

**SMUD-IDEC Project
OASys Retrofit Final Report**

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1. BACKGROUND

Evaporative cooling has enormous potential to reduce cooling energy use in hot-dry climates such as California's Central Valley. However, direct evaporative cooling, the predominantly available technology, can add an undesirable amount of humidity to the conditioned building space, because moisture is evaporated directly into the supply air stream. Davis Energy Group has developed a two-stage evaporative cooler (indirect-direct evaporative cooler, or IDEC) that cools air without moisture addition in an indirect evaporative heat exchanger before further cooling the air in a direct evaporative stage. The resulting air is both cooler and contains less moisture than air supplied by direct-only evaporative coolers. Occupants typically find buildings conditioned with IDEC coolers to be more comfortable than buildings with direct-only evaporative coolers because humidity more often stays within acceptable levels.

Davis Energy Group's IDEC patented cooler uses several innovations, including polymer construction, a variable speed blower and a novel quasi-counterflow heat exchanger, to maximize reliability and energy efficiency. In lab testing, this IDEC design has performed with wet bulb effectiveness well over 100%, to as high as 116% at low air flow rates, while the total power consumption remained below 700 watts and sensible energy efficiency ratios ranged from 40 to well over 100. Computer simulations based on these lab test results indicate that this IDEC system is capable of reducing peak load by 80% and annual energy consumption by 90%, as compared to a conventional 12 SEER vapor compression air conditioning system. Additional test result details and system specifications can be found in Appendix A.

Speakman CRS of New Castle, Delaware recently licensed DEG's IDEC technology and will be building and marketing the system with the name "OASys," standing for Outdoor Air SYStem (this name reflects the fact that evaporative coolers supply 100% outside air to the conditioned space and therefore produce excellent indoor air quality). In the Summer of 2004, Speakman built a pre-production "beta test" run of 20 systems. Following installation and observation of the performance of these systems, Speakman CRS will begin production of the system and anticipates general availability in Spring, 2006.

2. PROJECT DESCRIPTION

The Sacramento Municipal Utility District (SMUD) is interested in OASys for reduction of peak load and total energy consumption in its service territory. However, as the system has been in early beta test stages, information regarding reliability, occupant comfort and energy performance is not well known.

SMUD has therefore hired DEG to evaluate the performance of the Speakman beta test units. The work scope stipulates that DEG shall:

- Procure 5 beta-test OASys units from Speakman CRS
- Select installation sites
- Oversee installation and commissioning of the units
- Provide a 1 year warranty
- Monitor and analyze the performance of one system
- Follow up with site owners with a survey to assess satisfaction with the system

- Submit a final report documenting project outcomes

3. PROJECT OUTCOME

3.1. Procurement, installation and commissioning

In the Summer of 2004, DEG selected five sites for OASys installation based on diversity of installation type, access, installation ease, and proximity to DEG offices. All sites were previously cooled by “CoolTech” IDEC systems that had been installed in the late ‘90s. Installation of the OASys systems involved removing the CoolTech units and modifying ductwork and support hardware. Site details are as follows:

1. Pete Price residence, 2617 4th Avenue, Sacramento CA. Ducted attic installation.
2. Lee Coup residence, 2705 H Street, Sacramento, CA. Ductless attic installation.
3. Thompson medical building, 3536 H Street, Sacramento, CA. Rooftop installation.
4. Heather Raitt residence, 1817 4th Avenue, Sacramento, CA. Ductless exterior wall installation.
5. Ann Brenner Residence, 2244 Grizzly Court, Gold River CA. Ductless attic installation.

After site selection, DEG submitted a purchase order for 5 beta test OASys systems, and Speakman CRS shipped the units in the Fall of 2004. DEG staff concurrently designed and procured the required installation hardware and duct transitions to replace the CoolTech units. DEG then hired Allen Amaro of Amaro Construction to assist with installation of the OASys systems. **All systems were installed in late 2004.** Operation of the system was explained to each customer and they were provided with an operation and maintenance manual (included for reference in Appendix B).

Brenner Residence System. After the Brenner OASys system was installed, but before it was commissioned, the home was sold. DEG and SMUD have made repeated efforts to contact the new residents but have been unsuccessful. **The home is equipped with a backup vapor compression air conditioning system and it is assumed that the new residents are exclusively using this system.**

3.2 Warranty Activities

Required Retrofits. After the systems were installed, Speakman CRS determined that the water distribution header was prone to clogging after several weeks or months of use. DEG worked with Speakman to develop a new water distribution system that required a less powerful pump, modified direct stage and new distribution header.

The solutions were implemented in mid-Summer 2005 at all but the Brenner residence. Several building occupants complained of poor cooling performance prior to the retrofit, suggesting that the header had already begun to clog. The new pump required changes to the control board program to prevent “air locking” in the impeller housing. Without the program modification, wet out of the media was insufficient to provide acceptable

cooling. Several customers complained of this issue before the problem was resolved but to our knowledge they have been satisfied with the system performance following the retrofit.

Raitt Residence. The Raitt OASys system presented a number of service challenges that prevented it from operating through much of the 2005 cooling season. In total, five issues have prevented the unit from operating, as explained in detail below. Two of the problems are site-specific: the thermostat wire from the original IDAC installation was faulty, the drain line from the original installation is prone to clogging (the drain line will be replaced on 9/2/05). A third problem, having to do with air locking in the pump, was solved by a change to the board program. The fourth problem resulted from a DEG error when installing the chip containing the new board program. The final problem, an error with the water level sensor, was resolved by clearing debris from the sump. A screened hood was installed to prevent the further accumulation of debris.

A detailed log of warranty activities is included in Appendix C, with specific attention paid to the issues encountered with the Raitt system.

3.3 Monitoring Results

The Raitt residence was selected as the monitoring site in the Spring of 2005 because the OASys system is mounted on an exterior wall and easily accessible. The monitoring plan is included in Appendix D. Unfortunately, intermittent operation of the Raitt system as described above prevented collection of performance data during the peak cooling season. However, in the month of September the system functioned correctly and we were able to retrieve data to characterize its performance. There were 10 days in September in which a call for cooling occurred.

One-time measurements and other data issues

Readings of the data logger sensors were compared against a highly accurate and recently calibrated hand-held Vaisala Temp/RH sensor. The datalogger's outside temperature/RH sensor was found to read slightly low. A correction factor was determined and applied to the reported data.

Multiple airflow measurements and corresponding power were also taken to correlate power to airflow. The maximum airflow was determined to be 1700 cfm at 630 watts. Using the data, a curve was fit to the cubic fan law equation to provide the following equation for airflow:

$$\text{CFM} = -671.75 + 274.47 * (\text{Power})^{(1/3)}$$

The R-squared value for the coefficients of the regression is 0.92.

This equation was used for calculating capacity and EER in the results section. Details of the calculation are presented in Appendix D.

The outside temperature monitoring equipment is positioned in the intake plenum of the OASys unit to insure that accurate effectiveness calculations could be made. The unit is located on the East side of the house and consequently gets morning sun, which causes an

incorrectly high outside temperature reading. However, by the time the unit begins operation in the afternoon cooling hours, it is in the shade and the effect disappears.

Results

The figures in Appendix E show outside, inside and supply air temperature as well as the outside wet bulb depression, saturation effectiveness and power consumption during the ten days of operation of the Raitt system in September. Total energy and water consumption for each day are also included. As the figures show, the OASys unit maintained an indoor temperature set point of roughly 70°F with outside temperatures as high as 87°F. Daily water consumption ranged from 9 to 42 gallons, averaging 20.6 gallons per day. Daily power consumption ranged from 0.12 kWh to 0.65 kWh, averaging 0.46 kWh/day. The saturation effectiveness¹ of the system was consistently over 100%, ranged as high as 120%, and averaged 105.5%. In contrast, the most advanced conventional evaporative coolers are able to perform with saturation effectiveness in the low 90% range.

The system was frequently run in the evening in fan-only mode to dry the media, provide additional fresh air and gain extra free “economizer” cooling. These events are noted in the figures of Appendix E, however they are not included in the energy analysis. The production version of the OASys system will include automatic controls that provide fan-only operation at night.

Appendix F contains figures showing the sensible cooling capacity and sensible EER of the system on the September days when it operated. For the September conditions, the sensible sensible capacity of the unit averaged approximately 10439 Btu/hr with a maximum of 16702 Btu/hr. The sensible EER varied from 58.9 to 115.9, averaging 85.9.

Capacity is calculated by assuming the standard relief air temperature of 80°F that is used in the California Title 20 ECER calculation². These metrics are termed “sensible” because the direct evaporative process is isenthalpic (meaning no change in the sensible plus latent energy content of the air). Although there is a real change in energy in the OASys air in the indirect stage, this cannot be measured without significantly more detailed monitoring points. Therefore the capacity and EER measures reported here take into account only the change in the dry bulb temperature of the air. Provided that the indoor air remains within comfortable humidity levels, it is reasonable to compare these metrics to the capacity and EER of conventional vapor compression air conditioning systems.

When operating in “Auto” mode, the OASys control system works by changing the blower speed continuously in proportion to the difference between the inside temperature and the set point. If the difference between these two temperatures is 4°F or more, the blower runs at full speed. If the difference is below 4°F and greater than zero, the blower runs at a speed that is proportional to the difference. If the difference is zero or less, the blower turns off. Therefore the blower speed and energy consumption is an indicator of the building cooling loads. Because the power consumed by the blower did not exceed

¹ See Appendix D for a formal definition of saturation effectiveness.

² Using a fixed return temperature avoids the problem that true return air temperature depends greatly on the characteristics of the building being cooled, meaning that the capacity of the system would depend on the building in which it is installed.

200 watts in the period reported, and because the maximum power consumption measured for this unit was 630 watts, the cooling loads during the reporting period were relatively low. This demonstrates that the OASys system has a greater cooling capacity than reported and should be able to meet substantially greater loads.

3.4 Survey Results

Jerry insert survey results here.

3.5 Conclusions

Widespread installation of OASys systems in SMUD service territory could generate substantial reductions in annual and peak energy consumption. When operating, the installed OASys systems performed as expected from previous lab test results. The monitored system maintained an indoor temperature setpoint of 70°F and did so with an average sensible EER of 85.9. Because the cooling loads during the reported period were low, water and power consumption were relatively low at 20 gallons per day and 0.563 kWh per day, respectively. **Building occupants found the system to provide adequate cooling, especially after the water distribution system retrofit was complete.**

However, a spate of maintenance problems with the monitored unit demonstrated that beta test systems—especially in retrofit situations—must be watched closely and properly maintained. The maintenance problems with the Raitt system were all adequately resolved, and the lessons learned from operating these beta test systems will be incorporated into the production OASys system.

Appendix A: OASys Specification Sheet

Appendix B: OASys Operation and Maintenance Manual

Appendix C: Service Log

	Date	Problem	Service Performed
Raitt Residence	5/18/2005	System will not start	Water to the unit had not been turned on at the beginning of the cooling season. This is typically the responsibility of the homeowner.
	6/15/2005	Float switch error	Float switch stuck in up position. Cleaned debris from sump. Verified proper operation of float switch mechanism.
	7/18/2005	System not working in auto mode. Only works in manual.	Tested control board operation from the unit. Need to replace board.
	7/18/2005	Original manifold design needs updating (as with all units)	Retrofit - replaced water manifold with new design, replaced pump with 003, replaced pads.
	7/19/2005		Control board replaced
	7/19/2005	Monitoring equipment installed	Monitoring equipment installed
	08/08/05 to 08/09/05	System not wetting out completely	Pump position adjusted. Replaced old board PIC with OASYS 1.1 (cycles pump to purge air after startup). Noted small drain line from IDAC installation (3/8 copper?) may cause slow drain. Replaced direct stage with Munters 5090 (wrong Munters erroneously installed by technician on 7/18). Replaced flexible line between pump and manifold
	8/19/2005	System not working/drain mode error	Verified proper operation of float. Checked drain valve: appears clear from obstruction. Appears there is something stuck in the drain pipe.(insulation perhaps) Attempted to use a hose to blow out obstruction. Draining better, but still slow. Drain line should be replaced with larger line.
	8/26/2005	Call from Rait, who was on vacation since 8/13: Unit works intermittently	
	8/29/2005	Blower working intermittently	One prong on the PIC on control board was bent by a DEG engineer when installed on 8/8/05, which caused a poor connection between the chip and the board. Prong was straightened and board was replaced for good measure.
	9/1/2005		Larger drain line installed to improve drain flow, exhaust hood installed to keep debris from entering unit.
Thompson Building	05/24/05	Water leaking from overflow.	connected proper line and fittings for overflow and drain.
	06/19/05	insufficient cooling	completed retrofit
Price Residence	07/20/05	System not cooling to desired temperature.	Retrofit - replaced pump with 003, replaced water manifold, and pads.Allow more time to see if unit operates better after retrofit.
Coop Residence	07/20/05	System has several leaks	repaired all leaks except leak at city water connection.
	08/10/05	Leak at fitting/	Replaced pump with 003. A.Amaro fixed leak at water line fitting.

Detailed Explanation of Raitt Maintenance Issues

System not working in Auto Mode: This problem was traced to auto mode calibration issues with the control board. Although the board had passed testing at both the board manufacturer and DEG prior to installation, it was found to be out of calibration after installation. A new board was installed and it also ceased to function in Auto Mode. The thermostat and thermostat wire were subsequently replaced and a third board was installed. This resolved the problem. We have concluded that a short in the thermostat wire (which was installed with the original IDAC unit) was pushing the board out of calibration.

Drain mode error: Debris was found to have lodged in the drain line, which was originally installed for the IDAC unit and is 3/8" copper. It is not known whether the debris was lodged in the line before or after installation. DEG first cleared debris from the line, and recently replaced it with a larger line to facilitate unobstructed drainage.

System not wetting out completely: This problem resulted from air locking in the pump impeller housing, and was quickly resolved by installing a new board program that cycles the pump on and off to purge air from the housing after a sump refill. For good measure, the position of the pump was adjusted to prevent accumulation of air in the housing after sump refill. The pump cycling feature will be unnecessary for the next generation of units, because they will use a different pump that will not air lock.

Blower working intermittently: This resulted from a DEG error when installing the new board program chip. Because the problem manifested intermittently and because the house occupant was on vacation, it was not identified for two weeks. It is not endemic to the design of the unit.

Float switch error: The float switch has been found to occasionally stick in the up position in the current OASys design. This prevents the fill valve from providing makeup water and ultimately causes the unit to return an error code when it attempts to purge. It is important to maintain a clean sump and occasionally check the operation of the float switch. The next run of OASys units to be manufactured will include a different float mechanism that will be less prone to seizure.

Appendix D: Monitoring Plan

Appendix E: Temperature, Power, Effectiveness and Water Consumption Data