Desert CoolAire™ Package Unit Technical Assessment *– Field Performance of a Prototype Hybrid Indirect Evaporative Air-Conditioner*

Final Report - Executive Summary

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*This is the **Executive Summary** of the Desert CoolAire Technical Assessment published for distribution on July 1, 2007.*

*The **full report** has extensive information on the research objectives, evaporative technologies, design intent of the CoolAire equipment, lab testing, field installation, monitoring and analysis approach, core and system field performance, and next generation design.*

The full report is posted at:

www.newbuildings.org

www.smud.org/education/cat/index.html

www.nwalliance.org/research/index_research.aspx

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Desert CoolAire Technical Assessment - Executive Summary

In 2005, the Northwest Energy Efficiency Alliance (NEEA), recognizing the need for new approaches to reducing commercial cooling energy use, funded a performance investigation of a prototype package air-conditioning system in the Northwest. The research was later extended to the California market through participation of the Sacramento Municipal Utility District (SMUD) with support from the American Public Power Association Demonstration of Energy-Efficient Developments (DEED) Program.

The field research shows a highly promising new hybrid air-conditioner that demonstrated 50 percent demand savings and increased capacity during times of summer peak, provided pre-compressor cooling at temperatures that allow for aggressive compressor lock-out schemes, and delivered 100 percent outside air throughout the cooling season with no energy penalty.

The modeled performance of a next generation unit redesigned based on research findings had an average daily Energy Efficiency Ratio (EER) of 19 and a peak EER of 25 – significantly beyond anything available on the market today.

This combination of significant demand savings, energy control potential and indoor air quality benefits are compelling factors for the continued investigation of this equipment's performance and market potential. This project has been extended to continue field monitoring and analysis in the summer of 2007 with a supplementary report due at the end of 2007.

Background

Package rooftop units are the dominant commercial cooling equipment - cooling 47 percent of commercial floorspace. Package units of 10 tons or less capacity represent 90 percent of the units sold, with the 5 ton unit as the most popular. Yet, research on new package units (4 years old or less) showed that in-field energy performance was well below the efficiency specifications[1]. In addition, standard package units experience reductions in efficiency and capacity during hot outdoor conditions coincidental with times of strain on the electric supply.

Based on growing market interest in improved energy efficiency and indoor air quality, Desert Aire Corporation designed the Desert CoolAire™ air-conditioner in 2005. The Desert CoolAire combines a new indirect evaporative heat exchanger (HMX core), the Delphi HMX[2], with compressor-based cooling and gas heating to create a 5-ton capacity hybrid package unit. Twelve prototype units were manufactured; each with eight indirect evaporative cores, a 4-ton digitally controlled scroll compressor (DX), 100,000 British Thermal Units (btu) gas heat, variable speed fan, enhanced controls, and sensors for lab and field research testing.

Research Objectives and Approach

The research objectives for the technical assessment phase were:

1) Establish product performance.
2) Understand product design and installation requirements.

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[1] Results through the California Energy Commission's Public Interest Energy Research (PIER) Program. *Small Package HVAC System Integration* at http://www.energy.ca.gov/2003publications/CEC-500-2003-082/CEC-500-2003-082-A-12.PDF

[2] The heat exchangers were invented by Dr. Valeriy Maisotsenko and are patented by Coolerado/Idalex Corporation. The heat exchangers used in the test units were manufactured by Coolerado/Idalex Corporation. The heat exchangers are now licensed for manufacturing by Delphi Corporation and called the Delphi HMX.

3) Refine product design to increase performance and address cost, design and installation issues.

The efficiency target for the prototype unit was 50 percent energy savings over the federal standard at the time of SEER 9.7 for equipment of 5 tons or less capacity. Establishing production and installation costs was not part of the technical assessment research phase. The approach for completing the research included lab testing, installation and monitoring of units in distinct climates, analysis of data and establishment of findings to support next-phase decisions.

A preliminary unit received Electrical Testing Laboratories (ETL) approval and was lab-tested during summer 2005 and spring 2006. Eight field units were tested through the cooling season of 2006 with a geographic diversity intended to represent the western U.S. climate. Five were tested in hot climates (Sacramento, California, and Boise, Idaho) and three were tested in mild climates which only occasionally get hot (Portland, Oregon, and Vancouver and Seattle, Washington).

This report reflects the aggregated results for the Northwest and Sacramento sites during 2006. At the time of this report, field investigation has been extended into the summer of 2007 with additional findings expected in November 2007.

Lab Testing

Lab tests were conducted to evaluate air flow performance as well as cooling effectiveness and output in varying temperature and humidity conditions of both the indirect evaporative module and the CoolAire prototype package unit. Test conditions included a range of 11 ambient temperature and moisture levels to investigate performance relative to leaving air temperature set points of 55°F and 65°F.

The evaporative cooling effectiveness of the HMX core was better than 78 percent and as high as 98 percent, with an average of 82 percent for the lab conditions tested. The cooling output of the HMX core alone was as high as 66,434 Btu/hour (5.5 tons) with an EER as high as 33 for the moment of most extreme outside air condition tested (101°F and 32 percent relative humidity) and the unit's total cooling capacity at the same conditions was 92,519 Btu/hour (7.7 tons) with an EER of 13.

Field Testing

Each of the eight field tested units was monitored to collect 25 performance measures every minute with real-time data available on a project website and performance models developed for all operating modes.

As a means of comparing the operation of the CoolAire prototype unit (prototype) to a conventional DX unit hypothetical SEER 10 and SEER 13 DX units[3] (reference units) were simulated to meet the exact same cooling loads as delivered by the tested prototype unit. The reference units were simulated based on their efficiency specifications which are typically greater then their actual field performance as cited earlier, but without economizer cooling[4]. The prototype results are actual measured field performance. In addition, a next generation CoolAire (Gen2) unit was modeled based on redesign as suggested from the research findings. Based on these parameters the comparison of field operation of the CoolAire prototype and the simulated performance of conventional DX systems are believed to be conservative estimates of true side-by-side energy use.

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[3] The SEER 10 unit was used as proxy for the current federal standard (SEER 9.7) for 3-phase ≤ 60,000 Btu unitary equipment and the baseline used to target 50-percent energy savings. The SEER 13 unit represents the current minimum standard adopted by ASHRAE, the Consortium for Energy Efficiency and by some states. The date for federal adoption of the SEER 13 standard is currently dependant on factors at DOE and the legislature but will be in early 2008 or by 2010 at the latest.

[4] Economizers fail to operate as designed in 90 percent of field checked units (source: merged analysis studies from PIER, RLW Analytics, NBI and others presented at the California Public Utilities Commission hearing on Big Bold Strategies for HVAC savings June 2007 by Abram Conant of Proctor Engineering)

Key Findings

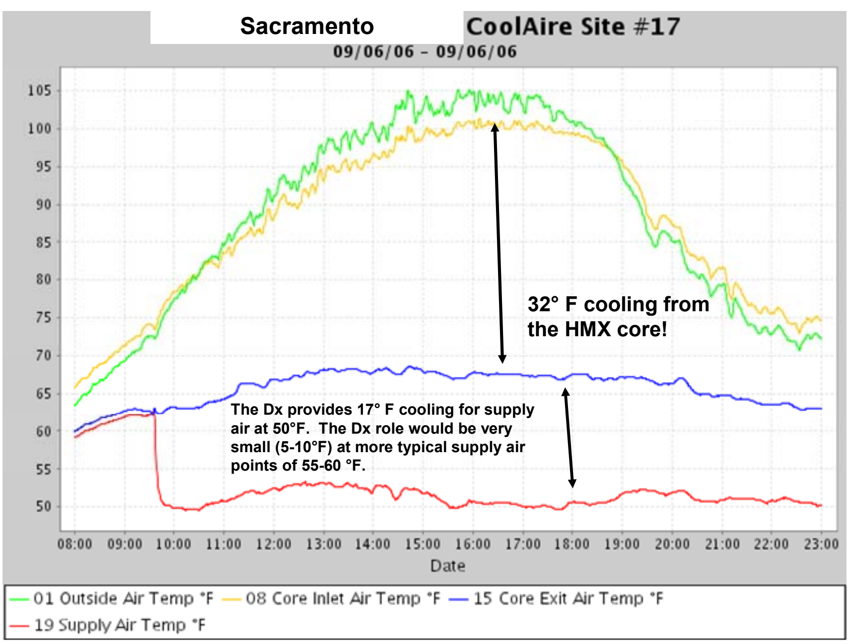
Key findings of the research are organized by "Successes" and "Challenges" for the equipment.

Successes

- Integration of the components into a hybrid package system proved successful and was able to fully meet cooling and heating commercial space conditioning needs.
- The prototype consistently demonstrated strong demand savings of 2-3 kW over reference systems (33 to 49 percent) with greatest demand savings aligned with periods of utility coincident summer peak (hot outdoor temperatures).
- The peak performance of the evaporative section was measured at 25 EER with the whole system performance prototype (evaporative and DX) measured at 15 EER at 103°F.
- Simulation runs for a next generation unit under the same load showed a peak EER of 25 at 103°F.
- At the time of this report the units had been operating under cooling conditions for about nine months. No scaling of the HMX core media (coated cellulose paper) was observed.
- Average daily energy savings of the prototype were significant, 23 percent compared to a conventional SEER 10 unit, but fell short of the targeted goal of 50 percent largely due to the poor performance of the compressor and fan.
- The prototype had a measured daily average EER of 12.3 including non-cooling and recirculation modes. The modeled performance of the reference units had a daily average EER of 9.6 for the SEER 10 unit and 11.6 EER for the SEER 13 unit.
- The HMX cores consistently delivered 65-72°F air temperature and 100 percent outdoor air with little or no increase in absolute humidity regardless of the inlet (outdoor) temperature to the core.

Figure 0-1 shows monitored data at a California site on a day that exceeded 100°F. The HMX core is cooling the outdoor (inlet) air by 32°F leaving a much smaller load for the compressor to carry.

Figure 0-1 CoolAire Monitored Data from Sacramento at 100°+F



- Space cooling could be supplied without compressor assistance during moderate cooling seasons (e.g. Northwest climates) or in applications conducive to supply air temperatures in the mid-to-high 60's.
- Given the performance of the evaporative section, it appears that the compressor could be aggressively controlled, or locked-out, as a demand strategy while continuing to deliver 65°F to the space.
- The 5-ton capacity prototype provided up to 6 tons of cooling (a 20% increase in capacity) during periods of hot outdoor temperatures whereas traditional package unit capacity decreases during hot outdoor periods.
- The research identified changes capable of making the system perform at the 50 percent energy savings target or better.

Table 0-1 shows the daily average EER for a high temperature event comparison of the measured as-operated performance of the CoolAire prototype and the simulated (modeled) performances of the next generation system (Gen2) and standard reference units.

Table 0-1 High Cooling Comparison of CoolAire and Reference Systems

EER Comparison of CoolAire and Reference Systems			
		High Cooling Case (Tmax 103F)	
	System	Avg. Daily EER	Tmax Hour EER
Reference	*SEER 10 (modeled)*	9.6	8.5
	SEER 13 (modeled)	11.6	10
Cool Aire	*Prototype (as operated)*	12.3	15
	Gen2 (modeled)	19	25

Challenges

- The following limitations resulted in an unreasonably low compressor cooling EER (not including fan energy) of 6-8 EER for the prototype significantly affecting overall system energy efficiency.
  - The variable-speed scroll compressor is widely misunderstood. The output can be precisely reduced from full output, but the input electric energy is not proportionally reduced. At less than full output, demand is reduced, but so is compressor energy efficiency.
  - Testing revealed that the compressor was inefficiently controlled (routinely invoked as second-stage cooling and then limited in output by cycling on/off) and oversized.
  - The prototype 4-ton compressor was oversized for the role of supplemental cooling to the HMX cores. Findings were that very little cooling was actually needed from the compressor - only about 10°F after the core - equivalent to approximately 1 to 1.5 tons of cooling.
- The prototype used a single plug fan to accomplish both supply air delivery to the space as well as pushing evaporative working air through the HMX core. This design required significant fan power during all modes and was a major issue affecting the energy efficiency of the prototype units.
- Core reliability for water bypass and bio-growth mitigation was not proven. Changes to the cores have been made for summer 2007 testing.
- Although water use during peak cooling periods was reasonable, the prototype used excessive amounts of water during moderate cooling periods. A new water control board has been developed and will be tested in summer 2007.

- The cost of the unit itself, although pricing estimates were not done for this project, is likely greater by 2+ times that of a comparably sized standard rooftop unit due to the integration of multiple technologies and more refined controls.
- The prototype unit is considerably larger, heavier and more sophisticated than conventional package units. This presents some installation issues, as well as unique maintenance requirements that remain for the product to become more applicable to wide market adoption, particularly as a replacement system.

Summary

Although the original prototype revealed several challenges, the substantial peak demand savings, ability to control for DX lock-out, the market attraction of 100 percent outside air and promising outlook for Gen2 were found to be sufficiently compelling by the sponsors to warrant ongoing investigation of the Desert CoolAire.

The revised core, water control box and control changes are being tested in the summer of 2007. A next generation unit incorporating the final set of redesign options will then need field research testing in summer 2008 with product availability targeted for 2009. SMUD has already expressed interest in sponsoring deployment and testing of the Gen2 systems.

At the time of this report publication new chemically treated cores have been installed in the current prototype units and July 2007 field inspections found them completely clear of biological growth. Based on this encouraging result and ongoing monitoring the work on the Gen2 design will continue as described in the full report.