Climate Wizard Indirect Evaporative Cooler - TriTool

Sacramento Municipal Utility District

SMUD™

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About the Customer Advanced Technologies Program…

SMUD's Customer Advanced Technologies (C.A.T.) program works with customers to encourage the use and evaluation of new or underutilized technologies. The program provides funding for customers in exchange for monitoring rights. Completed demonstration projects include lighting technologies, light emitting diodes (LEDs), indirect/direct evaporative cooling, non-chemical water treatment systems, daylighting and a variety of other technologies.

For more program information, please visit:
https://www.smud.org/en/business/save-energy/rebates-incentives-financing/customer-advanced-technologies.htm

1. Executive Summary

A manufacturing facility in Rancho Cordova, California, Tri Tool, installed a Climate Wizard cooling system. The Climate Wizard is an evaporative cooler using a proprietary indirect water-to-air heat exchanger. The cooling unit, shown in Figure 1, has a 24,000 ft^3/min capacity, and has no return air duct due to the exhaust needs of the facility. Approximately 10 months of unit performance data are collected, using both data from the Climate Wizard control software and from separate instrumentation.

Figure 1: Climate Wizard cooling unit.

Performance data for 2014 is summarized in Table 1. Temperature changes in excess of 40 ºF are possible on very hot, dry days. The evaporative effectiveness exceeds 100% at times because the theoretical limit of this system is the dew point temperature, rather than the wet bulb temperature of most evaporative coolers.

Table 1: Summary of Climate Wizard performance characteristics.

Climate Wizard Performance (2014):			
Metric:	Mean	Max	Unit
ΔT (T_outside - T_supply)	18	40	° F
Evaporative Effectiveness	70	115	%
Dewpoint Effectiveness	40	75	%
Water consumption	0.50	1.20	gal/min
Energy Efficiency Ratio (EER)	29	60	(Btu/hr) / W

2. Project Description

2.1 Background

The Climate Wizard is an indirect evaporative cooler which uses a heat exchange system which allows it to achieve higher evaporative efficiencies than traditional single-pass evaporative coolers and much higher efficiencies and much better peak performance than conventional air conditioning systems. The unit being analyzed is shown in Figure 2.

Figure 2: Climate Wizard 24,000 ft^3 / min cooling unit.

Advantages of the system include:

- Reduced cost of cooling due to very high efficiency
- Dramatically reduce peak demand of electricity
- Lower humidity conditioned air than direct evaporative systems, leading to greater comfort, and more suitable for cooling mechanical equipment
- The unit uses 100% outside air, which is useful for facilities needing ventilation and is the biggest benefit for Tri Tool
- Lower conditioned air temperatures allow for smaller ducts and less air flow than traditional evaporative systems.

Possible Disadvantages of the system:

- Initial cost. The climate wizard is more sophisticated than basic evaporative coolers. Seeley is working to reduce first costs by 50% in the next two years.
- Application specific return air advantages: having a return air duct, which is impractical with the Climate Wizard, can save energy in applications with minimal ventilation needs and good insulation

- Location specific: Performance drops dramatically as humidity increases, approaching zero at 100% humidity. This must be used in a dry location or have a refrigeration cycle as backup. But since Sacramento is predominantly hot and dry as much of the Southwest with needle peaks of electric consumption largely caused by declining efficiencies of conventional air conditioning, indirect evaporative systems have the potential of providing huge economic benefits to individual customers and across electric utility systems and Southwest US.

The manufacturer claims low maintenance but this study does not include long-term data on maintenance of the unit. Sometimes water circulation systems suffer from sediment buildup over time, and it is unknown if the complex heat exchanger will foul and incur future costs as the system ages.

The Climate Wizard has a sophisticated water management and recirculation subsystem with integrated into it. Some multi-pass indirect systems like the Coolerado simply consume water continuously, and the Climate Wizard reduces water consumption by recirculating it. The cost of this is some degree of mechanical complexity in the form of a tank, filters, chlorinator, and the necessary valves and controls for periodic flushing and monitoring. The chlorinator and some of the plumbing are shown in Figure 3.

Figure 3: Chlorinator and plumbing for water circulation system, which reduces water consumption over continuous flow competitors but increases complexity.

The Climate Wizard was equipped with extensive measurement equipment for this project. Some of the available data is shown in Table 2, and additional temperature measurements were taken near the exhaust fan and across the building near some refrigerant air conditioners.

Table 2: Available data from the Climate Wizard control unit.

[1] "Time"	[13] "EV.1.Cool.Enable"	[25] "EV.1Supply.Air.Temp"
[2] "VAV.M.2.Damper.Position"	[14] "Fan.Cmnd"	[26] "EV.1.Drain.Water.Total"
[3] "VAV.M.2.SAT"	[15] "Average.Space.Temp"	[27] "EV.1.Supply.Water.Total"
[4] "VAV.2.Space.Temp"	[16] "Space.Humidity"	[28] "Space.Temp.1..on.col..degF"
[5] "VAV.M.1.Damper.Position"	[17] "EV.1.Cooling.Signal"	[29] "Dev.11101..present.value"
[6] "VAV.M.1.SAT"	[18] "EV.1.Percent.Cooliing"	[30] "Outtide.Dewpoint"
[7] "VAV.1.Space.Temp"	[19] "EV.1.Fan.Speed.Cmnd"	[31] "Outside.Humidity..RH"
[8] "EV.1.Energy.Usage.kWh"	[20] "EV.1.Ehxhaust.Air.Temp.degF"	[32] "Outside.Humidity"
[9] "EV.1.Energy.Usage"	[21] "EV.1.Ehxhaust.Air.Temp"	[33] "OSA.Temp.degF"
[10] "EF.1.Speed.Cmnd"	[22] "EV.1.Supply.Air.Humidity..RH"	[34] "OSA.Temp"
[11] "EF.1.VFD.Speed.Feedback"	[23] "EV.1.Supply.Air.Humidity"	[35] "Ev.1.Drain.Water.Total"
[12] "Space.Temp.2..by.EF..degF"	[24] "EV.1Supply.Air.Temp.degF"	

Additional monitoring equipment was installed in other parts of the building to measure temperature and power consumption from the refrigeration cooling units on the other half of the building to check for interaction effects.

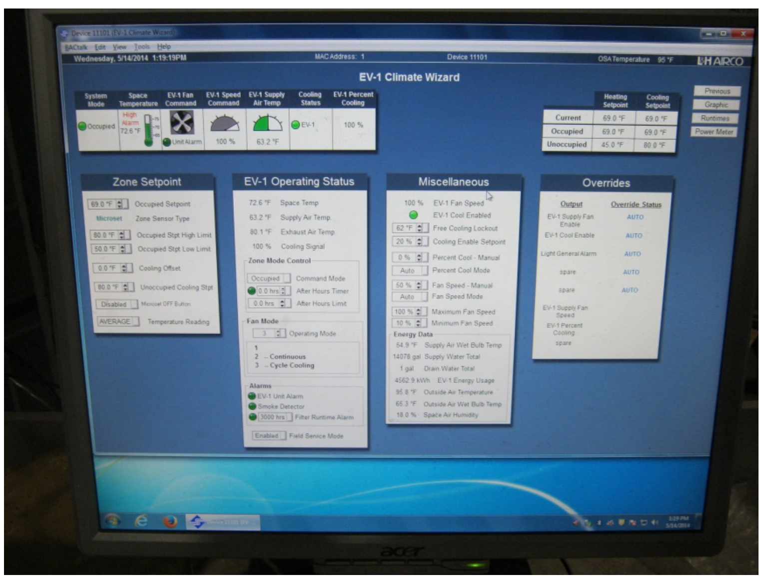

Figure 4: Screenshot of Climate Wizard control screen.

Generally evaporative coolers do not provide supply air temperatures as cold as a refrigeration cycle can, so larger airflows and associated larger duct work are required. The large ducts located at the current project are shown in Figure 5.

Figure 5: Large ducts for this manufacturing facility, bringing in much need fresh air. Note the system is balanced with and exhaust fan to not over pressurize the space.

2.2 Assessment Objectives

The goal of this study was to understand the performance characteristics of the Climate Wizard indirect evaporative cooler. This included monitoring the energy consumption and assessing performance characteristics including the evaporative efficiency and the energy efficiency ratio.

2.3 Methodology

The Climate Wizard is an indirect evaporative cooling system using a proprietary double channel heat exchanger. One channel pulls outside air through wet media and cools by direct evaporation. The other dry channel cools the air by dissipating heat to the cooler parallel channel. The moist air in the working-direct cooling channel is exhausted to the outside, as seen in Figure 6 below, and the cool dry air is supplied to the building interior. Direct evaporative systems are limited by the wetbulb temperature.

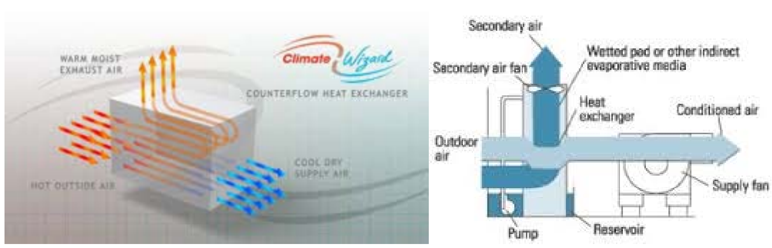

Figure 6: Indirect- Counterflow Cooling Heat Exchanger & System Diagram.

The limit of indirect evaporative systems is dew point temperature. As shown in Figure , a traditional evaporative cooler like a direct evaporative cooler would reduce its supply air temperature down by adding moisture in an evaporative process, which is the process traced by the diagonal green arrow. The horizontal green arrow illustrates the temperature reduction of the indirect Climate wizard system. The labels on the dry bulb temperature axis show that the climate wizard can reach temperatures lower than a traditional direct evaporative cooler.

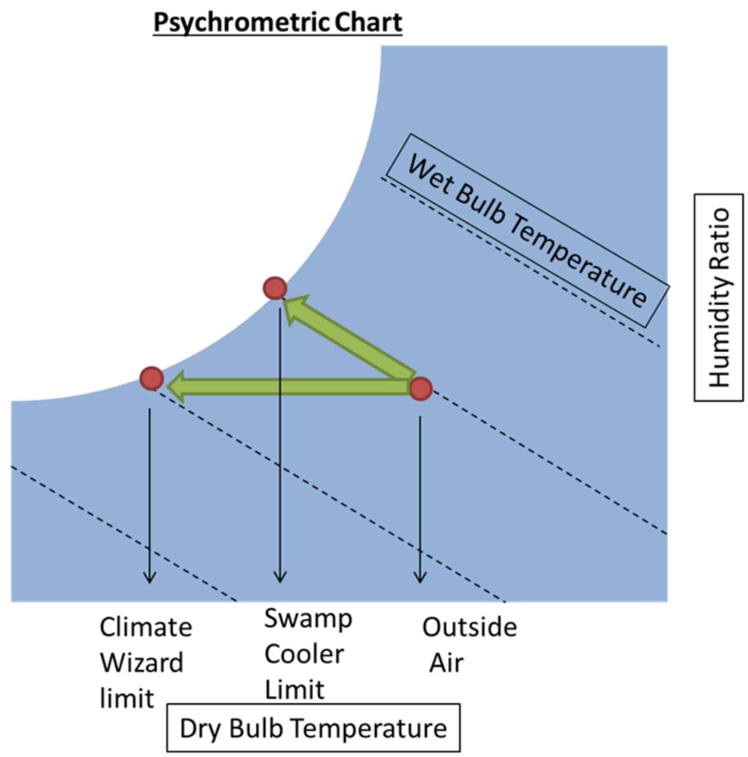

Figure 7: Psychrometric chart showing the temperatures of interest in efficiency calculations.

To measure the performance of this unit, the cooling demand is calculated using air properties, temperature measurements, and flow calculations. The power used is from independently verified power meters. Data was downloaded from the Climate Wizard computer, and additional measurements elsewhere in the building were taken independently. The performance metrics investigated include the Energy Efficiency Ratio (EER) and the evaporator efficiency. The decrease in temperature across the unit under varying outside air conditions is also investigated.

3. Results

The drop in air temperature across the climate wizard, defined as the outside air temperature in degrees Fahrenheit minus the unit exit temperature, is shown in Figure below. The change in temperature increases with outside temperature, up to a maximum of 40 °F. The Climate Wizard is an evaporation cooler, which causes its performance to drop off as the humidity increases. This is verified as the change in temperature across the cooling unit falls to zero as relative humidity approaches 100%.

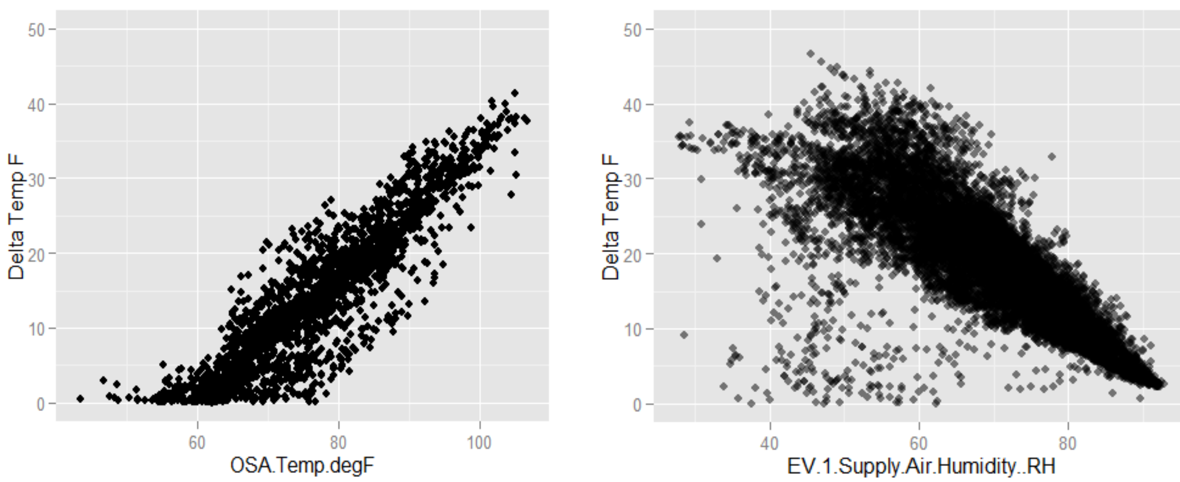

Figure 8: Drop in temperature across the Climate Wizard plotted as a function of outside air temperature and relative humidity.

The effectiveness of an evaporative cooler is calculated with the following equation:

$$Effectiveness = \frac{T_{db,in} - T_{db,out}}{T_{db,in} - T_{wb,in}} \times 100\%$$

where $T_{db,out}$ is the outlet dry bulb temperature, and $T_{db,in}$ is the inlet dry bulb temperature, and $T_{wb,in}$ is the outdoor wet bulb temperature. The Climate Wizard heat exchanger uses parallel paths for humid and dry air which allows cooling lower than the wet bulb temperature of the outside air (Figure 6). The theoretical limit is the dew point of the outside air, so for this type of cooler a more suitable measure is the dew point effectiveness,

$$DewpointEff = \frac{T_{db,in} - T_{db,out}}{T_{db,in} - T_{dp,in}} \times 100\%$$

where $T_{dp,in}$ is the inlet dewpoint temperature. The wet bulb evaporative effectiveness and the dew point evaporator effectiveness are shown in Figure .

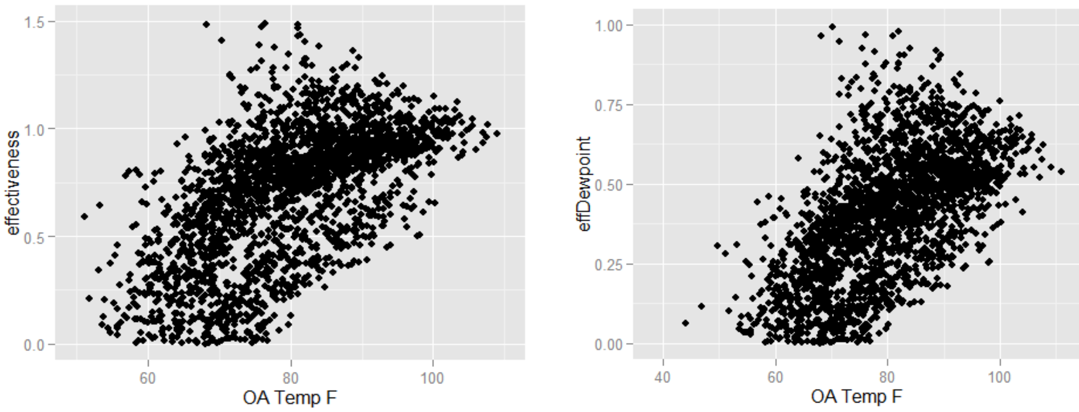

Figure 9: Evaporator effectiveness plots, with respect to the wet bulb and dew point temperatures.

The other common metric for measuring the performance of cooling systems is the energy efficiency ratio (EER). This is defined as

$$EER = \frac{Cooling\ Capacity\left(\frac{BTU}{hr}\right)}{Power(W)}$$

The cooling capacity is calculated using the equation

$$Q\left(\frac{Btu}{hr}\right) = 1.08 \times CFM\ \times (T_{db,OA} - T_{db,supply})$$

where 1.08 is a conversion factor including the density and specific heat of air (0.075 lb/ft^3 * 0.24 Btu/lb F * 60 min/hr), $T_{db,\ OA}$ is the dry bulb outside air temperature, and $T_{db,\ supply}$ is the cooled dry temperature air being supplied by the unit. EER is plotted as a function of temperature in Figure , with a maximum of about 60.

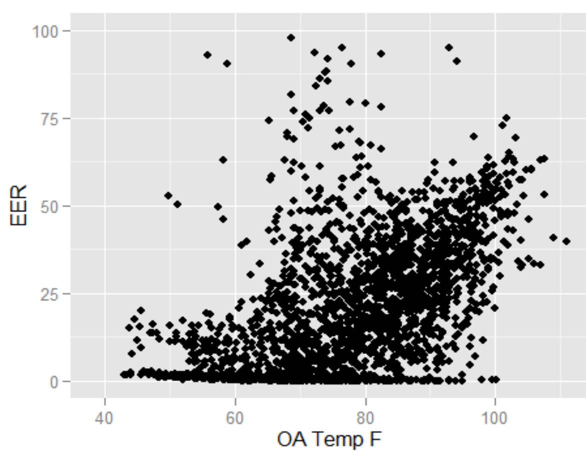

Figure 10: The Climate Wizard energy efficiency ratio (EER) for the 2014 dataset.

The Climate Wizard consumes water during its cooling process, but a recirculation system minimizes waste. However, as evaporation continues, undesirable materials build up in the cooling water and periodically it must be flushed. Frequency of flushing varies greatly depending on local water chemistry. To visualize the water consumption, the supply water flow rate is plotted as a function of outside air temperature in Figure 6.

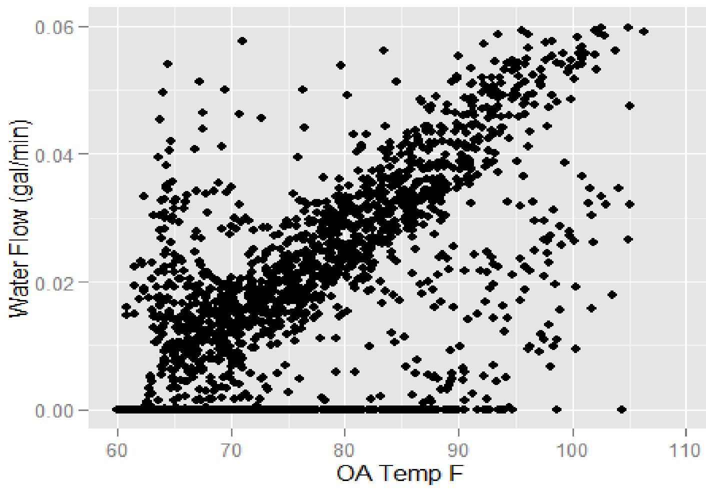

Figure 6: Water consumption as a function of temperature.

The performance results are summarized in Table 3.

Table 3: Climate Wizard Performance Summary

Climate Wizard Performance (2014):			
Metric:	Mean	Max	Unit
T_out - T_in	18	40	° F
Evaporative Effectiveness	70	115	%
Dewpoint Effectiveness	40	75	%
Water consumption	0.50	1.20	gal/min
Energy Efficiency Ratio (EER)	29	60	(Btu/hr) / W

4. Conclusion

The Climate Wizard performed very well during 2014 and saved the facility thousands of dollars in cooling costs and provides much cleaner and healthier air for working in the manufacturing area. Tri Tool in Sacramento is a good site for the Climate Wizard, because the summers are hot and dry, they had significant air quality challenges, the facility requires extensive continuous ventilation, and it is in an area where the amount of water consumed is not burdensome.

The Climate Wizard performance is superior to traditional one-pass evaporative coolers, and power consumption is much less than refrigeration cycles, but the initial investment is high and long term maintenance costs are unproven. Seelely is working to reduce initial costs by 50%

within two years. During hot, dry days, the system could drop the temperature by over 40 ºF, bringing the air from 105 ºF down to 65 ºF. Evaporative effectiveness was measured in excess of 115% for some instances, and averaged 70% throughout the year. The EER averaged 29, with a maximum of 60 on ideal hot dry days.

The Climate Wizard cannot reduce humidity in the supply air, or provide cooling in high humidity. During the (rare) hot and humid days over the summer, occupant comfort was reduced, and because Tri Tool has conventional air conditioning elsewhere in the building, condensation dripped from interior duct work because the ventilation air from the Climate Wizard was humid from the outside ventilation air. This was a brief problem.

Overall, Tri Tool management and employees are extremely pleased that the Climate Wizard is providing far better quality air in the manufacturing area while saving energy. Tri Tool offices are also more comfortable and using a lot less energy.

Before installation of the Climate Wizard, the existing 90 ton Trane system had to run full tilt and could not adequately cool the manufacturing area with poor air quality while over cooling the front offices which used terminal re-heat to minimize over cooling!

While Climate Wizard and associated exhaust fan add to Tri Tools electric consumption, the elimination of re-heating in the offices easily shows a significant energy savings overall.