Performance Report

of

Dual Indirect Cooling Energy Recovery (DICER) Plant installed

at

University of Technology Sydney

2 April 2008

TABLE OF CONTENTS

1. Executive Summary

This report provides the results of preliminary tests performed by the Facilities Management Unit, UTS with assistance from the Faculty of Engineering on the dual indirect cooling energy recovery (DICER) units installed at University of Technology Sydney. The Faculty of Engineering is currently in the process of setting up formal accessories and instrumentation for further demonstration of the capabilities of the DICER units over a range of climatic conditions.

Indirect evaporative cooling provides high air conditioning efficiencies under conditions of high ambient temperature and low humidity. The electricity demand for air conditioning in the Sydney CBD would be at the highest under such conditions. The DICER units were tested to determine their performance, using commercially available instrumentation between 22 February and 30 March 2008. The tests were done on the warmest days available since the commissioning of the plant.

The test results show that the climatic conditions prevalent in late February and in March 2008 did not provide sufficient and prolonged hot climatic conditions to provide a demonstration of the full capabilities of the DICER units.

However, short periods in mid afternoons were available to demonstrate the potential of the DICERs. These exercises demonstrated that the DICERs achieved a refrigeration coefficient of performance, COP as high as 10. The COP is a universal measure of the refrigeration effect produced by an electrical input. These demonstrated refrigeration efficiencies need only 20% of the electrical power needed to drive a split air conditioning unit at COP 2.

These DICER demonstration units will continue to be adjusted, tuned, further developed and tested for readings in the remaining period of 2008 by the UTS Faculty of Engineering. Such results will form a comprehensive dossier of valuable data on the performance under varying seasonal climatic conditions. Further, in the event hot ambient conditions are not available the Faculty intends to simulate such conditions by the use of artificial heating of the intake air and provide readings.

2. Introduction

In order to reduce the high peak electricity demand in the Sydney CBD, the NSW Department of Planning (DP) initiated a programme of investigations and funding to encourage high electricity users to undertake peak electricity demand reduction, or demand deferral projects. UTS was invited by this program to nominate suitable projects for possible funding by DP.

UTS Faculty of Engineering (FOEng) with the assistance of the UTS Facilities Management Unit, investigated and identified two air conditioning plant in the UTS Tower building also known as Building 1, where a sum total of 70 kVA electricity peak demand reduction could be achieved under hot weather conditions by the installation of Dual Indirect Cycle Evaporative Cooling (DICER) Equipment. The selected Plant Rooms were 7.01 and 7.06 situated on Level 7 of the Tower Building (Building 1). The installation of these DICER units will not change the existing air conditioning comfort conditions in temperature, humidity or air circulation of the air conditioned spaces supplied by them.

Each DICER unit supplies pre cooled air to the air handling unit (AHU), and thereby reduces the electrical energy required by the main chillers to provide chilled water. Under conditions of high ambient temperature and low humidity, the electrical energy consumed by the DICER unit will be significantly low in comparison to the electrical energy consumed by the chillers to provide a comparable cooling effect. Further, peak electrical demand load reduction and electrical energy savings throughout the year is accrued to varying degrees from the DICERs.

NSW Department of Planning accepted a detailed analytical proposal submitted by the FOEng, and offered a grant of $87, 000 to instal, specifically selected evaporative cooling units of FICOM manufacture. The grant was not transferable to other models, or to alternative manunufacturers. 53% of the cost of the project was been funded under the Demand Management and Planning Project (DMPP) of the NSW Department of Planning on acceptance of the proposal jointly submitted by the UTS Faculty of Engineering and Ficom P/L. UTS Facilities Management Unit funded the remaining 47% of the project.

The recorded performance of DICER units compares well with other similer air conditioning equipment. The DICER it self has no major moving componets other than a water pump and a blower fan. The available record show that there are DICER units installed 30 a years back are still in operation without major refurbishment.

The two demonstration DICER units were installed in January 2008 in Level 7 of UTS Tower Building. The project intends to demonstrate the ability to reduce the peak electrical demand on the CBD electricity grid due to air conditioning loads by treating intake air with evaporative cooling. The system was first proposed by Engineer Don Pescod when working at CSIRO in the early 1970's. Pescod's original work has since been further enhanced, as foreshadowed by Pescod, by heat sealing the plates to form the passages. This has allowed 3 principle improvements:

UTS Tower - Broadway, Sydney

- Preventing leakage between air passages
- Reducing pressure loss within the passages
- Uniformly wetting the exhaust air

In addition to Pescod's work the DICER system has been developed to deal with both the latent and sensible parts of the cooling and dehumidification load by working with a relatively small vapour compression system.

The energy, energy cost savings and GHG emissions reductions are achieved by the DICER system in two ways, both as a result of the improved Coefficient of Performance (COP) of the DICER unit in comparison to conventional air conditioning. Improved COP provides lower electricity consumption to achieve the same level of air conditioning comfort. Lower electricity consumption translates to lower GHG emissions, and to lower electricity bills. Due to the lower level of electricity consumption in kWh, the electricity power demand peak kVA of the DICERs will be correspondingly lower. Thus Demand Management and Planning Project (DMPP)'s primary focus of the electricity maximum demand peak reduction is achieved by the DICER units.

3. The installation at UTS

Air Conditioning Plant Rooms Plant Rooms 7.01 and 7.06 in UTS Tower Building Level 7 were selected for the installation of the DICER units. The larger DICER 1800 is installed in Plant Room 7.01 and the smaller version DICER 1500 is installed in Plant Room 7.01. 'As installed' schematic diagrams of the plant are given in the Appendices.

Rm 7.01 – Existing Air Handling Unit

Approximately 30% of the air supply to the conditioned spaces is now diverted, pre-treated and cooled by the DICER units using indirect evaporative cooling. The treated air is thereafter passed through the chilled water air handling units as before, and would now be extracting less cooling energy form the chilled water as it is pre-cooled. The process is a hybridised air conditioning unit using both non contact evaporative cooling and vapour compression (chilled water) cooling of air.

DICER 1 is installed in the Exhaust/ Return Air Plant Room 7.01 in the North West corner of the Tower building. The return air form the building is drawn in to the DICER unit past a filter and chilled water coil and exhausted from the DICER though the duct on top of the unit to the left. As water is sprayed on to the exhausting air in the DICER heat exchanger the exhaust air to the atmosphere leaves the unit with a high humidity level, providing latent cooling to the heat exchange process.

Rm 7.01 – DICER 1– Main Installation

DICER 1 has the manufacturer's original design fan shaft where both fans are mounted coaxially on the same motor shaft. The view shows the fan box and the fan shaft end. The cooling coil and the secondary air intake are located to the right rear of the view. The return air enters the plant room from duct entries in the far wall. The view also shows the intake air duct entry to the DICER fan box.

Rm 7.01 – DICER 1 – Blower Fan Box

Rm 7.06 – DICER 2 – Main Installation

DICER 2 is installed in the Exhaust/ Return Air Plant Room 7.06 in the North face of the Tower building. The encasing of the heat exchangers of this unit is of stainless steel material. This unit has the additional modification feature of two plug fans mounted in the air ducts, one at the discharge end of the treated primary air duct and the other at the end of the exhaust or secondary air duct.

Rm 7.01–DICER 1–VSD Main Return Air Fan

These high efficiency plug fans installed in DICER 2 also provides the opportunity to demonstrate the comparative behaviour and efficiencies between the two DICER units, and also utilise the ability to independently operate the two fans.

The DICER unit in Room 7.01 contains driving fans for the primary and secondary air system mounted coaxially on a single fan shaft. The unit also has a variable speed drive to reduce the speed of the main return air fan of the air handling unit (AHU), to lower negative pressure build up in the return air plenum plant room.

Rm 7.01 – DICER 1 Control Panel

The main control panel for the Room 7.01 DICER 1800 units is mounted near the unit, and contains controls for variable speed drives for the spray water pump and a variable speed drive for the fan motor. The panel is also provided with electrical transducers/ transmitters to as a convenient measuring point for the electrical power consumed by the spray pump and the fan motor.

Rm 7.01– DICER 1 – Chilled Water

Both DICER units are provided with heat exchangers at the entry point of secondary air/ return air to the DICER. These heat exchangers are supplied with chilled water from the central chilling plant located in the basement of the building. Chilled water cooling of the secondary air is utilised when the secondary intake air humidity is high. The chilled water lines are fitted with measuring points for temperature and also with a flowmeter. It is also provided with a bypass, and a modulating control valve on the return line.

Rm 7.06 – DICER 2 – Chilled Water

The condensate collected at the chilled water coil is piped back to the DICER sump for reuse as spray water in the heat exchanger. A water circulation pumps picks up the water from the DICER sump and returns to top of the heat exchanger via spray nozzles. The make up water is required due to evaporation in the DICER is monitored using a flow meter.

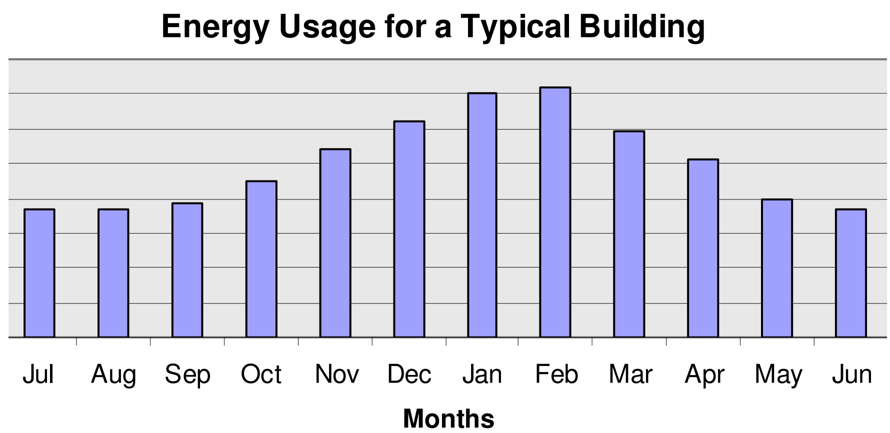
Rm 7.06–DICER 2–Plug Fan Exhaust

Two Ziehl-Abegg plug fans have been provided in the primary and secondary air ducts of DICER 2. These plug fans are controlled using dedicated controllers which are mounted on the walls of the DICER rooms. Speed variation of the plug fans to provide desired air flows in the ducts is achieved by this means.

4. Business Case

A brief business case is presented with this report taking extracts from the original project proposal **'Submission to DMPP for Air Conditioning of the UTS/ Tower Building (Building 1 Level & Plant Room) using Low Temperature Evaporative Cooling'** made by UTS in late 2005.

The original document is referred to as the 'Submission' in the discussion below. A few corrections and updates to reflect the applicable new pricings are also incorporated in this Business Case. The operation patterns of chillers have also changed significantly since 2004, due to new construction of the Science Block (Building 4). This building now requires the chillers to operate 24 hours 365 days to maintain low temperature rooms. These factors have been taken into consideration in the discussion below.



Submission Figure 6

Ref 'Submission' Figure 6 on Page 23 shows the base and the peak load for chillers. The base load for chillers is roughly during the 3 months which is June, July and August. As the weather conditions become severe, the peak demand for electricity due to air conditioning loads occur during the months of December, January, February and March.

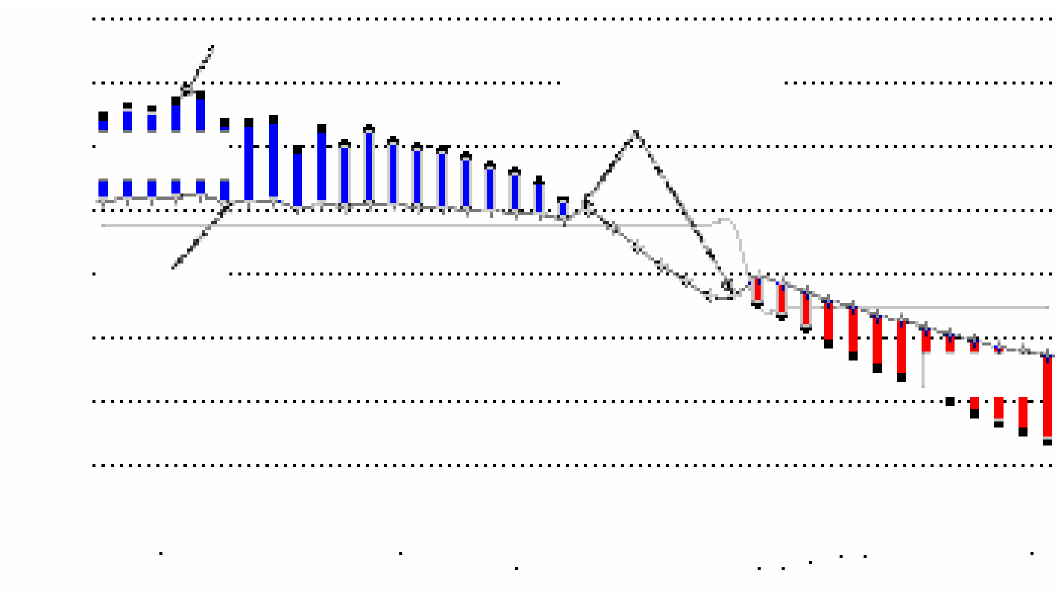
Thus during the entire year round operations, there are about 9 months which are above the base load where the chillers are operated to satisfy the additional air conditioning need. Out of these 9 months there are extreme peaks situations occurring in January and February. Also there are months which are under high demand conditions. These are September, October, November, December and March.

In UTS Tower Building (Building 1) the air conditioning operates 15 hours (6 AM till 9 PM) in a 24 hour period. In order to estimate the energy savings achieved by the operation of the system, the total operation day needs to be split into the various modes and a ventilation factor needs to be incorporated into the calculations. The ventilation factor which is defined as the ratio of operating hours to the number of hours in a day is 0.63 in this case. This factor is not relevant to the kVA demand peak reduction calculation.

Using the ventilation factor of 0.63 the number of hours for economy cycle would be 2,311 hrs, cooling cycle would be 1,391 hrs and heating cycle would be 1,817 hrs in a 24 hour 365 day operation. The value of the ventilation factor can be further refined taking into consideration the actual operating patterns of the plant at UTS, and during the period performance readings of the demonstration plant are taken this factor could be firmly established.

From data maintained by UTS Building Services for 2007/08 records the following costs for electricity were obtained for the Tower Building.

Network Monthly Electricity Max Demand Rate \$/ kVA /month	= \$1.6558
Network Monthly Electricity Capacity Demand Rate \$/ kVA /month	= \$4.6534
Therefore, Network Monthly cost at Peak Demand \$/kVA /month	= \$6.3092
Also, the peak/ shoulder Energy Only Charges for UTS per kWh	= \$0.0707



Submission Figure 5

4.1. Calculations – Plant Room 7.01 DICER 1800

Using the ventilation air pre-treatment we claim to save about 30 kVA or 30 kW on peak demand situation. But if we average over the entire year this would be in the order of 25 kVA (obtained from Figure 5)

DICER 1800 is fitted with a VSD at an additional investment of $5 000.00, and we can derive the following payback based on the extra energy saving of 5 kW

4.1.1. kVA Savings per year

= The peak demand savings (kVA) x Average cost at peak x number of months of chiller in operation

= (30+5) x 6.3092 x 9

= $ 1,987

The other reductions are in the overall kWh energy consumption for cooling and for heating

4.1.2. kW Savings per year for cooling

The total cooling hours in a year = 2,208 hrs

Energy cost ($) = 0.0707 per kWhr

kW savings averaged for the year (reference Figure 5) is = 30 kW

Ventilation Factor = 0.63

Normal operating Cost savings per year = Total cooling hours x cost of energy x ventilation factor x Average savings

= 2,208 x 0.63x 0.0707 x 30

= $ 3,442

4.1.3. kW Savings per year for heating

The total heating energy saved is the area indicated by the red hatched shown in Figure 5. With the given amount of ventilation air (2600 L/s) we conserve approximately 62,880 kWhr thermal heating energy. We take the boiler efficiency to be 0.8, so the primary energy (Natural gas) consumption for heating is 78,600 kWhr.

The cost of natural gas for year 2007 was $ 0.00638 per MJ or $0.023 per kWhr

Therefore heating cost savings

= 78,600 x 0.023

= $ 1,807

Total amount of dollars saved from DICER 1800 = $(1,987+3,442+1,807)

= $7,236

4.2. Calculations - Plant Room 7.06 DICER 1500

Using the ventilation air pre-treatment we claim to save about 30 kVA or 30 kW on peak demand situation. But if we average over the entire year this would be in the order of 25 kVA (obtained from Figure: 5). DICER 1500 is not equipped with a VSD on the main exhaust fan.

4.2.1. kVA Savings per year

= The peak demand savings (kVA) x Average cost at peak/month x number of months of chiller in operation

= 30 x 6.3092 x 9

= $ 1,703

The other reductions are in the overall kWh energy consumption for cooling and for heating

4.2.2. kW Savings per year for cooling

The total cooling hours in a year = 2,208 hrs

Energy cost ($) = 0.0707 per kWhr

Average savings in a year = 25 kVA

Ventilation Factor = 0.63

Normal operating cost savings per year

= Total cooling hours x cost of energy x ventilation factor x Average savings

= 2,208 x 0.0707 x 0.63 x 25

= $ 2,459

4.2.3. kW Savings per year for heating

The total heating energy saved is the area indicated by the red hatched portion shown in 'Submission' Figure 5 on Page 22. With the given amount of ventilation air (2100 L/s) we conserve approximately 50,788 kWhr thermal heating energy. We take the boiler efficiency to be 0.8, so the primary energy (Natural gas) consumption for heating is 63,485 kWhr.

The cost of natural gas for year 2007 was \$ 0.00638 per MJ or \$0.023 per kWhr

Therefore heating cost savings

= 63,485 x 0.023

= \$ 1,460

Therefore, the total dollars saved from DICER 1500 = \$(1,703+2,459+1,460)

= \$5,622

4.3.Simple Pay Back

Therefore the total annual savings from DICER 1800 & DICER 1500

= $(7,236+5,622) = **$12,858**

Therefore the simple payback for the whole project is:

$ 167,508/ $ 12,858

= 13 years

With the funding assistance of $ 87,000 from DMPP, simple payback period for UTS is:

= $ 78,000/ $ 12,858

= 6 Years

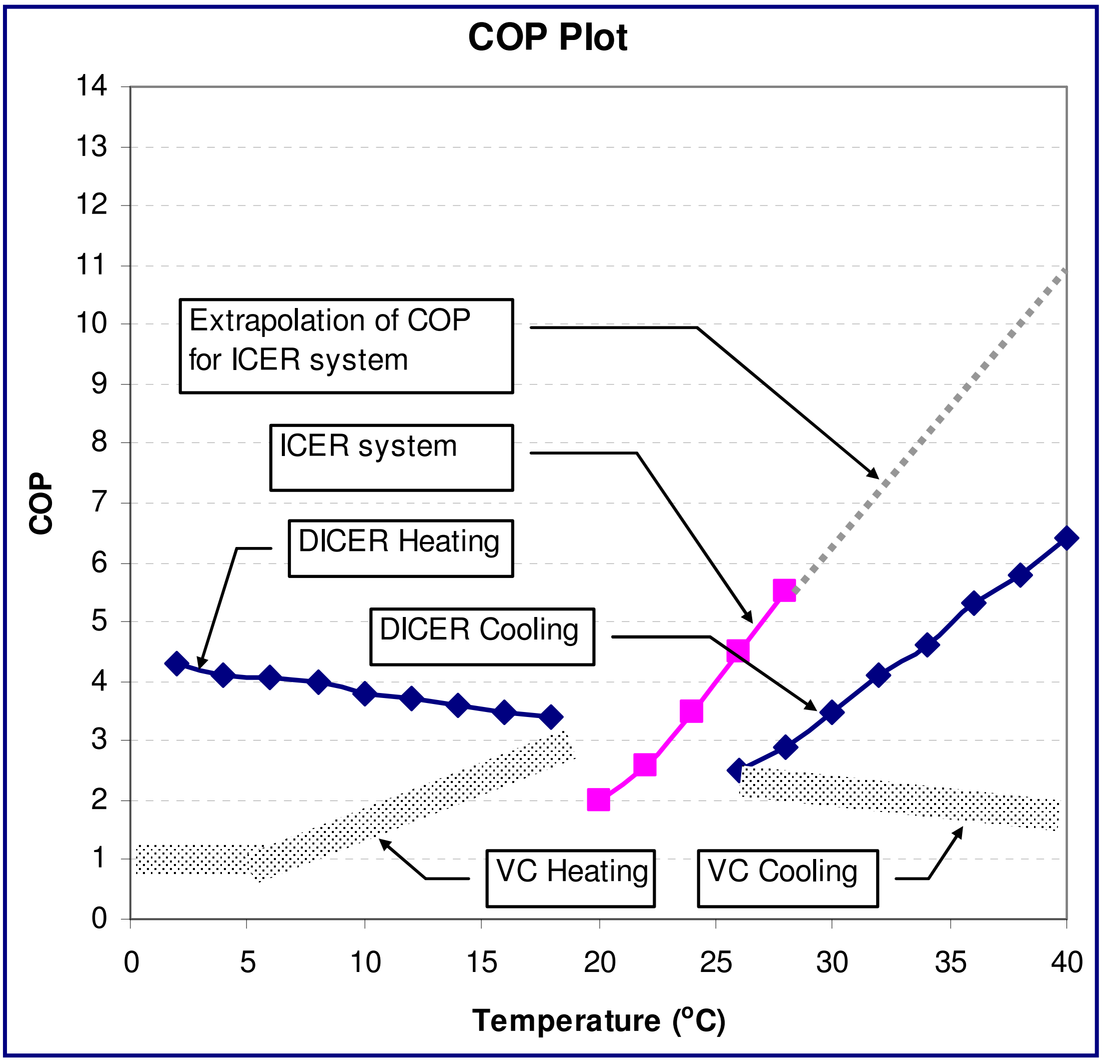
4.4.Peak Demand Shedding

The DICER plant have been installed for the primary purpose of demonstrating its electricity network demand peak shedding capabilities during periods of high air conditioning demand in the CBD. During the period of performance testing at UTS the weather conditions in Sydney have been unusual for a summer and extremely mild in the period January to March 08.

However, the performance tests done in the available windows of higher temperatures, and/or of low humidity have shown positive results. The results of those tests are attached as an Appendix to this report. These results show that in ambient temperature above 28 degrees which cause high air conditioning loads and consequent high electrical peaks, the DICER plant will perform to provide the necessary electrical load shedding.

The diagram below is a Coefficient of Performance COP Plot graph which shows in blue colour the performance of a DICER unit under shop testing conditions. The graph in pink is the performance of the unit as an ICER when chilled water is not used. In effect under these conditions it works as a an indirect evaporative cooling unit. The COP is the ratio of refrigeration effect produced for a given electrical kWh. Higher kWh invariably leads to higher kVA or demand peaks.

A scrutiny of the performance test results given in the appendix indicates that in the warmest temperature range of 26-27 degrees the DICERs at UTS performed to expectations at 5 to 6 COP. Such refrigeration efficiencies are less electricity intense in comparison to small to medium range vapour compression air conditioning split units which operate in the 2 to 2.5 COP range.



Plant Room 7.01 DICER 1800

Reference the excel data results sheets in the Appendix,

On 24 March 08, the plant performs to expectations in the 26 to 27 degree range, achieving COP between 4 and 7.5

Plant Room 7.06 DICER 1500

On 16 March 08 the plant performs to expectations in the 26 to 27 degree range achieving COP between 4 and 6

On 24 & 30 March 08 the plant performs to expectations in the 26 to 27 degree range achieving COP up to 10

UTS will continue to operate the demonstration DICER plant and gather data during remaining months of 2007 to prepare a comprehensive dossier of the performance pattern of the DICER units under varying seasonal climatic conditions.

4.5. Calculation Notes

The project cost is $167,508 plus GST (UTS78,000 and DP 89,508)

- Original estimation in DMPP Project Proposal the cost for both DICERs is $117,000 The cost for DICER 1800 with VSD is $61,000 (This amount is 52% of the total project cost)

- The final project cost is $167,508, and the original cost split between the two units is in the ratio DICER1800:DICER 1500 is 52:48.

- Based on this cost ratio the corresponding values for the increased final costs, the DICER cost split is

  DICER1800 is $ 87,104 and

  DICER1500 is $ 80,404

5. Appendices & Attachments

<u>Appendices</u>

Schematic Diagram - DICER 4B 1800 Installation

Schematic Diagram - DICER 4B 1500 Installation

Energy Balance Equations

<u>Attachments as Excel Files</u>

DICER 1800 Performance Test Data

DICER 1500 Performance Test Data

5.1 Schematic Diagram - DICER 4B 1800 Installation

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5.2 Schematic Diagram - DICER 4B 1500 Installation

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5.3 Energy Balance Equations

1. Heat input of primary air stream:

$$Q_{pr\ air}' = m_1' \cdot (h2 - h1)$$

m_1' is measured via traverse pitot tube
h is deducted from T_{db} & T_{wb}

2. Power requred from fan(s):

E_{elec} **1** is measured via power transmitter

3. Heat input from spray pump from pump:

E_{elec} **2** is measured via power transmitter

4. Heat input from spray pump from chilled water:

$$Q_{cw} = m_{cw}' \cdot C_P \cdot \Delta T_{cw}$$

m_{cw}' is measured via a pulse water metre
ΔT_{cw} is measured via submersion probes in the chilled water pipe line

5. Theoretical pump energy for chilled water:

$$P_{pumpCW} = DP \cdot V'$$

COP comparison of DICER

1. $COP_{dicer} = Q_{pr\ air}' / [E_{elec}\ 1 + E_{elec}\ 2 + E_{elec}\ cw]$

Where $E_{elec}\ cw = (Q_{cw} / COP_{cw}) + E_{elec\ cw\ pump}$

Where $E_{elec\ cw\ pump} = P_{pumpCW} / \eta_{pump}$

2. $COP_{normal\ AC} = Q_{pr\ air}' / COP_{normal\ AC}$

Where $COP_{normal\ AC}$ ~ 2.6 to 2.8 including energy consumption from fans and other support equipment.

5.4 DICER 1800 Performance Test Data

See Excel Attachments

5.5 DICER 1500 Performance Test Data

See Excel Attachments

END OF REPORT