NEXT GENERATION ADIABATIC CONDENSERS AND FLUID COOLERS

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ABSTRACT

This paper presents the design approach adopted for the development and application of a new range of adiabatic condensers and fluid coolers.

The design is based on making use of both the design wet and dry bulb weather conditions for any given location. The concept employs the placing of evaporative pre-cooler pads in front of a tube and fin heat exchanger. When operating in pre-cooling mode, the dry bulb air temperature of the air passing through the wetted pads is reduced prior to entering the condensing or fluid cooling heat exchanger. A simple observation is that in this mode the operation is similar to an air-cooled condenser or fluid cooler during low ambient dry bulb operating conditions.

This paper will discuss the design, operation, construction and advantages of this type of condenser or fluid cooler.

1. INTRODUCTION

This type of condenser has been developed in Australia over the past six years. The initial approach was to fit pre-cooler pads onto standard aircooled condensers; this was done on several project for both Freon and ammonia refrigerant installations. Although successful the retrofitting approach was both expensive and cumbersome and lacked design sophistication.

In 2002 the concept was further developed and refined into a range of standard built condensers. The range was also expanded and adapted to include closed circuit fluid coolers. These units could be retrofitted as cooling tower replacements on existing installations, alleviating Legionella problems. In time it has been proven that many new installations now opt for the new closed circuit wetted pad units, as they also provide significant water savings advantages.

2. BACKGROUND

In Australia there has been a long history of Legionella outbreaks, most of these have been linked to traditional open type water-cooling tower system installations. To counter Legionella outbreaks local authorities introduced strict regulatory conditions that included the registration of all cooling tower systems, as well as imposing onerous testing and reporting requirements, including regular tower water quality sampling, water testing and annual system auditing. Combined with this came the introduction of strict chemical water treatment regimes. For both condenser and cooling tower owners, this added considerable risk and compliance costs. In the legislation as drafted, a cooling tower system covers any open type of fan forced or induced cooling water system, this also includes evaporative condensers.

Not only have the adiabatic condenser and fluid cooler units catered for the OH&S shortfalls of traditional systems, the concept and application of this type of cooler has also proven to be more energy efficient as well as providing significant water savings when compared to the traditional systems. As Australia is a dry continent any water saving initiatives are considered both important and necessary.

3. PRINCIPAL OF OPERATION

The Condenser – cooler system consists of 4 main parts:

1. Evaporative pre-cooling circuit or open circuit (recirculation pump, water distribution system, water sump and evaporative pad media)
2. Finned-tube heat exchanger (closed circuit)
3. Fan(s) (Number off depends on size)
4. Controller that also include a switchboard and fan speed control

The pre-cooling system extracts energy from air through evaporation of the water on the surface of the evaporative media. Since no external energy is provided for this process, the result is the reduction in the dry bulb air temperature. This air is in turn used to cool a conventional finned-tube heat exchanger, through which is circulated a fluid requiring either condensing or cooling.

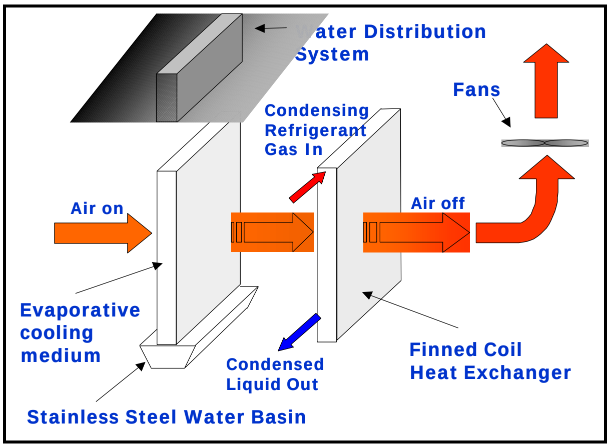


Figure 1. Working Principle – Dry Mode

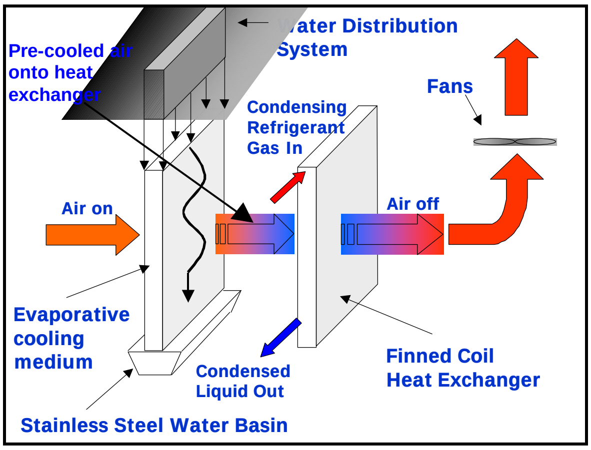
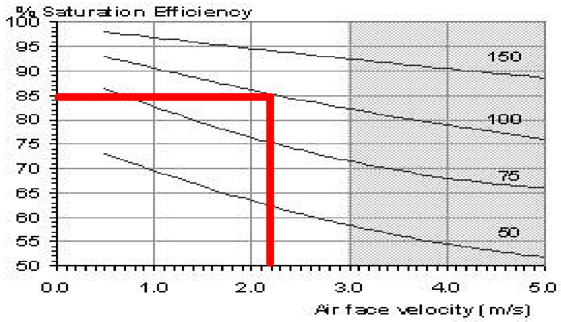


Figure 2. Working Principle – Pre-Cool Mode

5. PRE COOLING PSYCHROMETRIC PROFILE AND PAD EFFICIENCY

The following example outlines the cooling efficiency that can be obtained during the pre-cool operating mode. This example is based on Melbourne summer design conditions of 38°C DB / 21°C WB. The example shown equates to a cooling pad efficiency of 85%



T_{DB} = Dry Bulb Temp

T_{WB} = Wet Bulb Temp

h = Saturation Efficiency

$$T = T_{DB} - h\left(T_{DB} - T_{WB}\right)$$

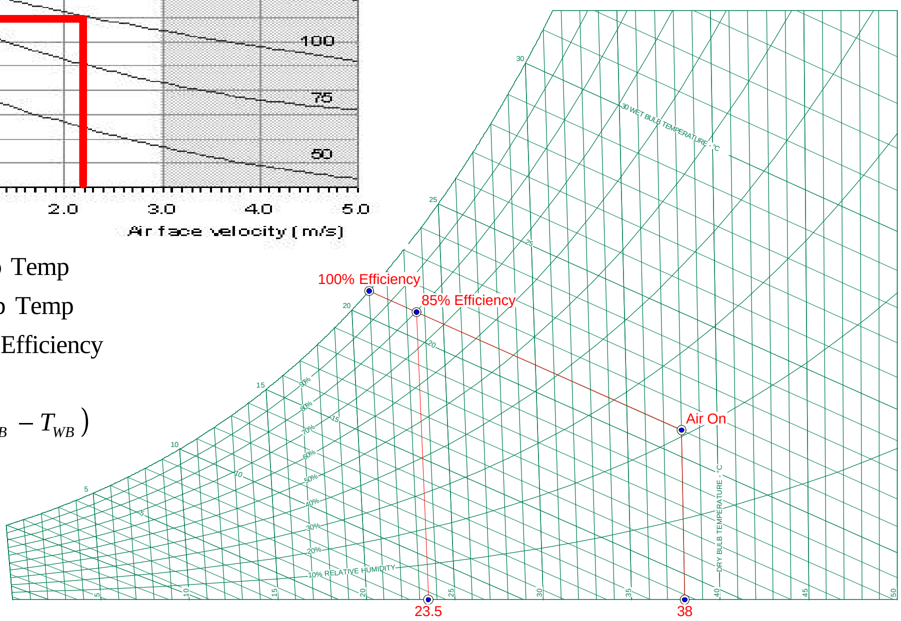
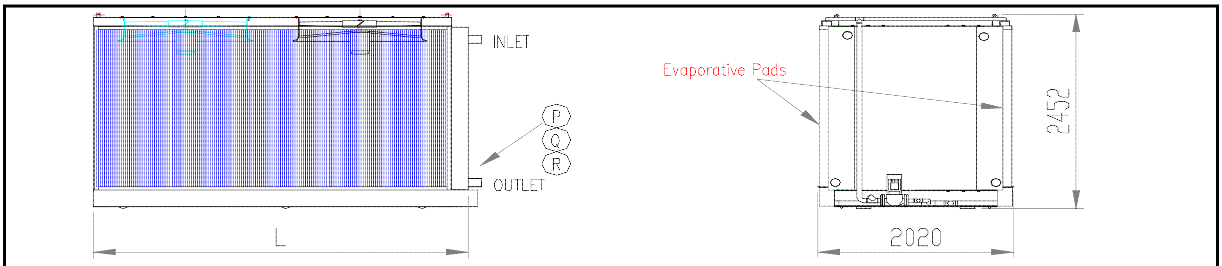


Figure 3. Pad Efficiency and Psychrometric Profile

6. TECHNICAL DATA



Model			H-DCA-2F-4R-8P	H-DCA-3F-4R-6P	H-DCA-4F-4R-4P
Nominal Capacity [1]	HOR	kW	420	630	815
Number of Fans			2	3	4
Fan Size	Dia	mm	1250	1250	1250
Fan Motors	M_f	kW	2 x 5.5	3 x 5.5	4 x 5.5
Fan Motor Amps (415V)	I	A	2 x 11	3 x 11	4 x 11
Evap Media Pump (230V)	M_p	kW	0.37	0.37	0.37
Overall Length	L	mm	3910	5700	7000
Overall Width	W	mm	2020	2020	2020
Overall Height	H	mm	2452	2452	2452
Refrig Inlet/Outlet Conn	OD	mm	105	105	105
Water Make-up (max) [2]	Q	l/s	0.27	0.40	0.50
Water Make-up Conn	P	inch	$^3/_4$ FBSP	$^3/_4$ FBSP	$^3/_4$ FBSP
Water Dump Conn	Q	inch	$1^1/_2$ FBSP	$1^1/_2$ FBSP	$1^1/_2$ FBSP
Water Overflow Conn	R	mm	2 x 25NB	2 x 25NB	2 x 25NB
Dry Weight	W_1	kg	3325	4165	4995
Operating Weight	W_2	kg	3985	5095	6285
Sound Pressure Level [3]	L_W	dBA	77	80	81

Figure 4. Technical Data Sheet for Standard H Model Ammonia Condensers

7. TYPICAL PIPING ARRANGEMENTS

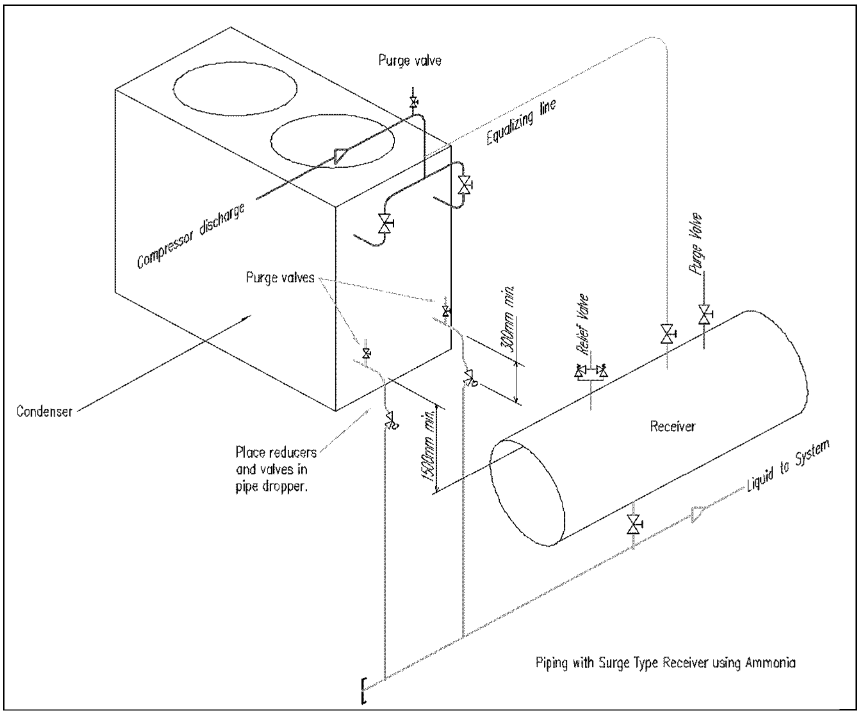


Figure 5. Piping with Surge Type Receiver Using Ammonia

The vertical liquid drain legs from each coil must have sufficient height and be individually trapped to prevent liquid backing-up inside the heat exchanger coils. For multiple units connected in parallel the refrigerant pipe work circuit must be as symmetrical as possible to equalise the discharge gas and liquid drain pressure drops to individual units.

8. CAPACITY LINE FOR CONDENSER SIZED AT CRITICAL DESIGN CONDITIONS

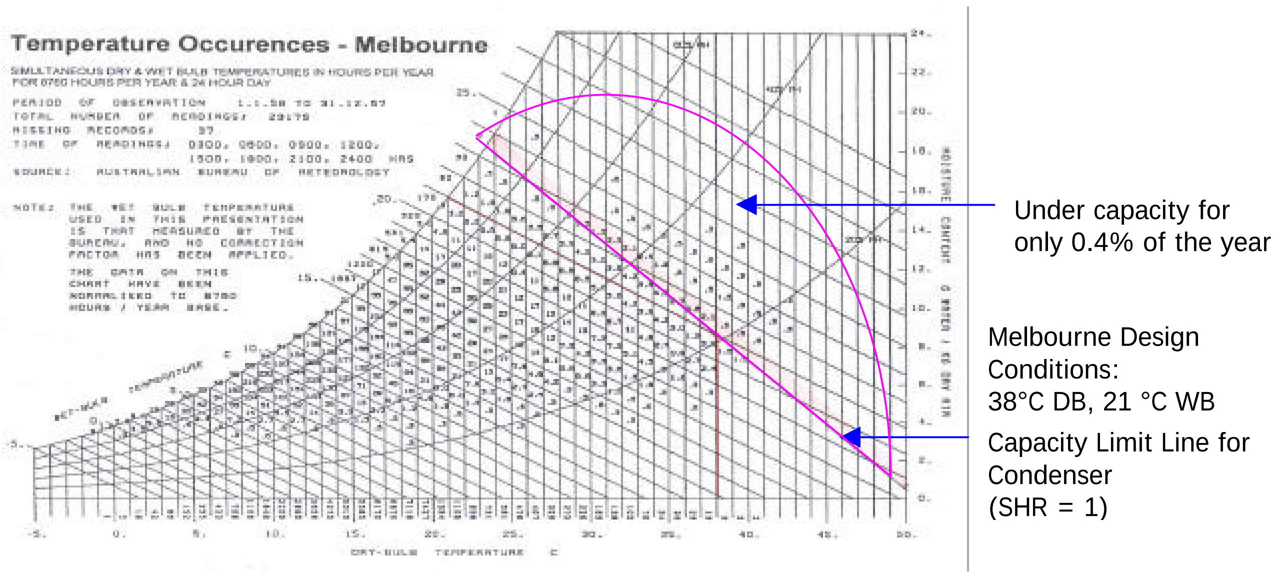


Figure 6. Condenser Capacity Line

This chart shows the inherent safety margin built into the condenser selection criteria. As shown when the condenser is selected for the regional design dry and wet bulb temperatures most of the time the condenser will be operating below the design point.

Using Melbourne as an example the hours per annum when the unit could be operating outside the design criteria is only 0.4%, or 38hours PA, in this instance the condensing temperature will increase marginally. The number of hours per year when the design dry and wet bulb temperatures occur at the same time is only 2.4hours, this means that for the rest of the year 99.5% of the time the condenser will be operating below the maximum design conditions.

9. MANUFACTURING PRINCIPLE OF CONDENSER COIL

Table 1. Manufacturing Data for Various Applications

DUTY	APPLICATION	TUBE DIA	TUBE PITCH	FIN MATERIAL
Ammonia	Condenser	12mm Gal Steel	36x31 Triangular	Aluminium –2.5mm
Freon	Condenser	9.5mm Copper	20x25 Triangular	Aluminium –2.5mm
Fluid Cooler	Water Cooling	9.5mm Copper	20x25 Triangular	Aluminium –2.5mm

10. STANDARD UNIT SELECTION TABLES

This table shows part of the range of capacities kW HOR, obtained from three standard ammonia duty models selected for a given condensing, dry bulb and wet bulb condition.

Table 2. Unit Selection Table

H-DCA Dricon Series (ammonia)

Capacity - kW HOR

	Model No.	H-DCA-2F-4R				H-DCA-3F-4R				H-DCA-4F-4R			
	Condensing temperature [°C]	33	35	37	39	33	35	37	39	33	35	37	39
Ambient design conditions	33°C DB / 21°C WB	364	436	504	575	545	653	755	861	688	823	955	1087
	35°C DB / 21°C WB	350	420	490	561	524	629	735	841	661	795	928	1060
	37°C DB / 21°C WB	339	409	480	551	508	612	719	826	640	775	907	1040
	40°C DB / 21°C WB	328	399	469	538	491	597	703	807	606	741	874	1006

Dricon Total Heat Rejection [kW] Table for NH3

11. MODE OF OPERATION

11.1 Dry Mode

During dry mode the evaporative media pump is disabled, therefore there is no evaporative pre cooling effect. Dry Mode is active when the ambient temperature is below the selected set point. The PLC trims the fan outputs using the VSD fan control, maintaining either the condenser pressure or water outlet temperature at the desired set point. If this set point is exceeded by a predetermined value the PLC switches fan control from VSD to full speed DOL mode to provide extra cooling.

11.2 Pre Cool Mode

The fan operation during Pre-Cool Mode is identical to Dry Mode. Pre-Cool Mode is activated when the ambient temperature rises above the pre-selected set point. The water make-up solenoid output is then energized to fill the sump with the sump level controlled by the float switch, the dump motorized valve output is de-energized and the evaporative media pump output is enabled to run. This saturates the pre cooler pads providing the evaporative cooling effect.

If both the VSD and DOL fan outputs are in operation and the feedback value continues to rise, once a maximum predetermined set point temperature is exceeded the water make-up boost solenoid output is enabled. This sprays water directly onto the coil, providing additional cooling.

11.3 Cleaning Cycle

A daily cleaning cycle is activated by the PLC at a user selectable time (off peak or night time). This effectively empties and dries out the Evaporator Unit. On completion of the cleaning cycle the PLC returns to the mode required to meet the current operating conditions at the time.

12. ENVIRONMENTAL AND SUSTAINABILITY

The operation and design of the unit is engineered to minimise utility waste and impact on the environment. *Legionella* risk is reduced to a negligible level by a combination of low operating temperature; a water dump and desiccation cycle every 24 hours, and the use of low air velocity, high efficiency evaporator pads to prevent the creation of an aerosol. It should be noted the new range of units have less than 50 litres of water in the sump during wet cycle duty operation.

These features remove the need for water treatment chemicals or services, which in turn allow the dump water to be used for other benign down stream purposes such as irrigation.

The unit can be operated on a water efficiency or power efficiency cycle. Where water efficiency is the prerequisite, the cooling evaporator pads should be run wet only under high ambient conditions. Where energy efficiency is desired, the evaporator pre-coolers can be operated for extended periods of time, thereby reducing the number of cooling fans required or fan speed control, where VSD is included this in turn reduces the compressor operating power costs.

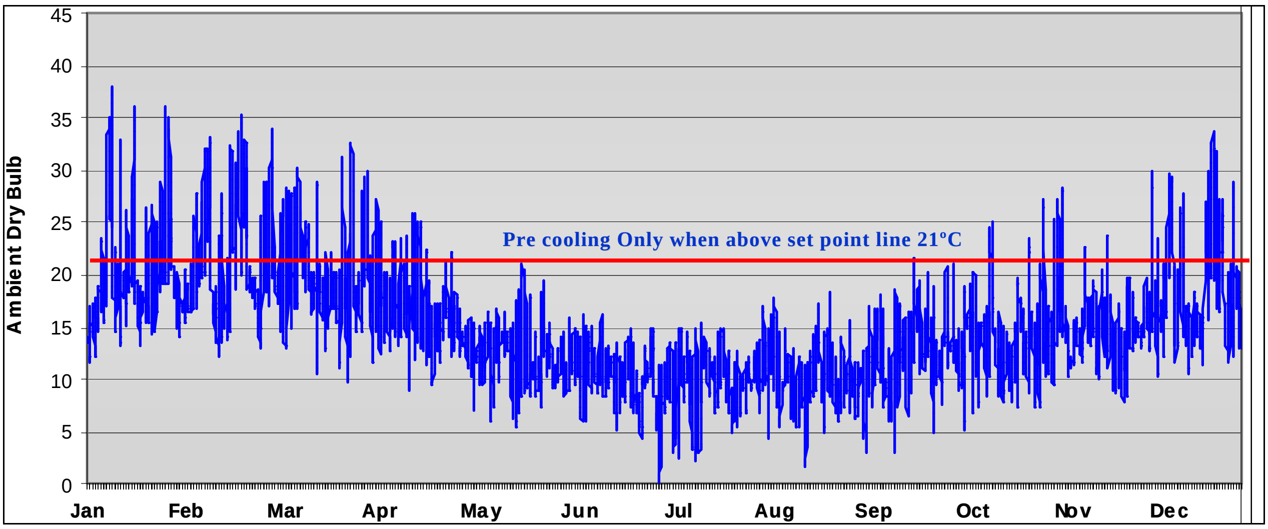


Figure 7. Melbourne – Drybulb Temperature Profile (Yr 1971)

The above graph shows that the water / cycle is only operating for 999 hours or 11.4% of the year, the rest of time the unit can be operated in the dry mode.

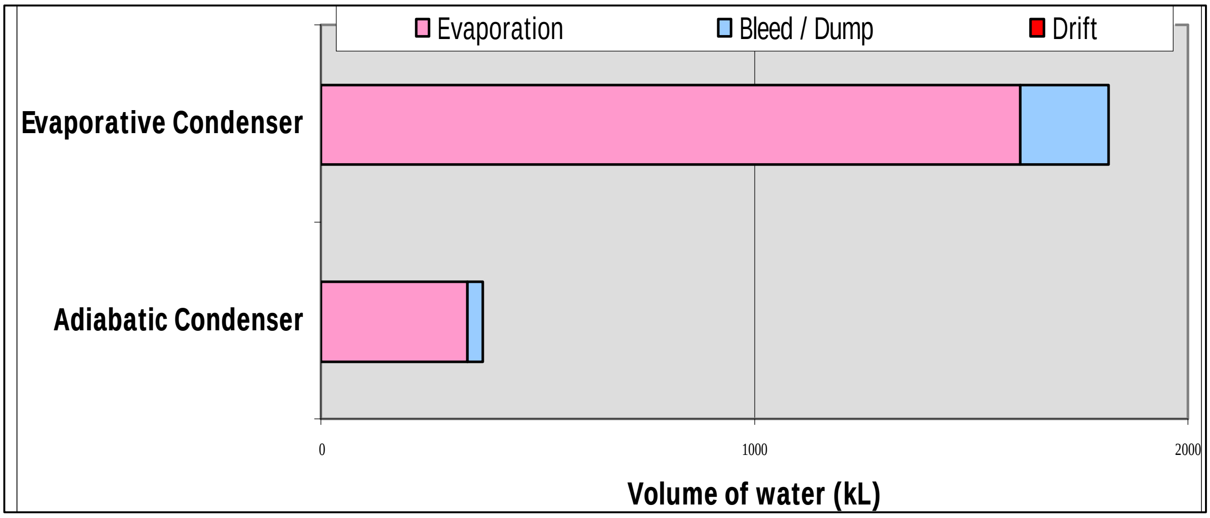


Figure 8. Annual Water Consumption Comparison Ammonia Condenser
Based on 440kW HOR Unit at Melbourne DB Profile Ref Yr 1971

Water Consumption Comparison			
Dricon vs Evap Condenser			
Annual Operation 24 hours / day - 7 days / week			
8 x Dricon H-DCA-4F-4R			
Design Capacity	**kW HOR**	**5900**	
Precooler Annual Operating Hours	**hrs**	**999**	
No. of Precooling Days	**days**	**98**	
Annual Evaporation	**kl**	**6737**	96.1%
Annual Dump Volume	**kl**	**274**	3.9%
Annual Water Consumption	**kl**	**7012**	100.0%
3 x Equivalent Evaporative Condensers			
Annual Operating hours	**hrs**	**8760**	
Design Capacity	**kW**	**5900**	
Diversity Factor		**0.55**	
Water Flow Rate	**l/s**	**160.8**	
Cycles of Concentration		**10**	
Annual Evaporation (rate 1%)	**kl**	**27890**	90.0%
Annual Bleed	**kl**	**3099**	10.0%
Annual Drift (0.002%)	**kl**	**56**	0.2%
Annual Water Consumption	**kl**	**30989**	100.0%
Annual Estimated Water Saving	**kl**	**23978**	**77.4%**

Figure 9. Water Consumption Comparison

13. TRANSPORTATION

All unis are designed to be transported in a shipping container. Each unit is provided with towing connections for removal from the container. Permanent rollers are fitted into the base to assist in moving the unit from the container or delivery vehicle. This is also useful for moving the unit into position. Bump guards are fitted to the base of each unit; these are designed to prevent damage while the system is in transit.

Lifting points have been provided on the unit and must be used when lifting or moving the unit into place.

14. ADVANTAGES AND DISADVANTAGES

14.1 Advantages

- The risk of Legionella is virtually eliminated.
- These units use up to 80% less water than traditional systems.
- There is no need for water treatment or chemicals.
- In Australia there is no compliance or auditing procedure regulations.
- Depending on the application, these units can offer energy savings.
- Discharge water can be used on gardens or non-potable uses.
- There is less maintenance as the coils operate dry, minimising corrosion and promoting a longer service life.
- All units are delivered assembled and fit into a container, eliminating site assembly costs.
- Units are supplied with own switchboard, pre programmed and designed for integration into the overall plant control system.
- When unit cost, water treatment costs, life cycle costing, water and energy savings are factored in these units are cost competitive, with payback in 2-3 years.

14.2 Disadvantages

- These units have a larger footprint and require more floor space than similar size traditional units.
- Similar capacity ammonia units are base price compatible, however in the larger sizes if multiple units are compared to a single large unit the price is more.
- The unit initial capital cost is more than traditional open cooling tower units.
- Efficiency reduces in high humidity (sub tropical) environments. However this is partially offset by lower design dry bulb temperatures in these areas.

15. SUMMARY

As demonstrated this type of condenser and closed circuit cooler provides a real alternative offering many advantages over traditional condensers, closed circuit fluid coolers and open type cooling tower systems.

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