Pacific Gas and Electric Company

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Emerging Technologies Program

Application Assessment Report # 0709

Evaluation of Advanced Residential Evaporative Cooler Technologies in PG&E Service Territory

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Executive Summary

Evaporative cooling is a technology that holds considerable promise for reducing cooling system energy use and peak load in dry Western climates where high outdoor dry bulb temperatures and generally dry conditions allow for good performance. In California, approximately 5% of households utilize evaporative coolers; typically low cost aspen pad coolers that have short equipment lives and mediocre cooling performance. This type of equipment has changed little over the past 60 years, earning the term "swamp cooler" to reflect the humid indoor conditions[1] and poor water quality characteristics common to many of these installed systems.

Many homeowners actually prefer the fresh, filtered outdoor air that evaporative cooling systems supply, and also value that evaporative cooling consumes only 20-50% of the energy used by typical vapor compression cooling systems. For low income housing, evaporative cooling is the only affordable cooling option. Advanced evaporative coolers that utilize more efficient rigid evaporative media, higher quality pumps and fans, and corrosion-resistant cabinets address the most important performance and comfort concerns associated with the 60-year-old technology. Through a combination of air temperature and high levels of air movement, occupant comfort can be maintained at an indoor relative humidity up to ~70%.

This project evaluated five different advanced residential evaporative coolers during the 2007 summer in six existing homes located in California's Central Valley. The advanced coolers included:

- A Breezair variable-speed direct evaporative cooler
- A Coolerado indirect evaporative cooler
- Two Essick Air direct units with 12" thick rigid media (on separate houses)
- An Essick Air direct unit coupled with an add-on indirect evaporative module
- An OASys indirect-direct evaporative cooler

Existing aspen pad evaporative coolers were present at two of the six sites, and were monitored prior to installation of the advanced coolers. Monitoring data points included system power, water use, indoor and outdoor temperature and relative humidity, supply air temperature, and attic air temperature. Monitoring results were used in an hourly computer simulation to project full-season energy and demand impacts.

Project results indicate the following:

1. Systems at four of the six sites (the three direct units and the OASys unit) performed close to manufacturers' nominal ratings. The Coolerado system and the Essick Air indirect-direct unit did not meet performance expectations. Installation and application issues were likely a major factor affecting the performance of the Coolerado. Average EERs[2] normalized to a 78°F indoor setpoint were 43.3 for the

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[1] Although high indoor humidity is a common complaint associated with evaporative cooling, much of the comfort problem can be attributed to poor envelope performance of many of the homes with evaporative cooling installed.
[2] EER is determined by calculating cooling delivered based on the "supply air to indoor temperature difference" as defined in Equation 3, divided by the energy consumed.

direct evaporative units, 50.9 for the OASys, 13.5 for the Coolerado, and 12.6 for the Essick indirect-direct system.

2. Hourly simulation evaluations were completed on a 1,600 ft^2 house prototype to predict advanced cooler energy savings relative to a standard SEER 13 air conditioner. Runs were completed for both retrofit and new construction cases. The retrofit results are more representative of current market opportunities since the penetration rate of evaporative coolers in new construction is virtually zero. Projected energy savings for the retrofit cases range from 74-82% in the Sacramento (881 to 974 kWh) climate and 66-78% in the Fresno (2098 to 2478 kWh) climate. Customer savings based on a conservative $0.15/kWh rate assumption average $140 per year in Sacramento and $347 in Fresno. Normalized energy savings average 580 kWh/year for Sacramento and 1450 kWh/year for Fresno, per 1000 ft^2 of floor area.

3. Peak demand for each of the advanced systems and the standard SEER 13 unit were calculated based on the average Noon to 7 PM demand over the consecutive three hottest summer days. Projected coincident peak demand savings relative to the standard SEER 13 air conditioner range from 64-78% in Sacramento (2.21 to 2.71 kW), and 70-83% (3.04 to 3.59 kW) in Fresno. Normalized demand savings average 1.60 kW for Sacramento and 2.09 kW for Fresno, per 1000 ft^2 of floor area.

4. Although none of the systems maintained comfort within the ASHRAE 55 comfort envelope on the hottest days of the summer (largely due to high indoor humidity), the homeowners felt that the advanced units tested provided improved indoor comfort and higher airflow than their prior units. The Coolerado unit came closest to meeting the ASHRAE comfort requirements, but excessive duct losses and lower than expected effectiveness reduced the delivered cooling to the indoor space.

5. The cost of the advanced coolers installed in the project is very high relative to the mass-market aspen pad units available at big box retail stores. The advanced coolers cost roughly four to seven times as much as a basic aspen pad unit. Current economics are marginal, but would improve if time-of-use electric rates were to become the norm. Actual project installed equipment costs for most of the advanced coolers are roughly comparable to typical SEER 13 retrofit costs, suggesting that for economics to be improved, these advanced systems must move beyond their current niche market status.

6. For all but the Coolerado unit, average water use ranged from 12 to 54 gallons per day (average of 33 gallons per day). (The Coolerado consumed an average of 160 gallons/day.) Water use is an important issue for the evaporative cooler industry to address and minimize.

7. Contractor attention to detail and follow through on system commissioning procedures appears to be consistent with the problems common to vapor compression installation. Despite the relative simplicity of evaporative coolers, two of the sites had installation/commissioning problems.

Recommendations for further work and evaluation include the following:

1. Conduct demonstrations and testing of advanced evaporative coolers in new residential buildings to identify performance and comfort in buildings with lower cooling loads.
2. Support hybrid evaporative cooler system research and testing through the Energy Commission's PIER program and other avenues. Hybrid systems that combine advanced evaporative technology with reduced size compressors would reduce peak cooling load and energy use and allow automatic switching between evaporative cooling and vapor compression cooling modes, simplifying operation and providing optimal comfort.
3. Support and advance efforts to develop a water-to-energy equivalence metric. The water-energy trade-off is an important issue that affects water agencies and environmental acceptance of evaporative cooling technologies.
4. Support the development of an evaporative cooler application manual. Such a manual would help guide architects, builders, and other decision-makers in the selection of cooling equipment that is appropriate to the climate and the needs of the homeowner; and would convey useful information on maintenance and energy savings.
5. Develop an evaporative cooler rebate program to encourage homeowners with existing evaporative coolers to stay with evaporative systems and to stimulate the market.

Project Background

Basis of Technology

Evaporative cooling involves the evaporation of water into a non-saturated air stream for delivery to a conditioned space. The greater the outdoor dry bulb temperature and the lower the relative humidity, the greater the potential for evaporative cooling. The cooling sensation experienced when a breeze evaporates perspiration from one's skin is likely the most common human experience with evaporative cooling. Evaporative cooling for space conditioning applications combines a fan, a water supply, controls, and wetted evaporative media through which the air travels to deliver cooled air. In contract to vapor compression systems, evaporative coolers consume significantly less energy per Btu of cooling delivered.

Key evaporative cooling performance descriptors include saturation effectiveness as defined in Equation 1:

$$e = \frac{t_{db} - t_s}{t_{db} - t_{wb}} \qquad \text{(Equation 1)}$$

Where,

ε = Effectiveness (%)

t_{db} = Outdoor dry bulb temperature

t_{wb} = Outdoor wet bulb temperature

t_s = Supply dry bulb temperature

The supply air temperature that an evaporative cooler delivers is dependent upon the effectiveness and the current outdoor dry and wet bulb temperatures. The greater the magnitude of the wet bulb depression (the difference in temperature between outdoor dry and wet bulb temperatures), the greater the potential temperature drop that can be achieved in an evaporative cooling process. For example, during a hot California valley summer day with dry bulb and wet bulb temperatures of 100° and 60°F, respectively, an 80% effective evaporative cooler would deliver 68°F air[3]. In contrast to vapor compression air conditioners, which generally dehumidify indoor air, most evaporative coolers[4] add moisture to the supply air stream.

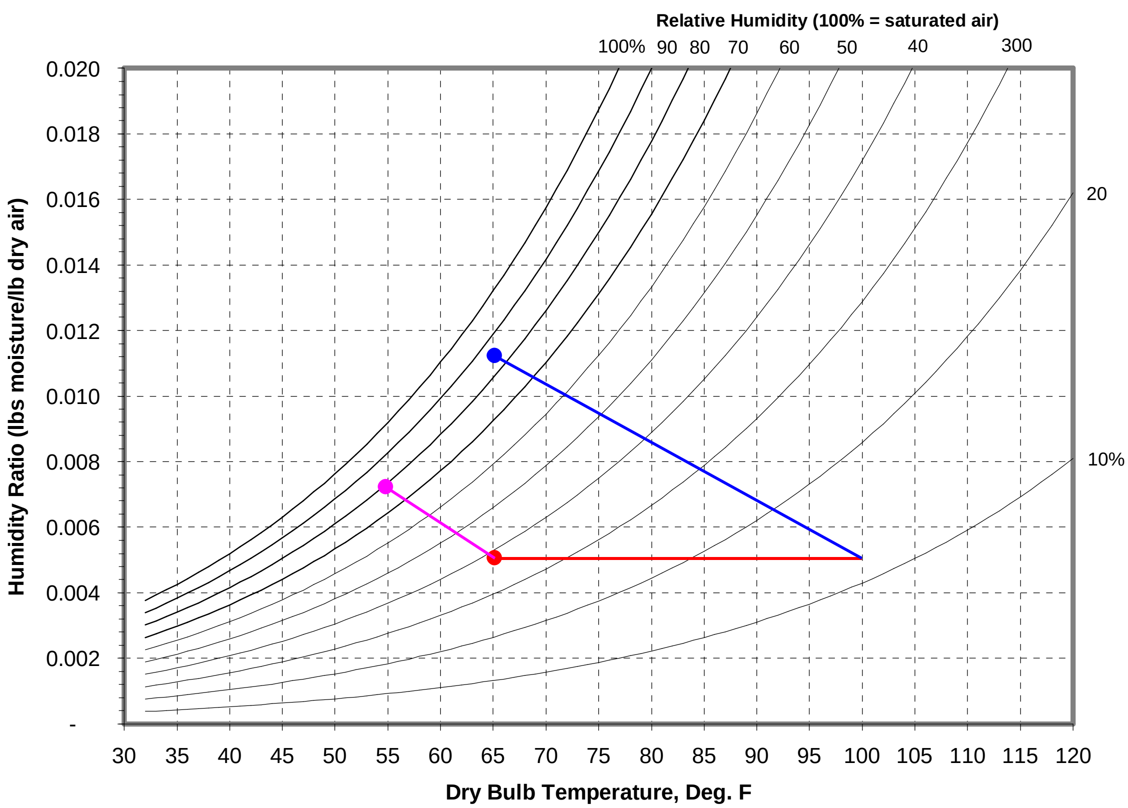
Evaporative coolers are used in residential, commercial, agricultural, and industrial applications where higher indoor humidity is acceptable and low operating cost is important. They can provide comfort equivalent to vapor compression cooling systems in dry climates, but during periods of hot, humid weather they will likely produce indoor conditions that are outside typical indoor “comfort” conditions. To date, evaporative coolers have largely been synonymous with

[3] 100°F – 80% × (100°F – 60°F) = 68°F
[4] With the exception of indirect only units

low-quality cooling as the typical market is lower income, cost-conscious consumers who don't expect to maintain comfort through the more severe heat spells.

Of the evaporative coolers common to the California market, a vast majority are direct evaporative coolers. These coolers pass outdoor air through a wetted media to deliver cooler, more humid air to the space. Indirect and indirect-direct evaporative coolers are much less common in the marketplace. These coolers utilize a heat exchanger between an evaporatively-cooled air stream and the supply air, which is cooled without moisture addition. Indirect-direct coolers add a direct stage downstream of the indirect stage to further cool supply air. Figure 1 schematically shows the three processes on a psychrometric chart. All three processes are shown to begin with outdoor air at approximately 100˚F dry bulb temperature and 13% relative humidity. The direct evaporative process (shown in blue) delivers air at ~65˚F, but at a moisture level (humidity ratio) more than twice as high as the outdoor air. The indirect cooler (red line) does not add moisture and therefore the process moves horizontally on the graph. Finally the indirect-direct unit (magenta line) takes the outlet air from the indirect stage and cools it with a direct process. The indirect pre-cooling allows the system to achieve a lower supply dry bulb temperature with less moisture addition than the direct unit.

Figure 1: Representation of Evaporative Processes on a Psychrometric Chart



All three system types offer both performance benefits and potential disadvantages. Table 1 provides a brief summary of general attributes.

Table 1: Comparison of Evaporative Cooler Attributes

Cooler Type	Benefits	Disadvantages
Direct	1. Inexpensive to purchase and to operate 2. Mechanically simple 3. Window units available – easy to install	1. Low-cost coolers typically have a shorter equipment life. Higher quality units with non-corroding sumps and better quality components will last longer, but are more costly. 2. Direct coolers have a greater likelihood of comfort issues due to greater moisture delivery to indoors
Indirect	1. No moisture addition (humidity ratio of supply air = outdoor air) resulting in better comfort 2. Multi-stage units, such as the Coolerado offer improved effectiveness	1. Higher first cost than direct 2. Higher parasitic power (W/cfm) than direct coolers
Indirect-Direct	1. Typically the highest cooling capacity of the three types 2. Improved indoor humidity relative to direct, but not as good as an indirect cooler	1. Higher first cost than direct 2. Higher parasitic power (W/cfm) than direct coolers

With vapor compression cooling becoming increasingly widespread, significant growth of the California evaporative cooling market is unlikely without broad program support and a strong consumer education effort. The popular perception that air conditioning is "good" and low cost direct evaporative units are "bad" exacerbates the need for incentive and educational programs to promote the benefits of evaporative cooling. According to the Energy Information Administration (EIA), by 1993 72% of U.S. homes had some form of air conditioning, with nearly 50% provided by central systems. EIA data for 2001 show that evaporative coolers are found in only about 3% of the houses in the Pacific region (Washington, Oregon, and California), down from 7% in 1990 (EIA 2002; EIA 1990).

Market Potential and Status

Evaporative coolers offer the potential to provide low energy and low peak demand cooling in dry climates. To date, evaporative coolers have largely been synonymous with low-quality cooling as the typical market is lower income, cost-conscious consumers who don't expect to maintain comfort through the more severe heat spells. Vapor compression air conditioning's dominant position has resulted in limited evaporative cooler impact in the new construction market as well as loss of market share as some homeowners convert evaporative cooling systems to vapor compression systems.

Water Use Issues

In the past ten years, evaporative coolers have received increasing interest as new products enter the market and concerns about energy efficiency and peak cooling electrical demands have increased. At the same time, water agencies have started to express concerns about evaporative cooler water consumption and evaluating opportunities to improve system water efficiency. For example, in an effort to conserve water (and perhaps, sell electricity), El Paso Water Utilities and El Paso Electric recently was offering a joint $300 cash incentive to customers who replace existing evaporative water cooling systems with central refrigeration cooling systems. The water vs. energy dichotomy is an important issue in dry Southwestern climates where evaporative cooling has the greatest energy savings potential.

Proposed changes in how evaporative coolers are handled in the 2008 Title 24 Residential Building Standards were delayed based on water use concerns expressed by the California Urban Water Conservation Council. Water use is dependent on several factors, including the method used by the cooler to refresh water and prevent scale (mineral) build-up on evaporative media, outside air temperature and humidity, and system operating hours. Systems that continually bleed a percentage of the recirculated water are not allowed in PG&E's rebate program because of their greater water use and tendency to maintain higher dissolved solids resulting in increased scaling. Systems that use a pump down system to refresh the water generally use less water and are approved for the program.

California Title 20 Efficiency Requirements

Effective January 1, 2006, evaporative cooler manufacturers selling product in California are required to meet the California Energy Commission's Title 20 Appliance Standards requirements. These requirements do not specify a minimum performance standard, but do require manufacturers to "test and list" their equipment. Table 2 lists the information that manufacturers are required to provide.

Table 2: Title 20 Evaporative Cooler Listing Requirements

Evaporative Media Saturation Effectiveness (%) (for direct evaporative coolers only)
Cooling Effectiveness (for indirect and direct/indirect evaporative coolers only)
Total Power (Watts)
Airflow Rate (CFM)
ECER
Media Type (Expanded Paper, Woven Plastic, Aspen wood, Rigid Cellulose, Other)

Two ASHRAE standards address evaporative coolers. Standard 143-2000 describes a method for rating indirect evaporative coolers and Standard 133-2001 addresses direct (one-stage) coolers. There is currently no standard that applies to direct-indirect (two-stage) coolers, but there is no limitation in using 143-2000 to calculate the direct-indirect cooling effectiveness. Both ASHRAE standards specify that results will be reported as performance curves using airflow rate as the abscissa, and will plot as ordinates the standard static pressure differential, standard power input, and standard saturation effectiveness (in the case of 133) or standard cooling effectiveness (in the case of 143). Standard rating assumptions can be assigned to indoor temperature and outdoor dry bulb and wet bulb temperatures enabling an ***evaporative cooler efficiency ratio*** (ECER) to be calculated using Equation 2.

$$ECER = \frac{1.08 \times (t_{in} - (t_{db} - e(t_{db} - t_{wb}))) \times Q}{W} \qquad \text{(Equation 2)}$$

Where,

t_{in} = standard indoor dry bulb temperature (80°F)

t_{db} = standard outdoor dry bulb temperature (91°F)

t_{wb} = standard outdoor wet bulb temperature (69°F)

ε = measured saturation effectiveness for direct evaporative coolers and cooling effectiveness for indirect and two-stage evaporative coolers.

Q = measured air flow rate (cfm)

W = measured total power (Watts)

Total unit power includes power used by fan motors, pump motors, and other devices needed to produce the cooling effect. Power for devices such as thermostats, transformers providing low voltage to control mechanisms, and freeze protection devices shall not be included in total unit power. The unit shall be tested at its highest fan speed at 0.3” external static pressure.

Product Warranties

Typical evaporative cooler product warranties vary considerably by manufacturer. Table 3 lists evaporative cooler product warranty information for the units involved in this field test project.

Table 3: Manufacturer Warranty Information

Manufacturer	Warranty
Breezair	2 years pump, motor, junction box; 10 years structural components; 25 years cabinet
Coolerado	5 year limited warranty
Essick Air	1 year cabinet; 2 years blower motor; 5 years evaporative media
Speakman CRS (OASys)	1 year full parts; 5 years parts (repair/replace) on cabinet and motor

Prior Research and Technology Assessments

Over the past fifteen years there has been significant research into advanced residential evaporative cooling systems. Much of the research has focused on indirect-direct and indirect systems that should provide improved indoor comfort by delivering cooler and dryer air to the conditioned space. Indirect systems in particular should offer indoor humidity levels comparable to standard vapor compression systems. The studies listed below that provide a broad survey of the residential evaporative cooler industry, as well as more specific evaluations of individual technologies. A Coolerado field test performance report is expected from the Sacramento Municipal Utility District in early 2008.

1. "SWEEP/WCEC Workshop on Modern Evaporative Technologies", Summary of July 9-10, 2007 workshop.

This summary report provides a detailed look at current evaporative technology trends, utility incentives, market barriers, and regulatory issues. The report provides an extensive syllabus of current evaporative cooling research. http://www.swenergy.org/workshops/evaporative/Summary.pdf

2. "Projected Benefits of New Residential Evaporative Cooling Systems: Progress Report #2", NREL/TP-550-39342, October 2006.

This report presents field results and DOE2 simulation projections for the OASys two-stage evaporative cooler in southwestern climates. The report looks at potential energy savings and indoor comfort impacts for several southwestern climates.
http://www.nrel.gov/docs/fy07osti/39342.pdf

3. "Evaluation of Advanced Evaporative Cooler Technologies", PG&E Technical and Ecological Services Report #: 491-04.7 (February 2004).

This test report from PG&E's TES facility compared laboratory performance of a traditional low-cost aspen pad unit, an advanced direct evaporative cooler with 8" rigid media, and the latter unit tested with an add-on indirect cooling module. Measured effectiveness varied from ~41% for the swamp cooler, 73-78% for the advanced unit, and 89-98% for the two-stage unit.

4. "Laboratory Evaluation of the Coolerado Cooler Indirect Evaporative Cooling Unit", PG&E Technical and Ecological Services Report #: 491-05.6 (March 2006).

PG&E testing of a Coolerado indirect cooling unit found average effectiveness of 86%, with performance ranging from 81 to 91%. Effectiveness was found to increase with increasing outdoor dry bulb temperature (at a rate of ~4% per 10˚F), with little sensitivity to outdoor wet bulb temperature.

5. "Evaluation of an OASys Indirect-Direct Evaporative Cooler Retrofit", Steven Winter Associates (January 2007).

This report evaluates the performance of an OASys indirect-direct cooler on a forty year old home in Sacramento, CA that had been previously cooled by a 5-ton air conditioner. Results indicate the system delivered approximately two tons of equivalent cooling at an efficiency level roughly three times that of a SEER 14 air conditioner.

http://OASysairconditioner.com/pdf/PATH_OASys_EvaluatioReportMar07.pdf

Additional reports on evaporative cooler performance can be found at the Emerging Technologies Coordinating Council at http://www.etcc-ca.com/database/index.php. Select evaporative cooling from the "Type of Technology" pull-down menu.

Project Objectives

The primary goal of this project was to collect field monitoring data on advanced residential evaporative cooler systems to determine performance characteristics, water use, comfort levels, and customer satisfaction. To complete this work PG&E hired Intergy Corporation in the role of prime contractor. Davis Energy Group, acting as a subcontractor to Intergy, had primary responsibility for monitoring system installation, data collection and evaluation, and reporting activities.

The project was structured as follows:

- Select six field test sites in California climate zones 11-13 (Central Valley) to test the following system types:
    a. OASys indirect-direct evaporative cooler
    b. Two sites with 12" rigid media direct evaporative coolers
    c. Breezair variable speed direct evaporative cooler
    d. Essick rigid media evaporative cooler with add-on indirect cooling module
    e. Coolerado (this test site in Fresno had the unit installed in 2006)
- Develop a monitoring plan for collecting continuous 15-minute interval data
- Install data acquisition systems at each of the six sites
- Pre-monitor existing evaporative cooler performance, if possible.
- Coordinate with HVAC contractors to install advanced evaporative systems
- Monitor advanced system performance for a minimum of two months
- Evaluate field performance and simulate savings using an hourly computer model
- Survey homeowner satisfaction
- Summarize project results.

The key project milestone dates were to:

- Install monitoring systems by June 15th at all sites
- Complete pre-monitoring by July 15th
- Complete advanced system retrofits by August 1st
- Continue monitoring through the end of September

Experimental Design and Procedures

A monitoring approach was developed to document the in-situ performance and comfort implications of the various tested technologies to assess their applicability to a broader range of the residential market. Specific monitoring objectives include:

- Measuring energy consumption, water use, and cooling efficiency/effectiveness
- Assessing comfort provided by the systems. For the sites that were pre-monitored, the homeowners in the test house

A monitoring plan was developed to satisfy these objectives. The monitoring plan specified equipment and procedures for installation of monitoring hardware. Individual monitoring systems were installed at each site to obtain, store, and transfer data. The installed monitoring and test equipment included:

- Data Electronics DT-50 dataloggers for temperature, power, air flow, and relative humidity measurement
- On-site modems for downloading data to the host monitoring computer
- Solid state or RTD temperature sensors for indoor, outdoor, attic, and supply air temperatures
- Solid state relative humidity sensors for indoor and outdoor air relative humidity
- Power monitors for generating pulsed output proportional to instantaneous demand
- Flow meters for measuring cooler water usage
- Flow hood for one-time airflow measurements

Table 4 lists the types of sensors used and their performance specifications. All temperature and humidity sensors were received with factory calibration certificates from a NIST-traceable device.

Table 4: Sensor Specifications

Application	Manufacturer/Model Number	Accuracy
Indoor temperature/RH	Automation Components, Inc. A/RH2-TTM100-(50-90)	±0.7 °F, ±2% RH
Outdoor temperature/RH	Automation Components, Inc. A/RH2-TTM100-(50-120)	±1.0 °F, ±2% RH
Water consumption	ISTEC pulsing water meter #1702	±1.5%
Supply air temperature	Automation Components, Inc. A/TTM100-(50-90)	±0.7 °F, ±2% RH
Electrical energy usage	Rochester Instrument Systems True RMS power monitors #PM1001-240	±0.5%
Attic air temperature	Automation Components, Inc. A/TTM100-(50-140)	±1.2 °F

The DT50 datalogger was programmed to scan all sensors every 15 seconds, and data were summed or averaged (as appropriate) and stored in datalogger memory on 15 minute intervals. Datalogger memory was sufficient to store at least five days of data, so that loss of modem communications would not interrupt the stream of data. Low voltage power supplies were used to power dataloggers with battery backup to protect against data loss during power outages.

Data in comma-delimited ASCII format were downloaded daily to a central computer and screened using software to review data quality. Out-of-range data were noted and further investigated visually to determine whether a sensor or monitoring error exists or equipment has failed. Data review was performed using an EXCEL spreadsheet that allows for loading and graphing of all key monitoring parameters in a weekly time series format. Weekly performance reports were developed for each site and emailed to the PG&E project manager. The reports included plots of temperature, relative humidity, unit power, water consumption, effectiveness, and EER. A sample report is included in Appendix A.

Cooling energy delivered by the evaporative coolers was determined from supply air temperature, house indoor air temperature, and airflow rate. For multi or variable speed systems, airflow measurements were completed at several fan speeds (five or more data points are needed to characterize variable speed systems) to allow development of an airflow vs. power relationship to translate measured 15-second power data into supply airflow. The supply airflow is then used to calculate 15-second delivered cooling, as shown in Equation 3.

$$Q_{clg}\ (\text{Btu/15-second}) = \rho_{air} * C_p * (CFM/4) * (T_{supply} - T_{indoor}) \qquad \text{(Equation 3)}$$

Where,
ρ_{air} = density of air (lb/ft^3)

C_p = specific heat of air (Btu/lb-°F)

CFM = supply airflow (ft^3 per minute)

T_{supply} = supply air temperature (°F)

T_{indoor} = indoor air temperature (°F)

This approach to calculate cooling is similar to that commonly used in monitoring conventional vapor compression equipment where cooling capacity is calculated based on the return air to supply air temperature difference[5]. Some evaporative cooling proponents claim the cooling delivered should be based on the outdoor to indoor temperature difference, although this approach does not reflect beneficial cooling to the space. Unlike properly-functioning vapor compression equipment that maintains a 15 to 22°F temperature drop between return air and supply air, evaporative cooler supply air temperature is based on outdoor conditions and system effectiveness[6] resulting in the potential for delivering supply air warmer than the indoor temperature.

The 15-minute summed Q_{clg} value was then divided by energy consumed over the 15-minute period to determine the Energy Efficiency Ratio, or EER.

Description of Monitoring Sites

Monitoring sites were identified based on PG&E's preferences for geographic location, house floor area, and homeowner flexibility in accommodating monitoring. PG&E was interested in testing advanced direct evaporative cooler performance in each of three regions of the Central Valley: North Valley (Redding, Red Bluff, Chico), Central Valley (Sacramento/Stockton vicinity, including foothills), and San Joaquin Valley (Fresno and Bakersfield). PG&E

[5] In the evaporative cooler case, indoor air substitutes for the return air condition.

[6] Supply air temperature = Outdoor dry bulb – ε * (Outdoor dry bulb – Outdoor wet bulb)

prescribed that one of the three directs units was to be a variable-speed Breezair Icon unit manufactured by Seeley International[7]. The remaining three sites were proposed to test the following technologies:

- A Coolerado R400 unit originally installed by a Fresno homeowner in 2006
- An OASys CRS-1000 to be installed in the Sacramento/Stockton geographic region
- An indirect-direct Essick Air unit to be installed in the North Valley or San Joaquin Valley

Additional site selection criteria included single-family homes, typical California construction, floor areas ranging from 1,200 to 2,500 ft^2, and occupants willing to operate their cooling equipment during the hot portions of the day. In mid-May, Intergy began making inquiries to identify potential sites. Intergy contacted HVAC contractors active in evaporative cooler installations. Additional leads came from PG&E personnel. Davis Energy Group provided a lead to a homeowner in Davis who had one of the original single blower/single sump indirect-direct units developed by DEG[8] in the early 1990s, which was a predecessor of the OASys. Site visits were made to the candidate sites to assess applicability and monitoring feasibility and a preferred list of sites were sent to the PG&E Project Manager. Once site selection was finalized, access agreements were secured with each of the homeowners.

Table 5 briefly characterizes each of the six selected sites. All of the houses were at least 17 years old with varying levels of envelope energy efficiency. None of the sites had advanced cooling efficiency measures such as low solar heat gain glazing or attic radiant barrier. Two of the sites (Chico and Fresno1) had marginal envelope efficiency, suggesting higher than normal cooling requirements.

Table 5: Monitoring Site Characterization

Location	Floor Area	Vintage	Description
Chico	1,175 ft^2	1960s	Single story; not well insulated; dual pane windows
Davis	1,300 ft^2	1970s	Single story; no major energy retrofits; mature trees provide some roof shading
Fresno1	1,200 ft^2	1950s	Single story; no wall insulation; ~R-13 ceiling insulation; mature vegetation nearby but no roof shading
Fresno2	2,100 ft^2	1970s	Single story; dual pane clear windows installed ~3 years ago; significant roof overhangs provide window shading
Fresno3	1,350 ft^2	1980	Single story; located in rural agricultural area outside of Fresno; significant irrigation from fields and home gardens may affect microclimate
Sonora	2,500 ft^2	1990	Two-story; well insulated (R-19 walls, R-34 ceiling); dual pane windows; located in wooded area

[7] The Breezair site was to be a fully ducted supply to test the hypothesis that a fully ducted system could provide summer comfort comparable to vapor compression cooling.
[8] Under a California Energy Commission Energy Technology Advancement Project grant

Table 6 describes both the existing evaporative coolers at each of the six sites and the advanced evaporative cooler installed during the course of the project. Three of the six sites had standard aspen pad evaporative units that are commonly available at big box retailers. The Davis site had an essentially non-functioning two-stage unit originally installed in 1994. The homeowner at Fresno1 had purchased and installed a Coolerado R400 in 2006. Fresno2 had an existing two-speed Breezair unit that was approximately 4 years old.

Product literature for the installed products can be found in Appendix B[9].

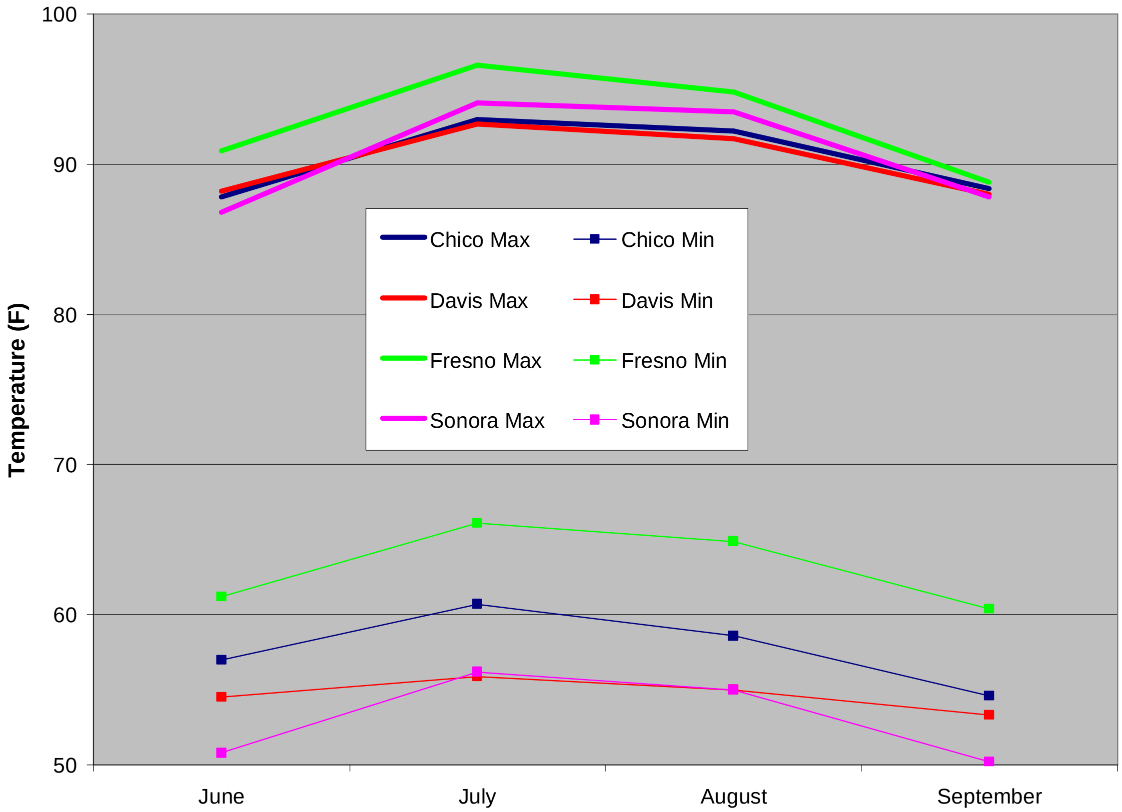
Table 6: Cooling System Characterization

Location	Existing Cooling System	Replacement Cooling System
Chico	Aspen pad unit purchased from big box store (~ 3 years old)	Essick Ultracool Complete AD1C7112 12" Rigid Media Unit (direct). House air was initially relieved through windows and doors; ceiling Upducts were added later.
Davis	Two-stage evaporative cooler from DEG's 1990 development project (cooler was barely operational)	OASys CRS1000 indirect-direct. Primary house relief was provided by Upducts.
Fresno1	Coolerado R400 indirect unit (installed by homeowner in 2006)	The Coolerado R400 was monitored in 2007. Primary house relief air was provided by whole house fan barometric damper.
Fresno2	Breezair two-speed direct evaporative cooler (installed four years ago)	Breezair EM275 variable speed direct unit. Each room had an Upduct, although homeowners used windows/ doors for additional control.
Fresno3	Aspen pad unit purchased from big box store (~ 4 years old)	Essick Ultracool Complete AD1C7112 12" Rigid Media Unit (direct) with IM-70-120 indirect module. Windows/ doors were used to relieve air.
Sonora	Aspen pad unit installed by homeowner ~18 years ago and regularly maintained by homeowner	Essick Ultracool Complete AD1C7112 12" Rigid Media Unit (direct). Relief air provided by single Upduct and windows/doors.

[9] The Coolerado R400 was discontinued in 2007. The R600 represents the replacement product.

Although five of the six sites are located in California's Central Valley, there are some climate differences between the locations. Figure 2 plots National Oceanic and Atmospheric Administration dry bulb temperatures[10] for Chico, Davis, Fresno, and Sonora. The data represents monthly average maximum and minimum temperatures for the peak summer months of June through September. Although the average high temperatures do not vary that significantly for the various locations, the range in low temperatures is nearly ten degrees. Lower nighttime temperatures typically contribute to a shortened daytime cooling period.

Figure 2: Field Test Site Average Summer Weather Conditions (1971-2000)



Project Results

Monitoring results from the six sites are summarized in this section with more detailed monitoring results included in Appendix C.

Weather conditions for the 2007 summer were fairly typical. Table 7 summarizes National Weather service data for the summer monitoring period from July through September. For both Sacramento and Fresno, July and August were warmer than typical, and September was cooler.

[10] Based on temperatures recorded over the 1971-2000 time period. Data can be found at http://cdo.ncdc.noaa.gov/climatenormals/clim81/CAnorm.pdf

The cooling degree days (CDD) and number of days exceeding 100°F highlight the difference in summer weather conditions between Sacramento and Fresno.

Table 7: National Weather Service Summer Data

Month	Days with 100°F+ Max Temperature	CDD	CDD deviation From normal
Sacramento			
July	2	390	Plus 7
August	9	407	Plus 46
September	2	188	Minus 82
Fresno			
July	14	569	Plus 45
August	14	560	Plus 82
September	3	274	Minus 33

Two of the six sites (Chico and Sonora) were pre-monitored with their existing aspen pad direct evaporative coolers. The pre-monitoring is useful for both characterizing the performance (energy and water use, effectiveness) of typical aspen pad units, and also providing a comfort benchmark for the homeowners to assess the advanced evaporative unit. The Chico unit was approximately 3 years old, while the Sonora unit was 18 years old. The age of the Sonora unit and continuing operation is a testament to the regular maintenance and repair efforts of the Sonora homeowner.

Table 8 summarizes monitoring results from the two pre-monitored sites. Reported values include average indoor and outdoor conditions, and evaporative cooler energy use, operating hours, water use, and efficiency. Efficiency is reported in terms of EER[11] (both measured and normalized to a fixed 78˚F indoor temperature to allow comparisons) and average measured effectiveness[12].

The Sonora site was monitored for half of July, while Chico was monitored for all of July. The Sonora site maintained a much cooler average indoor temperature, and lower average outdoor temperatures resulted in lower daily operating hours and energy usage. Water usage for the Sonora site was higher than typical[13], while Chico water usage was less than typical. Average

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[11] Btus of cooling delivered per Watt-hour of energy consumed

[12] The EER efficiency descriptor is clearly dependent on how the homeowner operates the system. If operation is confined to the hottest parts of the day when outdoor wet bulb temperatures, and therefore supply air temperatures, are typically highest, the EER will be lower than for a case where the system is operated for much of the day (lower average wet bulb temperature). Generally a higher EER indicates higher effectiveness and more operation in mornings and evenings when outdoor wet bulb temperatures are lower.

[13] Typical water usage is generally in the 3-4 gallons/ton-hour of cooling delivered, depending upon equipment type, water maintenance system type, and climate.

monitored EERs were comparable at ~19, although when normalizing conditions to a nominal 78˚F indoor temperature the EER for the Sonora site was roughly three times higher than for Chico. Average measured effectiveness for the Sonora unit was an impressive 81.6%, ~15% higher than the more typical Chico aspen pad effectiveness of 66.1%. The high Sonora effectiveness might be attributable to the dedicated maintenance and component replacement plan applied by the homeowner.

Table 8: Pre-Monitoring Data Summary

	Sonora	Chico
Time Period	July 1 - 17	June 30 - July 31
Average Indoor Temperature	71.5ºF	76.7ºF
Average Indoor RH	65.3%	57.9%
Total Unit kWh	91.1	172.5
Cooling kWh / day	5.4	8.2
Peak demand (kW)	0.49	0.62
Maximum airflow (cfm)	2285	2163
Operating hours / day	12.6	16.2
Total water use (gallons)	743	560
Gallons / operating hour	3.5	1.6
Gallons / ton-hour	5.1	2.1
Average EER	19.2	18.9
Average EER (@78°F)	57.3	23.9
Average Effectiveness	81.6%	66.1%

Monitoring results for the advanced system types are summarized in Tables 9 and 10. Table 9 presents the data on the three advanced direct evaporative coolers (Essick Air and Breezair). The Sonora and Chico sites both used the Essick Air direct unit with 12" rigid media. Two columns of data are shown for the Sonora site in Table 9. The column represents data prior and subsequent to a service call that was performed by the installing HVAC contractor on August 28th. The service call was initiated based on an observed decline in evaporative effectiveness and a corresponding rise in supply air temperature. The cause was found to be partial blockage on the water distribution feed system at the top of the evaporative media resulting in incomplete wetting of the media and reduced evaporative effectiveness. According to the HVAC contractor, the source of the blockage was likely from the manufacturing process. The post August 29th data shows considerably higher evaporative effectiveness and is consistent with the Chico data. The need for a post-installation service call highlights the need for proper system commissioning.

Table 9: Advanced Direct Evaporative Cooler Monitoring Summary

	Sonora		Chico	Fresno2
Time Period	July 26 – Aug 28	Aug 29 – Sept 6	Aug 3 – Sept 18	July 14 – Sept 18
Installed System	Essick Air		Essick Air	Breezair
Average Indoor Temperature	72.8ºF	71.0ºF	71.1ºF	76.0ºF
Average Indoor RH	76.6%	78.4%	61.5%	63.6%
Total Unit kWh	274.3	91.9	452.6	607.6
Cooling kWh / day	8.1	10.2	9.6	9.1
Peak demand (kW)	0.64	0.64	0.84	1.16
Maximum airflow (cfm)	2646	2646	2567	4406
Operating hours / day	16.0	20.4	16.1	15.3([1])
Total water use (gallons)	997	473	1,507	3,610
Gallons / operating hour	1.8	2.6	2.0	3.5
Gallons / ton-hour	1.6	2.4	3.0	2.6
Average EER	26.8	26.0	13.3	27.5
Average EER (@78°F)	45.4	54.2	34.1	41.5
Average Effectiveness	66.3%	81.9%	81.1%	85.6%

(1) On nine days during the summer, the homeowners utilized air conditioning for about 30 hours. AC was used when indoor RH was too high, or when guests were expected.

Comparing the Sonora and Chico data, one finds fairly comparable supply airflow, and higher Chico unit power (0.84 vs. 0.64 kW) likely due to a more restrictive duct system. Both sites maintained very low average indoor temperatures (<72ºF), resulting in an average of 16-20 operating hours per day. Interestingly, the Chico site indoor temperature was ~ 5.5ºF lower than in the pre-monitoring phase, suggesting both increased cooling capacity and some element of take-back effect, whereby the homeowners use their more effective cooling system to improve comfort. The normalized average EER (at 78ºF) for the two units ranged from 34 to 54.

The variable speed Breezair ICON unit installed at Fresno2 was operational in late June, but detailed airflow measurements vs. system power were not completed until July 13th. (These measurements are needed to characterize airflow as a function of system power.) The unit ran reliably all summer maintaining average indoor conditions of 76.0ºF and 63.6% RH. Cooling energy use for the house was comparable to the Chico and Sonora houses at 9.1 kWh/day. Most impressive about the Breezair system was the maximum supply airflow level measured at 4,406 cfm. Breezair touts their "one-piece aerodynamic fan design" as one of their innovative features. For the 2007 summer, roughly 1/3 of the Breezair unit's operation was at full-speed, 1/3 was between 60 and 100% airflow, and the last 1/3 was below 60% airflow. Overall system EERs improve at lower airflow levels due both to improved evaporative effectiveness and reduced "Watts per cfm".

It should be noted that the Fresno2 homeowners did operate their parallel ducted vapor compression cooling system on nine days, totaling about 30 hours of air conditioning operation. According to the homeowner, these occurrences were due to either excessive indoor humidity or the homeowner's need to provide air conditioning when guests were coming over. The average effectiveness of 85.6% was very close to the Title 20 listed value and slightly higher than the Essick direct unit[14].

Table 10 summarizes the monitoring data from the three advanced systems that utilize indirect cooling (Coolerado, OASys, and Essick Air two-stage). The Davis and Fresno3 sites were indirect-direct evaporative coolers[15] and the Fresno1 site was a Coolerado indirect cooler installed by the homeowner in 2006. The Davis homeowner was a fairly "energy" frugal homeowner who lived in a mature neighborhood that limited solar exposure to windows and also reduced roof solar gains. This cooler microclimate and the homeowner's regular use of the OASys as a nighttime ventilation device resulted in very low cooling energy consumption (2.2 kWh/day). The OASys was operated extensively on the few 100ºF+ days recorded during the 2007 summer. The OASys staged three-speed fan operated mostly in the 2nd stage during even the hottest weather. The monitored effectiveness of 96.1% is slightly lower than the Title 20 listed 102% effectiveness. The 78ºF EER was calculated at 50.9.

Problems with the Fresno1 and Fresno3 sites (Coolerado and Essick Air indirect-direct, respectively) were identified during the 2007 monitoring period. The Coolerado system was installed by the homeowner in the summer of 2006. He used the existing duct system, connecting the roof-mounted Coolerado into the existing furnace ducting located in an interior closet. Initial airflow readings indicated that only 629 of the nominal 1000 cfm were being delivered to conditioned space[16]. This was remedied by the end of the monitoring period when the duct system was modified and a 931 cfm final airflow reading at the supply registers was recorded. A second problem related to the much lower than expected effectiveness readings. Sensor readings were verified using a Vaisala HMI141 hand-held device, confirming that the data are accurate. Over the July 4th weekend, the homeowner replaced the Coolerado heat exchanger but there was no subsequent appreciable change in performance. On July 23rd a Coolerado field engineer inspected the system and made adjustments. He found two drippers plugged and also added a new circuit board to improve control of water flow to the unit. His measurements found the unit to be operating close to design specifications[17]. This was in contrast to the monitoring system, which reported an average effectiveness of 70.1% over the course of the summer. Other results from Fresno1 site monitoring indicate:

1. Indoor relative humidity averaged 48.1%, the lowest of the six sites, despite the unit operating an average of 15.5 hours per day.
2. Indoor setpoint was not maintained in this poorly insulated house, partly due to the unit only delivering 629 cfm to conditioned space (until the duct problems were remedied).

[14] Essick units are not currently listed in the Title 20 database.
[15] A key distinction between the Davis unit (OASys) and the Fresno unit (Essick Air) is that the OASys is an integrated two-stage cooler, while the Essick Air is essentially a stand-alone indirect module (with dedicated fan) that is added to the direct evaporative cooler at the jobsite.
[16] The remaining airflow was lost via duct leakage.
[17] Title 20 listed effectiveness of 90%.

On the hottest days, indoor temperatures rose to the upper 80's, despite continuous cooler operation.

3. Water use, even with the improved water control system, was very high; averaging 15 gallons per ton-hour, or four to five times more than typical evaporative coolers.

The Fresno3 site problems were twofold: First, the installing HVAC contractor installed the unit in the middle of the first major heat spell of the summer. The initial installation work was incomplete and sub-par and the homeowner was not initially pleased. Second, the unit never achieved expected effectiveness levels that should approach 95-100%. Initial effectiveness readings average 83.7%[18] despite a return service visit by the installing HVAC contractor. A second visit by a specialty evaporative cooling HVAC firm found minor problems that resulted in a slight improvement in performance (88.3% effectiveness). Despite the sub-par performance, the homeowners found the new unit to be an improvement in terms of comfort (cooler and lower indoor humidity).

Table 10: Advanced Indirect/Indirect-Direct Evaporative Cooler Monitoring Summary

	Davis	**Fresno1**	**Fresno3**
Time Period	July 13 – Sept 18	July 1 – Sept 15	July 14 – Sept 18
Installed System	OASys	Coolerado	Essick Air
Average Indoor Temperature	73.0ºF	80.3ºF	80.2ºF
Average Indoor RH	57.2%	48.1%	54.1%
Total Unit kWh	137.4([1])	589.2	338.2
Cooling kWh / day	2.2	7.8	6.6
Peak demand (kW)	0.66	0.56	1.11
Maximum airflow (cfm)	1405	629 (931)	1885
Operating hours / day	4.9	15.5	7.7
Total water use (gallons)	717([2])	12,162	599
Gallons / operating hour	3.0	10.3	1.5
Gallons / ton-hour	3.7	15.0	1.7
Average EER	24.7	16.5	21.5
Average EER (@78F)	50.9	13.5	12.6
Average Effectiveness	96.1%	70.1%	83.7% / 88.3% ([3])

(1) ~20% of unit operation was in nighttime "whole house fan" mode.
(2) Water meter operational as of August 1st
(3) First effectiveness reading is prior to HVAC service call; 2nd is afterwards

[18] The monitored effectiveness is negligibly higher than that measured with the Sonora and Chico units (identical Essick Air direct units). The addition of the indirect module and the added pressure drop and parasitic, reduced supply airflow by ~25% and roughly doubled the Watts/cfm.

Computer Simulations

Hourly computer modeling was completed to assess potential energy and demand savings of each of the evaporative technology types: Essick Air and Breezair direct evaporative, Coolerado, OASys, and Essick Air Indirect-Direct. A research version of the MICROPAS hourly building energy simulation model developed under an Energy Commission PIER-funded project was used to estimate performance. The model accepts Title 20 evaporative cooler performance descriptors (full speed supply air flow and system power, and system effectiveness) to model evaporative cooler performance on an hourly basis using hourly weather files (dry bulb and wet bulb temperature). A limitation of the MICROPAS model, as well as other building energy simulation models, is the inability to accurately model moisture flows into and out of the house. This limitation precludes any valid assessment of indoor comfort.

Modeling was completed for both new and retrofit cases. New construction represents a preferred application for advanced evaporative coolers, since efficient envelopes result in lower cooling loads and a far greater likelihood that indoor comfort will be maintained (fewer run hours = less moisture addition to indoor space). The problem is that no production home builders are installing evaporative coolers in new homes. Retrofit applications offer greater opportunities, but as seen as in the 2007 field monitoring, indoor comfort is often compromised given the poor envelope quality of many evaporative cooler equipped homes. For this study, evaluations were completed for both retrofit and new construction cases: retrofit results are reported in the body of the report, and new construction results can be found in Appendix D.

Table 11 summarizes the MICROPAS performance inputs for the five equipment types based on the 2007 monitoring. Title 20 performance values are also listed in parentheses for those units listed in the Energy Commission's Appliance Standard's database. The Breezair unit matched very well with its Title 20 performance levels. The Coolerado was found to be well below its rated effectiveness level. Lower field-monitored system demand could be attributed to use of a variable speed motor at the test site. The OASys was found to be close to the Title 20 specifications. Supply airflow was considerably higher, but the non-ducted field installation should exhibit higher airflow relative to 0.3" static test assumption for Title 20. Higher airflow would also contribute to slightly lower effectiveness.

Table 11: Performance Assumptions

Equipment Type	Supply Airflow (cfm)	Effectiveness (%)	System Power (kW)
Essick Direct	2606	81.5%	0.74
Breezair Direct	4,406 (4,789)	85.6% (84.9%)	1.16 (1.208)
Coolerado	931 (1,092)	70.1% (90%)	0.56 (1.042)
OASys	1,405 (1,141)	96.1% (102%)	0.66 (0.586)
Essick Indirect-Direct	1885	88.3%	1.11

Simulation runs were completed for a prototypical 1,600 ft^2 single-story house with an approximate age of 30 years. The evaluation scenario assumes the homeowner will replace an existing evaporative cooler with either a central air conditioner or an advanced evaporative cooler. In the former case, the assumption is made that a cooling setpoint of 78ºF will be maintained through the summer months. For the evaporative cooler cases, a higher 81°F setpoint was assumed for two reasons: 1) higher evaporative cooler airflow provides additional comfort as defined by 2007 ASHRAE Handbook of HVAC Applications (page 51.12), and 2) ceiling fans are assumed to provide additional air movement[19]. These assumptions are speculative but not unreasonable given the perceived relaxed comfort criteria of many occupants in evaporatively cooled homes. Characteristics of the house are summarized in Table 12.

Table 12: Modeled Retrofit House Characteristics

Characteristic	Description
Wall R-value	R-11 equivalent
Ceiling R-value	R-30*
Glazing U-value	1.29 (single glazed, metal frame)
Glazing SHGC	0.60*
Glazing area	14.5% of floor area (232 ft^2), uniformly distributed by orientation

"*" R-value and SHGC adjusted to reflect impact of mature vegetation typically surrounding established neighborhoods

Table 13 presents cooling energy use and coincident peak demand projections from the MICROPAS research model. Peak demand for the season is defined as the noon to 7 PM average demand for the months of June through September. "3 day" peak demand is defined as noon to 7 PM average demand for the three hottest consecutive days on the weather tape[20]. The projected energy use for a 13 SEER air conditioner in Sacramento is about 40% of that for Fresno, and the peak demand is ~50% that of Fresno for the full summer, but nearly 80% during the three peak days when air conditioner operation is more consistent.

Table 14 summarizes savings relative to the SEER 13 base case. Projected energy savings range from 66-82% and demand savings (for the three hottest days) range from 64-83%, with slightly higher percentage savings in Fresno. At an assumed average PG&E summer electric rate of $0.15 per kWh, projected Sacramento savings average $140 per year and Fresno savings average $347 annually. If overall household usage is high, PG&E's tiered rate structure could result in cost savings twice this amount.

[19] The ceiling fan assumptions assumed two 100 W ceiling fans operating at full speed. For Sacramento, the use assumption was 6 hours a day for 80 days a year, and for Fresno, 10 hours per day for 120 days.

[20] For Sacramento the three days are 100, 103, and 103°, while for Fresno the values are 102, 106, and 105°

Table 13: Project Cooling Energy Use and Coincident Peak Demand

	Sacramento			Fresno		
	Cooling	Coincident Peak kW		Cooling	Coincident Peak kW	
Type	kWh/yr	Season	3 days	kWh/yr	Season	3 days
SEER 13 AC	1184	1.22	3.47	3170	2.54	4.35
Essick Direct	219	0.34	0.91	738	0.62	0.98
Breezair Direct	210	0.33	0.83	692	0.60	1.15
Coolerado	281	0.37	0.76	981	0.65	0.76
OASys	230	0.34	0.83	784	0.63	0.86
Essick Indir-Dir	303	0.42	1.26	1072	0.88	1.31

Table 14: Projected Cooling Energy and Peak Demand Savings

	Sacramento		Fresno	
Equipment	Cooling	Coincident	Cooling	Coincident
Type	kWh/year	Peak kW	kWh/year	Peak kW
Essick Direct	965 (82%)	2.56 (74%)	2432 (77%)	3.37 (77%)
Breezair Direct	974 (82%)	2.64 (76%)	2478 (78%)	3.20 (74%)
Coolerado	903 (76%)	2.71 (78%)	2189 (69%)	3.59 (83%)
OASys	954 (80%)	2.64 (76%)	2386 (74%)	3.49 (80%)
Essick Indirect-Direct	881 (74%)	2.21 (64%)	2098 (66%)	3.04 (70%)

Applicability Limitations

The energy and demand savings presented in Table 14 do not take into account indoor comfort conditions. This is an important consideration since comfort issues represent a significant market barrier for evaporative cooling, and inadequate comfort can prompt homeowners to revert to air conditioning on peak days. Figure 3 plots the average indoor conditions[21] for periods when the evaporative coolers were operating continuously, relative to the ASHRAE Standard 55 "comfort zone" (the inscribed box in the figure). The solid symbols represent the average conditions during the full monitoring period, while the outlined symbols represent conditions when outdoor temperatures exceeded 95°F.

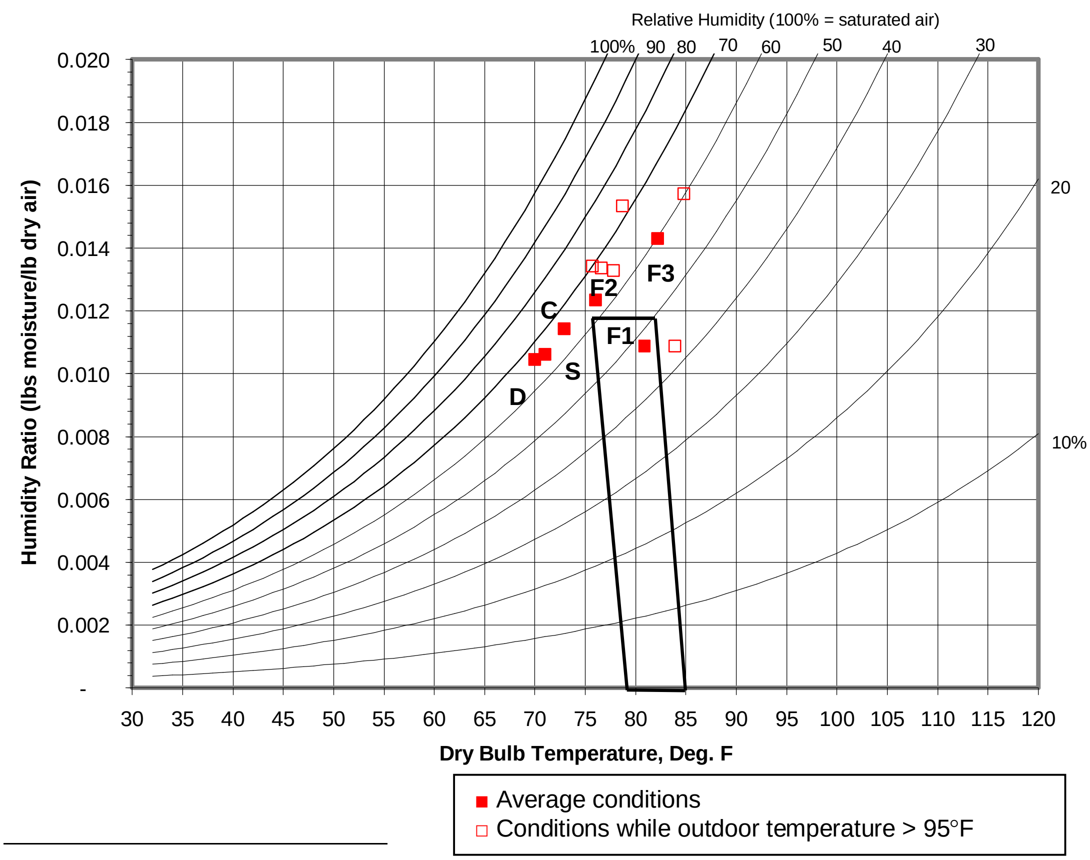
Looking at the *averaged* conditions, Fresno1 ("F1") is the only site that falls within the ASHRAE comfort envelope. Interestingly, four of the five remaining sites all exhibit temperatures at or below the cool end of the comfort spectrum. Most of this is due to

[21] Each site is noted by the first letter (and in some cases number) of the site location.

homeowners starting their cooler early in the day with the expectation[22] that they need to get a head-start on cooling their house since indoor temperatures will rise later in the day as rising outdoor wet bulb temperatures result in increased supply air temperatures. It is likely that these four sites (all except Fresno3) would move into the comfort envelope if the homeowners were to select higher setpoints. This may happen as the homeowners gain more experience with the performance characteristics of their new coolers.

Focusing only on the hot weather data, one finds that all data points are outside the ASHRAE comfort zone primarily as a result of higher humidity levels, but also higher temperatures for the F3 site. The one exception is the F1 Coolerado site that demonstrates drier indoor conditions relative to the full F1 dataset, but the unit is unable to maintain reasonable indoor temperatures during the hot weather[23]. Chapter 51 of the 2007 ASHRAE Handbook of HVAC Applications shows modified comfort envelopes for spot cooling industrial applications where higher airflow levels extend the acceptable comfort range to higher temperatures and relative humidity. Although higher airflow is certainly a factor that will improve evaporative cooler comfort over conventional forced air vapor compression systems, the expanded comfort range is not broad enough to capture all of the indoor conditions experienced at the field monitoring sites.

Figure 3: Average Indoor Condition Relative to the ASHRAE Standard 55 Comfort Zone



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[22] This hypothesis could relate to the sub-par performance with lower quality coolers requiring homeowners to get a head start on the upcoming mid-day cooling demand.

[23] During the full monitoring period ~1/3 of the supply airflow was being lost from the duct system. If this problem had not occurred, indoor comfort would have been significantly improved.

Incremental Costs

Table 15 summarizes the equipment costs (not including installation labor and site-specific expenses) for the five cooler types installed in this project. The final entry is a price for a standard aspen pad unit obtained from a big box retailer. Incremental equipment costs for the advanced coolers range from $1,200 to $2,900. Our experiences in this project indicate that the cost of installation (including addressing site issues) can greater than or equal to the cost of the equipment. For the economics of the advanced evaporative cooling systems to improve the following must occur:

- Equipment costs and distributor markups must come down to make the products competitive in the marketplace. Higher production volumes are needed, but market demand and/or incentives must "prime the pump".
- Time-of-use electric rates would improve customer economics by sending a more realistic price signal to the homeowner. Current standard tiered residential rates penalize increased consumption, but otherwise do not differentiate between on and off-peak consumption.
- The marketplace needs to see increased competition among contractors to avoid treating these systems as boutique products.

Table 15: Evaporative Cooler Equipment Costs

Equipment Type	Equipment Cost	Total Installed Cost*
Essick Direct	$1,750	$4,815 (avg)
Breezair Direct	$2,630	$3,250
Coolerado	$3,400	n/a†
OASys	$3,100	$6,285
Essick Indirect-Direct	$2,800	$3,515
Big Box Aspen Unit	$400-$500	n/a

"*" includes site-specific costs

"†" installed by homeowner

An informal survey of two area HVAC contractors, suggest typical retrofit costs for a 3 ton SEER 13 or SEER 14 unit (with new indoor coil) would cost approximately $4,300 to $5,500. These costs are certainly not out of line with the costs experienced with the installations in this project. This suggests that from a first cost perspective, an air conditioner retrofit is certainly a cost-competitive alternative, although many existing evaporative cooler installations would require a complete duct system retrofit to accommodate a fully ducted distribution system appropriate for a vapor compression air conditioning system.

Product Service Life

Most of the evaporative coolers currently in the market are sold through the big box distribution network. Do-it-yourselfers purchase and install these low cost systems as an economical cooling system that may last only three to five years. The advanced coolers evaluated in this study employ non-corrodible components and are designed for long life and improved maintenance. If these units are provided with regular quality maintenance, expected service life of 10-15 years is certainly achievable, and is in fact warranted given the high current costs of these units.

Discussion

Customer Feedback and Contractor Issues

Customer feedback for the Evaporative Cooler Monitoring program was divided into three primary categories: Contractor issues, program issues, and evaporative cooler issues.

Contractor Issues

In general, the customers at the six different were happy with the contractors that were used by the program to install the equipment. Most of the sites were either Satisfied or Very Satisfied with the contractors. The lone exception was the Fresno3 site, where the homeowner had a bad experience with the original contractor, although a second contractor fixed the problems and was rated highly by the homeowner. The comments of the owner were:

> *1st Contractor—Unit installed ok. However, completely mis-wired, incorrect thermostat and control box*
>
> *2nd Contractor—Corrected problems and cooler was much more effective*

Program Issues

This section of the survey sought to elicit more information about the homeowner's experience with the monitoring program, as well as suggestions for evaporative cooler programs in general.

The homeowners were offered a choice of mail, email, or phone as choices of avenues for the delivery of information about PG&E programs. The answers varied between each household, with mail being the top choice followed by phone. However, as phone calls by telemarketers are generally unwelcome, this may not be a good method for promoting a statewide program.

Most of the homeowners were willing to pay more for a rigid media evaporative cooler unit. However, the numbers provided varied widely from $0 to $1500 for an improved unit. All of the homeowners believed that if PG&E was able to monetize the benefits that this would be helpful in making a decision.

Evaporative Cooler Issues

Most of the homeowners did notice a change in energy usage, although only one saw a reduction in usage and the others saw an *increase* in energy usage relative to their prior evaporative coolers. For one of the sites this was due to the two-stage cooler and the resulting increase in parasitic energy (two fans and pumps, and additional airflow restriction). None of the homeowners were able to determine if there was a change in water usage.

All of the homeowners noticed lower humidity levels, improved comfort, shorter run times, and most found increased airflow. However, the homeowner of Fresno3 did not believe that the improved comfort made up for the increase in energy usage.

Most of the units were on thermostats, allowing for improved control of the system. Some of the homeowners used doors or windows for air relief, even if they had ceiling barometric relief dampers installed. Some of them homeowners used the units in fan only mode to provide night ventilation similar to whole house fan.

Most of the homeowners also had service contracts for their coolers. It may be a good option to research using these contractors to promote various programs from PG&E.

A section was provided for specific complaints and suggestions. The homeowner who stated that they would pay nothing extra for a rigid media system explained:

> *We feel the unit was as expensive as an air conditioner would be.*

Another homeowner suggested additional options for the unit:

> *Higher fan speed, variable speed controller, and a programmable timer to set operation times of the unit.*

Feasibility for Widespread Implementation

In the short term, evaporative cooling will likely remain a niche market in California. The retrofit market is the primary market although some new homes will continue to be built with evaporative cooling. Homes in desert climates can save a substantial amount of energy by using evaporative coolers in conjunction with air conditioners. The typical operating pattern is to rely on evaporative cooling during milder and dryer conditions, but use vapor compression air conditioning on the days when comfort is compromised. This approach will generate energy savings for the homeowner, but unfortunately will have little peak load reduction impact. Evaporative coolers can also find a strong market as stand-alone systems in mild climates or in situations where the homeowner is pursuing efficiency and/or green technologies. Time of use electric rates that reflect the true cost of providing service would certainly improve the market for evaporative cooling technologies.

Estimated Market Size and Market Potential

According to the Residential Appliance Saturation Survey[24] database, evaporative coolers are installed in approximately 5% of California single-family homes. Anecdotal evidence suggests that the market share is slowly eroding as homeowners move to vapor compression cooling, if they can afford the expenditure (both installation and operating cost). A vast majority of evaporative coolers sold are aspen pad units purchased at big box retail outlets. Most of these are probably rooftop or wall units and sold as replacements. The expected service life of these low cost units is roughly 3-5 years[25], depending upon how well the unit is maintained. By contrast, advanced evaporative coolers are a premium product, usually installed on the ground, more durable, and more architecturally acceptable than roof or wall mounted coolers. The

[24] http://websafe.kemainc.com/RASSWEB/DesktopDefault.aspx

[25] due to generally lower quality construction

market for advanced evaporative coolers is promising in climate zones 2 through 8 (coastal and coastal transitional zones) and 16 (higher elevation foothill and mountain regions), where cooling loads can be relatively easily met with evaporative cooling while maintaining comfort. In these locations advanced evaporative cooling can displace conventional air conditioning, but a significant effort would be required to convince production builders and homebuyers to accept the evaporative alternative. However, this is where the greatest peak load reduction opportunities exist. The market is also somewhat promising in climate zones 14 and 15 (southern California desert), where evaporative cooling may cost-effectively supplement vapor compression cooling. The market could be significantly improved if there were a hybrid system that could automatically deliver the most cost-effective type of cooling while maintaining comfort. The market in the remaining climate zones will probably be limited to lower income households (using inexpensive direct evaporative coolers) and highly energy conscious homeowners.

Installation Challenges and Market Barriers

Evaporative coolers are typically installed outdoors and ducted into the house, whereas air conditioners (and furnaces) are installed in interior spaces or attics. As a result, converting an existing house to evaporative cooling can be difficult and costly. Evaporative coolers can share ductwork with air conditioners if suitable backdraft dampers are installed. Evaporative coolers also require that relief dampers be installed in the ceiling. Many existing houses will not be viable candidates for evaporative cooling because of these requirements. New houses can be adapted to meet these installation requirements if they are accommodated in the design of the house. Installed cost, comfort issues, and the perception of evaporative cooling as a substandard system (the “swamp cooler” image) are the primary market barriers. If advanced evaporative cooling can displace conventional air conditioning, the incremental cost can be substantially reduced or eliminated. Otherwise, energy savings must support the full incremental cost.

As indicated by Figure 3, ASHRAE Standard 55 comfort criteria were not continuously met for the test houses. Five of the six sites demonstrated average indoor relative humidity above 60%, a level that many may find uncomfortable. Higher thermostat settings may have actually improved comfort conditions[26].

Long-term equipment reliability is also a significant factor affecting market acceptance of these technologies and is related to the swamp cooler image. Evaporative coolers do require more frequent maintenance than vapor compression systems, although the homeowner can perform much of the required maintenance. Media and pump replacement and scale removal are the primary factors affecting maintenance costs.

In an era of constrained water supplies, water use, even for a highly energy-efficient technology such as evaporative cooling, is a major environmental issue. Water utilities are especially concerned about meeting water demand during peak summer days when irrigation use is also high. With typical evaporative coolers consuming about 3 gallons per ton-hour of capacity, peak day water usage may approach 100 gallons per day. Using the dumped sump water for irrigation is possible, although high mineral content or local code issues may prevent water reuse.

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[26] Three of the six had low average indoor temperatures (less than 73°F)

Although most evaporative coolers are relatively simple mechanical devices, some level of contractor familiarity is needed to insure that the systems are installed properly, that evaporative media is receiving adequate and uniform water flow, and that the water quality maintenance system (typically a pump-down configuration) is operating properly. Our contractor experiences during the 2007 monitoring were generally good, although we did experience the common mid-summer problem of slow contractor response time during the peak installation and repair season. In one situation, this led to a rushed and incomplete installation and in another it lead to partial clogging of the water distribution system due to incomplete system commissioning[27].

Market barriers can be at least partially addressed by educating builders and homeowners, and providing contractor training on installation commissioning of the various evaporative cooler system types. Development of an application guide would also help speed the market adoption of evaporative cooling and would assure proper application. The application guide should describe what climates are suitable for evaporative cooling, what the energy savings potential is in the various climate regions, comfort and maintenance expectations, costs, and approximate paybacks. This guide could be made available through retail and wholesale distribution chains and used in utility training programs.

Conclusions

Field evaluations of the five different evaporative cooler types completed in this project, as well as energy simulations, showed that some have the potential to provide significant energy and demand savings relative to existing vapor compression cooling systems. However, these savings are climate and occupant behavior dependent. The current 5% market for low cost evaporative coolers is the most likely candidate for conversion to high performance coolers that offer greater comfort and better insurance against the installation of air conditioners.

Field testing presents a different set of challenges relative to laboratory testing, including site characteristics and constraints, installation issues, and occupant effects. All these factors make a direct performance comparison difficult, especially given the very small sample size.

Project results indicate the following:

1. Systems at four of the six sites (the three direct units and the OASys unit) performed close to manufacturers' nominal ratings. The Coolerado system and the Essick Air indirect-direct unit did not meet performance expectations. Installation and application issues were likely a major factor affecting the performance of the Coolerado. Average EERs normalized to a 78°F indoor setpoint, averaged 43.3 for the direct evaporative units, 50.9 for the OASys, 13.5 for the Coolerado, and 12.6 for the Essick indirect-direct system.
2. Hourly simulation evaluations were completed on a 1,600 ft^2 house prototype to predict advanced cooler energy savings relative to a standard SEER 13 air conditioner. Runs were completed for both retrofit and new construction cases. The retrofit results are more representative of current market opportunities since the penetration rate of evaporative

[27] The monitoring indicated slowly rising supply air temperatures as the clog was occurring. Supply air temperatures then reached an equilibrium condition at an acceptable, but underperforming level. Without monitoring, this problem may not have been diagnosed.

coolers in new construction is virtually zero. Projected energy savings for the retrofit cases range from 74-82% in the Sacramento (881 to 974 kWh) climate and 66-78% in the Fresno (2098 to 2478 kWh) climate. Customer savings based on a conservative \$.15/kWh rate assumption average \$140 per year in Sacramento and \$347 in Fresno. Normalized energy savings average 580 kWh/year for Sacramento and 1450 kWh/year for Fresno, per 1000 ft^2 of floor area.

3. Peak demand for each of the advanced systems and the standard SEER 13 unit were calculated based on the average Noon to 7 PM demand over the consecutive three hottest summer days. Projected coincident peak demand savings relative to the standard SEER 13 air conditioner range from 64-78% in Sacramento (2.21 to 2.71 kW), and 70-83% (3.04 to 3.59 kW) in Fresno. Normalized demand savings average 1.60 kW for Sacramento and 2.09 kW for Fresno, per 1000 ft^2 of floor area.
4. Although none of the systems maintained comfort within the ASHRAE 55 comfort envelope on the hottest days of the summer (largely due to high indoor humidity), the homeowners felt that the advanced units tested provided improved indoor comfort and higher airflow than their prior units. The Coolerado unit came closest to meeting the ASHRAE comfort requirements, but excessive duct losses and lower than expected effectiveness reduced the delivered cooling to the indoor space.
5. The cost of the advanced coolers installed in the project is very high relative to the mass-market aspen pad units available at big box retail stores. The advanced coolers cost roughly four to seven times as much as a basic aspen pad unit. Current economics are marginal, but would improve if time-of-use electric rates were to become the norm. Actual project installed equipment costs for most of the advanced coolers are roughly comparable to typical SEER 13 retrofit costs, suggesting that for economics to be improved, these advanced systems must move beyond their current niche market status.
6. For all but the Coolerado unit, average water use ranged from 12 to 54 gallons per day (average of 33 gallons per day). The Coolerado consumed an average of 160 gallons/day. Water use is an important issue for the evaporative cooler industry to address and minimize.
7. Contractor attention to detail and follow through on system commissioning procedures appears to be consistent with the problems common to vapor compression installation. Despite the relative simplicity of evaporative coolers, two of the sites had installation/commissioning problems.

Recommendations for Future Work

The following recommendations for additional work are offered to reduce market barriers and to capitalize on the energy savings and load reduction potential that evaporative coolers can provide:

1. Conduct demonstrations and testing of advanced evaporative coolers in new residential buildings. Evaporative cooling must enter the new construction market to achieve higher visibility for these advanced technologies and to achieve energy and demand savings by displacing vapor compression air conditioning. Continuing field monitoring

demonstrations in new energy-efficient homes are needed to effectively demonstrate the technology and to see how systems perform on efficient homes. Lower cooling loads translate to less cooler operating time, improved comfort, and better setpoint control on peak days. Testing on new efficient homes is an important step in assessing the potential for mass-market acceptance.

2. Support hybrid evaporative cooler system research and testing through the Energy Commission's PIER program and other avenues. A hybrid system could integrate a downsized compressor with advanced evaporative technology to provide additional capacity on the design cooling days where many evaporative systems struggle to meet the load, and could include controls that would solve the problem of when to apply evaporative and vapor compression cooling.
3. Support and advance efforts to develop a water-to-energy equivalence metric. The water-energy trade-off is an important issue affecting water agency and broader environmental acceptance of evaporative cooling technologies as a beneficial technology. The current Title 24 Building Standards utilize a Time Dependent Valuation for energy on an hourly basis. A similar approach could be developed for water.
4. Support the development of an evaporative cooler application manual. Such a manual would help guide architects, builders, and other decision-makers in the selection of cooling equipment that is appropriate to the climate and the needs of the homeowner; and would convey useful information on maintenance and energy savings.
5. Develop an evaporative cooler rebate program to encourage replacement of existing low cost, low performing coolers with advanced evaporative coolers. Market barriers in this sector should be lower because ducting for evaporative cooling is already in place resulting in lower installation cost. Also, homeowners would be less likely to have an aversion to evaporative cooling. This type of program could be used to "prime the pump" and help manufacturers develop an installation and service infrastructure that could lead to lower installed costs, and expansion to other markets. This replacement program would also help prevent conversions to air conditioning

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Pacific Gas and Electric Company. 2006. *Laboratory Evaluation of the Coolerado Cooler Indirect Evaporative Cooling Unit.* PG&E Technical and Ecological Services Report No. 491-05.6.

Pacific Gas and Electric Company. 2006. *Laboratory Evaluation of the OASys Indirect/Direct Evaporative Cooling Unit.* PG&E Technical and Ecological Services Report No. 491-06-12.

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Appendix A:

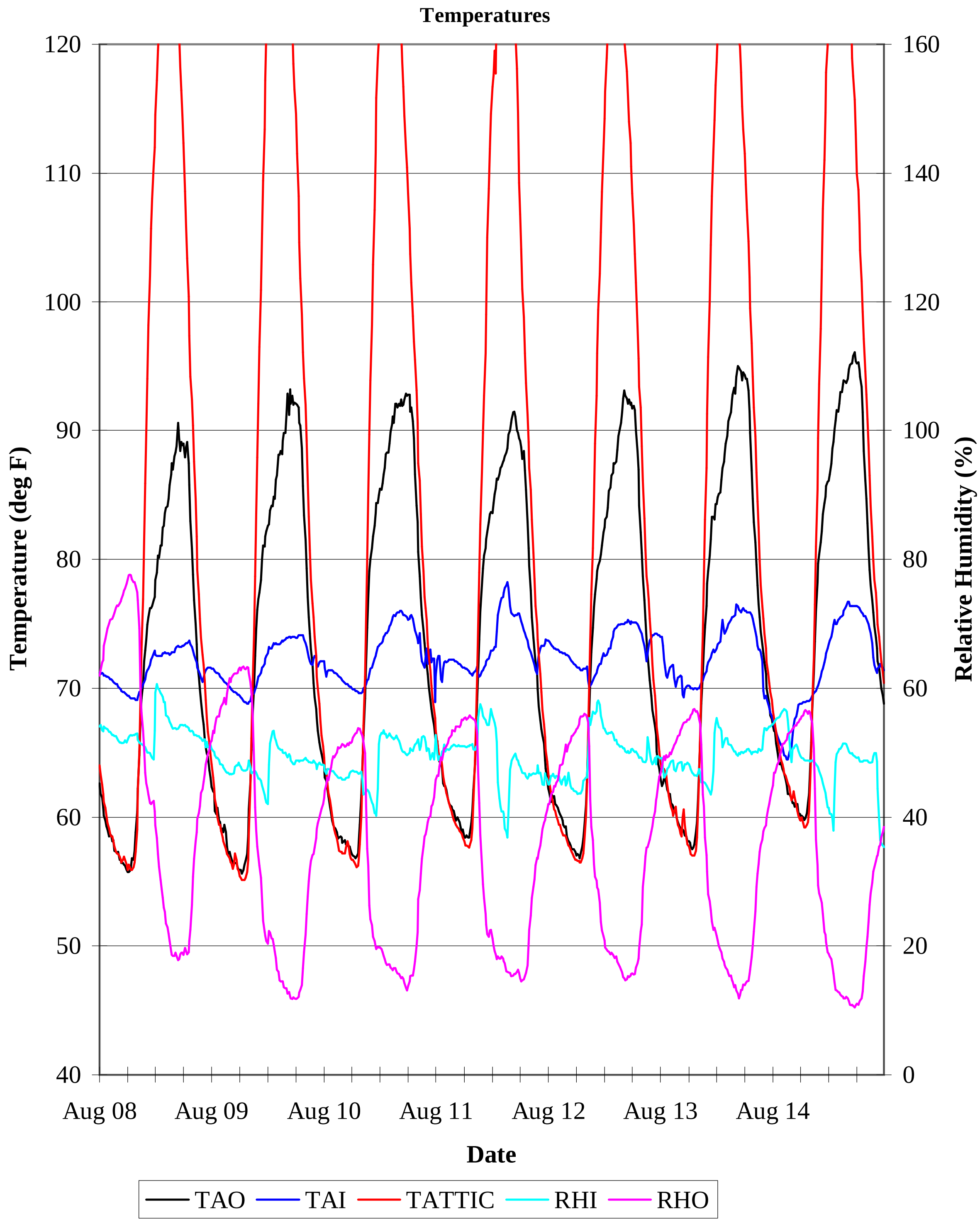
Sample Weekly Monitoring Report

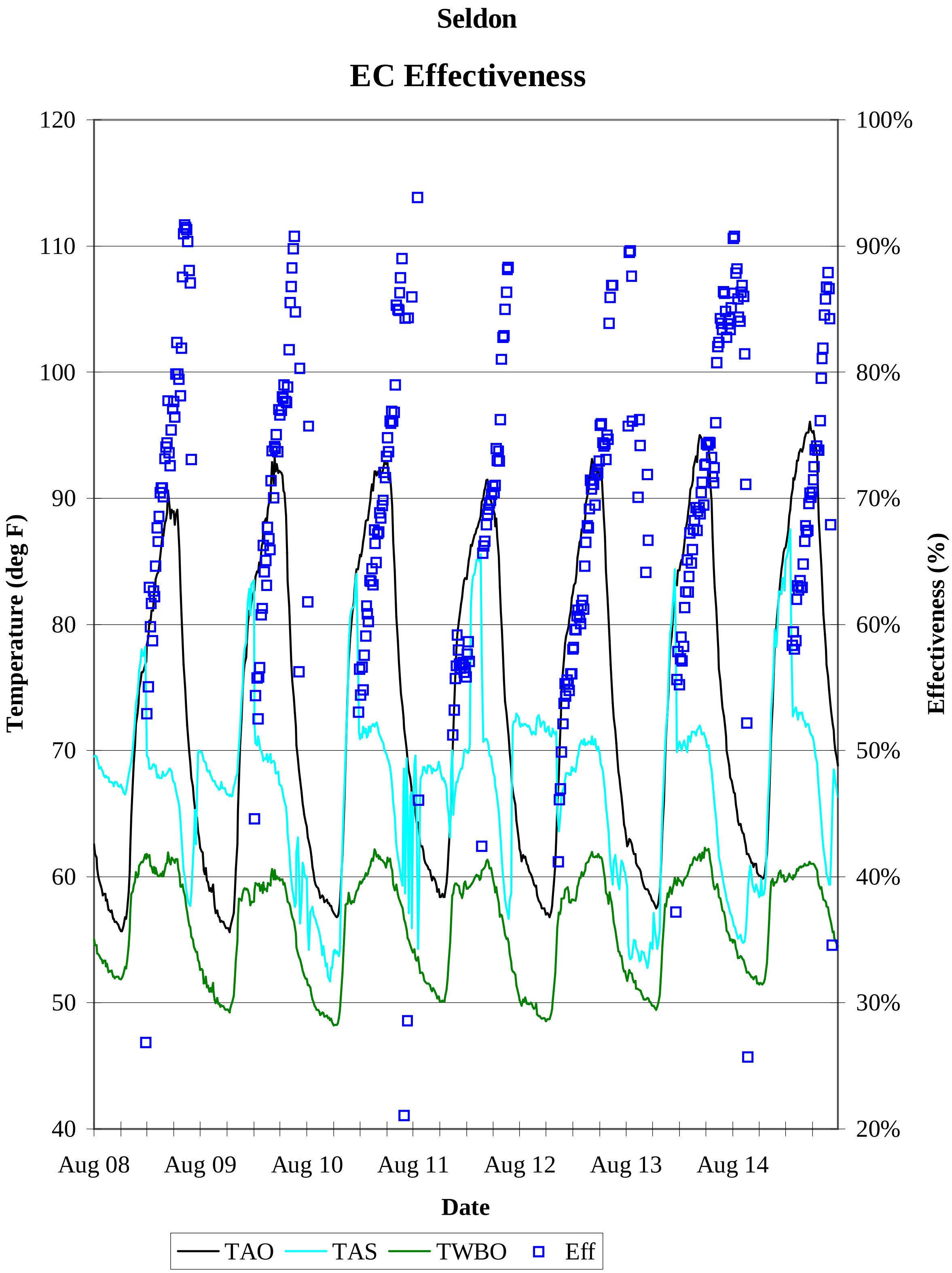
PG&E Evap Cooler Weekly Monitoring Check

Start Date:	August 08 00:00	Site:	Seldon
Stop Date:	August 14 23:45		
Missing:	0		

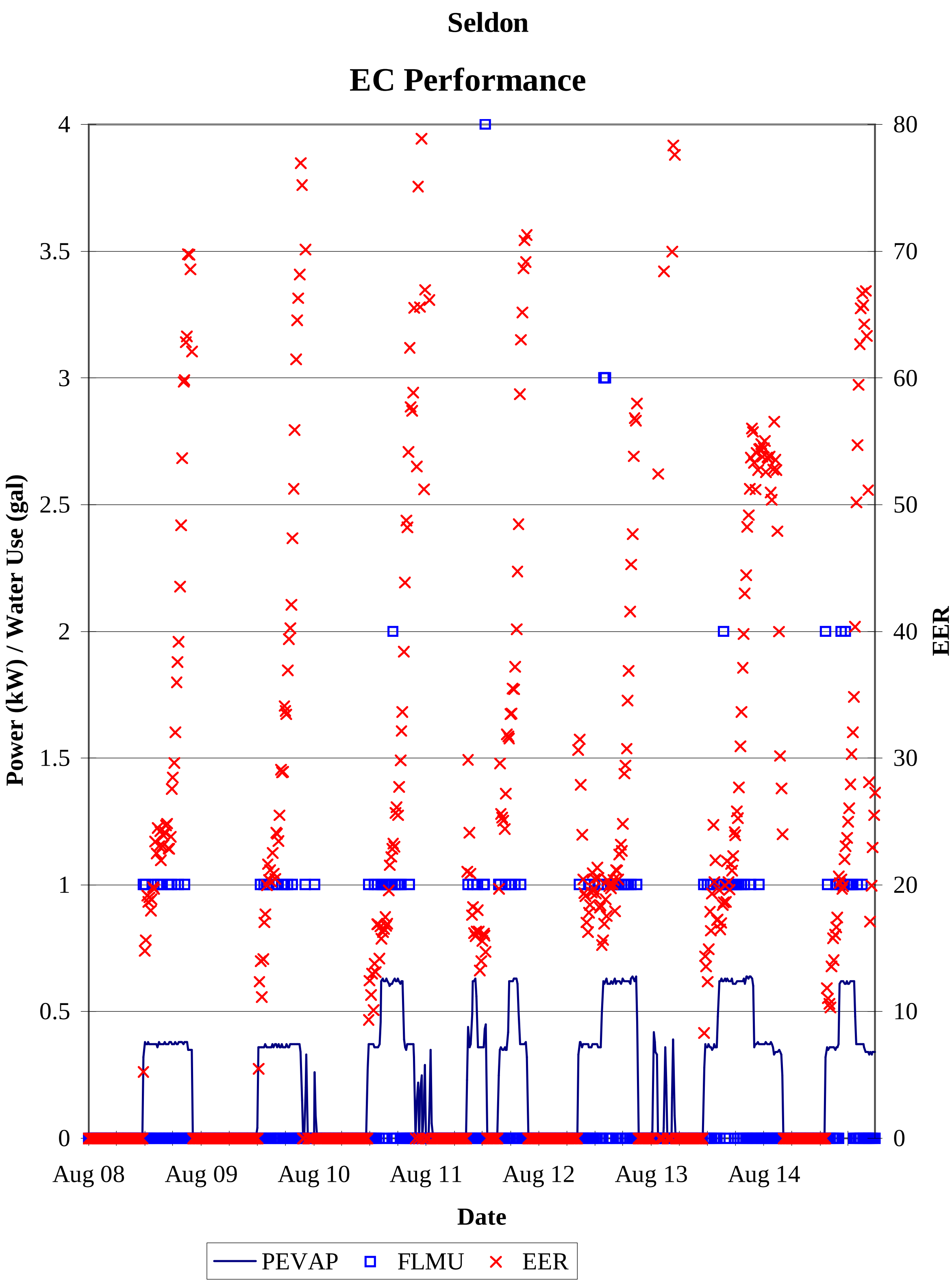
Point	Units	Average	Min	Time of Min	Max	Time of Max
TAI	deg F	72.3	64.5	Aug 14 03:00	78.2	Aug 11 15:15
RHI	%	49.5	35.3	Aug 14 23:45	60.7	Aug 8 12:15
TAO	deg F	74.1	55.6	Aug 9 06:30	96.1	Aug 14 17:30
RHO	%	36.4	10.4	Aug 14 17:30	77.6	Aug 8 06:30
TAS	deg F	67.1	51.7	Aug 10 05:15	87.5	Aug 14 13:00
TATTIC	deg F	86.9	55.1	Aug 9 06:30	136.5	Aug 14 14:30
PEVAP	kWh/kW	37.6	0.000	Aug 8 00:00	0.640	Aug 12 20:00
FLMU	Gallons	143	0	Aug 8 00:00	6	Aug 9 12:15
QCS	kBtu/Btuh	-1217	-36236	Aug 12 20:45	2676	Aug 14 13:15
PLR	hours/frac	84.0	0	Aug 8 00:00	1	Aug 8 12:00

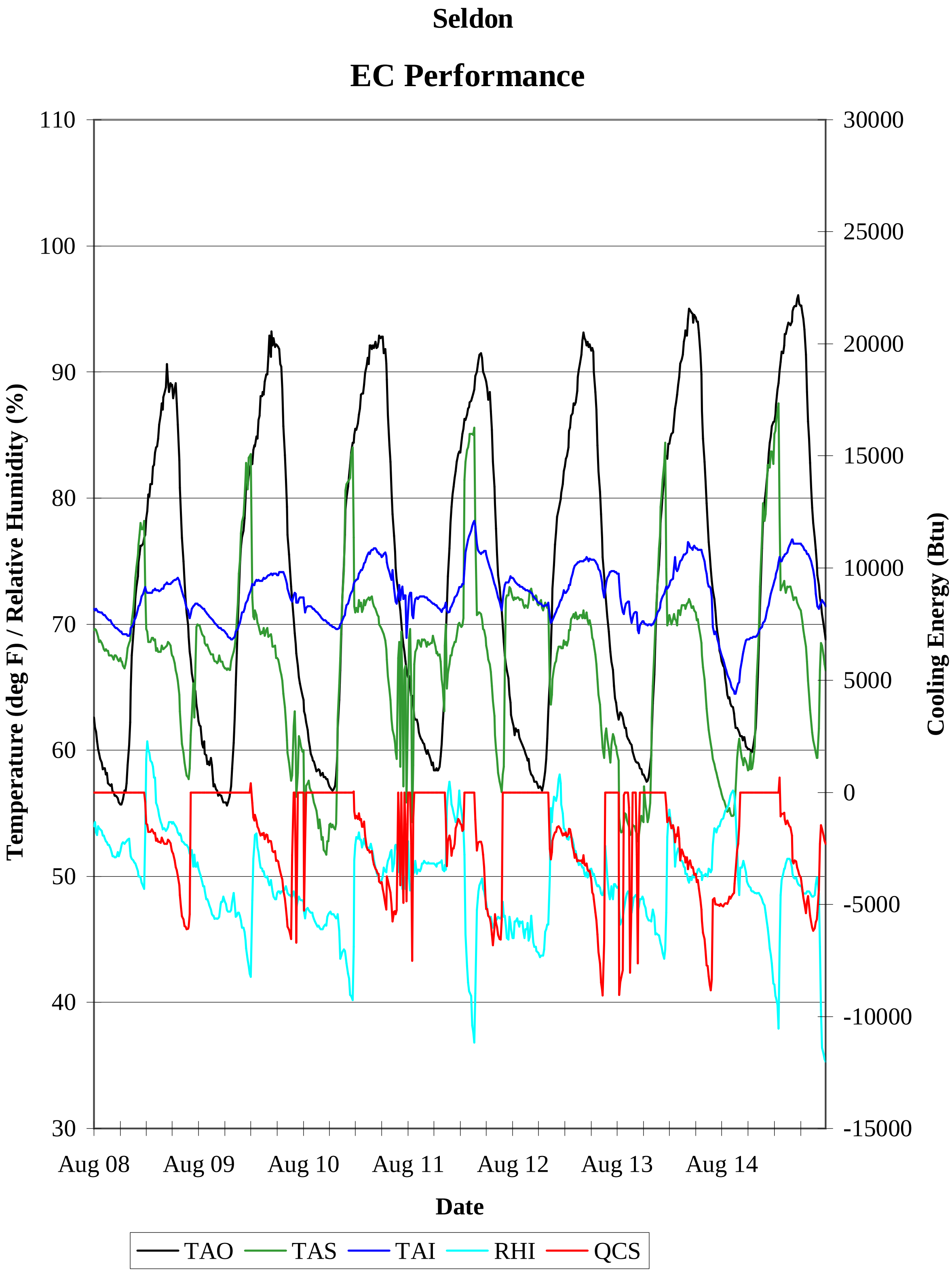
Seldon


Temperatures
Temperature (deg F)
Relative Humidity (%)
120
110
100
90
80
70
60
50
40
160
140
120
100
80
60
40
20
0
Aug 08
Aug 09
Aug 10
Aug 11
Aug 12
Aug 13
Aug 14
Date
TAO
TAI
TATTIC
RHI
RHO



Seldon
EC Effectiveness
Temperature (deg F)
Effectiveness (%)
120
110
100
90
80
70
60
50
40
100%
90%
80%
70%
60%
50%
40%
30%
20%
Aug 08
Aug 09
Aug 10
Aug 11
Aug 12
Aug 13
Aug 14
Date
TAO
TAS
TWBO
Eff


Seldon
EC Performance
Power (kW) / Water Use (gal)
EER
Date
0
0.5
1
1.5
2
2.5
3
3.5
4
0
10
20
30
40
50
60
70
80
Aug 08
Aug 09
Aug 10
Aug 11
Aug 12
Aug 13
Aug 14
PEVAP
FLMU
EER


Seldon
EC Performance
Temperature (deg F) / Relative Humidity (%)
Cooling Energy (Btu)
110
100
90
80
70
60
50
40
30
30000
25000
20000
15000
10000
5000
0
-5000
-10000
-15000
Aug 08
Aug 09
Aug 10
Aug 11
Aug 12
Aug 13
Aug 14
Date
TAO
TAS
TAI
RHI
QCS

Appendix B:

Advanced Cooler Product Literature

Product literature follows for Breezair, Coolerado, Essick Air (both direct unit and the IM70 indirect module), and OaSys.

High powered cooling at your fingertips.

The Breezair Elite™ Series of evaporative coolers combines unsurpassed cooling capability with incredible convenience in two great models:

- The variable speed Breezair Elite EX™ evaporative cooler features a remote control that allows you to select the amount of cooling you need and automatically drain the cooler with the push of a button. The Elite EX™ also includes an exclusive Seeley Water Manager and Automatic Drain System as standard equipment.
- The original Elite™ model offers your choice of a 2-speed motor or variable speed motor with SensorTouch™ climate control. Both the Water Manager and Automatic Drain System are optional on the original Elite model.

Advanced Technology

- Structural polymer cabinet will not corrode
- Exclusive water distribution system won't clog
- Dynamically balanced structural polymer fan is whisper quiet
- Chillcel™ pads provide maximum saturation effectiveness
- Sealed bearings never need oiling

Exclusive Warranty

- Cabinets guaranteed corrosion-free for 25 years
- Structural components guaranteed for 10 years
- Pump, motor & junction box guaranteed for 2 years

Call your Breezair representative. And put high powered cooling at your fingertips...today!

Breezair™

Specifications

The Breezair Elite™ Series comes with the following features:

Remote Control System: Features a programmable handset with three modes of operation, including a “drain” selection (not available on the original Elite model).

Cabinet & Louver Panels: Constructed from molded high strength structural polymers with built-in telescoping support legs.

Fan: Double inlet/width, forward curved centrifugal fan molded in one-piece polypropylene. Stainless steel hollow fan shaft square sectioned for stability.

Bearings: Supported in single row radial ball bearings, prelubricated and sealed with double routing seals. Adjustable motor pulleys.

Safety Features: On board isolation switch, overload circuit breaker protection on pump and motor circuits, thermal protection on water pump and motor.

Fan Housing: Molded high strength structural polymer, complete with integral bearing housing.

Water System: Non-corrosive plastic float valve. Patented tray style water distribution system can never be blocked.

Filter Pads: Takes four Chillcel™ 3.5” pads with water distribution header block.

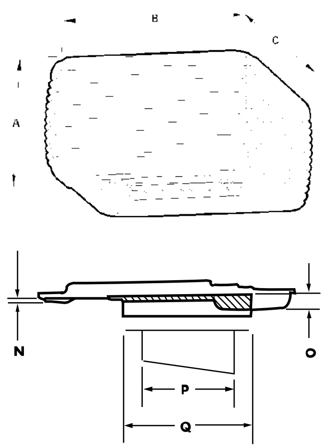
Tornado™ Water Pump: Water-tight, thermally protected, compartmentalized motor.

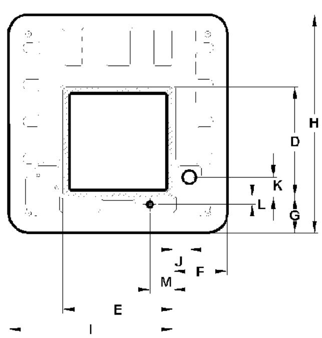
Water Manager: Because it monitors water quality electronically, the Water Manager detects harmful impurities in the water ***before*** they build up on cooler pads and reduce cooling efficiency (optional with the original Elite model).

Automatic Drain System: Eliminates the algae and dirt build-up common to evaporative coolers because it enables the cooler to be completely clean and dry when it's not in use, thereby eliminating odors and reducing maintenance (optional with the original Elite model).

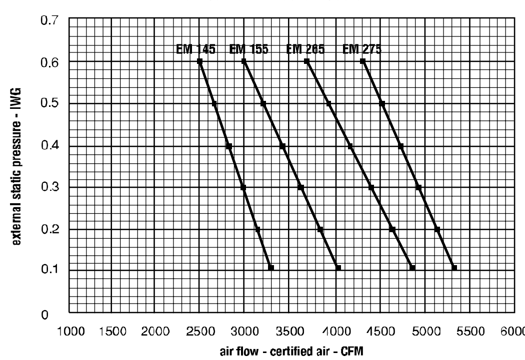
STOCK #	CABINET HEIGHT	CABINET WIDTH	CABINET DEPTH	DUCT OPENING	DUCT OPENING	DUCT LOCATION	DUCT LOCATION	DUCT LOCATION	DUCT LOCATION	DRAIN LOCATION	DRAIN LOCATION	WATER VALVE LOCATION	WATER VALVE LOCATION	TANK DEPTH	TANK DEPTH	ROOF JACK OPENING	ROOF JACK TOP FLANGE
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
EM 1	26	45.66	45.66	19.75*	19.75*	11.75	8.25	45.25	32	4.25	3.25	2.5	3.66	1.5	3.33	17.75*	21.75
EM 2	34	45.66	45.66	19.75	19.75	11.75	8.25	45.25	32	4.25	3.25	2.5	3.66	1.5	3.33	19.75	21.75

*NOTE: EM 145 and EM 155 are supplied with a 19.75 x 19.75 to 17.75 x 17.75 Transition Adaptor





Fan Curves - Breezair Coolers



Elite Model #	Industry STD Rating	Motor H.P.	Certified Air Delivery (CFM) (inches of static pressure) 0.0	0.1	0.2	0.3	0.4	0.5	0.6
EM 145	4500	.5	3450	3330	3180	3010	2900	2750	2540
EM 155	5500	.75	4240	4030	3830	3670	3470	3260	3020
EM 265	6500	.75	5080	4870	4640	4390	4130	3900	3670
EM 275	7500	1	5590	5380	5170	4980	4720	4530	4320
EX 155V	5500	.75	4240	4030	3830	3670	3470	3260	3020
EX 275V	7500	1	5590	5380	5170	4980	4720	4530	4320

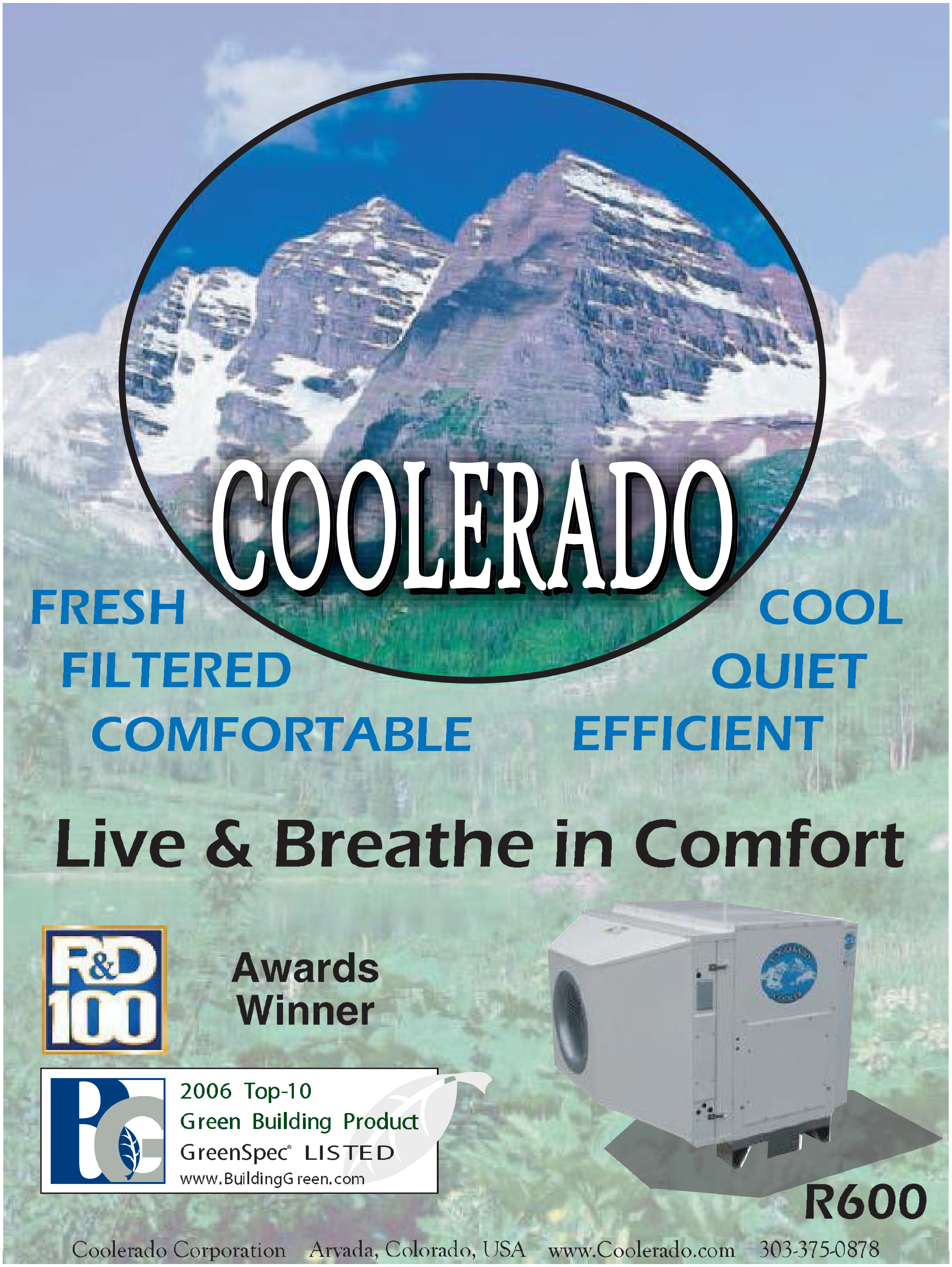
Elite Model #	Cabinet Size	High Speed Amps Two Speed	High Speed Amps Variable Speed	Water Reservoir (gal.)	Belt Length (inches)	Blower Pulley Pitch Diameter (inches)	Blower Wheel (inches) Diameter	Blower Wheel (inches) Width	Operating Weight (lbs.)	Breezair Seelectric™ 2-Speed & Variable Motors H.P.	Phase	Volts
EM 145	EM 1	5.9	5.1	3.7	48	8	15	15	156	.5	1	115
EM 155	EM 1	8.4	7.2	3.7	48	8	15	15	156	.75	1	115
EM 265	EM 2	8.4	7.2	3.7	57	9	18	15	172	.75	1	115
EM 275	EM 2	11	10.5	3.7	57	9	18	15	183	1	1	115

Stock # Area	Pad Dimension No	H	W	T	Effective (sq. in.)	Shipping Dimensions (including pallet) H	W	D	WT (lbs.)
EM 1	4	17.5	31.5	3.5	2200	30.5	45.66	45.66	132
EM 2	4	25	31.5	3.5	3150	38.5	45.66	45.66	145

For more information or to order the Breezair Elite Series and other fine products from Seeley International (Americas), call your Seeley representative today!

Global leaders in natural climate control solutions.™

Seeley International (Americas)
1202 North 54th Avenue
Building 2, Suite 117
Phoenix, AZ 85043 USA
602-353-8066
602-353-8070 FAX
www.breezaircooler.com


COOLERADO
FRESH
FILTERED
COMFORTABLE
COOL
QUIET
EFFICIENT
Live & Breathe in Comfort
R&D 100
Awards Winner
2006 Top-10
Green Building Product
GreenSpec® LISTED
www.BuildingGreen.com
R600
Coolerado Corporation Arvada, Colorado, USA www.Coolerado.com 303-375-0878

Features and Specifications — Coolerado R600

5 year limited warranty. EER 40+ (Energy Efficiency Ratio). Cooling capacity increases as temperature increases. No chemical refrigerants. Easy maintenance. Low water use. No moisture added to conditioned air. New, patented thermodynamic cycle.

1. 304 stainless steel pan, frame and internal components that directly contact water. Electro-galvanized and powder coated steel housing.
2. All electrical and plumbing connections can be interchanged to either side for installation flexibility. Integrated electrical panel and control system.
3. Tapered intake plenum increases fan efficiency and evens air distribution.
4. Tool-less air filter access from either side. Uses standard 1" or 2" thick filters.
5. Discharge plenum provided for easy ducting by cutting any size or shape hole into the plenum face.
6. Side panel access to the HMXs and drain. Can also be used for ducting exhaust or optional louver.
7. Two, ¼" diameter threaded bolts at each corner for easy addition of adjustable legs for sloped roof mounting.
8. Frame feet sized to receive nominal 2"x4" lumber for easy moving and rigging. Breaks down into three sections that will all fit in between 24" on center joists or rafters for installation in attics or crawl spaces.

Top View

Conditioned Air

Product air flow at 1,400 CFM without ducting losses (intake airflow at 2,800 CFM, and exhaust airflow at 1,400 CFM). Product air is cooled to approximately 90 percent of intake air's wet bulb at sea level without changing moisture content (product air will be approximately 1 percent cooler for every 1,000 ft increase in elevation).

Discharge Plenum View

42.5" Height

47.5" Length

Left Side

50.5" Width

Intake Air View

Right Side

Power

1250 Watts AC, 120V, 60Hz

Water

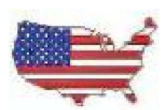
3/8" water supply line at 35 PSI

Weight

425 lbs dry (shipping), 525 lbs wet (operating)

Options

a. High efficient electronically commutated (EC) motor - 200-280V, 50-60Hz, 750 W maximum.
b. Auto-variable thermostat motor speed controller (available with high efficient motor).
c. Manual-variable motor speed control (available with high efficient motor).
d. Exhaust louver with drift eliminator.



Made in USA

Designs and specifications may change without notice.

- **The Complete Cooling System** Ready-to-Install Unit Includes Motor, Pump, Thermostat and Purge System
- **Thermostat & Purge System Included** Wall-Mounted, Low-Voltage Thermostat Provides a Comfortable Atmosphere. The Thermostat Dump Cycle Control Automatically Purges the Unit, Conserving Water and Eliminating Mineral Build-Up on Pads and Components.

- **Most Powerful** Unique Perforated Air Inlet Screen Provides More Airflow Than Competition
- **Low Maintenance** Rust-Free Structural Plastic Reservoir
- **High-Performance Rigid Media** Available in Two Sizes - 8" and 12" – For Total Cooling Comfort
- **Energy Efficient for Energy Savings** Uses Up to 75% Less Electricity Than Conventional Air Conditioning, and with Thermostat, Operates at Optimum Efficiency
- **Resist Impact & Weather** Tough Polyester Powder Coated Finish – Inside & Out!
- **Best Warranty** Limited-Lifetime Warranty on Cabinet Against Leakage Due to Rust Out
  5-Year Limited Warranty on Media
  2-Year Limited Warranty on Pumps
  1-Year Limited Warranty on Parts
- **UL Classified & Made in the U.S.A.**

50 SERIES COMPLETE COOLER PACKAGES

Packages With 8" Media

- Long-Lasting, High-Efficiency 8" Rigid Cellulose Media
- 28"H x 42"W x 45"D
- 3/4 HP, 2 Speed Motor
- Cools up to 1600 Square Feet

DOWN DISCHARGE MODELS

AD1C50 (115V Unit)

AD2C50 (230V Unit)

SIDE DISCHARGE MODELS

AS1C50 (115V Unit)

AS2C50 (230V Unit)

Packages With 12" Media

- Long-Lasting 12" Rigid Cellulose Media with Higher Efficiencies than 8" Media
- 28"H x 42"W x 49"D
- 3/4 HP, 2 Speed Motor
- Cools up to 1600 Square Feet

DOWN DISCHARGE MODELS

AD1C5012 (115V Unit)

AD2C5012 (230V Unit)

SIDE DISCHARGE MODELS

AS1C5012 (115V Unit)

AS2C5012 (230V Unit)

70 SERIES COMPLETE COOLER PACKAGES

Packages With 8" Media

- Long-Lasting, High-Efficiency 8" Rigid Cellulose Media
- 34-5/8"H x 42"W x 48"D
- 1 HP, 2 Speed Motor
- Cools up to 2200 Square Feet

DOWN DISCHARGE MODELS

AD1C70 (115V Unit)

AD2C70 (230V Unit)

SIDE DISCHARGE MODELS

AS1C70 (115V Unit)

AS2C70 (230V Unit)

Packages With 12" Media

- Long-Lasting 12" Rigid Cellulose Media with Higher Efficiencies than 8" Media
- 34-5/8"H x 42"W x 52"D
- 1 HP, 2 Speed Motor
- Cools up to 2200 Square Feet

DOWN DISCHARGE MODELS

AD1C7012 (115V Unit)

AD2C7012 (230V Unit)

SIDE DISCHARGE MODELS

AS1C7012 (115V Unit)

AS2C7012 (230V Unit)

UP DISCHARGE MODELS

AU1C7012 (115V Unit)

AU2C7012 (230V Unit)

CFM* SPECIFICATIONS FOR CHAMPION ULTRACOOL COMPLETE COOLERS

SERIES	H.P.	CFM* INCHES STATIC PRESSURE 0	0.1	0.2	0.3	0.4	0.5	0.6
50 Series with 8" Media	3/4	3788	3630	3450	3260	3020	2806	2570
50 Series with 12" Media	3/4	3606	3472	3317	3135	2918	2661	2379

SERIES	H.P.	CFM* INCHES STATIC PRESSURE 0	0.1	0.2	0.3	0.4	0.5	0.6
70 Series with 8" Media	1	5024	4820	4630	4450	4280	4100	3900
70 Series with 12" Media	1	4941	4747	4572	4394	4208	3996	3749

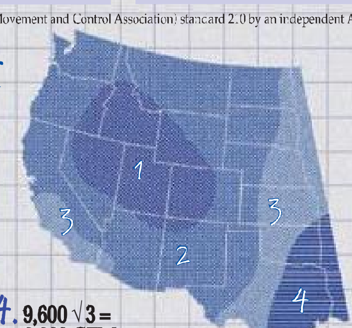
*Cubic Feet per Minute   CFM ratings are based on test data to AMCA (Air Movement and Control Association) standard 210 by an independent AMCA approved laboratory.

Sizing A Cooler

1. Consult zone map to find correct zone.
2. Consult table below to find correct "Minutes per Air Change" for your zone.
3. Determine area to be cooled in cubic feet (building length x width x height).
4. Divide cubic feet (step 3) by minutes per air change (step 2) to determine Cubic Feet per Minute (CFM).
5. Select the correct Champion Cooler model in the data table above according to CFM and expected static pressure. If CFM falls between models, choose the larger model.

EXAMPLE – What cooler is needed to cool a house in Phoenix, Arizona, 40 feet long by 30 feet wide with an 8 foot ceiling that is insulated and has no unusual heat sources?

1. Zone 2
2. Minutes per Air Change = 3
3. 30 x 40 x 8 = 9,600 cubic feet
4. 9,600 √ 3 = 3,200 CFM
5. Referring to the specifications charts, Champion UltraCool Complete 50 Series with a 3/4 horsepower motor is indicated assuming a typical static pressure of 0.2"W.G.



MINUTES PER AIR CHANGE

INTERIOR HEAT LOAD	EXTERIOR HEAT LOAD	ZONE 1	2	3	4
HIGH	EXPOSED	2	1.5	1.3	.7
HIGH	INSULATED	3	2	1.5	1
NORMAL	EXPOSED	3	2	1.5	1
NORMAL	INSULATED	4	3	2	1.3

- **INTERIOR HEAT LOAD:** High means places with unusual heat sources from hot equipment or processes, crowded conditions, etc. Normal means no unusual heat sources - typical home or office.
- **EXTERIOR HEAT LOAD:** Exposed means walls, roof exposed to sun, poor insulations, etc. Insulated means walls and roof well insulated and/or shaded.

CHAMPION COOLER

Designed with You in Mind!

5800 Murray Street
Little Rock, Arkansas 72209
1-800-643-8341
www.championcooler.com

MADE IN U.S.A.

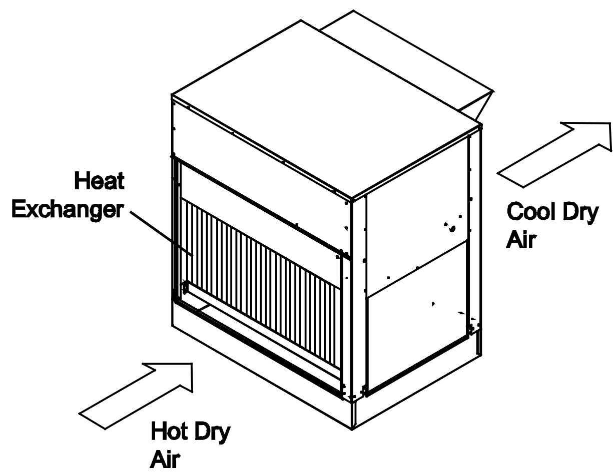
Catalog No. CCB-March 2005

Indirect Cooler Module
Users Manual

Model
IM70

2 Stage Evaporative Cooling

The IM70 indirect cooling module (ICM) is a pre-cooler used in 2-Stage or Indirect/Direct evaporative cooling. The ICM cools the air without adding any additional moisture. It accomplishes this by circulating water downward through a heat exchanger, while a fan draws air upward through the heat exchanger. This air and water are cooled by evaporation and in turn cool the walls of the heat exchanger. The removed heat is exhausted from the unit with the moist air. Hot, dry outside air is pulled horizontally through the cooled walls of the heat exchanger by the attached evaporative cooler. This air is cooled and since it does not contact water, there is no moisture added.



The dry air cooled by the ICM is then cooled more by the direct evaporative cooler. The dry bulb temperature of the air after going past the ICM drops as does the wet bulb or saturation temperature. This cooled dry air from the ICM is pulled through wet evaporative media in the direct evaporative cooler which cools the air and adds moisture. The temperature leaving the evaporative cooler is lower than what is possible without the ICM, often below the ambient wet bulb temperature.

The IM70 can be mounted directly to Champion's Ultracool 51 & 71 series evaporative cooler models for a complete 2-stage evaporative cooling process.

Safety Rules

1. Read instructions carefully.
2. Electrical hook up should be done by a qualified electrician, so that all electrical wiring will conform to your local standards.
3. Always Disconnect from Power Source before installing or performing any maintenance.
4. The IM70 will run on 120V A.C., single phase, 60 Hz (cycle) current only.
5. The pump and motor are equipped with an automatic thermal overload switch which will shut motor off when it overheats. The motor may start unexpectedly after it cools down.

Installation

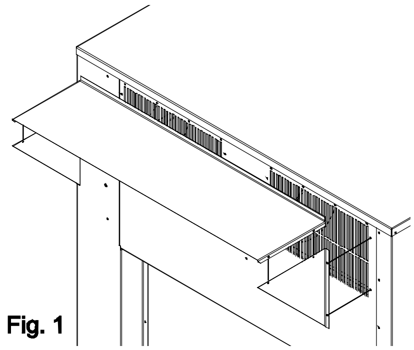


Fig. 1

⚠***CAUTION:*** **Make sure that the mounting surface is strong enough to support the operating weight of the cooler when in use. (For operating weight, see Specification Table.)**

⚠***CAUTION:*** **Never start cooler until installation is complete and unit has been tested for rigidity.**

- **Install rain guard.** A 3 piece rain guard kit is included with the unit. Refer to figure 1 for installation instructions. Place the flange of the top piece over the side piece and screw together with the provided screws. Repeat for both left and right sides. Slide the flange of the top section under the top pan. Screw the sides of the rain guard into the holes in the exhaust panel.

- **Mount unit to the evaporative cooler.** For two stage evaporative cooling, attach the IM70 to an Ultracool 51 or 71 unit (sold separately). Remove the perforated grill on the Ultracool. Attach weather stripping (not supplied) around the perimeter of the Ultracool. Slide the IM70 next to the cooler making sure the units fit snugly together. Using the provided mounting brackets and self drilling screws, locate the bracket below the top of the inspection panel on the IM70 (Fig. 2). Attach using the provided screws. Making sure that there is a good fit between the IM70 and the cooler, screw the self drillers into the cooler to lock it into place. Repeat for opposite side. Install the perforated grill removed previously to the rear of the IM70.
  Note: If this unit is mounted to another unit besides an Ultracool 51 or 71 series unit, you will need to purchase separately a 51 series perforated grill (part #222130-078).

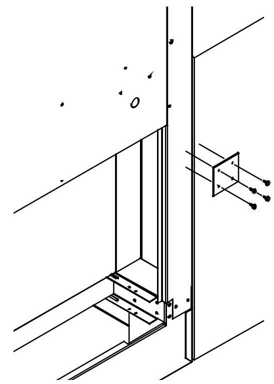


Fig. 2

Electrical Installation

⚠***WARNING:*** **Disconnect all electrical service that will be used for this unit before you begin the installation.**

- **Remove junction box.** The electrical junction box is located inside the unit above the inspection panel door. Remove two screws and slide the junction box down to gain access to wiring (Fig. 3).

- **Hook up electrical.** Electrical hook up should be done by a qualified electrician, so that all electrical wiring will conform to your local standards. This unit is suppled with a 120V pump and fan motor. See figure 4 for the wiring diagram.

⚠***WARNING:*** **Make sure the cooler cabinet is properly grounded to a suitable ground connection for maximum safety.**

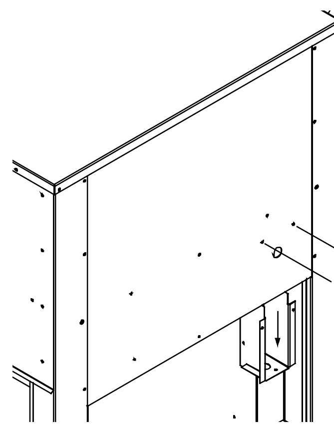


Fig. 3

Wiring Diagram

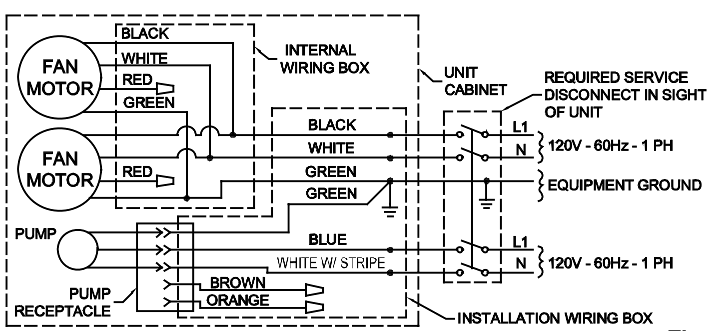


Fig. 4

Water Connection

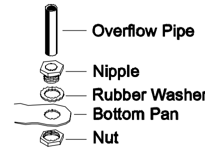


Fig. 5

- **Install overflow assembly.** Place drain nipple through the hole in the bottom pan, with the rubber washer between the pan and the head of the drain nipple (Fig. 5). Screw on nut and draw up tight against bottom of pan. Insert the overflow pipe in the nipple to retain water. The overflow pipe may be removed to drain the pan when necessary. A garden hose may be screwed onto the drain nipple to drain water away from your unit.

- **Connect water supply line.** Find the closest supply of water. Run 1/4" tubing from the unit to the water supply. You may use a saddle valve (Fig. 6) to connect 1/4" tubing to the cold water supply or a Sillcock and water valve connected to an outside faucet (Fig. 7). Place the nut and ferrule on the tubing and tighten the nut until water tight. Insert the tubing into the float hole of the corner post. Remove the perforated grill if installed to have access to the float. Attach the tubing to the float using a nut and ferrule. Tighten until water tight. **IMPORTANT:** Do not connect the water supply to any soft water applications. Soft water will cause corrosion and decrease the life of the unit.

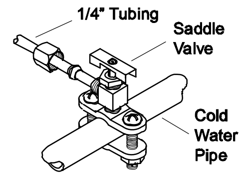


Fig. 6

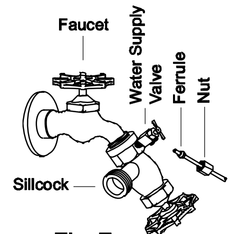


Fig. 7

- **Fill pan.** Allow water to fill to approximately 3" in the bottom pan and adjust the float to maintain this water level. This can be accomplished by bending the float rod.

Maintenance

⚠*WARNING:* **Before doing any maintenance be sure power is off. This is for your safety.**

Spring Start-Up

- **Clean heat exchanger.** Clean the inlet face of the heat exchanger with a garden hose. Remove any obstruction and lightly clean any scale buildup. To clean the top of the heat exchanger, remove the top pan. Remove the media brackets holding the filters in place and remove the filters. Cover up the blower housings so no water comes into contact with the motors. Clean with a hose, removing any obstruction and scale buildup.

- **Clean or change filters.** There is a 3 piece filter set located under the heat exchanger. Remove the inspection panel to access these filters. Remove the filters and clean out the openings with a garden hose. Clean off the face any scale or other obstruction to the passages. Slight scraping may be required to remove hardened scale. There are also mist eliminating filters above the water distribution system. Remove the top pan to gain access to these mist eliminating filters. The media brackets will need to be removed before removing the mist eliminating filters. If cleaning the mist eliminating filters while in the unit, make sure to cover the fan blower housings so that water does not come in contact with the motors. The filters should be replaced after 5 years or when necessary.

- **Clean pump.** Periodic cleaning of the pump will prolong the life and efficiency of the pump. For your safety, make certain the unit is disconnected from the power source before servicing pump. Remove the pump from the pump mount. Refer to figure 8 for disassembling the pump. DO NOT open the sealed portion of the unit or remove housing screws. Remove the intake screen. Remove the volute mounting screws. Lightly clean any corrosion or debris which may clog the impeller. Use a brush and penetrating oil and lightly scrape to remove encrusted material. Turn the impeller by hand to make sure it turns freely. After cleaning, reinstall in reverse order. Do not forget to replace the water delivery tube onto the pump outlet.

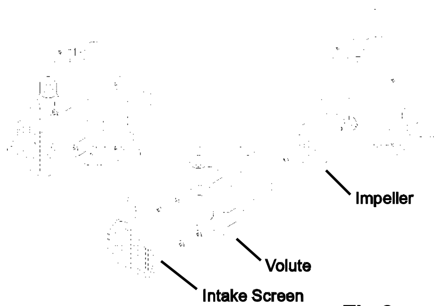


Fig 8

- **Clean bottom pan of any debris.**

Winter Shut-Down

- **Drain water.** Always drain all of the water out of the unit and water supply line when not in use for prolonged periods, and particularly at the end of the season. Keep the water line disconnected from both the unit and water supply so that it does not freeze.

- **Unplug pump.** When cooler is not used for extended periods unplug the pump from inside cooler.

- **Cover unit.** To protect the life of the finish, a cover for the unit is suggested in extended periods of non use.

Replacement Parts List

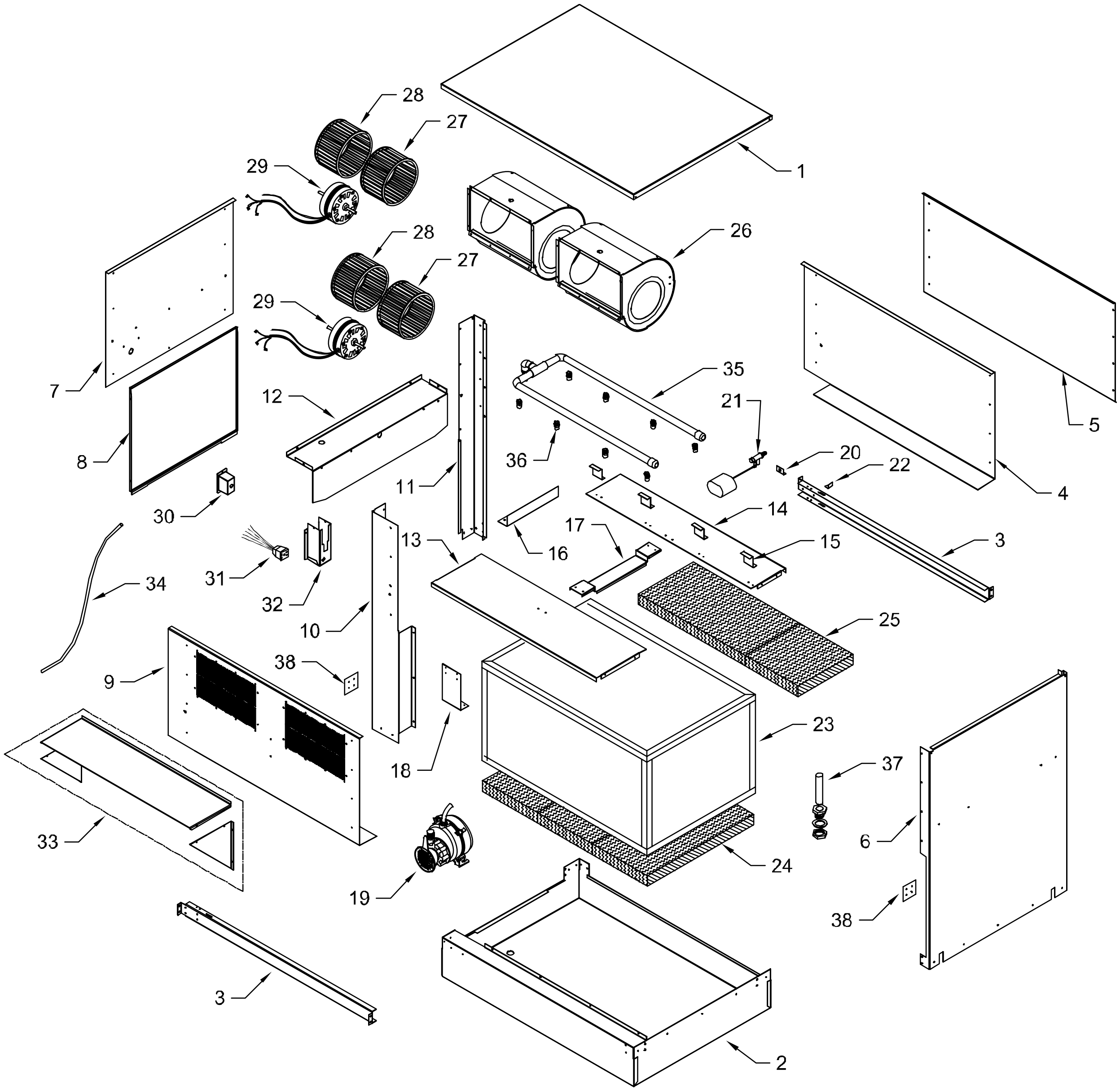
When ordering parts, please be sure to furnish the following information on all orders. Failure to do so may delay your order.

1. Cooler model number
2. Cooler serial number
3. Description and part number
4. Date of purchase

No.	Description	IM70
1.	Top Pan	222150-001
2.	Bottom Pan	322150-002
3.	C-Channel Bracket (2)	216150-001
4.	Inlet Panel	222150-006
5.	Grill Insert Panel	222150-013
6.	Left Side Panel	2 22150-005
7.	Right Side Panel	222150-010
8.	Inspection Panel	22 2150-016
9.	Outlet Panel	220150-001
10.	Corner Post, Outlet	222150-003
11.	Corner Post, Inlet	2 22150-004
12.	Side Filler Panel	222150-009
13.	Outlet Support Bracket	22015 0-003
14.	Inlet Support Bracket	220 150-004
15.	Media Bracket (4)	22 2150-007
16.	Media Filler Panel	222150-015
17.	Water Distributor Support Bracket	222150-008
18.	Pump Mounting Bracket	220150-0 02
19.	Pump	110437
20.	Float Mounting Bracket	222150 -014
21.	Float Valve	FL-C
22.	Squaring Bracket	22 0150-005
23.	Heat Exchanger	110140
24.	Filter Pad	310105-101
25.	Mist Eliminator Filter Pad	31010 5-201
26.	Blower Housing (2)	324 102-005
27.	Blower Wheel, Left (2)	1107 47
28.	Blower Wheel, Right (2)	110748
29.	Blower Motor (2)	1 10441-C
30.	Fan Motor Junction Box	281004- 002
31.	Receptacle, Pump	1103 61
32.	Electrical Junction Box	3220 09-004
33.	Rain Guard Kit	322150-011
34.	Water Delivery Tube	3107 17
35.	Water Distributor Assembly	3D-29
36.	Nozzles (8)	110141
37.	Over Flow Assembly	3OA-2
38.	Connecting Bracket (2)	220150-006

NOTE: Standard hardware items may be purchased from your local hardware store.

Parts Drawing



Specifications

Model	Voltage	Total Fan Motor Amperage	Pump Amperage	Approx. Reservoir Capacity	Weight (Lbs.)	
					Shipping	Operating
IM70	115 V	*8 Amps	1.5 Amps	17 Gal.	240	377

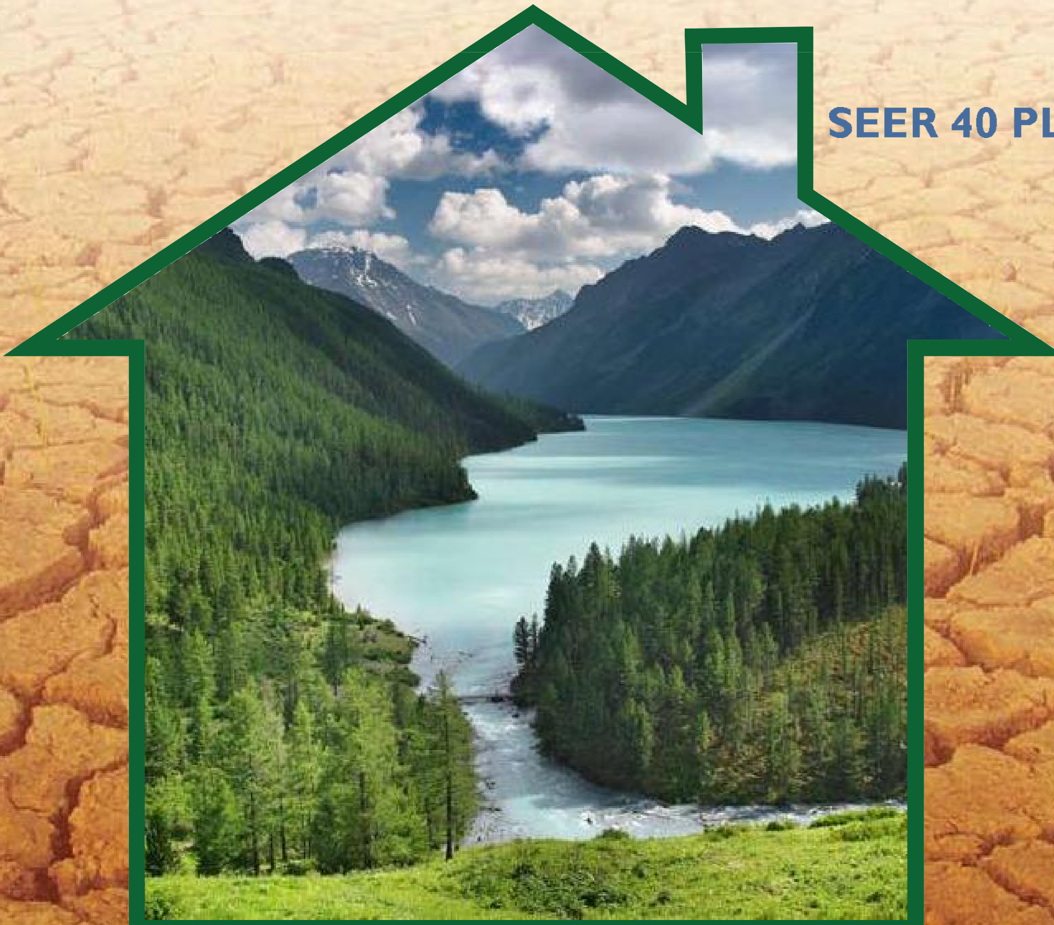
* Motor amperage is for 2 motors.

CHAMPION COOLER LP
5800 Murray St.
Little Rock, AR 72209
(800) 643-8341

www.championcooler.com

OASys™

HYBRID Air Conditioner with IDAC TECHNOLOGY



SEER 40 PLUS

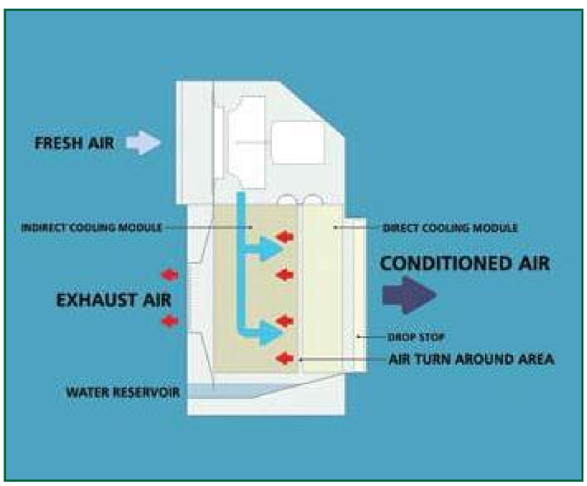
THERE'S A CHANGE IN THE AIR®

...AND IN YOUR ENERGY BILL

The OASys Advantage

- **80% REDUCTION** in energy consumption (SEER 40+)
- **SUPERIOR AIR QUALITY** - continuous fresh air
- **COOLS** without environmentally threatening CFCs
- **ECONOMICALLY** compatible with renewable energy sources
- **MULTI-SPEED** motor maintains set temperature and maximizes comfort
- **OPTIMIZES** indoor air humidity level
- **ENGINEERED** for quick serviceability and low maintenance

How Does OASys Work?



THE HEART OF OASys is the Indirect Cooling Module (ICM) which first cools incoming fresh air without adding moisture. The air then passes through the Direct Cooling Module (DCM), is cleansed and humidity is optimized. The cooled air enters the space directly or through conventional duct configurations and exits by roof vents or other openings.

THE SMALL AMOUNT of water used in this process is renewed periodically by a self-purging reservoir. This waste water can be used to irrigate landscaping or garden areas. The OASys cools, cleans and circulates the air using less than 600 watts.

OASys *and* Fresh Air

A STUDY conducted by the Lawrence Berkeley National Laboratory supported by the California Energy Commission concluded that:

- **CONTINUOUS** supply of outside air removes indoor pollutants.
- **OASys USE** was effective in controlling indoor generated pollutants such as formaldehyde.
- **OASys PROVIDES** thermal conditioning comparable to conventional systems
- **OASys USED** less energy
- **OASys CAN** simultaneously improve indoor environment quality and reduce energy expenditure

OASys Saves Energy *and* Money
without Sacrificing Comfort

Life Cycle Cost Comparison

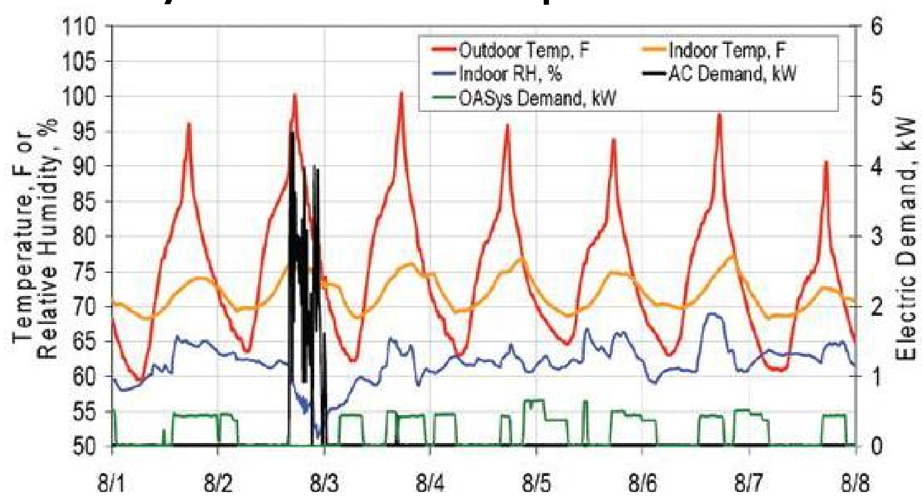
According to the National Appraisal Institute (Appraisal Journal - Oct 1999), a home's value increases $20 for every $1 reduction in annual utility bills.

	Base Model Compressor	High Efficiency Compressor	OASys
Capacity (tons)	3	3	3
Energy Efficiency Ratio	10	13	56
Energy Cost	$0.15	$0.15	$0.15
Annual Energy Cost	$1,130	$869	$176
Annual Energy Savings		$261	$954
Lifetime Energy Cost	$11,933	$9,179	$1,856
Lifetime Energy Savings		$2,754	$10,077

Calculations are from the U.S. Department of Energy, Federal Energy Management Program Energy Star calculator
All calculations use Palm Springs CA @ $.15kWh
Lifetime Energy Cost is the sum of the discounted value of annual energy costs based on assumed air conditioner life of 15 years.
OASys EER from PG&E Emerging Technologies Program report Test Data Summary Outside Air EER

INDEPENDENT FIELD TESTING conducted by Steven Winters Associates for the HUD PATH program proves OASys saves money without sacrificing comfort. "Ultimately, comfort is the most important performance aspect of any cooling system. The Sacramento house provided a unique opportunity to evaluate the comfort performance of the OASys in that the homeowners always had the option of operating their existing 5-ton AC system.

OASys SEER 40 Plus Demand Comparison: Sacramento Site



THIS CHART presents the indoor temperature and relative humidity conditions in the house during a typical summer week along with outdoor temperature. The electric demand due to the AC and the OASys are also noted on a separate scale on the right side of the graph. During this week, the OASys was operated in both day time evaporative cooling and night ventilation cooling modes. Over the course of this seven day period, the homeowners only operated the AC for a few hours during the evening of 8/3 when the outdoor ambient temperature reached 100 oF. During the six afternoon periods when the OASys alone was used for cooling, indoor temperatures did not exceed 76 oF. Corresponding relative humidity was between 60% and 70% RH."

COOLING using OASys cost about five cents per hour while cooling using the five ton AC unit cost over thirty cents per hour - more than six times as expensive.

OASys For the Right Geography

OASys COOLING is effective wherever the mean coincident wet bulb temperature is below 70 degrees For humidity is below 60%.

The Wise Choice

COMPERABLE COOLING and improved indoor environment quality with 80% reduction in energy cost and less expensive installation.

Flexible Installation

OASys MAY be installed on the roof, wall mounted or on a concrete pad. There is a clean attractive solution for every space.

2.5-3 Ton Cooling Capacity

THE BASIC OASys MODEL operates as a 2.5 to 3 ton air conditioner and produces 1,500 cfm of fresh conditioned air for residential, commercial or institutional spaces. Multiple units can be used in larger configurations. Because of its unique flexibility the OASys can efficiently air condition smaller spaces as well–for pennies a day.

Energy Savings

- SEER 40 PLUS
Improved Indoor Air Quality
Environmentally Responsible

THE CALIFORNIA ENERGY COMMISSION sponsored the development of the OASys Air Conditioner and achieved its goal of producing an enhanced energy efficient air conditioning system. OASys is a technological breakthrough in Indirect/Direct evaporative cooling. The key to OASys is a unique heat exchanger combined with a single pump/blower configuration. Unlike conventional air conditioning systems, which recirculate indoor air, OASys continuously conditions and delivers fresh outdoor air - the Outdoor Air System.

The OASys produces up to 3 tons of cooling while using less than 600 watts for an energy efficiency equivalent to better than 40 SEER. Switching to OASys cooling will result in an 80% energy savings without sacrificing comfort.

SPEAKMAN® CRS Clean Renewable Sustainable

Appendix C:

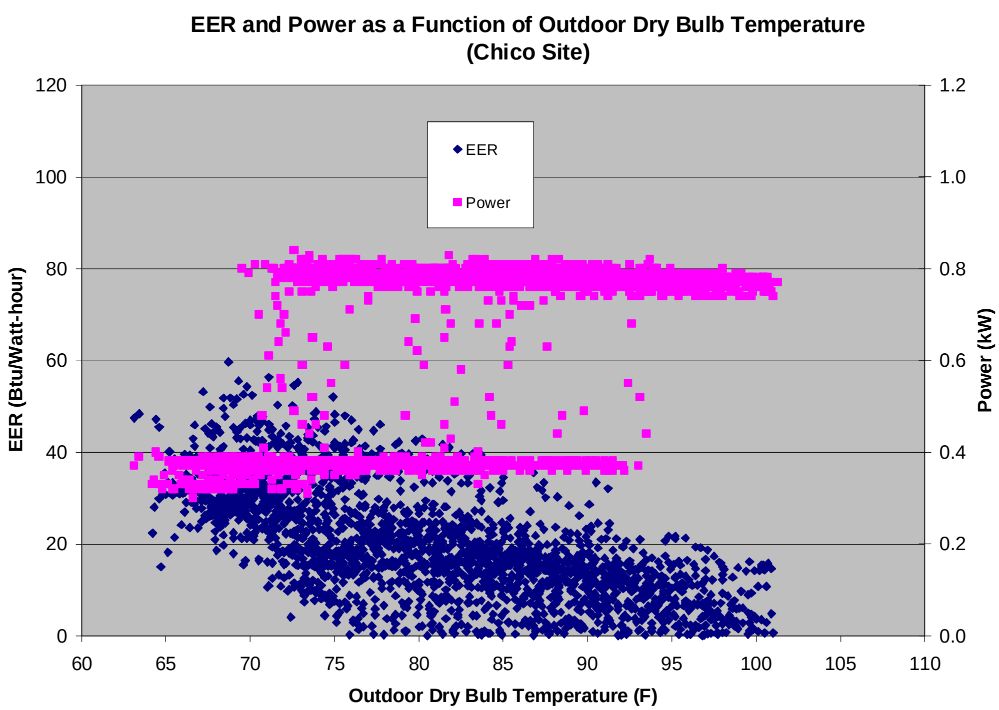
Detailed Monitoring Results

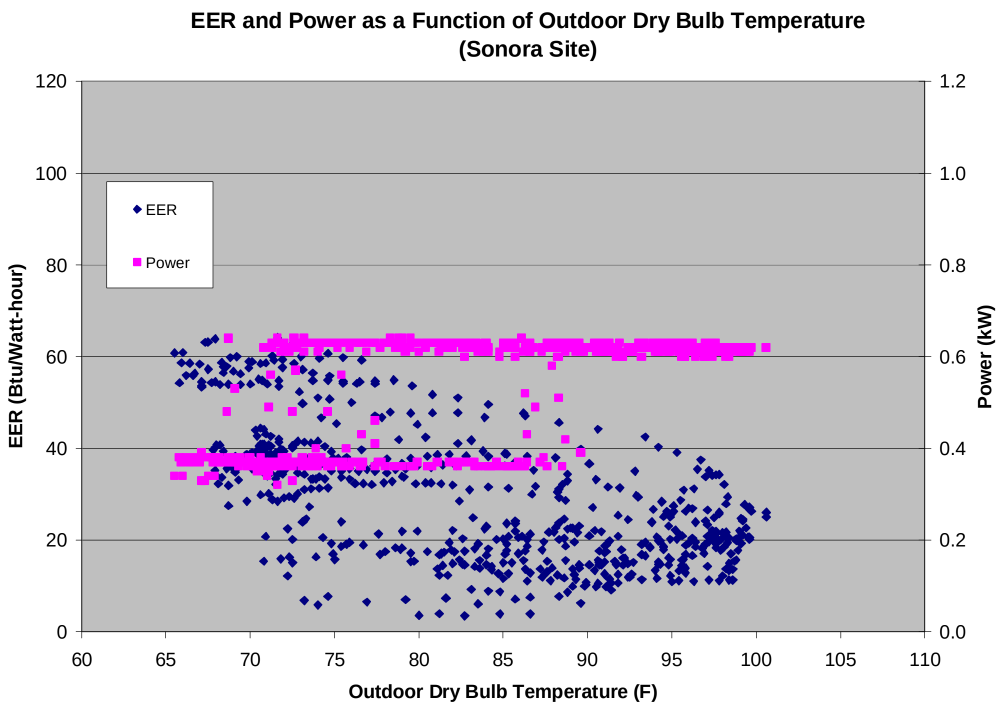
Two types of data are included in this Appendix. The first set represents performance data for the advanced coolers from each of the six sites, and the second set includes indoor comfort conditions superimposed on the ASHRAE 55 comfort envelope.

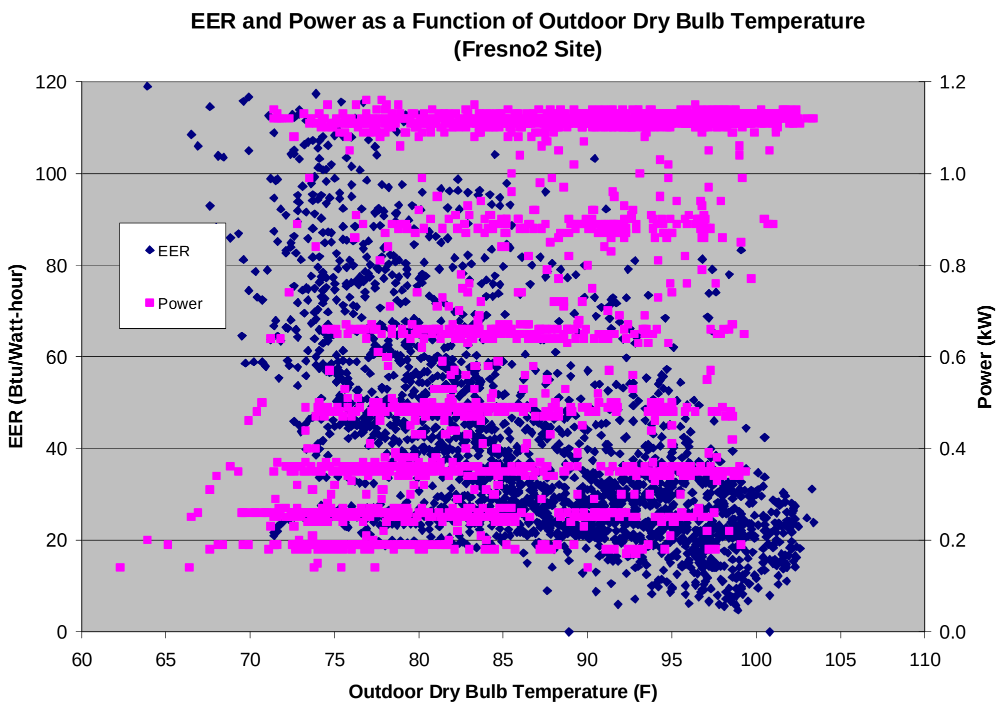
<u>Performance Plots</u>
The following performance graphs depict full-load (the unit operated the full 15 minute period) monitoring data from each of the sites. The data shown represents advanced unit power data and calculated EER as a function of outdoor dry bulb temperature. Power data reflects multiple and/or variable speed operation, for those units that have that capability.

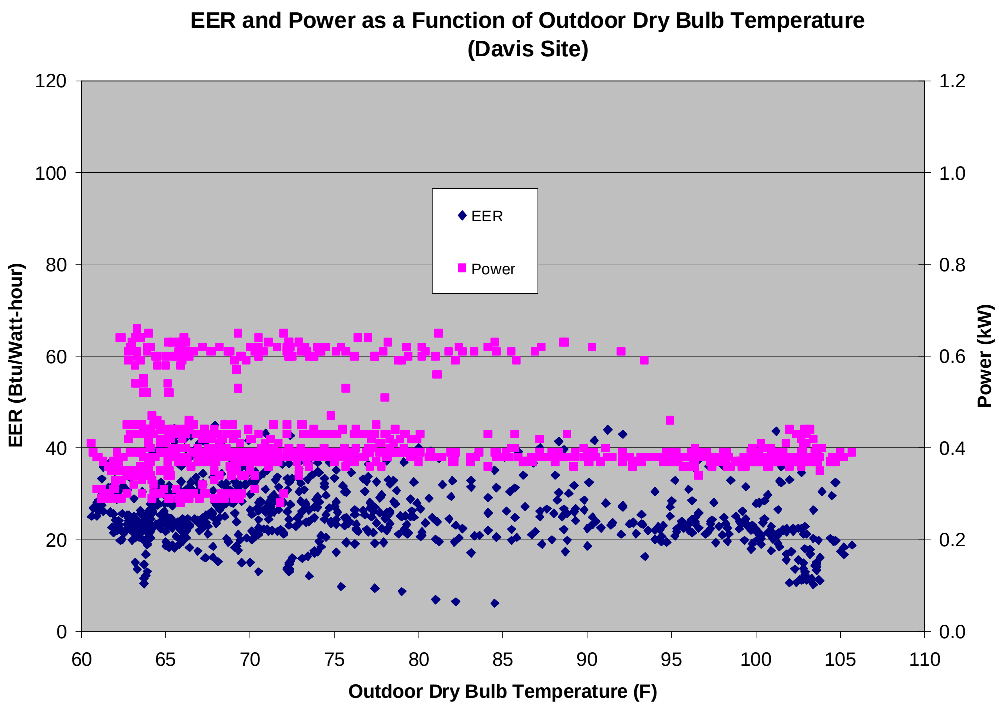
EER as defined in this study, is based on the temperature difference between indoor air and supply air. Homeowner cooling setpoint has a large influence on EER. Low indoor setpoints may result in EER's approaching zero as the supply air temperature may be no cooler than the indoor temperature. With this in mind, EER's should be a viewed as a site-specific parameter with the key interest being how it varies with outdoor temperature.

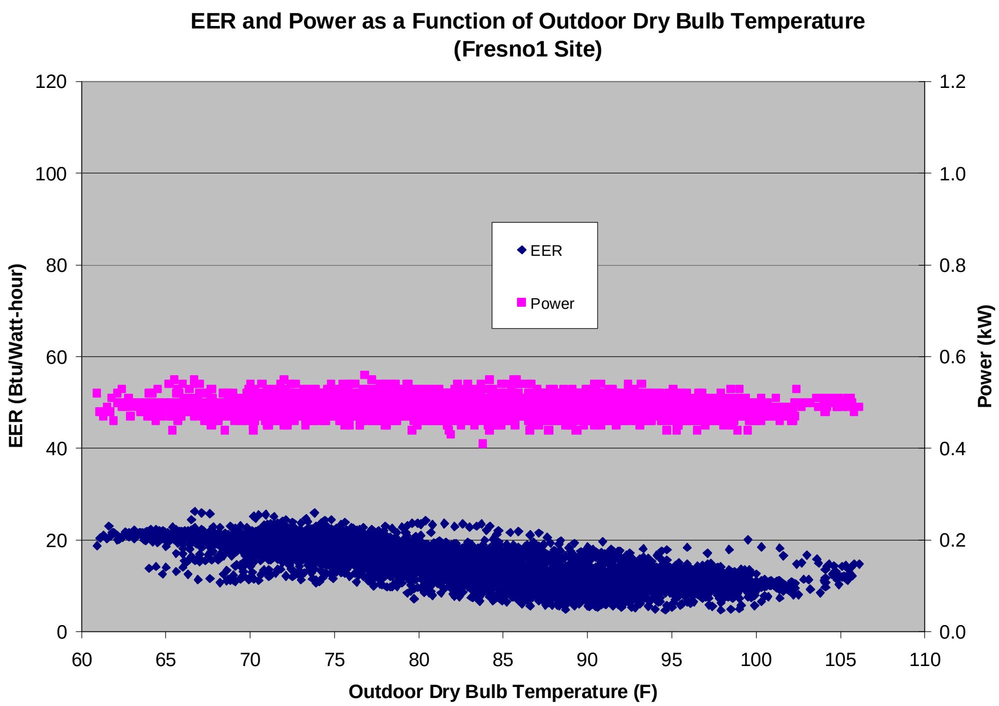
<u>Comfort Plots</u>
Comfort plots are shown for each of the six sites. Each datapoint represents a period when the cooler operated the full 15-minute period. This data was used to develop the average and peak day plots displayed in the body of the report.

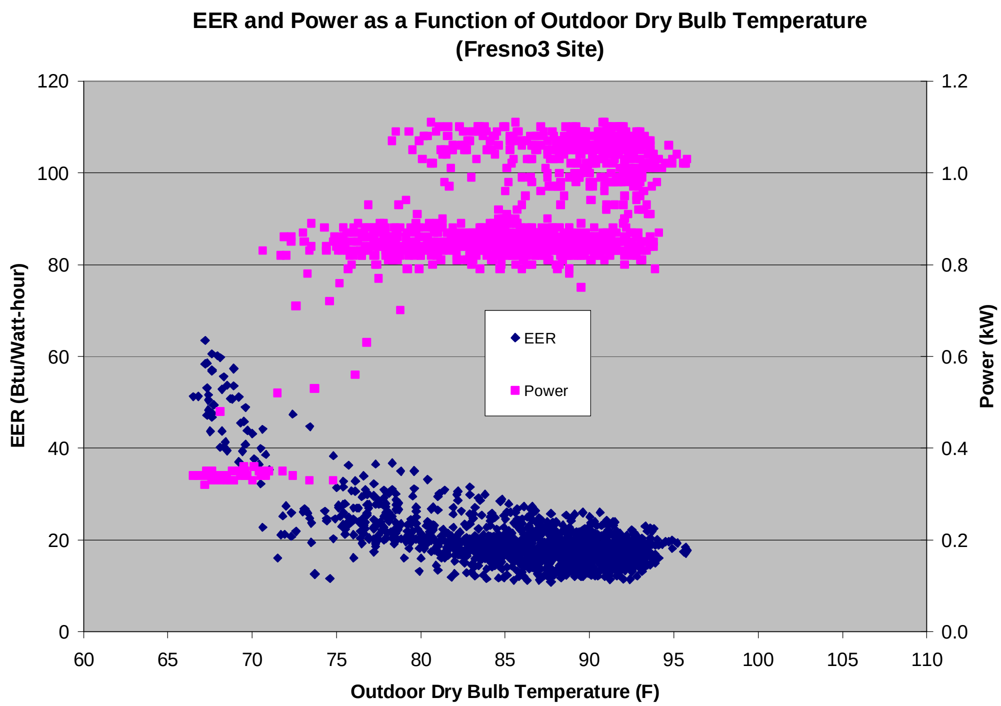



EER and Power as a Function of Outdoor Dry Bulb Temperature
(Sonora Site)
EER (Btu/Watt-hour)
Power (kW)
Outdoor Dry Bulb Temperature (F)
EER
Power
0
20
40
60
80
100
120
0.0
0.2
0.4
0.6
0.8
1.0
1.2
60
65
70
75
80
85
90
95
100
105
110

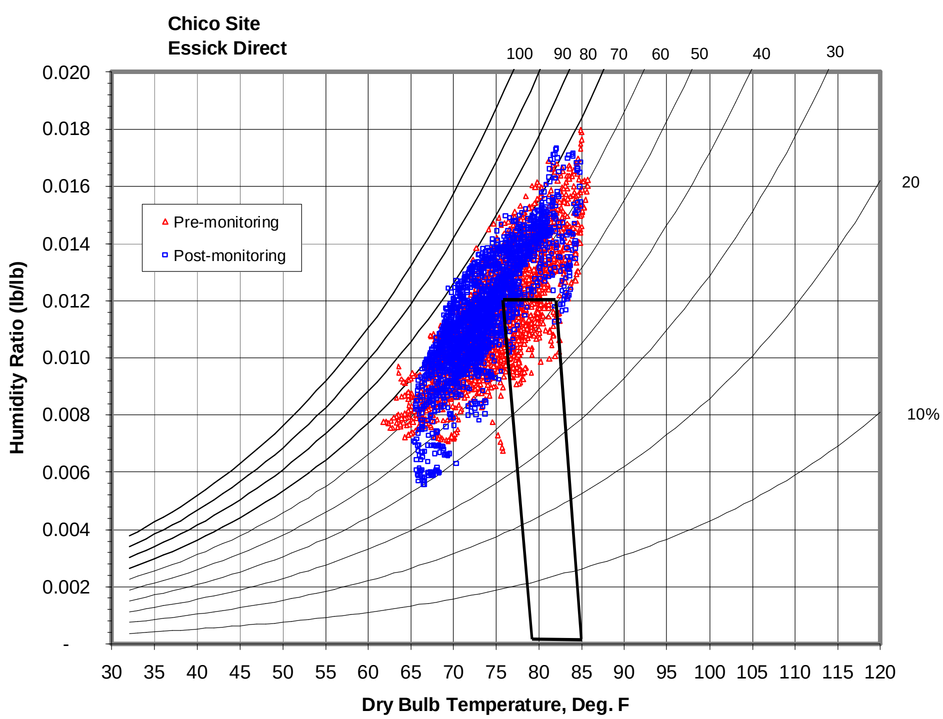

EER and Power as a Function of Outdoor Dry Bulb Temperature
(Fresno2 Site)
EER (Btu/Watt-hour)
Power (kW)
Outdoor Dry Bulb Temperature (F)
EER
Power
0
20
40
60
80
100
120
0.0
0.2
0.4
0.6
0.8
1.0
1.2
60
65
70
75
80
85
90
95
100
105
110


EER and Power as a Function of Outdoor Dry Bulb Temperature
(Davis Site)
EER
Power
EER (Btu/Watt-hour)
Power (kW)
Outdoor Dry Bulb Temperature (F)
0
20
40
60
80
100
120
0.0
0.2
0.4
0.6
0.8
1.0
1.2
60
65
70
75
80
85
90
95
100
105
110

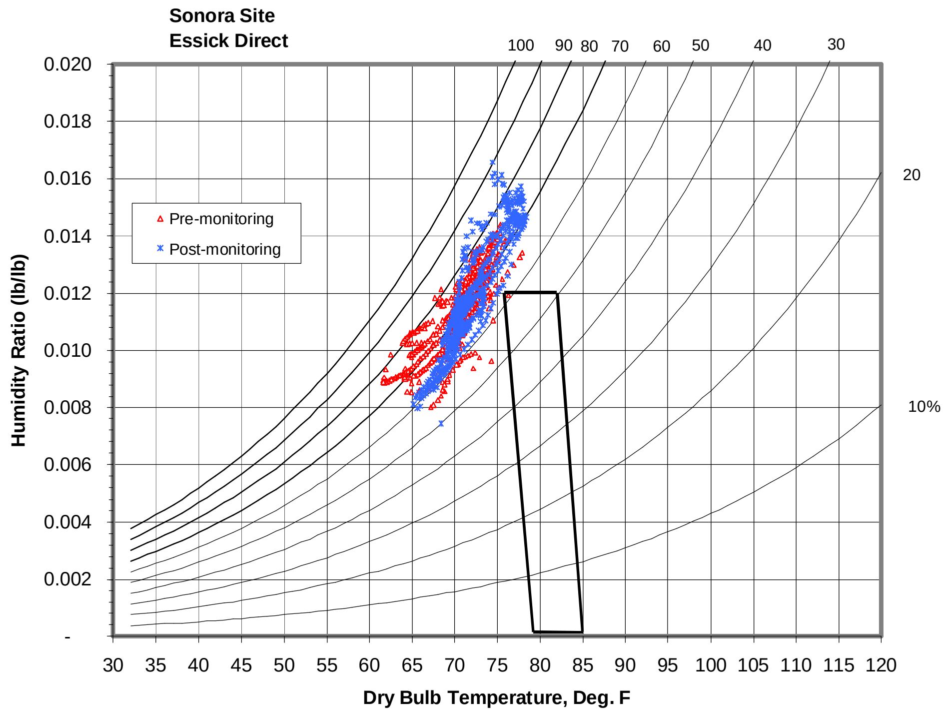

EER and Power as a Function of Outdoor Dry Bulb Temperature
(Fresno1 Site)
EER
Power
EER (Btu/Watt-hour)
Power (kW)
Outdoor Dry Bulb Temperature (F)
0
20
40
60
80
100
120
0.0
0.2
0.4
0.6
0.8
1.0
1.2
60
65
70
75
80
85
90
95
100
105
110

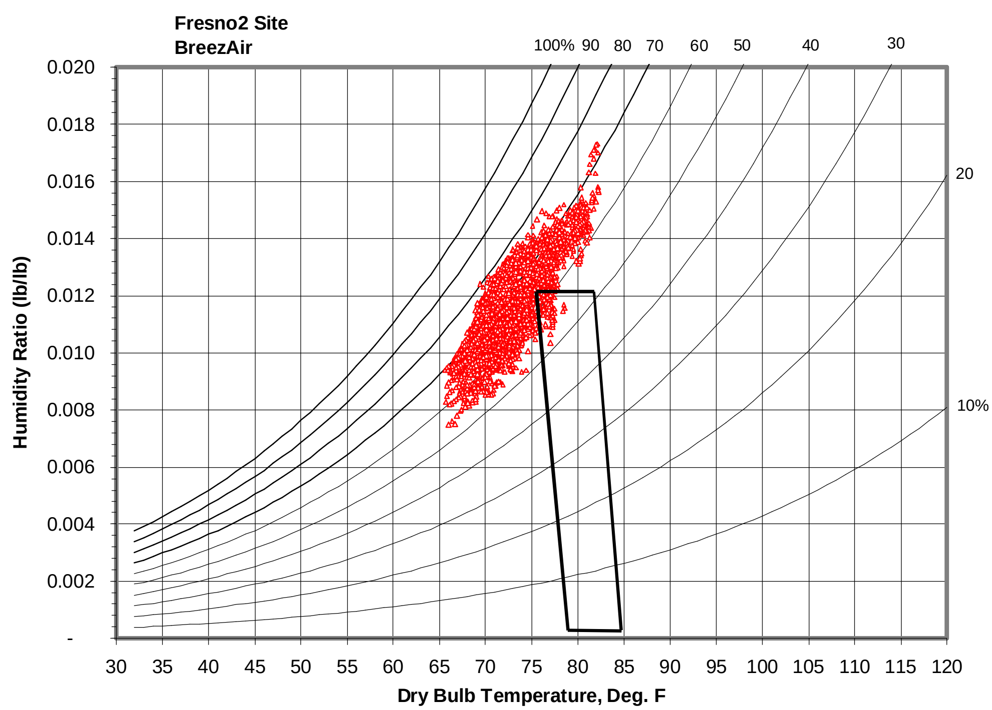


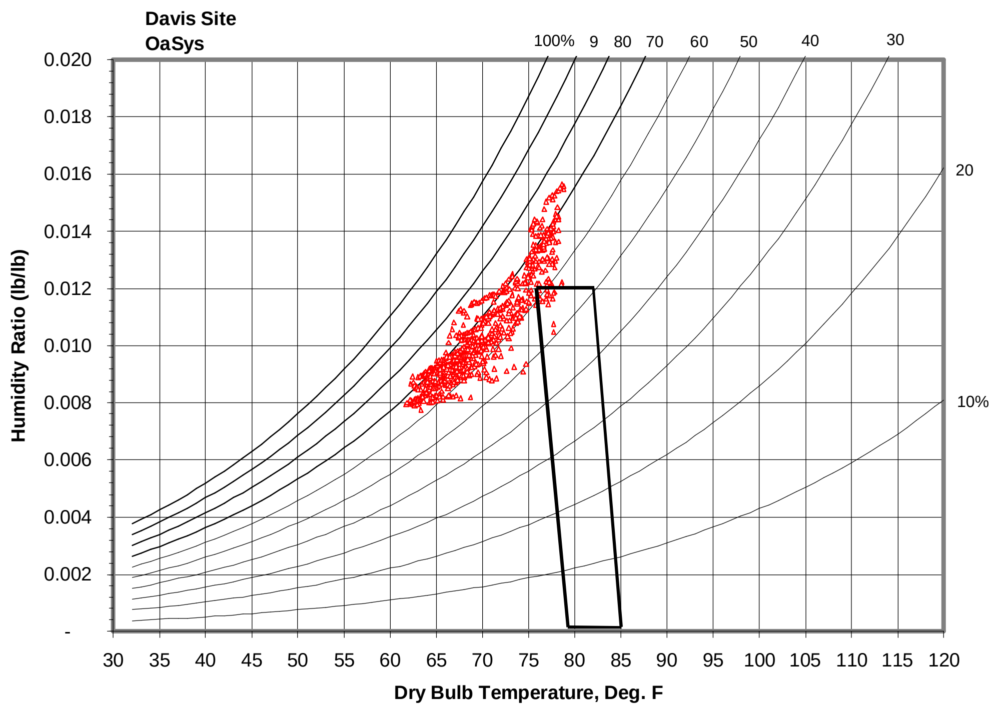
EER and Power as a Function of Outdoor Dry Bulb Temperature
(Fresno3 Site)
EER (Btu/Watt-hour)
Power (kW)
EER
Power
Outdoor Dry Bulb Temperature (F)
120
100
80
60
40
20
0
1.2
1.0
0.8
0.6
0.4
0.2
0.0
60 65 70 75 80 85 90 95 100 105 110

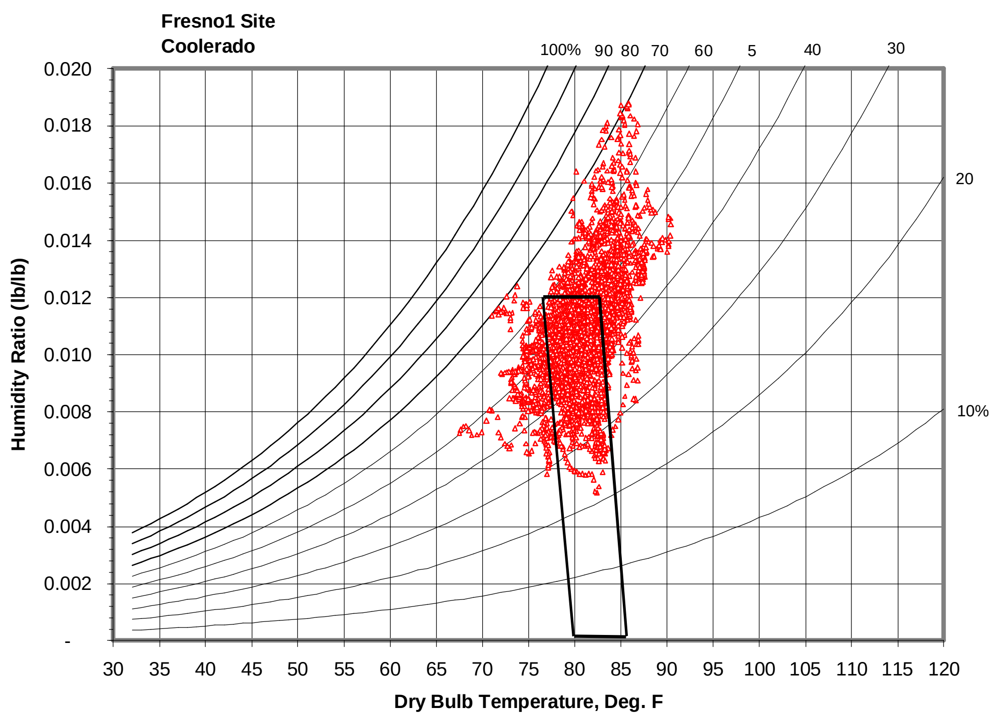


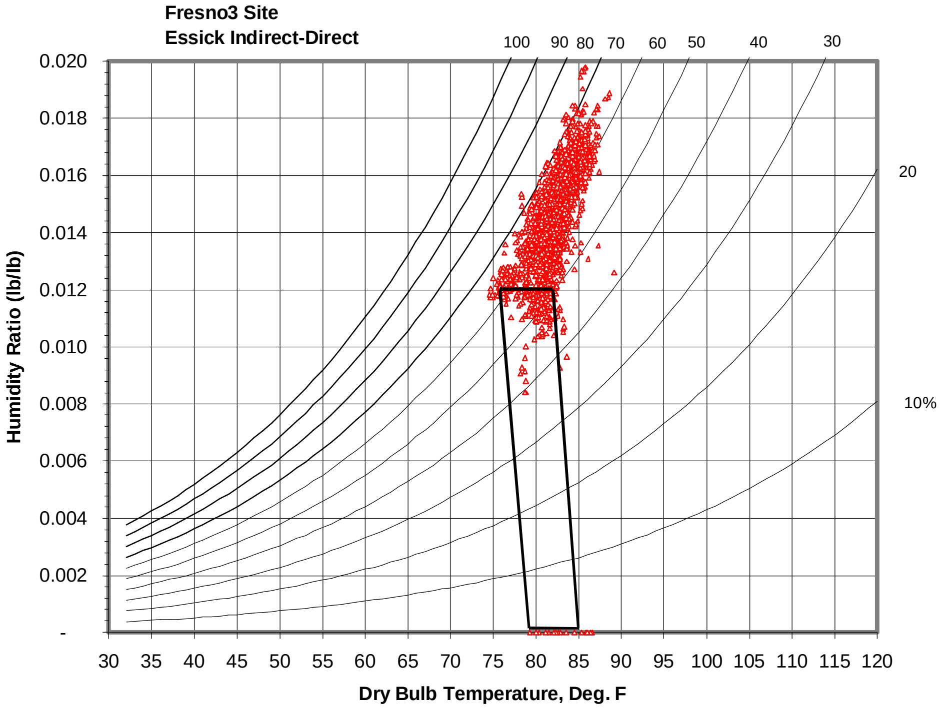
Chico Site
Essick Direct
100 90 80 70 60 50 40 30
20
10%
Pre-monitoring
Post-monitoring
Humidity Ratio (lb/lb)
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
-
30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120
Dry Bulb Temperature, Deg. F


Sonora Site
Essick Direct
Pre-monitoring
Post-monitoring
100
90
80
70
60
50
40
30
20
10%
Humidity Ratio (lb/lb)
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
-
30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120
Dry Bulb Temperature, Deg. F


Fresno2 Site
BreezAir
100%
90
80
70
60
50
40
30
20
10%
Humidity Ratio (lb/lb)
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
-
30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120
Dry Bulb Temperature, Deg. F


Davis Site
OaSys
100% 9 80 70 60 50 40 30
20
10%
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
-
Humidity Ratio (lb/lb)
30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120
Dry Bulb Temperature, Deg. F


Fresno1 Site
Coolerado
100% 90 80 70 60 5 40 30
20
10%
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
-
Humidity Ratio (lb/lb)
30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120
Dry Bulb Temperature, Deg. F


Fresno3 Site
Essick Indirect-Direct
100
90
80
70
60
50
40
30
20
10%
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
-
Humidity Ratio (lb/lb)
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120
Dry Bulb Temperature, Deg. F

Appendix D:

New Construction Simulation Results

The body of the report includes performance projections for the advanced evaporative coolers in typical retrofit applications. This Appendix contains results from simulations based on 1,600 ft2 new construction case in both Sacramento and Fresno. New construction applications are intriguing because improved building envelopes and glazing significantly reduce cooling loads, resulting in fewer cooler operating hours and therefore a reduced indoor humidity level.

Simulation runs were completed for a prototypical 1,600 ft^2 single-story house complying with the 2005 Title 24 Building Standards. All runs were completed with a 78ºF summer cooling setpoint. Characteristics of the house are summarized in Table 1. Runs were completed for both standard 13 SEER air conditioning and each of the technology options with a fixed summer cooling setpoint of 78°F.

Table 1: Modeled House Characterization

Characteristic	Description
Wall R-value	R-19
Ceiling R-value	R-38, with attic radiant barrier
Glazing U-value	0.57
Glazing SHGC	0.40
Glazing area	16.5% of floor area (264 ft^2), uniformly distributed by orientation

Table 2 presents cooling energy use and coincident peak demand projections from the MICROPAS research model. Peak demand for the "season" is defined as the noon to 7 PM average demand for the months of June through September. "3 day" peak demand is defined as noon to 7 PM average demand for the three hottest consecutive days on the weather tape. The projected energy use for a 13 SEER air conditioner in Sacramento is about 40% of that for Fresno, and the peak demand is similarly less than half that of Fresno.

Table 2: Project Cooling Energy Use and Coincident Peak Demand

	Sacramento			Fresno		
Equipment	Cooling	Coincident Peak kW		Cooling	Coincident Peak kW	
Type	kWh/yr	Season	3 days	kWh/yr	Season	3 days
SEER 13 AC	800	0.81	2.27	2140	1.70	2.98
Essick Direct	247	0.25	0.65	608	0.44	0.67
Breezair Direct	227	0.23	0.78	602	0.47	0.89
Coolerado	360	0.33	0.52	827	0.46	0.53
OaSys	258	0.25	0.58	636	0.43	0.57
Essick Indir-Dir	403	0.40	0.97	993	0.69	0.97

Table 3 summarizes savings relative to the SEER 13 base case. Projected energy savings range from 50-72% and demand savings (for the three hottest days) range from 57-82%, with slightly higher percentage savings in Fresno. At an assumed average PG&E summer electric rate of $.15 per kWh, projected Sacramento savings average $75 per year and Fresno savings average $211 annually. Higher cooling energy consumption or a higher average PG&E rate tier could result in savings twice this amount.

Table 3: Projected Cooling Energy and Peak Demand Savings

	Sacramento		Fresno	
Equipment Type	Cooling kWh/year	Coincident Peak kW	Cooling kWh/year	Coincident Peak kW
Essick Direct	553 (69%)	1.62 (71%)	1532 (72%)	2.31 (78%)
Breezair Direct	573 (72%)	1.49 (66%)	1538 (72%)	2.09 (70%)
Coolerado	440 (55%)	1.75 (77%)	1313 (61%)	2.45 (82%)
OaSys	542 (68%)	1.69 (74%)	1504 (70%)	2.41 (81%)
Essick Indirect-Direct	397 (50%)	1.30 (57%)	1147 (54%)	2.01 (67%)