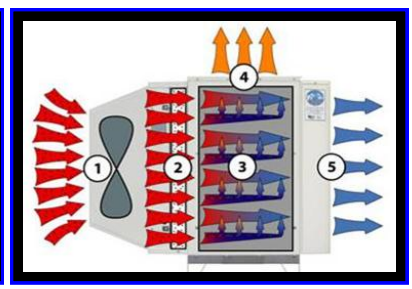
Customer Advanced Technologies Program
Technology Evaluation Report

The Coolerado™



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Executive Summary

In 2004, the first commercially available Coolerado™ was installed at Applied Behavior Consultants School (ABC School) in Sacramento, California. After six years of research and many revelations the story is finally ready to be told.

The Coolerado is an indirect evaporative cooling system that may offer a viable alternative to conventional air conditioners (i.e. vapor-compression systems with chemical refrigerants). The system (Figure 1) consists of an axial fan, a water distribution and control system, and a patented heat exchanger known as the heat-mass exchanger or HMX. The HMX transfers heat from the supply air stream via an indirect evaporative process known as the Maisotsenko Cycle. What makes the Coolerado unique is the ability to cool the supply air down to one or two degrees above wet bulb temperature without adding any moisture to the supply air stream.

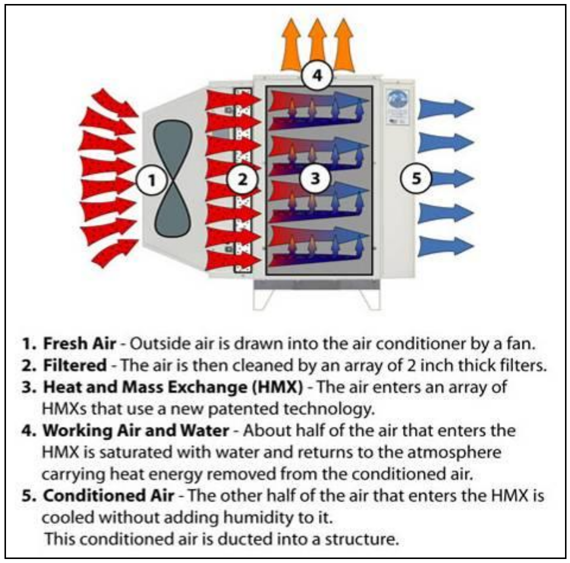


Figure 1: The Coolerado. Drawing Provided by the Coolerado Corporation.

SMUD worked with local customers and ADM Associates Inc. to evaluate the performance of the Coolerado system. At one point the test included eight units at five sites. Ultimately, two of the participants opted out of the project and installed conventional air conditioning systems, and one of the sites was vacated, so the monitoring efforts shifted to the remaining five units.

The first test site was ABC School; the second was a 50 year old single-story residence. These two sites were monitored from 2006 through 2009. During this time, the Coolerado units underwent several modifications including new HMXs. Consequently, it took a long time to gather the required data. An abbreviated summary of the results of this project is presented below. For more details, please refer to the main sections of this report.

Thermal Performance

The Coolerados were able to maintain indoor temperatures of between 77°F and 80°F, even when the outside air temperatures were at or above 100°F. However, when one of the participants set the indoor thermostat to 75°F, the unit ran continuously for three days. This experience reinforced the need to educate consumers about the capabilities and limitations of evaporative cooling systems.

Peak Electrical Demand Reduction and Energy Savings

Neither of the two test sites had conventional air conditioners before the installation of the Coolerados, so the project team decided to use building simulation software and monitoring data from the Coolerados to estimate peak electrical demand reduction and energy savings. For comparison purposes, a conventional 3-ton air conditioner with efficiencies of 12 EER and

14.5 SEER was selected as the base case unit. The peak electrical demand reduction was calculated for periods when the outside air temperature is105°F. Based upon this methodology, a Coolerado system in Sacramento could reduce electrical demand by 2.3 kW and save from 236 to 470 kWh annually.

Water Consumption

Most evaporative cooling systems use pumps to re-circulate water within the system. The Coolerados tested in this project are "once through" systems that inject water directly from the municipal supply into the HMX. The water that does not evaporate (excess water) is used to keep the HMXs clean and is discharged from the unit. Our monitoring efforts captured the total water consumption but did not distinguish between the water being evaporated verses the excess water being discharged to the drain. Water consumption is estimated to be from 10,922 to 13,650 gallons per unit per year. To put this into perspective, a family of three in California uses an average of 100,000 gallons of water per year. Unfortunately, local building codes required connecting the drain lines to the sanitary sewer, so we were not able to reuse any of the discharged water.

Short Term Reliability and Maintenance Requirements

Early versions of the Coolerado experienced problems with the HMXs and water control systems. However, significant improvements were made to these components so the newer units are much more reliable (please refer to the **Product Improvements** section of this report for more details. Like all other cooling systems, the Coolerado requires periodic maintenance including replacing the outside air filters on a monthly basis, checking and refilling the pump reservoir (annually), and winterizing the system.

System Improvements

As a direct result of this study the Coolerado Corporation has implemented several design improvements including:

- Energy-efficient, variable speed fan motors that draw 50% less power (750 Watts instead of 1500 Watts).
- Synthetic HMXs designed to last 7-10 years and meet Underwriters Laboratory (UL) requirements for fire and smoke.
- HMXs are now housed within polypropylene cartridges which include integrated water delivery systems and a single water connection point.
- Advanced water controls which adjust the water flow to meet cooling loads.

Conclusions

After more than six years of field testing and refinements, the Coolerado may offer a viable alternative to conventional air conditioning for certain applications - especially for cooling applications with high ventilation requirements. As you read through this report, remember that the Coolerado Corporation has made several improvements to the system which should significantly improve the performance and energy savings potential.

The Coolerado may provide significant electrical demand and energy savings, yet care must be taken to properly set expectations. For example, it is not realistic to expect any evaporative cooling system to maintain indoor temperatures below 75°F in a 50 year old home during a Sacramento heat wave. The cost of the Coolerado appears to be comparable to conventional air conditioning systems with one exception: the system does not include provisions for heating, so this must be taken into account .

The Coolerado Corporation now offers a range of indirect evaporative cooling products. Their newest offering, the H80 Hybrid AC, is a combination of Coolerado's HMX technology and a conventional air conditioning system. Based upon independent laboratory test data, this system should provide most of the energy savings of evaporative cooling, while meeting indoor comfort requirements under virtually all situations. To learn more about the H80 and other Coolerado products, visit their website at: http://www.coolerado.com.

Introduction

Evaporative cooling systems have great potential to reduce cooling demand requirements in hot-dry climates. Since conventional direct evaporative coolers (a.k.a. swamp coolers) produce moisture-laden air, their acceptance in the market has been limited to consumers who live in hot, dry climates and are willing to accept higher indoor humidity levels in exchange for lower energy bills and installation costs. In an effort to help overcome this market barrier, Idalex Inc. developed a revolutionary new technology known as the Coolerado.

In 2004, the first commercially available Coolerado was installed at Applied Behavior Consultants School (ABC School) in Sacramento, California. This was the beginning of an interesting six year research project. At one point there were eight units undergoing testing. Some of these units have been retired, while others are still going strong.

In the right application, the Coolerado may offer comfort levels comparable to conventional (vapor compression) air conditioning systems, yet use only a fraction of the electrical demand. This report provides an overview of the Coolerado system and some lessons learned from SMUD's research project.

Principles of Evaporative Cooling

Before discussing the Coolerado, it may be helpful to review some basic principles of evaporative cooling. When air comes into contact with water, some of the water evaporates. This happens because the temperature and vapor pressure of the water and air attempt to equalize. As the water molecules become a gas (evaporate), they absorb heat from the surrounding air and lower their temperature. The heat is still present, however; it has just been captured in the form of water vapor within the air (humidity). This phenomenon is known as *adiabatic cooling* and is found throughout nature - lakes, rivers, oceans, anywhere there is water.

Some Cool Terms

Dry bulb temperature: temperature of air independent of its moisture content. It may be measured by using common thermometers.

Wet bulb temperature: the lowest theoretical temperature achievable by evaporating water in a quantity of air at a given dry bulb temperature and humidity level, using only the heat within the air. It is measured by placing a moist piece of fabric over the thermometer and blowing air across it. The air evaporates the water, lowering the temperature on the thermometer to the wet bulb temperature[1].

Absolute humidity: the amount of water vapor present in air.

Relative humidity: the amount of water vapor present in air compared to the maximum amount it could hold.

Direct evaporative cooler: system in which the air comes into direct contact with wetted pads before entering the conditioned space. Commonly called swamp coolers.

Indirect-direct evaporative cooler (IDEC): system that uses a combination of direct evaporative cooling and an indirect evaporative heat exchanger. Commonly called two-stage evaporative coolers.

[1]"Death of the Swamp Thing: Evaporative Cooling Delivers Dry Air," by Peter Crisione, ET Currents Number 41, April 2005. Platts Research & Consulting, 3333 Walnut Street, Boulder, CO 80301-2515. USA, tel (303)-444-7788, www.esource.platts.com

Today people use evaporative cooling systems for a wide variety of purposes – comfort cooling, manufacturing processes and other applications. The effectiveness of evaporative cooling depends greatly upon the humidity or amount of water vapor in the air. **Simply stated: the drier the air, the more effective evaporative cooling will be.**

Air conditioning technicians often used a special thermometer known as a sling psychrometer (Figure 2) to determine how much water vapor is present in the air. Essentially, this measurement involves placing a wet cloth (wick) on a thermometer and spinning the psychrometer until the water has evaporated and recording the lowest temperature obtained. Today more modern electronic instruments are used, yet the principle remains the same. Regardless of the exact instrument used, this measurement is known as the wet-bulb temperature. What is important to understand about the wet bulb temperature is that it tells us what the theoretical lowest supply air temperature for direct evaporative coolers will be. For example, standard design conditions for sizing residential cooling systems in Sacramento, California are:

- Outside air (dry bulb) temperature: 101°F
- Wet bulb temperature: 70°F (relative humidity 23%)
- Desired indoor temperature: 78°F

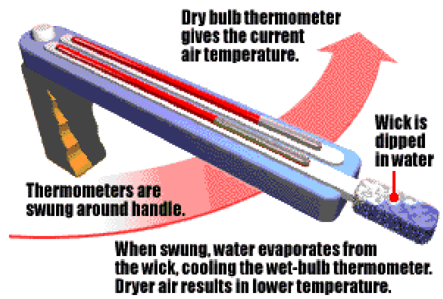


Figure 2: A sling psychrometer[2].

Under these conditions, the lowest theoretical supply air temperature that a standard evaporative cooler could provide would be 70°F. Realistically speaking, most direct evaporative cooling systems would only be able to achieve a supply air temperature of 74°F[1]. To put this into perspective, conventional refrigerant-based air conditioning systems are designed to deliver supply air at 55°F to 65°F. At first glance, it appears that direct evaporative coolers would never work in Sacramento. After all, it may be difficult to cool a home using 74°F air. To make matters worse, direct evaporative coolers increase the humidity within the house – making conditions even less comfortable. Fortunately, these shortcomings are somewhat mitigated by what is known as 'effective temperature.' Since evaporative coolers run at airflow rates that are 3 to 5 times higher than conventional air conditioning systems, they create a 'cooling breeze' that makes the occupants of a room feel four to six degrees cooler than the actual temperature[3]. Even with this additional benefit, wide spread acceptance of direct evaporative cooling systems has been limited to climates with relatively low humidity levels.

For a thorough discussion on different types of evaporative cooling systems, please download the OASys Technology Evaluation Report from the Customer Advanced Technologies program Web site: http://www.smud.org/en/education-safety/cat/Pages/index.aspx.

[1] "Death of the Swamp Thing: Evaporative Cooling Delivers Dry Air," by Peter Crisione, ET Currents Number 41, April 2005. Platts Research & Consulting, 3333 Walnut Street, Boulder, CO 80301-2515. USA, tel (303)-444-7788, www.esource.platts.com

[2] USA Today Research by Chad Palmer, available http://www.usatoday.com/weather/wsling.htm

[3] Evaporative Cooling," California Energy Commission, available at www.consumerenergycenter.org/homeandwork/homes/inside/heatandcool/evaporative_coolers.html

Technology Description: The Coolerado

A new type of evaporative cooling system was introduced to SMUD in 2004 – the Coolerado. This system includes a unique indirect evaporative heat exchanger that cools the air multiple times before it enters the conditioned space. In essence this creates a cascade effect that enables the Coolerado to cool the supply air *below* ambient air wet bulb temperatures (supported by National Renewable Energy Labs testing) without adding any moisture to the supply air stream. However, achieving supply temperatures below wet bulb significantly reduces the amount of supply air. Production Coolerado units in Sacramento achieved supply air temperatures of 1 or 2 degrees above wet bulb. The Coolerado (Figure 3) consists of an axial fan, a water distribution and control system, and a patented heat exchanger known as the heat-mass exchanger or HMX. The HMX is designed to take advantage of the Maisotsenko Cycle (Figure 4). The original HMXs were constructed from cellulose fiber and Ethyl Vinyl Acetate (more on this later) and separated the incoming air into two air streams Working Air and Product Air (aka Conditioned Air). The Working Air is the air used to produce the cooling effect. As it travels through the wet channels of the HMX, it comes into direct contact with wetted surfaces. When this happens, some of the water evaporates and absorbs heat (indirectly) from the Conditioned Air stream, which is traveling through the dry channels of the heat exchanger. This process is repeated several times within the HMX.

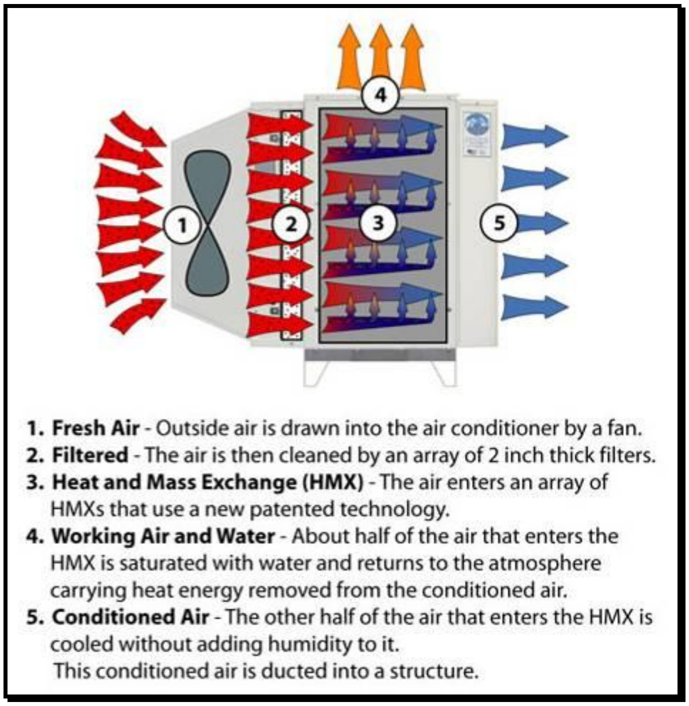
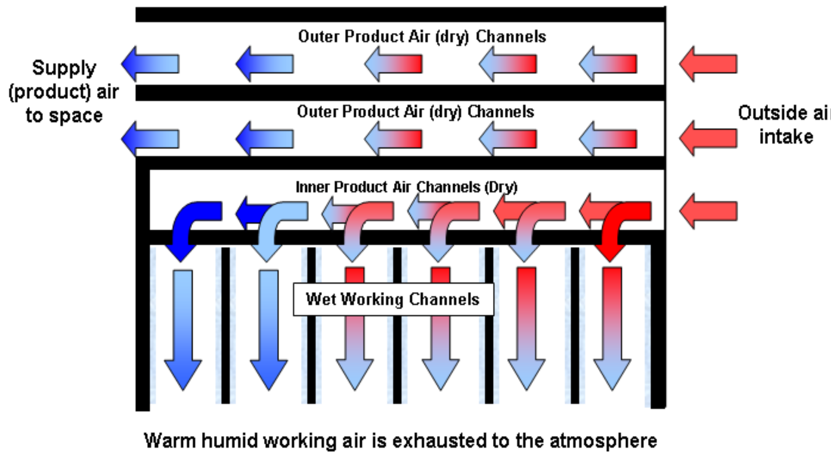


Figure 3: How the Coolerado works. Drawing provided courtesy of the Coolerado Corporation.

Figure 4: This simplified schematic illustrates the Maisotsenko Cycle. The Coolerado's HMX uses wet and dry channels with a much different geometry and airflow. The working air (air used to evaporate water) is incrementally cooled by the continuous exhaust of heat followed by additional cooling. This cycle allows the product air (the air supplied to the conditioned space) to be cooled *below* the wet bulb temperature of the incoming working air (confirmed by NREL laboratory tests), without adding moisture to the product air stream. However, achieving supply temperatures below wet bulb significantly reduces the amount of supply air. Production units tested in Sacramento typically achieved temperatures of 1 or 2 degrees above wet bulb.



SMUD's Research Project Overview

SMUD worked with local customers and ADM Associates Inc. to evaluate the performance of the Coolerado. Project objectives included assessing the following attributes:

- Thermal performance
- Water consumption
- Short-term reliability and maintenance requirements
- Peak electrical demand reduction and energy savings

The first Coolerado in Sacramento was installed at Applied Behavior Consultants (ABC School) in September of 2004. Since the unit initially performed very well, the project was expanded to include seven more units at five locations.

During the course of this project, several issues surfaced including problems with the water control systems and HMXs. Ultimately two of the participants opted to replace their units with conventional air conditioning systems. In retrospect, expecting one Coolerado R600 to provide adequate cooling for an older 2,600 square foot home with two stories and no exterior shading (Figure 5) was overly optimistic, so it is not surprising this homeowner decided to opt out of the research project.

Figure 5: In retrospect, expecting one Coolerado R600 to provide adequate cooling for an older 2,600 square foot home with two stories and no exterior shading in Sacramento was overly optimistic.

During the summers of 2006-2009, four units at ABC School and one unit at a 1,000 ft^2 single family residence (Site 2) were extensively monitored. The following sections contain detailed site descriptions, monitoring results and some of the lessons learned. As you read through the details of this report, remember that many improvements have been made to the Coolerado system, which should significantly improve the performance and energy savings potential.

Showcase Project (Site 1)

System and Background Information

Coolerado Model: R600

HMXs: Six HMXs
First generation HMXs were cellulose material
Second generation HMXs were Polypropylene

Fan/Motor: Single Speed
110 Volt (no longer offered)
12.5 amps
1500 Watts

Figure 6: The first Coolerado was installed at ABC School in 2004.

In 1998, ABC School opened a state-of-the-art, environmentally friendly school in Sacramento. The new facility featured high efficiency lighting, straw bale wall construction and indirect-direct evaporative cooling (a.k.a. IDEC) systems. Unfortunately, the IDECs proved to be troublesome and a source of many comfort-related complaints (for more information, download the report entitled "Operation IDEC Rescue" available at the Customer Advanced Technologies Program Web page http://www.smud.org/en/education-safety/cat/Pages/index.aspx).

Figure 7: Crew installing the controls for the new unit. Note the IDEC immediately next to the Coolerado.

In August of 2004, ABC agreed to participate in a new research project. The purpose of this project was to test the thermal performance and reliability of the Coolerado system while providing some much needed relief for ABC's staff. The unit (Figure 6) performed well in 2005. Based upon these positive results, ABC School installed three more Coolerado R600 units in April of 2006. Each unit included six HMXs and delivered an average of 1,010 cfm.

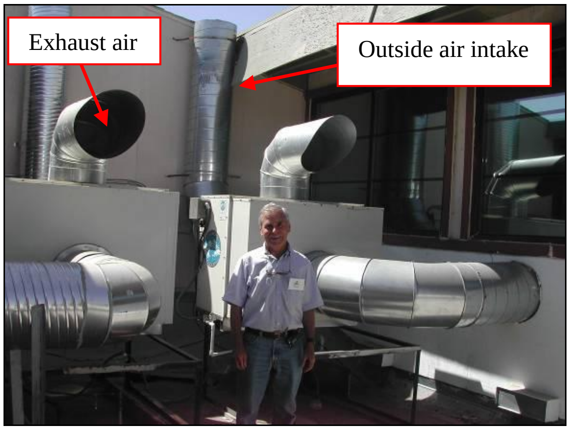


Figure 8: Dr. Valeriy Maisotsenko, inventor of the Maisotsenko Cycle. Note the ducted outside air intakes and sheet metal elbows used to direct the exhaust air away from the intakes.

Three of the units at ABC are located in a very challenging environment - a poorly ventilated roof well with almost constant exposure to direct sunlight. To make matters worse, there are three IDECs in the same area (Figure 7). Since the project team was concerned about the possibility of short-cycling (humid exhaust air being drawn into the outside intakes), ductwork and sheet metal elbows were installed to prevent this from occurring. Because the contractors were not comfortable cutting out large openings in the straw bale walls, the outside air intakes were directed upwards (Figure 8). One of the biggest problems with the original IDECs was that the ductwork was very restrictive and severely reduced airflow (Figure 9). Because of this, the team decided to remove the existing ductwork and install new ductwork within the classrooms (Figure 10). This significantly increased the cost of the project.

From 2004 through 2007, three of the four units at ABC School were monitored and routinely inspected. Throughout this period, new upgrades were installed and control strategies were implemented.

Figure 9: The original ductwork for the IDECs was very restrictive.

Objectives

As stated earlier, the purpose of this project was to determine the thermal performance, short-term reliability, water consumption, maintenance requirements, energy savings and electrical demand reduction potential of the Coolerado system. To accomplish this goal, SMUD hired ADM & Associates Inc. to obtain and analyze the necessary field data. The following parameters were monitored:

- Outdoor air dry-bulb temperature
- Outdoor air wet-bulb temperature
- Indoor air dry-bulb temperature
- Indoor air wet-bulb temperature
- Supply air flow (delivered to classrooms)
- Water consumption
- Energy usage

Figure 10: The project team decided to install new ductwork for the Coolerado. Photo credit: ADM Associates Inc.

In addition to monitoring the units, visual inspections were performed by representatives from SMUD, ADM, the Coolerado Corporation, Delphi and Aircon Energy.

Heat-Mass Exchangers (HMXs)

The original HMXs were constructed from cellulose fiber and Ethyl Vinyl Acetate. These HMXs produced excellent thermal results but suffered from some serious maintenance issues. The main problem was the formation of mold on the outside edges of the HMXs. Although the mold was *not* on the passages leading to the conditioned space, it was still a cause for concern. Over the course of three years, various types of new materials, anti-microbial treatments and control strategies were implemented to address the issue. During this same period, the project team conducted numerous inspections. Whenever mold was found, the project participant was notified and the HMXs were either cleaned or replaced.

Success finally came in 2009, when a new material was used to make the HMXs. In April of 2009, new HMXs were installed for all remaining Coolerados in the Sacramento area. When these HMXs were inspected In December 2009, no visible mold was found (Figure 11). However, after reviewing monitoring data, another issue was discovered. The thermal performance of the new HMXs was comparable to the original cellulose based units with one exception: seasonal start up. It is more difficult to saturate the new HMXs with water (a.k.a. wet out).

Addressing this issue required the addition of a small pump to inject a very small amount of surfactant (mild soap) into the water supply line, and periodically flush the HMXs with water during extended periods of inactivity. This helps keep the HMXs from drying out. The downside to this approach is that the surfactant reservoir needs to be checked and refilled on an annual basis.

Figure 11: During 2009, new HMXs were installed in the Coolerados. During subsequent inspections, no visible mold was found.

Water Control and Distribution Systems

The water controls on the first Coolerados consisted of two screws installed in the drain line that functioned as electrodes (Figure 12). During operation, low voltage was applied to one of the screws. As long as enough water was present in the drain line, the electric circuit was completed and the water supply was turned off. When the circuit was interrupted, the water supply valve would be turned on until the drain line was once again filled with enough water to complete the circuit. This simple approach had several shortcomings:

- On several occasions, the installation contractor inadvertently shorted the wires to the frame of the unit. This created a false signal that shut off the water flow to the unit.
- Occasionally debris would partially clog the drain lines. This caused the water controls to behave erratically.
- Since the system did not account for varying weather conditions, it wasted water during low cooling load conditions.

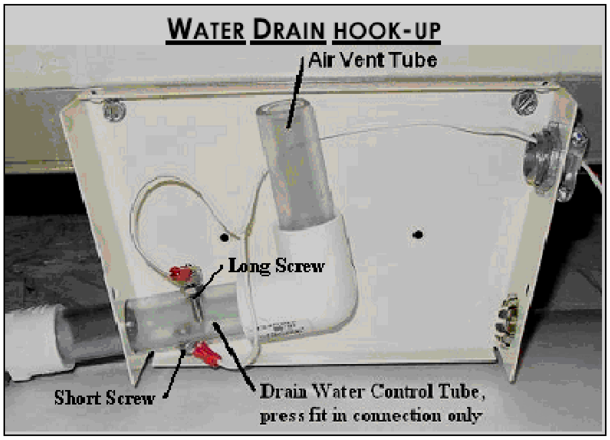


Figure 12: The original water control system.

In 2007 the Coolerado Corporation introduced a much more sophisticated control system (please refer to the **Product Improvements** section of this report for more detailed information).

Hard Water Scale

Historically speaking, hard water scale has been an issue for evaporative cooling systems – especially at ABC School. When ABC School was chosen to be one of the SMUD test sites, there was some concern about potential problems with water scale. Routine inspections, however, found no appreciable scale deposits within the interior surfaces of the HMX.

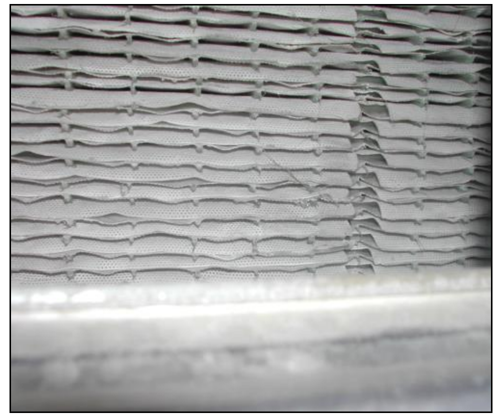


Figure 13: inspections revealed that the Coolerado HMX experienced no problems associated with hard water scale.

During the summer of 2006, we received a complaint that one of the Coolerado units was no longer working properly. The service technician discovered that the water supply line connected to the Coolerado system was fouled with scale. When the Coolerados were installed, the contractor reused the existing flexible water supply lines. Once this line was replaced, the unit returned to normal operation.

Thermal Performance

In July 2006, Sacramento experienced a record breaking heat wave. Figure 14 (next page) shows measured dry-bulb air temperatures as well as the outside air temperature served by the Coolerados for the four classrooms at ABC School. Some observations:

- Three of the four units were able to keep the classroom temperatures at or below 80°F even when the outside air temperature soared well above 100°F.

- The Coolerado serving Room 5 experienced problems with the water controls on July 16, 2006. This is evident by looking at how closely the temperatures for Room 5 coincided with the other rooms then suddenly jumped about five degrees higher.

- The Coolerados were able to keep the indoor air temperatures near or slightly below 80°F at the SMUD test sites, except when there were problems with the water control systems. The new water control systems appear to be much more reliable.

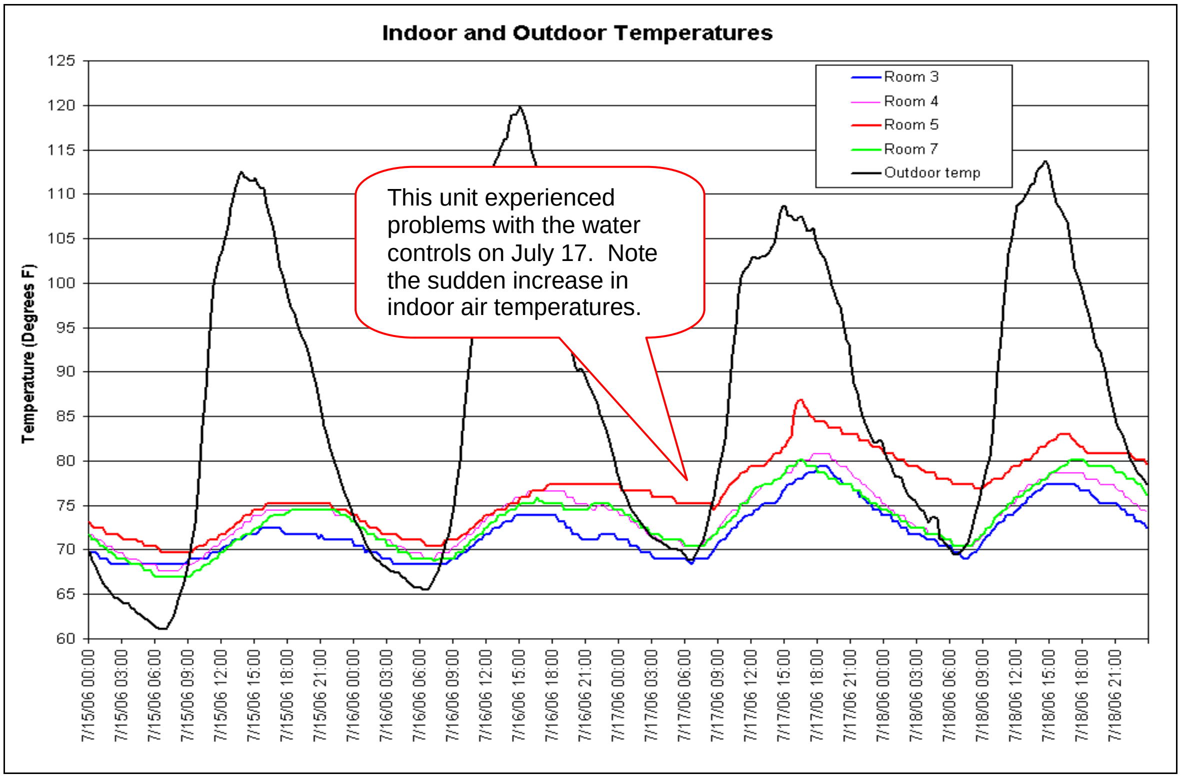


Figure 14: Measured dry-bulb air temperatures for the four classrooms served by the Cooleradoss as well as the outside air temperatures.

In April of 2009, the cellulose-fiber HMXs at ABC School were replaced with synthetic units and the monitoring continued. During the summer of 2009, almost all of the days with outside temperatures of over 100°F occurred during the weekends or during periods when the school was not in session. Although our data set for higher temperatures during the summer of 2009 is not exhaustive, we were still able to obtain some useful data. Figures 15-17 show the performance of the Coolerados serving the classrooms with the new synthetic HMXs.

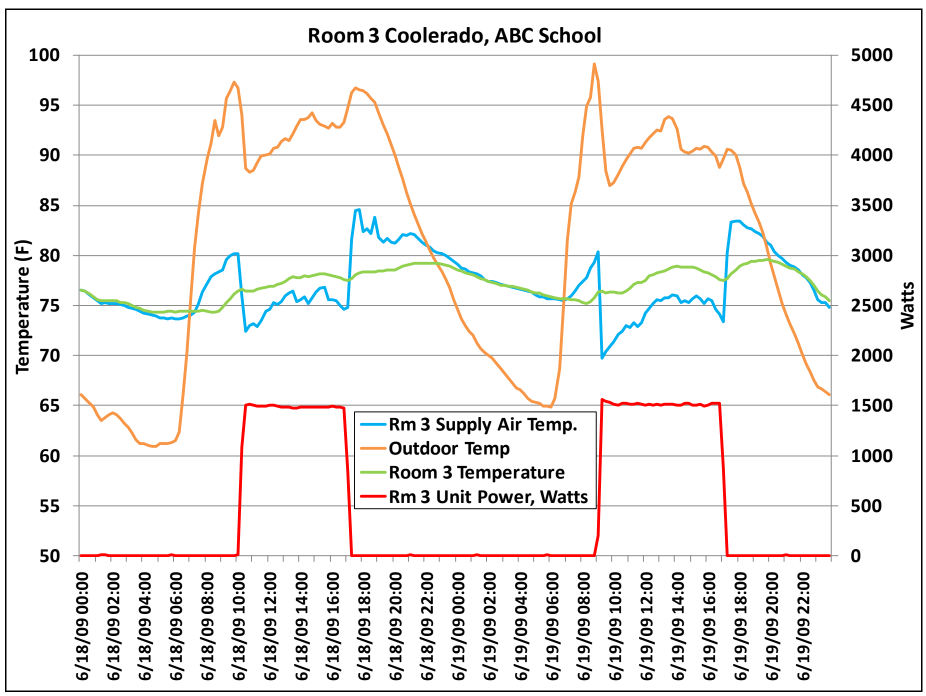
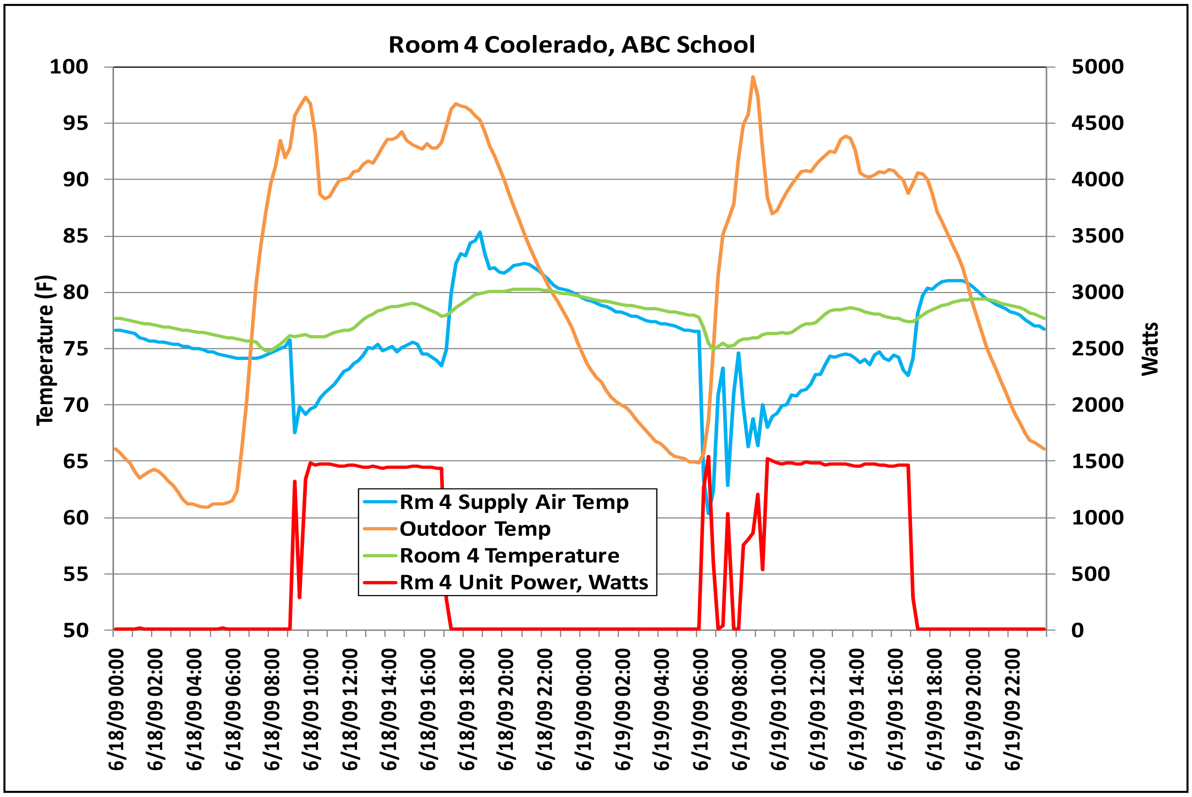


Figure 15: Monitored performance of the Coolerado serving Room 3 after being retrofitted with the synthetic HMXs. Note that the indoor air temperature (green line) was maintained below 80°F.



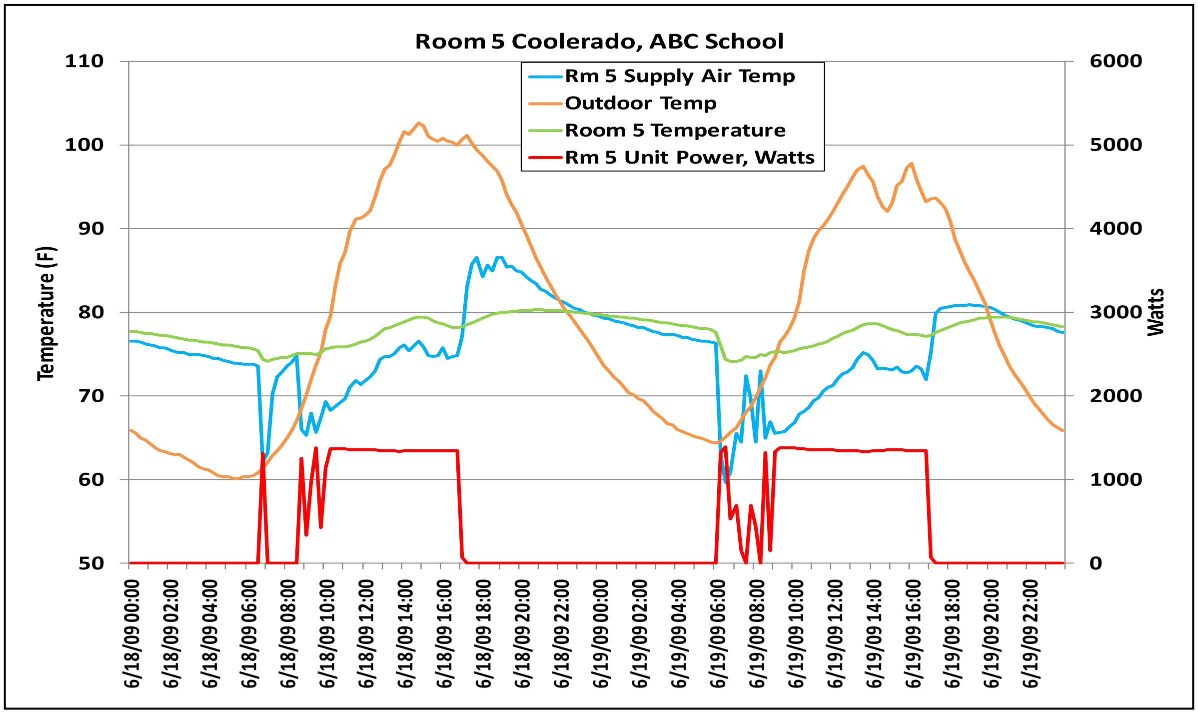


Figure 16: Monitored performance of the Cooleradoes serving Rooms 4 and 5 after being retrofitted with the synthetic HMXs. The indoor air temperatures (green lines) were kept below 80°F. The red lines show the power consumption of the Cooleradoes. Note that the units were shut off when the classrooms were unoccupied.

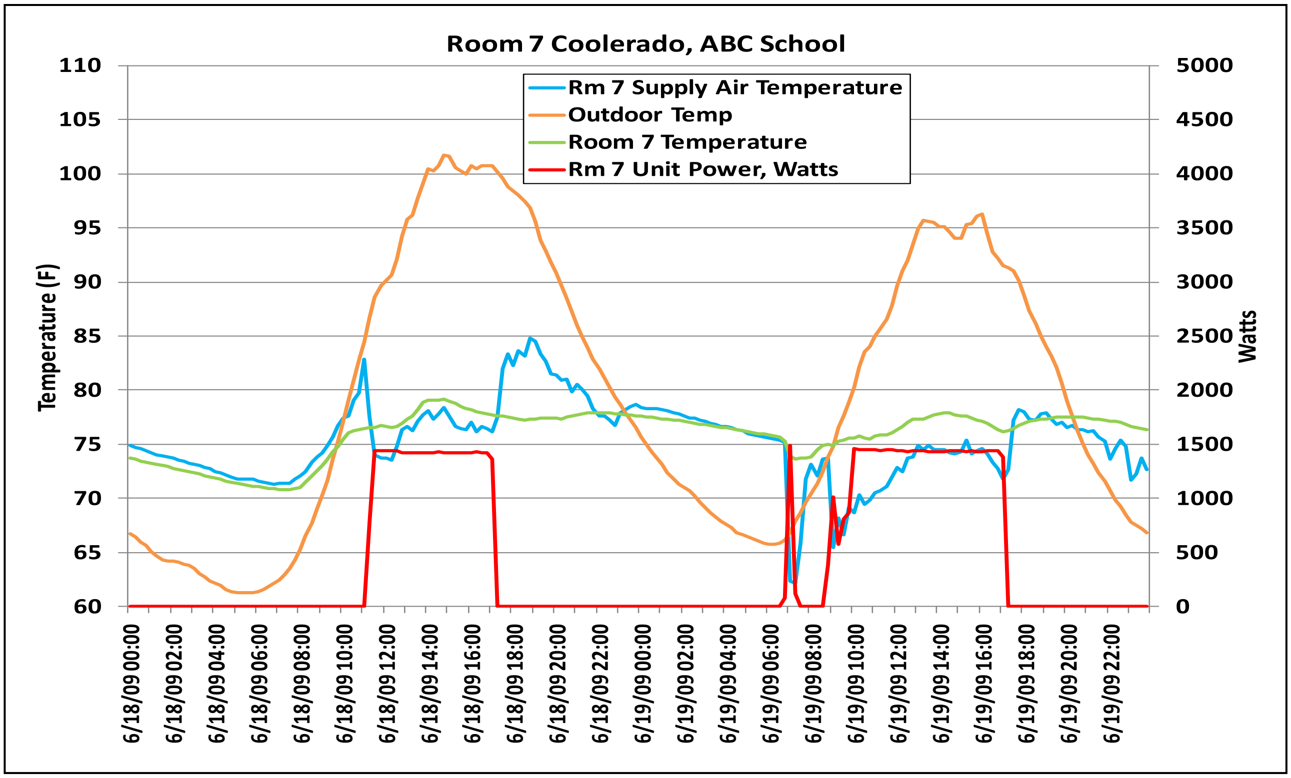


Figure 17: Monitored performance of the Coolerado serving Room 7 after being retrofitted with the synthetic HMXs. Once again the indoor air temperature (green line) was kept below 80°F. The red line shows the power consumption of the unit. Note that the unit was shut off when the classroom was unoccupied.

Some general observations:

- All four units were able to keep the classroom temperatures between 78°F and 80°F even when the outside air temperature was above 100°F. Although this was higher than the 76°F - 78 °F desired by the customer, it is remarkable considering this was accomplished without adding any moisture to the supply air stream.

- The units were operated from 8:00 a.m. to 3:30 p.m.

- Spikes in supply air temperatures occurred after 3:30 p.m. when the units were turned off. This was due to radiant heating of the ductwork by the sun (remember part of the ductwork is on the roof). Since the fans were also off at this time, this had no impact upon the indoor temperatures.

- The power consumption of the Coolerado was approximately 1.5 kW and remained relatively flat. This makes sense since the main component of the system was a single speed supply air fan motor.

Energy Savings and Electrical Demand Reduction

Since the original cooling system at ABC School consisted of indirect-direct evaporative cooling systems, this site did not facilitate a direct comparison between the Coolerado and traditional air conditioners (refrigerant based vapor compression systems). Therefore, ADM used monitoring data and modeling software to prepare an estimate of the savings. The following assumptions were used:

- Use of a 3-ton traditional air conditioner (12 EER, 14.5 SEER).
- Operating hours: 8:00 a.m. to 3:30 p.m.
- Cooling season: primarily from mid-April to mid-October (183 days per year).
- Indoor thermostat set point: 77°F.
- Electrical demand reduction (maximum connected load) was calculated based upon outside air condition of 105°F DB and 71°F WB indoor.

Based upon these assumptions, at this location each Coolerado would save:

Estimated kWh: 236 kWh per year
Estimated electrical demand reduction: 2.0 kW

The energy savings was somewhat lower than expected primarily due the fact that a properly sized traditional air conditioner would cycle on and off, whereas the Coolerado typically operated continuously whenever the classrooms were occupied. Newer Coolerados include variable speed motors which draw only half of the power of the units at ABC School.

Water Consumption

Coolerados use water to provide cooling and maintain moisture levels in the HMXs during periods of non operation. In-line water meters, such as the one shown in Figure 18, were used to measure the water consumption for each of the units. Our monitoring efforts only captured the total water consumption and did not distinguish between the water being evaporated verses the excess water being discharged to the drain. The average water usage during 2009 was 29.9 gallons per day per unit or 10,922 gallons per unit per year. These values are based upon unit operation from mid-April to mid-October. To put this into perspective, a family of three in California uses an average of 100,000 gallons of water per year.

Figure 18: The water consumption for each of the units at ABC School was measured using Omega Engineering (FTB4605) in-line water flow meters with pulse output resolution of less than one ounce of water, a range of 0.15 to 20 gpm and an accuracy of +-1.5%. Photo: ADM

The water usage rate during hot days can be over 100 gallons per unit per day. The water consumption for each of the units at ABC School is provided in the table below.

Water Use	Room 3	Room 4	Room 5	Room 7	Average
Gallons per Year	10,984	9,445	16,525	6,734	**10,922**
Gallons per Day	30.1	25.9	45.3	18.4	**29.9**

Showcase Project (Site 2)

System and Background Information

Coolerado Model: R400 (discontinued model)

HMXs: Four HMXs
First generation HMXs were cellulose
Second generation HMXs were Polypropylene

Fan/Motor: Single Speed
110 Volt (no longer offered)
12.5 amps
1500 Watts

Figure 19: Site 2 was a 50 year old, single story residence in Sacramento, California.

Site 2 is a 50-year old single story residence (Figure 19) in Sacramento, California with the following characteristics:

- Approximately 1,000 ft^2 of living space (not including the attached garage)
- No wall insulation
- R30 attic insulation
- Black composition tile roof
- Moderate shading
- Natural gas wall furnace
- No previous air conditioning system

Figure 20: Coolerado R400 at Site 2.

Before the Coolerado was installed, the residents stated that they would spend hot afternoons at the shopping mall or literally leave town during extended heat waves.

A Coolerado R400 was installed in September of 2005. This unit is smaller than the R600s at ABC School and includes four HMXs. The unit was mounted on the roof (Figure 20) and included new flexible ductwork within the attic space.

The Coolerado at this site was monitored from 2006 through 2009. Throughout this period, new upgrades were installed (including new synthetic HMXs) and control strategies were implemented. This location provided some additional valuable information. A discussion of key findings is presented below.

Key Findings

Air Filters

The Coolerado system relies on disposable air filters to protect the HMXs from excessive dirt build-up. Since the Coolerado uses 100% outside air, it is important to replace the air filters on a regular basis and winterize the units. Failure to do so may result in soggy, dirty air filters (Figure 21). The challenge is if the Coolerado is installed on a rooftop it will be easy for users to forget to follow these important procedures. Owners who are uncomfortable with traversing rooftops should consider obtaining service agreements from contractors who have been trained by the Coolerado Corporation.

Figure 21: If the Coolerado is installed on a rooftop, it may be easy to forget to change the air filters on a regular basis.

Thermal Performance

The chart below (Figure 22) shows typical performance of the Coolerado equipped with the new synthetic HMXs at Site 2 during the 2009 cooling season. The Coolerado was able to keep the indoor temperatures between 75°F and 80°F. Note that the data also reveals an interesting revelation: since the indoor thermostat was set at 75°F, this unit ran *continuously* and the power consumption stayed constant at roughly 1,200 Watts throughout this period.

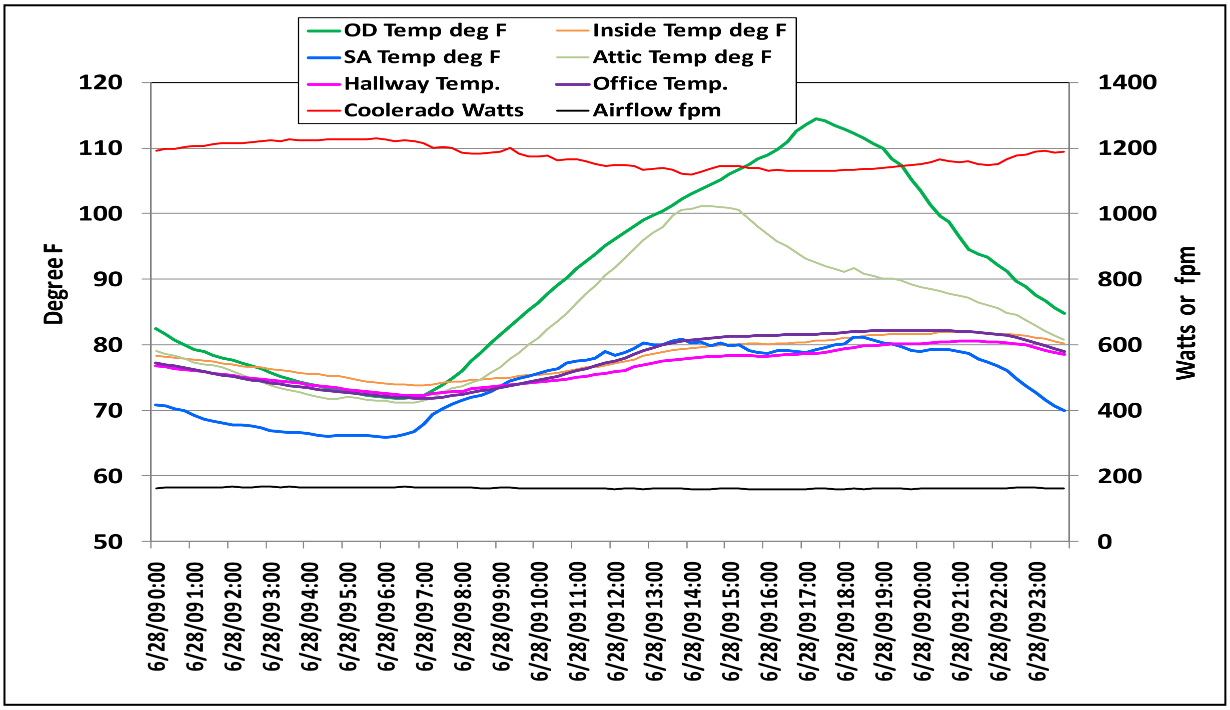


Figure 22: Measured conditions for Site 2. Note that the Coolerado was able to maintain indoor temperatures between 75°F and 80°F but ran continuously since the thermostat was set at or below 75°F.

Energy Savings and Electrical Demand Reduction

Based upon monitoring data, the estimated energy consumption of the Coolerado system for this residence is projected to be 1,435 kWh per year. To put this into perspective, a typical home of this size in Sacramento with conventional air conditioning uses around 1,100 kWh per year for cooling. Since this homeowner routinely set the indoor thermostat to 75°F, ADM used monitoring data and modeling software to prepare a savings estimate. The following assumptions were used for calculating the savings:

- Use of a 3-ton traditional air conditioner (12 EER; 14.5 SEER)
- Cooling season: mid-April to mid-October (183 days per year)
- Indoor thermostat set point: 75°F
- Electrical demand reduction (maximum connected load) was calculated based upon outside air conditions of 105°F DB and 71°F WB.

Based upon these assumptions, the Coolerado at this location would save:

Estimated kWh: 470 kWh per year

Estimated electrical demand reduction: 2.3 kW

Water Consumption

Since the Coolerado at this site was used 24 hours per day, it used more water than the units at ABC School. Based upon monitoring data, water use for this unit during a typical year would be 13,650 gallons or an average of 37.4 gallons per day. The water use during hot days may be over 200 gallons per day.

Product Improvements

The Customer Advanced Technologies program enables SMUD to test emerging technologies before they go to market, and provides manufacturers an excellent opportunity to improve upon their product. The Coolerado Corporation took full advantage of this opportunity. The product that is commercially available today includes several improvements over the units studied during this research project.

Fan Motor

One of the most significant changes occurred with the fan motor. The Coolerados tested during this project used 110 volt, single speed fan motors which consumed as much as 1500 Watts of power. Newer Coolerados use a 200-280 volt variable speed motor which has a maximum power consumption of 750 Watts – a 50% reduction in power. The graph shown in Figure 23 (next page) was provided by the Coolerado Corporation and shows monitoring data for a Colorado M50 tested by a third party in Henderson, Nevada.

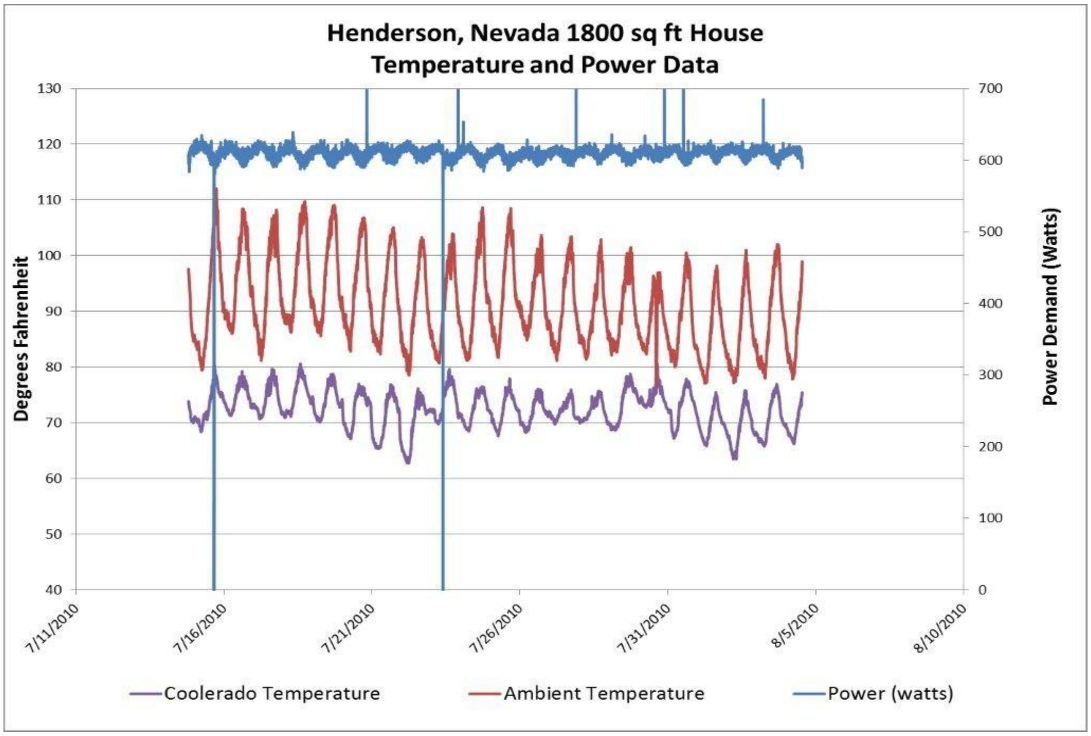


Figure 23: Monitoring data from a test site in Henderson, Nevada. Note that the maximum power consumption was approximately 700 Watts – a significant improvement over earlier units. Graph provided by the Coolerado Corporation.

The table below (Figure 24), provided by the Coolerado Corporation, shows the measured operating characteristics of the new fan motor. It is interesting to note that reducing the fan speed results in colder supply temperatures, due to longer contact time with the HMX.

Fixed Static Pressure (inches H20)	Fan Speed (% of full speed)	Product Air Flow (CFM)	Watts	Product Air % of Wet Bulb Approach	Product Wet Bulb	Working Air Flow (CFM)
0.1	100%	1533	704	94%	+2	1234
0.1	90%	1379	654	97%	+1	1127
0.1	80%	1226	442	100%	WB	1013
0.1	75%	1149	388	103%	-1	954
0.1	50%	766	188	111%	-4	666
0.1	25%	383	80	117%	-6	437
Example: Design 98 DB / 62 WB, 0.1" ext. static at full speed 98 - 62 = 36, 36 * 0.94 = 33.8, 98 – 33.8 = 64.2 ºF Product Air Temperature ≈ Design WB + 2 = 64 ºF						

Figure 24: Operating characteristics of Coolerado's new fan motor. Note that reducing the fan speed results in colder supply temperatures. Table provided by the Coolerado Corporation

Water Controller

Based upon lessons learned from the research project, Coolerado introduced a much more sophisticated water control system in 2007 (Figure 25). The new microprocessor based control system actually measures weather conditions (temperature and humidity) and calculates the evaporation rate. The control board, working in conjunction with a solenoid valve, adjusts the water supply to meet the actual cooling loads. The control algorithms may also be adjusted (via dip switches) to account for elevation and local water quality conditions.

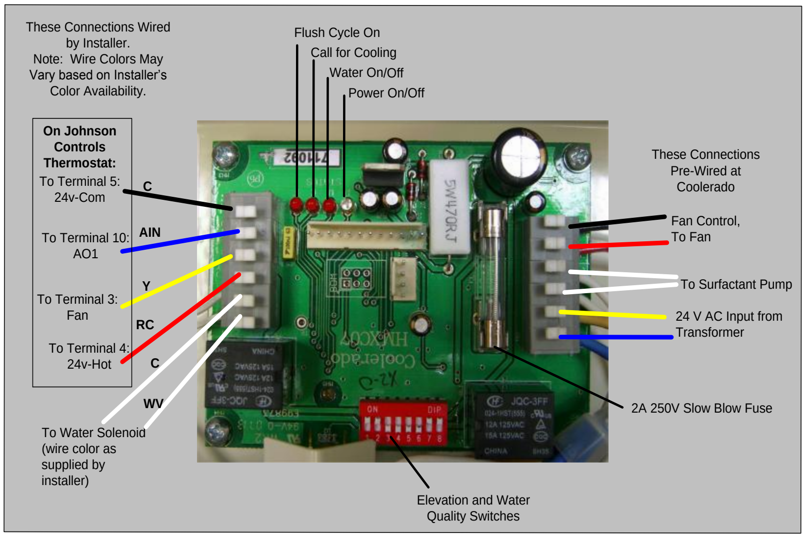


Figure 25: Coolerado's new microprocessor based controls measures weather conditions and supply air temperatures and adjusts the water supply to meet the actual cooling loads. Picture provided by the Coolerado Corporation.

Figure 26: Coolerado's new HMXs offer several advantages over the original cellulose based units. Picture provided by the Coolerado Corporation.

Heat Mass Exchangers (HMXs)

Today Coolerado's HMXs are made from polypropylene and are installed in a modular cassette (Figure 26). According to the manufacturer, this new HMX offers several advantages including:

- Eliminates biological growth in the HMXs
- Less resistance to airflow enables the use of a smaller, more energy efficient fan motor.
- Complies with U.L. fire and smoke requirements
- Fully integrated water delivery system with a single water connection point.

Conclusions

The Coolerado is an innovative indirect evaporative cooling system that may offer a viable alternative to conventional air conditioning in certain applications. Like any technology the Coolerado has both advantages and disadvantages:

Advantages

- Prototype units have been thoroughly field tested. This led to the implementation of several design improvements including more energy efficient, variable speed fan motors, advanced controls and synthetic HMXs.
- None of the tested HMXs experienced any problems due to hard water scale, even in locations known to have had past problems with hard water.
- Electrical demand reductions (connected load) of up to 66% compared to traditional air conditioning systems. This will become increasing more important as many electric utilities move toward implementing time-of-use rates via Smart Meters.
- Previous versions of the Coolerado offered energy savings of up to 25% (verses DX systems). Based upon information provided by the manufacturer, newer Coolerado systems should offer significantly higher savings. However, additional independent testing may be needed to quantify the potential savings.
- Promotes good indoor air quality by introducing 100% outside air into the conditioned space. May provide an excellent option for spaces with high ventilation requirements such as commercial kitchens and automotive service bays. Could also be used to handle ventilation requirements for big box retail stores.
- Unlike most evaporative cooling technologies, the Coolerado provides cooling without adding moisture to the conditioned air stream.
- Does not use chemical refrigerants.

Disadvantages

- Cooling capability is limited by the humidity of the outdoor air. Based upon our testing, the system should be able to maintain indoor air temperatures at or near 80°F during summer peak conditions in Sacramento. However, this temperature may not be low enough to satisfy some end users.
- Uses water to provide cooling.
- Does not include provisions for heating (except for the H80 product, see next page).

- Limited availability of trained contractors (Editor's note: the Coolerado Corporation has initiated a comprehensive training program to increase the number of trained contractors in California and other target market areas).

Technology Transfer

In the right application, the Coolerado may offer significant peak demand reduction compared to conventional air conditioning systems, and is now eligible for energy efficiency rebates (commercial customers only) under SMUD's Custom Incentive program. For more information, please call SMUD Commercial Services at 1-877-622-7683.

Final Thoughts

After six years of field testing and refinements, the Coolerado may now be a viable alternative to conventional air conditioning for certain applications. This may be especially true for cooling applications with high ventilation requirements (i.e. applications that require 100% outside air). Care must be taken, however, to properly set customer expectations. For example: although the Coolerado is remarkable, it is not realistic to expect one R400 system to maintain indoor temperatures below 75°F in a 50 year old home during a Sacramento heat wave.

Figure 27: Coolerado's H80 Hybrid Air Conditioner.

Coolerado now offers a range of indirect evaporative cooling systems. Their newest offering, the H80 Hybrid Air Conditioner (Figure 27), is a combination of Coolerado's HMX technology and a conventional vapor compression system. Based upon laboratory test data, this system should be able to provide most of the energy savings of evaporative cooling, while meeting indoor comfort requirements under virtually all situations. A prototype H80 system was installed in Sacramento and will be monitored during the summers of 2010 and 2011. In the meantime, to learn more about the H80 and other Coolerado products visit their website at: http://www.coolerado.com.

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