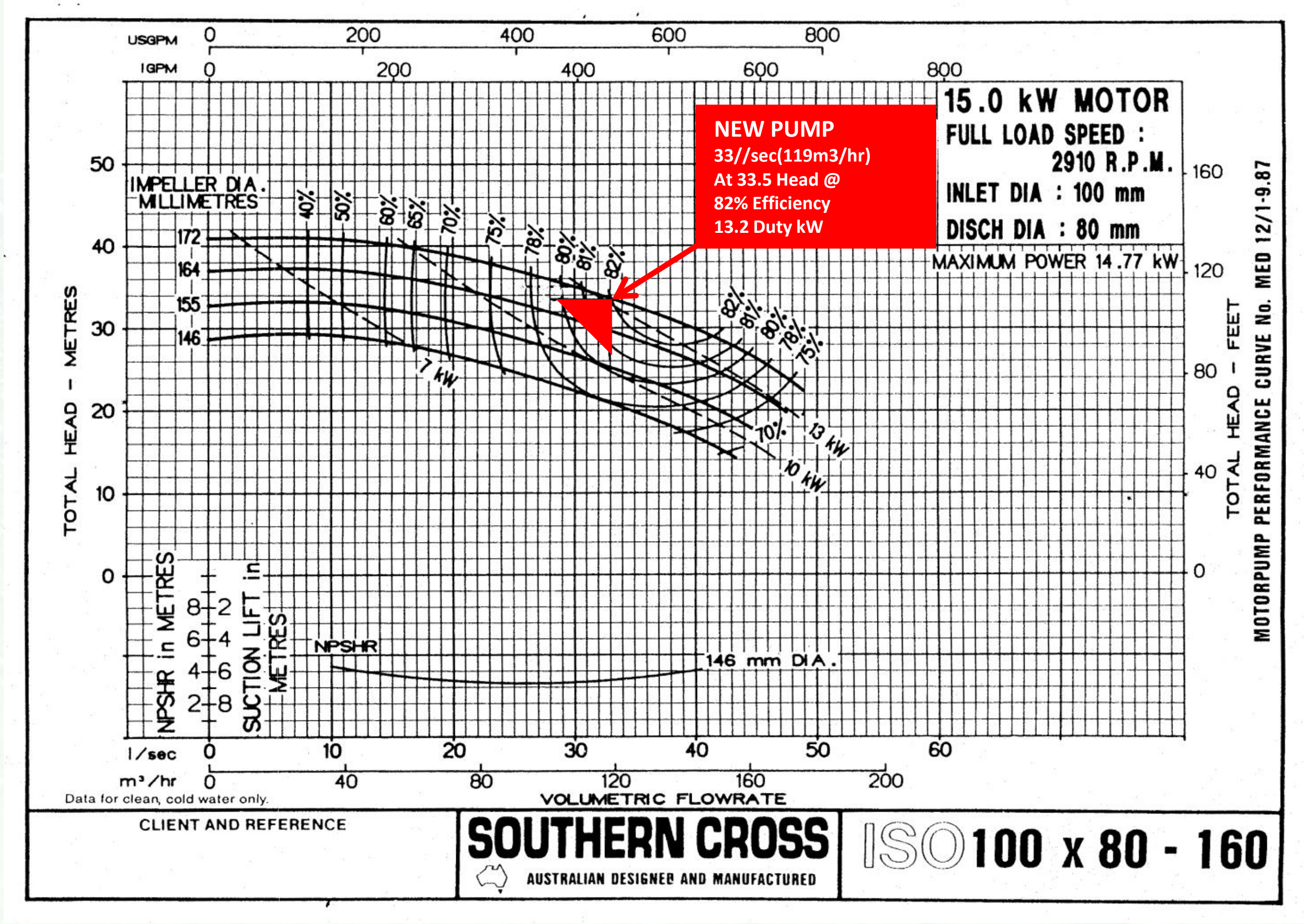
- We specified a minimum of two compressors with each compressor being able to deliver 62% of maximum capacity in case of failure of one compressor.

- The refrigeration capacity diversity factor was increased from 69% during 2012 to 85% for the expanded plant.

High Energy Efficiency Measures Taken

- VSD’s were fitted to all compressors.
- Soft starters for all electric motors 5.5 kW and above.
- ECM motors were specified to drive the fans on the new glycol coolers.
- A conservatively rated condenser was specified by specifying a high ambient wet bulb of 20°C, 4.3°C higher than the average wet bulb in November.
- Installing the Siemens flow regulating valve as a diverting valve into the PGC pump suction to maintain full flow through the coolers, giving max heat transfer rates at very low temperature differences between glycol and air.
- Future expansion was planned as follows:
    - Alfa Laval glycol PHX capacity increased to 650 kW
    - Ammonia piping increased to add two larger compressors.
    - Glycol circulating pump capacity increased for 650kWR including glycol pipes.
    - The entire facility will be refrigerated by this expanded plant, including replacement of a DX R22 system, servicing rooms 1, 2 and 3.
    - This season the capacity in room 5A is doubled with a very heavy duty cooler installed in room 5B to see if it can cool fruit in less than 24 hours.

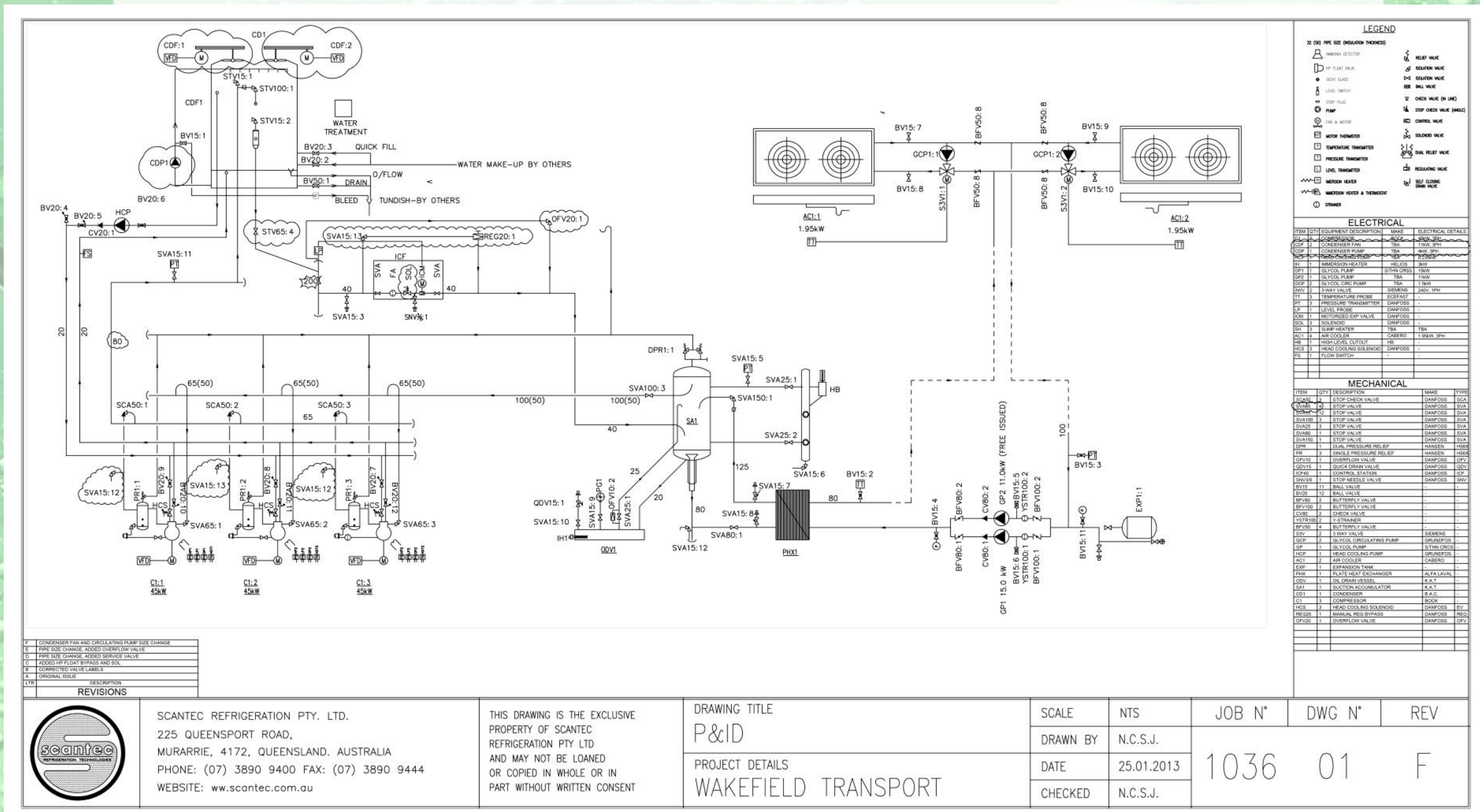
New PGCP Performance for Future Expansion. NB High Efficiency.



ATMO sphere ASIA technology & innovation natural refrigerants

Ammonia-Glycol System PLID for New Pressure Cooling Room 6A and 6B

NB. Existing Rooms 4, 5A & 5B Not Shown.



KAV CONSULTING PTY LTD
Advisers to the Refrigerated Food Industries

ATMOsphere ASIA technology & innovation natural refrigerants

MD and Electrical Energy Consumption in Peak Season

Analysis of Electrical Energy Accounts

Parameter		Year		
No.	**Month**	**2011**	**2012**	**2013**
1	**August**			
	1. kWh	129,096	143,095	210,998
	2. MD. kW	388	388.43	404.4
	3. Metering Period, Hours	744	744	744
	4. Load Factor, %	44.7	49.5	70
	5. Cost, $K (Total kWh)/$ per kWh)	18.95/0.147	24.05/0.168	36.06/0.171
2	**September**			
	1. kWh	158,522	152,922	206,443
	2. MD. kW	388	361	404.4
	3. Metering Period, Hours	720	720	720
	4. Load Factor, %	56.7	58.8	71
	5. Cost, $K (Total kWh)/$ per kWh)	22.15/0.14	12.92/0.085	29.84/0.145

KAV CONSULTING PTY LTD
Advisers to the Refrigerated Food Industries

Conclusions

- The maximum demand (MD) generated by the new system increased by only 16.4kW or 4.2% whilst the new plants connected electrical load has increased by 22.2%.

- The above was achieved with a refrigeration capacity increase of about 60%.

- The electrical energy consumption of the orange sterilisation process increased by 47% and 35% when comparing the months of August and September 2012 and 2013 respectively. During the 2013 period the amount of fruit handled was doubled compared to 2012 thus the specific energy consumption per pallet reduced by 26 to 32%, a very pleasing result above expectations. This was particularly due to using a much oversized second hand evaporative condenser (EC) as the new EC from China would not be delivered on time. The fans on the second hand EC hardly ever operated.

Conclusions *(Continued)*

- Considering the small MD increase and the load factor together it is clear that the new system operated more efficiently over a longer period of time.

- The forward planning is already paying off with the capacity doubling and trebling in Rooms 5A and 5B respectively at minimal expense for the coming seasons.

- The main circuit heater size on the switch board was increased from a rating of 700 Amps to 1050 Amps. (500 to 750 kVA). Considering that the current MD of the plant is 404.4 kW early indications are that this expense was unjustified to cater for varying the effective capacity in Rooms 5A and 5B by more than 100% and converting Rooms 1, 2 and 3 to glycol cooling when the remaining R22 plant needs to be phased out.

Acknowledgements

1. We wish to acknowledge with thanks the clients CEO Mr Ken Wakefield for accepting our recommendations and commissioning us to do the project analysis, design documentation for him.
2. We also acknowledge with thanks the assistance and cooperation with us by providing the energy data in slide 16, the clients general manager Ms Vicki Krake for her permission to use it publicly.
3. We wish to acknowledge the excellent performance of the contractor Scantea Refrigeration Technologies PTY LTD out of Brisbane, for:
    1. Their excellent work in building the skid mounted refrigeration.
    2. Their valued assistance in sourcing a grossly oversized but suitable second hand evaporative condenser (EC) when the new EC from China would not be delivered on time.
    3. Their prompt attention to initial problems with the compressor shaft seals which were incompatible with the mineral oil used in the compressors. Initial high vibration at around 30 Hertz compressor speed was also attended to quickly.

Universal Applicability with Secondary Refrigerants

1. Conversions from HCFC and HFC Refrigerated Secondary Refrigerants. Natural refrigerants like ammonia, CO_2 and hydrocarbons are possible anywhere.
2. Smaller capacity NH_3 compressors are increasingly becoming available.
3. The following four developments would greatly assist the more wide spread use of NH_3
    1. Formulation of an oil miscible with NH_3.
       Automatic mechanical oil return to the compressor is technically quite feasible, but expensive.
    2. Improved oil separators are also worth investigation.
    3. Small two stage NH_3 compressors would also assist to get around high discharge temperatures.
    4. The development of efficient heat exchangers for both the condensing and evaporating functions. Micro channel designs come to mind.

KAV CONSULTING PTY LTD
Advisers to the Refrigerated Food Industries