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Efficient Cooling for California Campus

By Tony Costa, P.E., Member ASHRAE

The William B. Race Health Sciences Building on the Santa Rosa Junior College Campus houses the college's Health Science Department and Student Health Services. The 38,500 ft^2 (3577 m^2), three-story, building provides state-of-the-art instructional facilities for the existing health sciences programs such as nursing, dental assistant, radiological technology, and others.

This article describes how three separate wet-bulb conditions are used by three evaporative cooling air-handling units and a chiller with an evaporatively cooled condenser to reduce electrical energy costs for summer air conditioning of the Health Sciences Building.

All-OA Design for Improved IAQ

Indoor air quality (IAQ) in classrooms is always a concern because of high occupancy levels. Add to this the treatment of patients who may have contagious respiratory infections, and the problem of maintaining a safe indoor environment becomes even more difficult. A variable air volume (VAV) all-outdoor air design was selected to provide a reduced risk of airborne infection of students and staff.

Santa Rosa, Calif., is a semi-arid climate where an indirect/direct evaporative cooling design may be used in summer to introduce 100% outdoor air with a 38% reduction (*Figure 1*) in design day cooling tonnage. The more conventional classroom design uses a 30% minimum outdoor air economizer cycle, using a direct spray heat pipe air-to-air heat exchanger with a 70% indirect evaporative effectiveness (IEE) for indirect or dry evaporative cooling coupled to a 90% effective wetted media direct evaporative cooling component.

The all-outdoor air design reduces the ambient condition of 99°F (37°C) dry bulb (DB), 69°F (20.5°C) wet bulb (WB) to 62.6°F (17°C) DB, 61.2°F (16.2°C) WB. This is an enthalpy reduction of 3.7 Btu/lb (8.6 kJ/kg), compared to the 30% airside economizer at the same summer design condition.

As in most of California, Santa Rosa has a mild winter. The winter design (median of extremes) condition is 27°F. (–2.8°C) In cold weather, the air-to-air heat exchanger, with the indirect sprays turned off, will use the heat available in the building return air to preheat outdoor air from 27°F to 58.3°F (–2.8°C to 14.6°C). With many VAV designs in

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winter, IAQ can become a casualty. This is because supply air volume to the building decreases as ambient temperatures drop, taking the fresh air fraction below acceptable minimums required by ANSI/ASHRAE Standard 62, *Ventilation for Acceptable Indoor Air Quality*. The free preheating of outdoor air by the heat pipe allows VAV terminals at each building zone to be set up with all outdoor air minimum flow settings that exceed code ventilation rates per person.

Ceiling diffusers with a high air diffusion performance index were selected carefully to provide minimum stratification and good mixing of room and primary supply air under all anticipated flow conditions. This, coupled with the 100% outdoor air design, ensures that minimum ventilation rates of 15 to 20 cfm (7 to 9.4 L/s) per person are met under all conditions.

Other benefits of 100% outdoor air design are: the air supplied to the occupied zones will have CO_2 levels lower than comparable recirculated air systems; outgassing from building materials and furniture is exhausted directly from the building; and the lead time for transient occupancy is minimized. While no actual measurements were taken for ventilation effectiveness, CO_2 levels, and inside contaminants, field surveys of the building occupants and maintenance staff have shown a low number of complaints due to temperature, lethargy, drafts, or stuffiness.

The Wet Bulb Triple Dip

An interesting aspect of this design is the use of three separate wet-bulb conditions to minimize cooling load energy consumption for the building (*Figure 2*).

• **Building Return Air WB.** Usually in the range of 60°F to 65°F (15.5°C to 18.3°C) for conditioned spaces, the building wet bulb is used to dry cool the outdoor air from summer design of 99°F (37°C) DB, 69°F (20.5°C) WB to 75.2°F (24°C) DB, 61.2°F (16.2°C) WB. This return air condition is much more stable and dependable than ambient air for producing the first stage of indirect evaporative cooling. Hygroscopic building materials absorb ambient moisture so the return air to the air-handling units has a lower absolute moisture content than the supply air condition.[1] This phenomenon results in higher cooling capacity for the heat pipe exchanger during afternoon hours, when ambient relative humidity is the highest.

• **The Indirect Evaporative Cooling WB.** The lower wet-bulb condition generated by the indirect evaporative cooling process allows the adiabatic direct evaporative cooling component to deliver the required supply air temperature of 53°F (11.7°C) DB, 52°F (11.1°C) WB. ASHRAE bin weather data for central California indicates that 30% to 40% of the annual cooling hours (when ambient dry-bulb conditions are more than

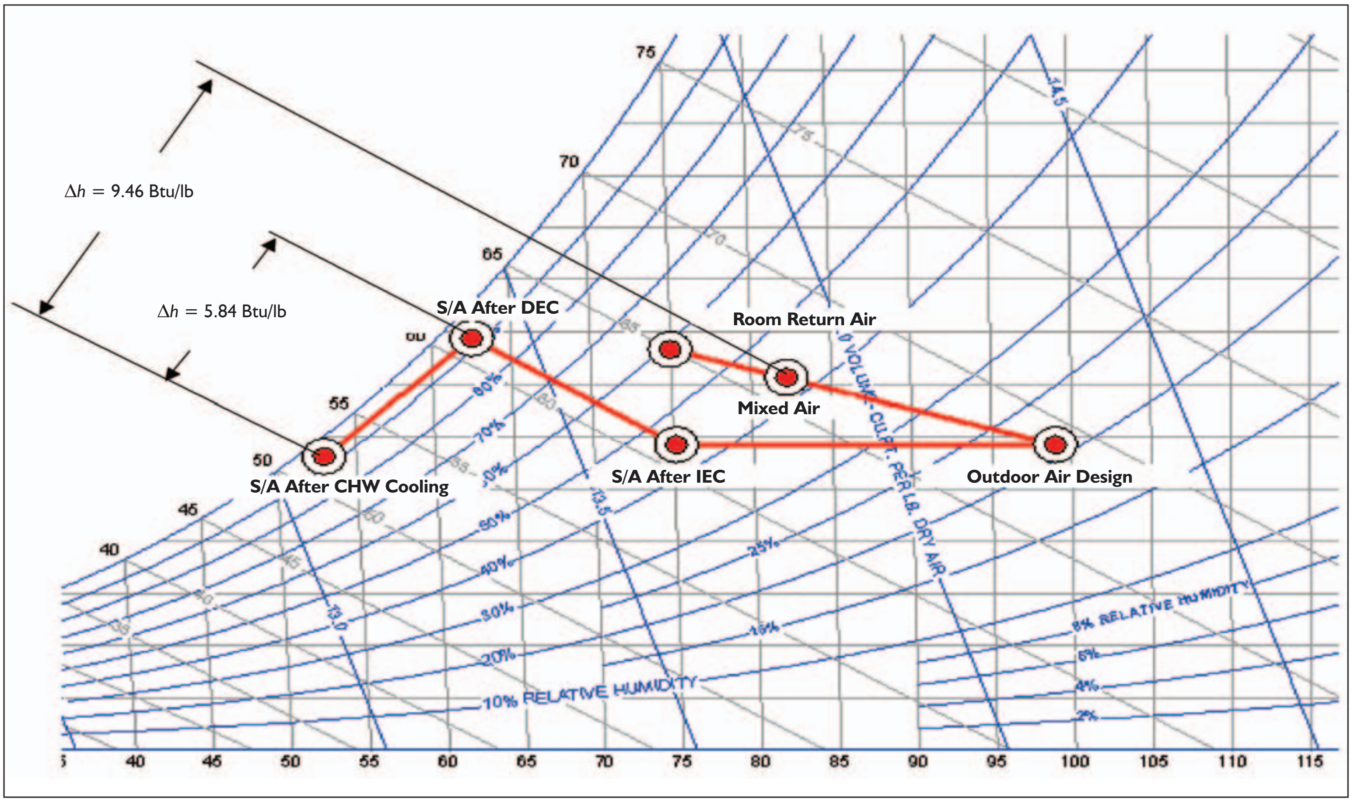

Figure 1: Santa Rosa, Calif., is a semi-arid climate where an indirect/direct evaporative cooling design may be used in summer to introduce 100% outdoor air with a 38% reduction in design day cooling tonnage.

55°F [12.8°C]) may be satisfied with a 90% effective direct evaporative cooling component alone.[2]

• **The Ambient WB.** The use of the ambient wet bulb in lieu of dry-bulb temperatures to reject the heat of compression from the refrigeration final stage of cooling.

The Evaporative-Cooled Condenser

During the last 40 years in California, the use of air-cooled water chillers for applications under 100 tons (350 kW) almost has been a given. In Santa Rosa, the wet-bulb depression (design DB – design WB) equals 30°F (17°C) on the hottest day of the year. Compared to an air-cooled condenser, an evaporative refrigeration condenser will reduce chiller energy consumption by 30% to 35%.[3]

A look at summer bin weather data for California's Central Valley shows that a wet-bulb depression of 20°F (11°C) or greater exists for most of the afternoon hours when electrical energy rates are the highest in a deregulated market. By lowering the condensing temperature of the compressor, the refrigeration capacity is increased, as is the compressor life expectancy. ASHRAE lists the same 20-year service life for both air-cooled and evaporative-cooled condensers, which reflects this fact.

Performance Monitoring and Field Measurements

A snapshot of the two-stage evaporative cooling system performance was taken on Aug. 25, 1999, which turned out to be the hottest day on record for Santa Rosa, with the weather bureau listing a high temperature of 101°F (38.3°C).

Two of the three air-handling units were commissioned on that date and both the indirect and direct evaporative cooling components were activated with the variable frequency drives (VFD) set at 60 Hz (full flow) for the two 13,300 cfm (6276 L/s) air-handling units AHU-1 and AHU-2. After six hours of continuous operation, at 4 p.m. the evaporative cooling systems, without refrigeration, were maintaining the building between 71°F and 76°F (21.7°C and 24.4°C) return air dry bulb with relative humidities of 60% and 50% respectively. Supply air conditions to the space for both units were measured at 60°F (15.6°C) DB, 58°F (14.4°C) WB, with ambient inlet conditions measured at 95°F (35°C) DB, 67°F (19.4°C) WB for Unit 1 and 98°F (36.7°C) DB, 67°F (19.4°C) WB for Unit 2. The IEE indicated by the tests for the heat pipe were 78.8% for Unit 1 and 74.3% for Unit 2. The direct evaporative cooling components were measured at an effectiveness of 81.8% and 85.7%, respectively. Since the supply air fans are positioned to blow through the indirect and direct evaporative cooling components, fan heat was included in the system cooling performance.

In 2001, Pacific Gas and Electric Company (PG&E) commissioned a third-party energy monitoring company to perform an evaporative cooling case study for this building to provide information on how the technology works, how well it works, and overall cost effectiveness.

Monitoring began on May 1, 2001 and continued to Oct. 31, 2001. A total of 29 points were monitored and the results were stored at 15-minute intervals. Data were downloaded via modem for analysis at the monitoring company's offices.

Direct evaporative cooling was the primary source of space cooling during the monitoring period, contributing nearly 73% of the total cooling. The heat pipe contributed just below 23% of the total cooling, and the chiller system less than 5%. The simple payback for the evaporative cooling systems, based on energy savings, was estimated to be 6.7 years in Santa Rosa.

This report, entitled "Evaporative Cooling Case Study: Santa Rosa Junior College," may be obtained from www.pge.com/pec/resourcecenter, select e-library and search for the title.

Maintenance and Operating Cost

Corrosion, scale and fouling of any wetted heat transfer surface need to be addressed carefully. The motivating force for the evaporation of water off the wet side of the heat pipe is a function of the temperature difference between the ambient outdoor air dry-bulb temperature and the return air wet-bulb temperature. This is usually a temperature difference of only 30°F (17°C), so that the evaporative rate of water is quite modest. Assuming an ambient outdoor air temperature of 95°F (33°C) and a return air wet-bulb temperature of 65°F (18.3°C), the wetted surface temperature of the heat pipe would average approximately 75°F (23.9°C). At these low temperature levels, corrosion, scaling and fouling would proceed at a slow rate, but nonetheless need to be monitored.

It is important that the wet side surface of the heat pipe be completely flooded, not only to increase the efficiency of heat transfer but also to minimize scale buildup due to alternate wet and dry conditions of this surface.

A typical control sequence for these indirect evaporative coolers would activate the water sprays on a "first on" and "last off" sequence of operation. This would ensure that the wet side surface would remain flooded during the bulk of the summertime cooling hours. Cycling of the wet side sprays should not be permitted for cooling capacity control.[4]

The best protection against corrosion, scale and fouling is an adequate bleed rate. In the evaporative cooling sumps, water hardness should be maintained between 200 to 500 ppm total dissolved solids. The PG&E study estimated a water usage of 39 gallons/ft^2 (1589 L/m^2) per year, at an annual cost of $334 for the three units at the Race Building.

At the end of the occupied duty cycle, water is drained from each unit sump and the direct evaporative cooling media is dried out by the supply fan for 45 minutes after shutdown to eliminate the possibility of microbial growth and subsequent musty odors in the supply airstream.

Conclusions

The application of evaporative cooling techniques to the cooling load in the air-handling units, with both indirect and direct evaporative cooling and at the refrigeration condenser, provides greatly reduced electrical energy demands during peak cooling requirements. These systems work best to reduce refrigeration in afternoon hours, when the building owner pays the most for electrical energy.

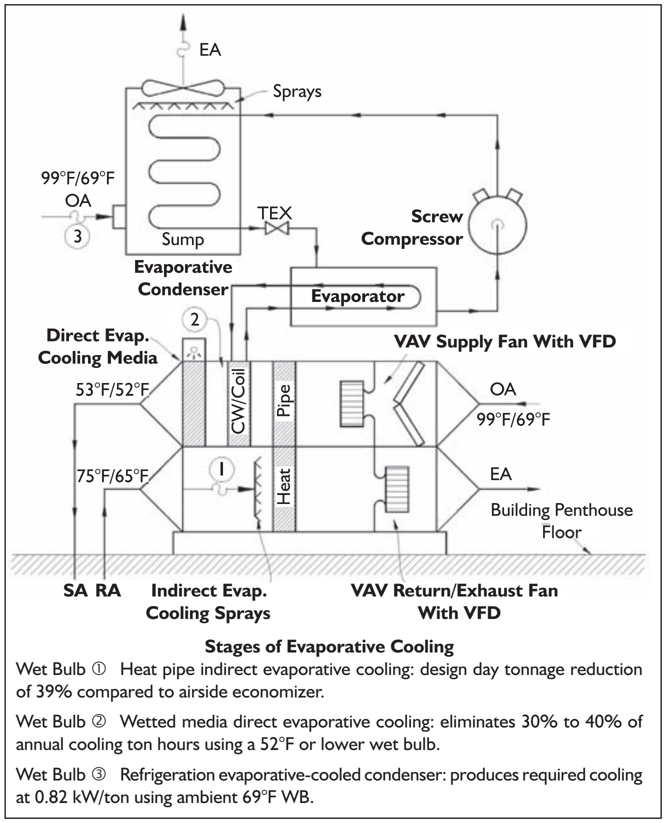

Figure 2: Evaporative cooling triple dip (design summer flow).

With winter heat recovery, air-handling units may introduce 100% outdoor air to starving VAV systems for better IAQ. With winter daytime California temperatures normally above 40°F (4.4°C), the direct evaporative cooling component may be used as a humidifier, using recycled heat available in the building return air to add beneficial moisture to the supply air during the driest periods of the year.

In semi-arid climates such as Northern California, three-stage evaporative cooling systems can eliminate the need for a substantial amount of fossil fuels or hydroelectric power generation. These systems use water as the refrigerant in lieu of halogenated hydrocarbons, thereby helping to reduce the depletion of the ozone layer in the upper atmosphere and helping to reduce the production of greenhouse gases such as carbon dioxide.

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