PROJECT REPORT

CONDENSER AIR PRE-COOLER RETROFITS FOR ROOFTOP UNITS

Contrails Dining Facility
Beale Air Force Base
Marysville, California

May 13, 2013

WESTERN COOLING EFFICIENCY CENTER

UC DAVIS
UNIVERSITY OF CALIFORNIA

PREPARED FOR:

Karl Johnson

California Institute for Energy & Environment
1333 Broadway, Suite 240
Oakland, CA

PREPARED BY:

Jonathan Woolley
Associate Engineer

David Grupp
Associate Engineer

Paul Fortunato
Outreach Coordinator

Western Cooling Efficiency Center
University of California, Davis
215 Sage Street #100
Davis, CA 95616

wcec.ucdavis.edu

ABOUT THE WCEC

The Western Cooling Efficiency Center was established along side the UC Davis Energy Efficiency Center in 2007 through a grant from the California Clean Energy Fund and in partnership with California Energy Commission Public Interest Energy Research Program. The Center partners with industry stakeholders to advance cooling-technology innovation by applying technologies and programs that reduce energy, water consumption and peak electricity demand associated with cooling in the Western United States.

TABLE OF CONTENTS

SECTIONS

GRAPHS

TABLES

1.0 EXECUTIVE SUMMARY

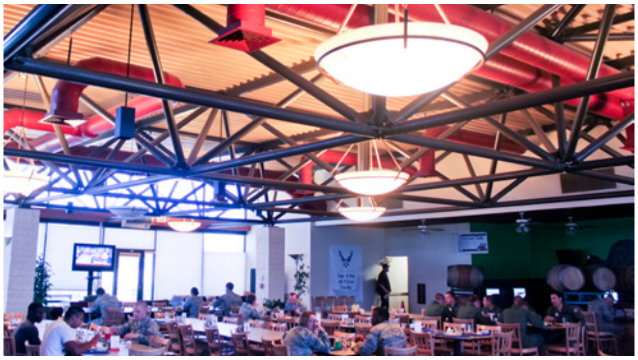
The California Energy Commission's Public Interest Energy Research (PIER) program established the new California Smart Grid Center (CSGC) at CSU Sacramento. The CSGC is developing a multi-year partnership with Beale Air Force Base (BAFB) related to smart grid development. One of the first projects the CSGC carried out was the facilitation for the installation of energy-efficient lighting and HVAC retrofits at the Contrails Inn Dining Facility in partnership with the California Institute for Energy and Environment (CIEE) in the specification and management of these demonstrations. CIEE has managed over 100 demonstration sites in the PIER State Partnership for Energy Efficiency Demonstrations (SPEED) market transformation program in conjunction with the California Lighting Technology Center (CLTC) and the Western Cooling Efficiency Center (WCEC) at the University of California, Davis.

A CSGS and BAFB working team was established to recommend and install PIER solutions at the Contrails Inn Dining Facility as the first step to show how these technologies might be successfully implemented at other Air Force bases and facilities. As part of this task, the team evaluated base energy loads, occupant usage patterns and facility operation schedules. Based on this data, the working team was able to present lighting and HVAC retrofit recommendations.

This document summarizes the evaporative condenser air pre-cooler retrofit on a 50-ton Trane® chiller portion of the demonstrations at the 15,000 square foot Contrails Dinning Facility. The project demonstrated the overall energy savings, peak-time energy savings, lifetime energy cost savings and simple payback for a condenser air pre-cooler over a multitude of possible facility sizes served, and over a large range of chiller capacities (25-tons to 200-tons) for climate zone 11. This system uses water evaporation to cool outside air before it crosses the condenser coil. A lower condenser air inlet temperature increases the capacity and efficiency of a vapor-compression chiller. Water flow to the condenser air pre-cooler is intelligently controlled based on ambient air temperature, relative humidity, and power draw of the compressors to manage the amount of water used.

DEMONSTRATION SAVINGS	
Peak Savings	20%
Cooling Energy & Co_2 Savings	22%
Energy Reduction	280 kWh/yr-ton
Water Usage	0.9 gal/day-ton
Lifetime Energy Cost Savings	**$19,600 (@$0.07/kWh for 20 yr life)**

Through monitoring of the retrofit from August 2 through September 9, 2012, it was determined that the retrofit for this specific application in climate zone 11 reduced energy use by 22% and reduced peak-time power draw by 6kW. In addition to these specific demonstration findings, this report also includes savings information for a range of facility and chiller sizes in order to better determine the efficacy of this type of retrofit across various buildings.



Contrails Dining Facility at Beale Air Force Base in Marysville, California

2.0 ABOUT THE TECHNOLOGY

Evaporative pre-coolers are effective retrofits to reduce the temperature of air that cools the condenser coil in air-cooled chillers, RTUs and other DX equipment. In these systems, the outside air stream passes over a wetted surface before it reaches the condenser, heat from the outside air is absorbed by water evaporation thus cooling the air stream. Evaporative condenser pre-coolers are applicable to most all climate zones, but have even more energy impact in lower humidity areas, such as California.

Evaporcool™ is one such evaporative condenser-air pre-cooler. The system uses a microprocessor controller to manage the spray of filtered domestic water onto an evaporative media. The flow rate of water delivered changes with outside air temperature and relative humidity so that the system delivers roughly only as much water as is needed for evaporation. The system has no sump, and no drain or water bleed.

Some benefits of the Evaporcool™ system include:

- Easy installation – The media mounts to the exterior of a conventional chiller using magnets. They are easily installed, easily removed and do not require any mechanical fasteners. The system can be installed on new equipment or as a retrofit.
- Evaporation occurs at the pads; not on the coils – Since water does not contact the condenser coil, this expensive equipment component will not corrode, and will not become fouled by mineral deposits left behind by the evaporating water. The evaporative media is made of an inexpensive durable polymer that is easily cleaned or replaced when minerals deposits accumulate. Evaporative media also acts as a filter to reduce the amount of dust and debris settling on the condenser coil.

Ongoing costs for condenser air pre-coolers are small:

- Evaporative media adds some resistance to airflow across the condenser. This can reduce airflow across the condenser, which reduces equipment performance if evaporation is not providing some useful cooling.
- The systems must be maintained and cleaned occasionally when mineral deposits or debris accumulate on the media.
- The evaporative system and any outdoor plumbing must be shut off and drained for winterization in order to protect from freeze damage.

Evaporcool™ condenser air pre-coolers installed on the 50-ton Trane® Chiller at Beale Air Force Base

3.0 DEMONSTRATION: CONTRAILS DINING FACILITY, BEALE AIR FORCE BASE

An Evaporcool™ system was installed as a retrofit at Beale Air Force Base Contrails Dining Facility, near Marysville, CA. The unit retrofitted was a 50 ton Trane® Air Cooled Cold Generator, or 'chiller' with two refrigerant circuits and four compressors. The four compressors are programmed to actuate sequentially as required to maintain a target chilled water supply temperature. The system chills water to provide cooling for the commercial kitchen and dining facility.

Installation of the system included:

» Plumbing with filtration and non-chemical water treatment to supply water to the pre-cooler

» Removal of the existing inlet grilles and attachment of the Evaporcool™ frame with media

» Setup of sensors and control system

Some costs for such a retrofit will scale with the size of the chiller on which it is installed. On the contrary, costs for controls, sensors, and external plumbing elements are roughly fixed. Therefore, retrofit of larger systems should be more cost effective than retrofit of smaller systems.

Plumbing with filtration

Removal of existing inlet grilles

Setup of sensors and controls

3.1 RESULTS

Water temperature was measured at the inlet and outlet of the chiller. Since chilled water is circulated with a constant speed pump, the difference between supply and return water temperature was used as a proxy for the cooling capacity delivered within each 5 minute measurement interval. Electric power consumption, outdoor temperature and outdoor relative humidity were measured on similar intervals. These measurements allow for a complete assessment of equipment efficiency.

Baseline performance data was collected for several weeks prior to the retrofit, from September 1st 2011—October 10th 2011. Post retrofit data was collected the following summer from August 2nd—September 9th 2012. Post retrofit data preceding August 2012 was not used because one refrigerant circuit in the chiller needed repair.

Figure 1 compares electric energy use for the chiller during the pre and post-retrofit periods. Regression models for the data in each period were developed to model chiller energy consumption as a function of outside air temperature and humidity. A projection of these trends across typical annual meteorological conditions indicates that the complete SPEED suite of efficiency measures installed in the facility reduced chiller energy use by 18,000 kWh/year, or 29% of the baseline. The annual energy savings that can be attributed to the Evaporcool™ is 14,000 kWh/year or 22%.

Chiller electric power consumption was analyzed as a function of cooling capacity, as plotted in Figure 2. The figure shows that electricity use in the post-retrofit period is significantly lower than the baseline period for any given cooling capacity. The energy used to carry a particular chilled water temperature difference has a much higher variance during the post retrofit period. This is due in part to the impact of humidity on condenser pre-cooler performance. The high variance is also likely due to a more highly variable cooling load as a result of the other SPEED variable capacity retrofits in the building. Some of the efficiency measures deployed include constant volume to variable speed fan retrofits, and the addition of demand controlled ventilation for kitchen exhaust and occupied dining spaces. Since the impact of evaporative pre-cooling increases with temperature, the energy savings will be greater for high chilled water temperature differences and less when the load is smaller.

To control for the independent impact of the Evaporcool™ retrofit, the trends in Figure 2 were used together with trends for cooling load as a function of outside air temperature to predict the annual energy savings that could be attributed to the condenser air pre-cooler. A regression model to describe the pre-retrofit cooling load as a function of outside air temperature was used to predict the baseline cooling load for every hour of a typical year in California Climate Zone 11. The cooling load in each 5 minute interval was used together with the trends in Figure 2 to predict the total annual chiller electricity use for operation with and without the Evaporcool™. Comparison of the annual sum of electricity use for each scenario indicates that the Evaporcool™ reduced annual chiller electricity use by 14,000 kWh/year, or 22%. At peak cooling load conditions, on average, the Evaporcool™ saves 20% on electric demand or roughly 6kW for this application. The calculation of peak cooling savings is based on the reduction of average power required at the highest outdoor air temperatures, and may be different than that which is calculated for utility incentives.

These results should be applicable for evaporative condenser air pre-coolers of different sizes installed on the condenser sections of a variety of air cooled equipment, such as roof top package units or split systems in similar climates. Even better performance can be expected in hotter and drier climates zones.

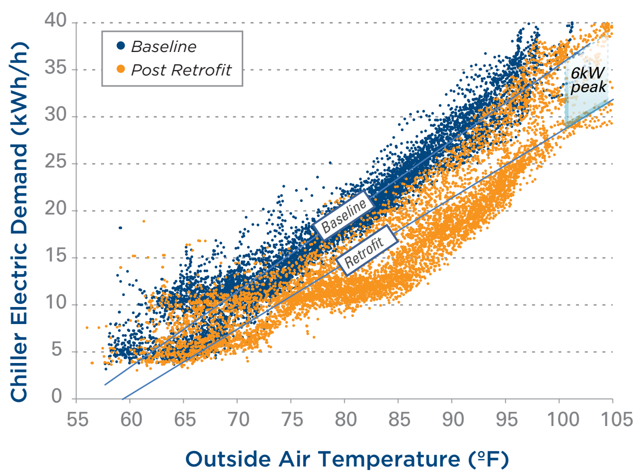


Figure 1: Chiller electric demand as a function of outside air temperature

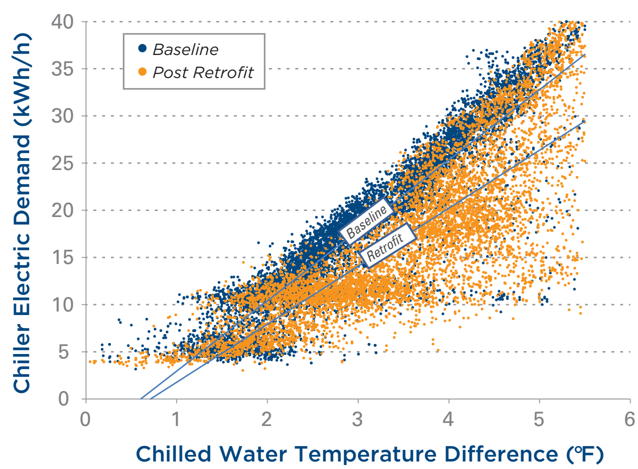


Figure 2: Chiller electric demand as a function of chilled water temperature difference

3.2 Economic Evaluation

Economic value of a condenser air pre-cooler retrofit depends on the cost of installation, water and electricity rates, annual meteorological conditions, and the amount of energy used for cooling in a particular facility. Typical costs will range from 150 $/ton to 200 $/ton depending on the size of the unit being retrofit, this estimate does not include the labor involved in installing the system and plumbing water to the Evaporcool™ system. Once all costs are factored in, a system installation on systems less then 100 tons might cost somewhere around 300 $/ton - 400 $/ton. The Evaporcool™ system demonstration at Beale Air Force Base cost a total of $17,260 including equipment, installation, and commissioning; this amounts to roughly $345 per ton. The installation cost for this project on a secure military base were somewhat higher than most sites due to the remote location for team mobilization and site access restrictions. The marginal cost for materials and services that scale with equipment size is such that cost-per-ton should be less for larger capacity systems. Much of the cost is for hardware and services that are independent of system size. A more typical cost for large commercial installations greater than 100 tons may be $200-$250/ton. A more precise cost estimate can be obtained from the vendor who will be installing the equipment.

Figure 3 charts the total installed cost as a function of equipment capacity serviced for three cost-per-ton possibilities. The Beale Air Force Base installation (electricity rate of $0.07 per kWh) is located on the plot, along with two hypothetical scenarios for larger systems. Example 1

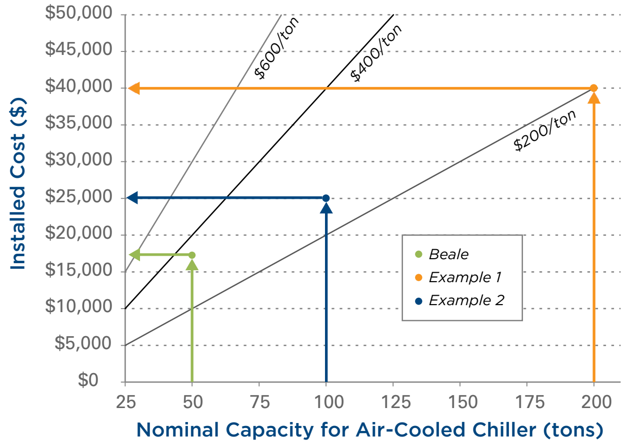


Figure 3: Installed Cost Estimator. Use nominal size of air-cooled chiller, and cost-per-ton for retrofit to estimate project cost

(orange) locates the annual savings for a 50,000 ft^2 facility with 5 kWh/ft^2-yr annual cooling energy intensity and an assumption of 30% annual energy savings. Example 2 (blue) is for a 30,000 ft^2 facility and 3.5 kWh/ft^2-yr cooling energy intensity, this example assumes 20% annual energy savings. These examples where chosen to demonstrate the potential range of savings that might be expected by using the Evaporcool™ retrofit in various climates on different sizes of equipment. The annual cooling energy used will vary significantly by building use and climate zone, and the specific application must be considered in detail before installation.

Figure 4: Energy Savings Estimator. Use facility size serviced (ft²), fraction of estimated cooling energy reduced (%), and facility annual cooling energy intensity (kWh/ft²-yr) to determine annual energy savings (kWh/yr).

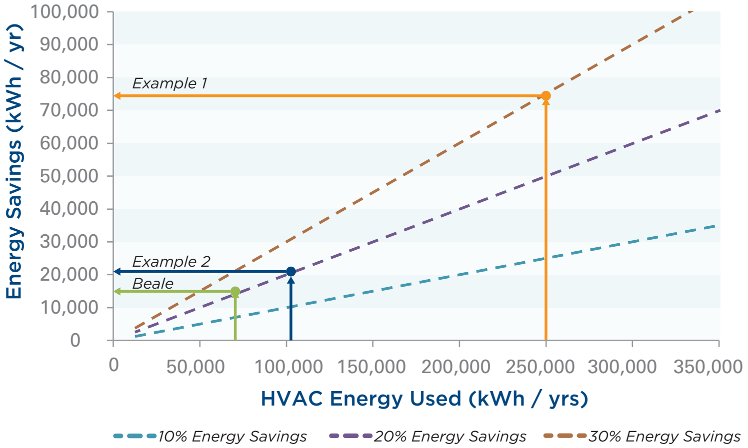
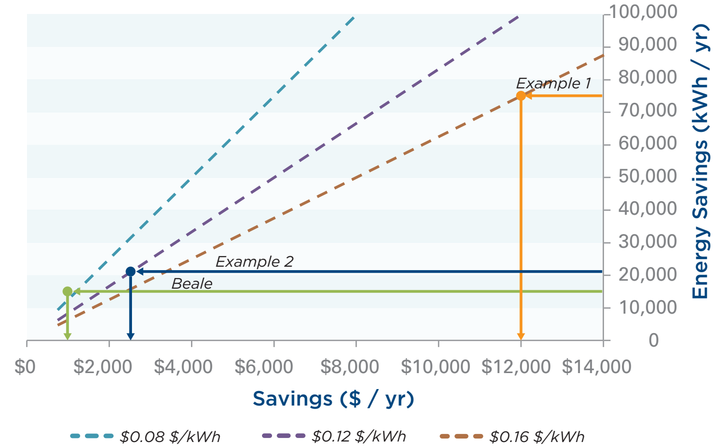


Figure 5: Dollar savings amount per year. Use Annual energy savings from Figure 4 (kWh/yr) and electricity cost ($/kWh) to determine dollar savings per year.



Figures 4 and 5 can be used to estimate the annual savings that can be expected by installing an evaporative condenser air pre-cooler. The savings can be determined by locating the annual electricity used by current HVAC equipment (estimated from current billing or by floor space and use type as outlined above) along with an appropriate savings factor. For the installation at Beale AFB, located in California Climate Zone 12, the savings factor was found to be roughly 22%. Greater savings can be expected in hotter drier climates. The Beale Air Force base retrofit and the two hypothetical examples are plotted. The estimated results for the three examples shown in Figures 3, 4 and 5.

This economic evaluation does not account for the value of peak demand savings, equipment lifetime extension, or the potential to reduce equipment size due to added cooling capacity at peak. The calculations also ignore the cost of water consumed. Average water consumption for the demonstration was 44 gal/day in August – September 2012. Currently the most expensive water in California is found in San Diego. Using a worst case estimate of $0.006/gal, this equates to roughly $48 over a 6 month cooling season, and can be considered negligible. A full financial evaluation would also include lifetime maintenance considerations and any potential rebates that might be available through programs such as the UC/CSU/IOU Partnership and financing options such as utility On Bill Financing and through the Statewide Energy Partnership program.

Facility	Cooling Energy Intensity kWh/ft²-yr
Office	3
Restaurant	5.7
Retail	2.2
Food Store	2.9
School	1.2
Health	3.8
Lodging	2.4

Table 1: Energy use intensity for cooling in various facilities. Excerpted from California Commercial End Use Survey.

		Beale Air Force Base (green)	Example 1 (orange)	Example 2 (blue)
Figure 3	Equip. Capacity Serviced (ton)	50	200	100
Figure 3	Cost-per-ton ($/ton)	345	200	250
Figure 3	Total Installed Cost ($)	17,261	40,000	25,000
Figure 4	Facility Size (ft^2)	15,000	50,000	30,000
Figure 4	Cooling Energy Int. (kWh/ft^2-yr)	4.3	5	3.5
Figure 4	Fractional Savings (%)	22	30	20
Figure 4	Annual Savings (kWh/yr)	14,000	75,000	21,000
Figure 5	Utility Rate ($/kWh)	0.07	0.16	0.16
Figure 5	Simple Payback (years)	17.6	3.3	7.4

Table 2: Savings, Investment & Characteristics of the three examples: Beale Air Force Base, Example 1 and Example 2 as plotted in Figures 3, 4, and 5

4.0 Collaborators

California Energy Commission provided funding for the whole building retrofit demonstration. Beale Air Force base provided collaboration and support. California Institute for Energy and Environment, UC Davis Western Cooling Efficiency Center, provided project management, technical guidance, and performance evaluation. Air Systems of Sacramento conducted installation, commissioning, and training for the Evaporcool™ system.

Any questions about this project, including technology costs, can be directed to:

JONATHAN WOOLLEY

UC Davis
Western Cooling Efficiency Center
jmwoolley@ucdavis.edu
wcec.ucdavis.edu

KARL JOHNSON

California Institute for Energy and Environment
Karl.johnson@uc-ciee.org
uc-ciee.org