Sub Wet-Bulb Evaporative Chillers for Building Cooling Systems

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Abstract

Cooling loads constitute approximately 13% of the total electricity demand for the United States, and in the western states, hot, dry summers drive cooling loads and peak demand. Currently, the market is driven by compressor-based systems, which are inherently limited in efficiency. Hot and dry climates have the potential to incorporate evaporative cooling. Typical evaporative systems, such as cooling towers or swamp coolers, are limited to cooling to the ambient wet-bulb temperature.

The researchers tested two different designs of high efficiency sub-wet-bulb evaporative coolers (SWEC) that produce chilled water below the wet-bulb temperature of the ambient air. The chilled water can then be used for a radiant cooling or fan-coil system, with no introduction of humidity to the building. The theoretical limit for the supply water temperature is the dew-point of the ambient air.

As part of this project, the researchers (1) evaluated the performance of two SWEC systems in the laboratory under a range of environmental conditions, (2) built an analytical model of one SWEC design, (3) validated the model using the laboratory data, and (4) performed a comparative analysis of the SWEC technologies tested.

Water temperatures 2-5°F below wet-bulb were demonstrated with high efficiency ($5<COP<30$), where the efficiency of the technology increased as outdoor air temperature increased. The researchers are pursuing field demonstration of the technologies. One system was featured in a residential home at the 2015 Solar Decathlon. The second system is planned for installation at an office building with an existing radiant floor.

Introduction

Cooling loads constitute approximately 13% of the total electricity demand for the United States, and in the western states, the hot dry summers drive cooling loads and peak demand throughout the season. Currently, the market is driven by compressor based systems, which are inherently limited in efficiency and constrain the electric infrastructure. In California, because the climate is hot and dry, there is potential to expand the market to incorporate evaporative cooling. Most ordinary evaporative systems, such as cooling towers, are limited to cooling to the ambient wet-bulb, which limits their cooling capacity, and their applicability in chilled water cooling systems. The sub wet-bulb evaporative chiller (SWEC) technology has a significant advantage over other evaporative technologies because of its ability to cool below the ambient wet-bulb. Chilled water below the ambient wet-bulb could be utilized in a radiant floor or ceiling cooling system, or a fan-coil system. In light commercial buildings, this type of cooling system could replace typical roof top units with air duct systems.

The University of California at Davis Western Cooling Efficiency Center (WCEC) completed laboratory testing of two SWEC technologies in the laboratory and, in one case, used this data to validate a model of the system's performance. The first system was a residential scale system that provided chilled water. The system was a prototype manufactured by the proprietor, Nexajoule, Inc in Boulder, Colorado. The second system was a slightly larger scale system (larger residential or light commercial) that provided both chilled water and chilled air. The system was designed by Tsinghua University and manufactured by Xinjiang Refreshing Angle Air Environment and Technology Company, both located in China. Xinjiang Refreshing Angle Air Environment and Technology Company has manufactured chillers that chill water only and water/air (Jiang and Xie 2010). In both cases, the chillers were shipped to WCEC for testing and evaluation.

The SWEC technology offers the following potential benefits:

1. Chilling of supply water to lower temperatures than conventional cooling towers
2. Cooling efficiencies higher than a conventional mechanical chiller
3. No introduction of humidity to the building
4. Ventilation air flow (for Tsinghua SWEC Technology)

The objective of this assessment was to evaluate the performance of two SWEC designs in the laboratory under a range of environmental conditions and operating modes. For the Tsinghua technology, a secondary objective was to validate a previously published theoretical model that can predict performance under a range of operating conditions. The supply water temperatures, system efficiency, and the water consumption required for cooling were measured. The analysis provides insight to the potential efficiency benefits in applying the SWEC technology in comparison to traditional compressor based systems.

Technology Description

The SWEC technology uses an evaporative cooling process to chill water for use in building cooling systems. The SWEC designs tested utilized multi-stage indirect evaporative cooling designs to chill water below the wet-bulb temperature of the outdoor air. The theoretical limit for the supply water temperature is the dew-point of the outdoor air.

Nexajoule SWEC Design

The Nexajoule SWEC has four independent air streams which each pass through a heat exchanger, an evaporative media, and a second heat exchanger (Figure 1). As air passes through the first heat exchanger, it is sensibly cooled by the previous air stream exiting the adjacent evaporative media. The result is a reduction in both the dry-bulb temperature and wet-bulb temperature of the air stream. The chilled air then passes through an evaporative media which evaporatively cools the air and chills the water. After the air exits the evaporative media, it precools the next air stream in the second heat exchanger and is exhausted.

The water used in the SWEC is returned from the building and is distributed over an evaporative media and flows into a sump on the outer perimeter of the unit. The water is collected in the outer sump and is distributed over the inner evaporative media by a pump in the SWEC. The flow rate from the pump is balanced by means of a valve inside the SWEC which is adjusted to match the supply flow rate. The water is then pumped from the inner sump to the building. This two stage process is designed to provide a lower supply water temperature than would be achieved with a one stage process.

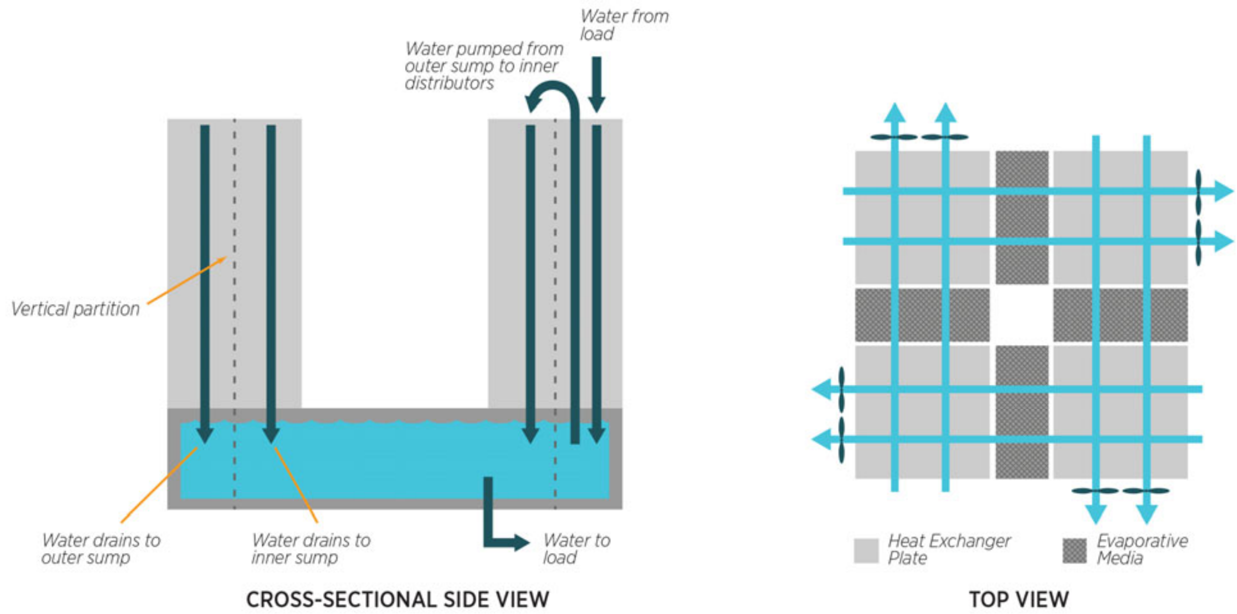

Figure 1. Diagram of SWEC water chilling technology prototype manufactured by Nexajoule, Inc.

Tsinghua SWEC Design

The Tsinghua SWEC first cools an outdoor air stream using an indirect evaporative cooling process. Part of this cooled outdoor air is delivered to the building as ventilation air; the rest is then used in the direct evaporative cooling process, after which it is exhausted. The ratio of exhaust air to ventilation air is controlled with a damper (Figure 2). Three water loops consist of an air-to-water heat exchanger to sensibly cool incoming air, and an evaporative media for direct evaporative cooling. One water loop consists of a water-to-water heat exchanger to chill return water from the building and an evaporative media.

The arrangement of the SWEC is such that the water loops are used to sensibly precool the incoming air before it is used to evaporatively cool the water. Because the sensible cooling reduces the wet-bulb temperature of the air, the evaporative cooling process can chill air and water below the ambient wet-bulb temperature. The theoretical limit of the supply water provided by the SWEC is the ambient dew-point.

The water loops consist of a pump, an evaporative media, and a tube-and-fin coil. Water is pumped to the evaporative media, where the evaporative process chills the water. The water is then passed through the coil, where it precools the inlet air, and then returns to the pump. Upon startup, the process successively cools the water loops, and then the inlet air, until steady state is reached. The water loops act independently, however there is a pipe that connects all of the sumps to a water makeup valve. This pipe allows for sump balancing and some mixing takes place as a result. The chiller has a built-in control system and an interface where the user can change the fan speed and turn specific pumps on and off.

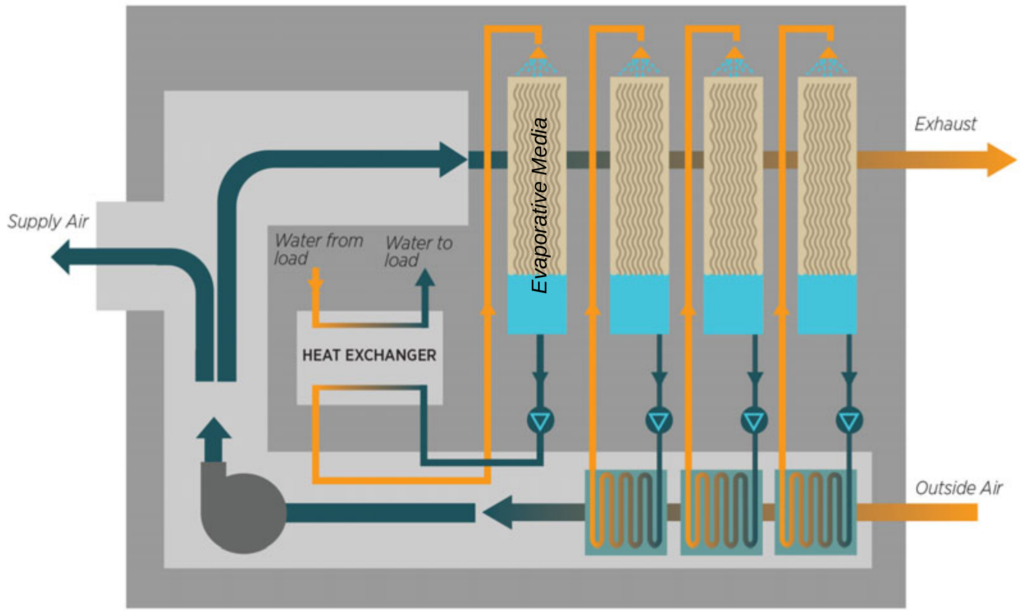

Figure 2. Diagram of SWEC water chilling technology manufactured by Xinjiang Technology.

Laboratory Test Methods

The SWEC under test was installed in the WCEC environmental chamber to simulate desired outdoor air conditions. The environmental chamber was controlled to provide the desired conditions within 2°F test condition (dry-bulb and wet-bulb temperatures) at the desired air flow rate. The exhaust of the SWEC was ducted to be conditioned and recirculated and the air pressures were balanced so that conditions seen by the SWEC were representative of a typical outside installation. The test setup of Nexajoule SWEC is shown in Figure 3 (left) and the Tsinghua SWEC is shown in Figure 3 (middle). A load rig was constructed to re-heat, pump, and deliver a constant return water temperature to the SWEC (Figure 3, right).

For both the Nexajoule and Tsinghua SWECs, the following measurements were recorded: outdoor air dry-bulb temperature, dewpoint, and flow rate; exhaust air dry-bulb and dewpoint; sump temperatures; makeup water flow rate; supply and return water temperatures and water flow rate; and voltage, current, and power for the total system and the fans. For the Tsinghua SWEC, the temperature, humidity, and flow rate of ventilation air was also measured (Southern California Edison 2015).

Dry bulb and water temperatures were measured with resistive temperature devices (accuracy ± 0.40°F). Dewpoint temperatures were measured using chilled mirror hygrometers (accuracy ± 0.40°F). Water flow rates were measured using paddlewheel type flow meters (accuracy ± 1.5% of reading). Power measurements were made using Dent Power Scout 3 true power meters (accuracy ± 1% of reading). Air flow rates were measured using two methods: 1) measuring the pressure drop of air through flow nozzle assemblies and 2) using a tracer gas airflow measurement system, where a known flow rate of carbon dioxide is injected into the airstream and the resulting concentration is measured downstream. The flow nozzle assembly was used for measuring the air flow rate for the Nexajoule chiller testing and both the flow nozzle assembly and tracer gas system was used for the Tsinghua chiller testing. The accuracy of both methods is ± 2%. For each test, error propagation methods were used to estimate the uncertainty of capacity, efficiency, and water use calculations. Calculation methods for capacity, efficiency and water use are available in more detail in laboratory test reports published by Southern California Edison (Southern California Edison 2015).

Figure 3. Nexajoule SWEC installed in the environmental chamber (left), Tsinghua SWEC in the WCEC laboratory (middle), and load rig for heating and supply return water (right).

Test conditions

The rationale for selection of test conditions was different for the Nexajoule SWEC and Tsinghua SWEC. For the Nexajoule SWEC, all testing was completed at outdoor air conditions of 105/73°F (Dry-bulb (DB)/Wet-bulb (WB)) and 90/64°F (DB/WB) (Table 1). Then, the performance of the SWEC was evaluated as the return water temperature, water flow rate and air flow rate varied, in order to understand how to optimize the water and flow rates based on load. For the Tsinghua SWEC, the vast majority of testing was completed at one airflow rate (Total=1700cfm Supply Air Fraction=33%) and one water flow rate (~9.3gpm) and the performance over a wide range of climate conditions was evaluated (Table 1). Although caution should be made in making a direct comparison between the two technologies, because the Tsinghua SWEC supplies ventilation air whereas the Nexajoule SWEC does not, the team replicated two test conditions for the two technologies in order to allow for comparison. These tests are indicated by the shaded rows in Table 1.

Table 1. Test conditions for the Nexajoule SWEC and the Tsinghua SWEC. Shaded row is closest matching test.

Nexajoule Test Conditions					
Test	Ambient Temps (°F DB/ °F WB)	Return Water Temp (°F)	Air Flow (CFM)	Water Flow (GPM)	Ventilation Air Fraction
1	90/64	71	1800	4	0%
2	90/64	71	1350	4	0%
3	90/64	71	900	4	0%
4	90/64	71	2250	4	0%
5	90/64	71	2250	5	0%
6	90/64	71	2250	6	0%
7	90/64	71	2250	3	0%
8	90/64	74	2250	3	0%
9	90/64	74	2250	4	0%
10	90/64	74	2250	5	0%
11	90/64	74	2250	6	0%
12	105/73	71	1800	4	0%
13	90/64	77	1800	4	0%
14	105/73	74	1800	4	0%
15	105/73	77	1800	4	0%
16	105/73	80	1800	4	0%
17	105/73	83	1800	4	0%
18	90/64	65	1800	4	0%
19	90/64	68	1800	4	0%
20	90/64	74	1800	4	0%

Xinjiang Test Conditions					
Test	Ambient Temps (°F DB/ °F WB)	Return Water Temp (°F)	Air Flow (CFM)	Water Flow (GPM)	Ventilation Air Fraction
1	90/64	68	1652	9.3	33%
2	90/64	68	1716	9.2	0%
3	90/64	68	1770	9.3	50%
4	90/64	68	1684	9.3	67%
5	90/64	64	1700	9.3	33%
6	90/64	66	1701	9.3	33%
7	90/64	71	1694	9.3	33%
8	105/68.8	68	1660	9.3	33%
9	95/65.7	68	1660	9.3	33%
10	85/62.3	68	1646	9.4	33%
11	75/58.7	68	1613	9.3	33%
12	65/54.8	68	1598	9.4	33%
13	105/73	70	1744	9.2	33%
14	95/70.1	70	1654	9.3	33%
15	85/67.1	70	1638	9.3	33%
16	90/64	68	3309	9.2	0%
17	105/73	74	3315	9.2	0%

Modeling Methods

A model of the Tsinghua SWEC was built based on physical heat transfer principles and calibrated with experimental data. The purpose of the model is to predict performance for test conditions other than those tested in the laboratory. A model enables the simulation of the technology to predict annual performance in a range of climate zones.

Tsinghua SWEC Model

The numerical model of the Tsinghua SWEC simulates the performance of the chiller under a range of outdoor air conditions and return water conditions. Similar to the Nexajoule model, the iterative model was built in Matlab and based on heat transfer equations. The model includes both the performance of the three identical fin-and-tube air-to-water heat exchangers and four identical evaporative media (Figure 4).

The model for sensible heat transfer of the fin-and-tube air-to-water heat exchangers is based on the Effectiveness-NTU method and manufacturer reported performance data (DeWitt 2002). The data input into the model for air-to-water heat exchanger calculations is the inlet air mass flow rate (M_a) and outdoor air temperature (T_{oa}) and the inlet water mass flow rate (M_w) and temperature (T_{w1}, T_{w3}, T_{w5}). The model output includes outlet air temperature and outlet water temperature (T_{w2}, T_{w4}, T_{w6}). The outlet air temperature for heat exchanger 1 is the inlet air temperature for heat exchanger 2, the outlet air temperature for heat exchanger 2 in the inlet air temperature for heat exchanger 3, and the outlet air temperature for heat exchanger 3 (T_{supply}) is the supply air to the space and the process air entering the evaporative media

The output water from each of three fin-and-tube heat exchangers is pumped the top of an evaporative media. The return water to the building ($T_{w,return}$) exchanges heat through a plate heat exchanger that isolates the chiller loop from the building. The return water from the chiller loop (T_{w8}) is pumped to the top of a fourth evaporative media. A portion of the outdoor air, already sensibly cooled from passing through the air-to-water heat exchangers (T_{supply}), enters the four evaporative media sequentially in cross-flow while the water is sprayed over the top. The equations describing the energy balance model for the evaporative media are too lengthy to be included here and are available by reference (Jiang and Xie 2010). For each evaporative media, the inputs are the inlet air conditions and inlet water conditions. For evaporative media 4, the inlet air conditions are the supply air temperature (T_{supply}) and the outdoor air dew-point temperature ($T_{oa,dp}$). The outlet air conditions for evaporative media 4 are the inlet air conditions for evaporative media 3, the outlet air conditions for evaporative media 3 are the inlet air conditions for evaporative media 2, and so on. The air mass flow rate for all four evaporative media are equal ($M_{a,evap}$). The water mass flow rate is equal for all media (M_w) and the inlet water temperature is the output from the air-to-water heat exchanger model (T_{w2}, T_{w4}, T_{w6}) and the output from the building load (T_{w8}). The evaporative media model outputs the exhaust air temperature and dew-point and outlet water temperature (T_{w1}, T_{w3}, T_{w5}, T_{w7}). The supply water temperature ($T_{w,supply}$) is calculated from manufacturer specified plate heat exchanger efficiency.

Because the inputs for the air-to-water heat exchanger model are the outputs for the evaporative media model, and vice versa, a set of initial conditions are established and the solution is iterated until a steady state is reached.

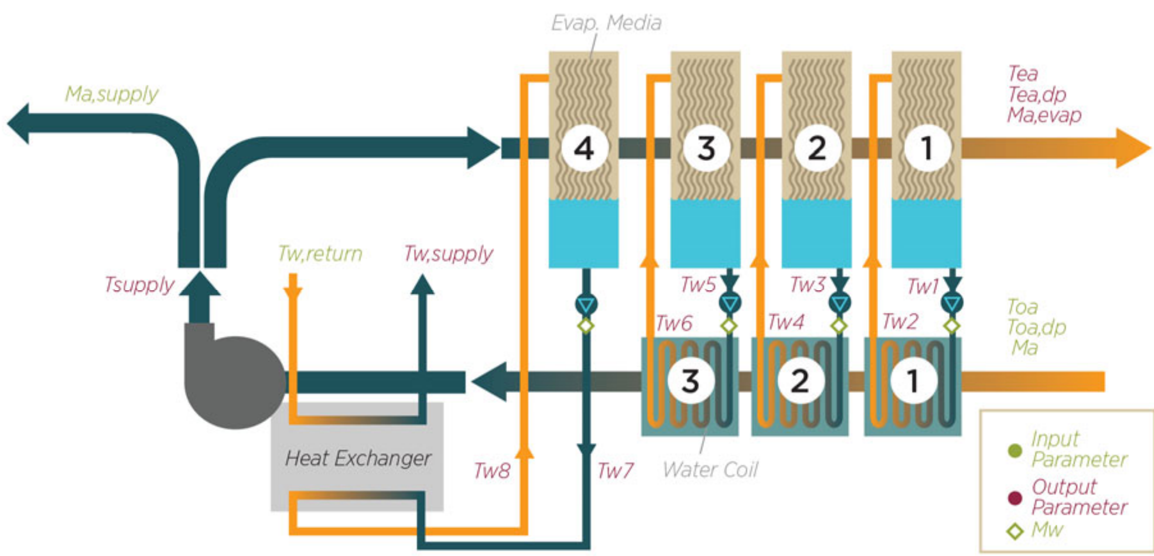

Figure 4. Tsinghua SWEC Model

Laboratory Test Results and Comparison to Model

Laboratory test results for both the Nexajoule SWEC and the Tsinghua SWEC were analyzed and, in the case of the Tsinghua SWEC, compared to the modeled predictions.

Nexajoule SWEC Results

A summary of the laboratory test results characterizes the performance of the SWEC (Figure 5 - 7). Figure 5 compares eight test results at varying water flow rates and two different return water temperatures. The outdoor air conditions for the all eight tests were 90°F dry-bulb and 64°F wet-bulb. One series of four tests was run at a return water temperature of 71°F and the other series of four tests was run at 74°F. For each data series, the varied parameter was the water flow rate (varied between 2.5-6.5 gpm). As the flow rate of water was increased with constant return water temperature, the temperature differential of the water decreased, and the supply water temperature increased. In general, increasing the water flow rate also raised the total cooling coefficient of performance (COP), except in the case of the 74°F return water, which dropped in total efficiency above a water flow rate of 5 gpm. Although the cooling COP increased rapidly as water flow rates increased, the tradeoff was warmer supply water (an increase of approximately 3°F). While not shown explicitly, the power for the fans is fixed for these tests with fixed airflow rate, so the capacity trends follow the COP trends. Water use per ton hour of cooling delivered was reduced slightly as water flow rate increased.

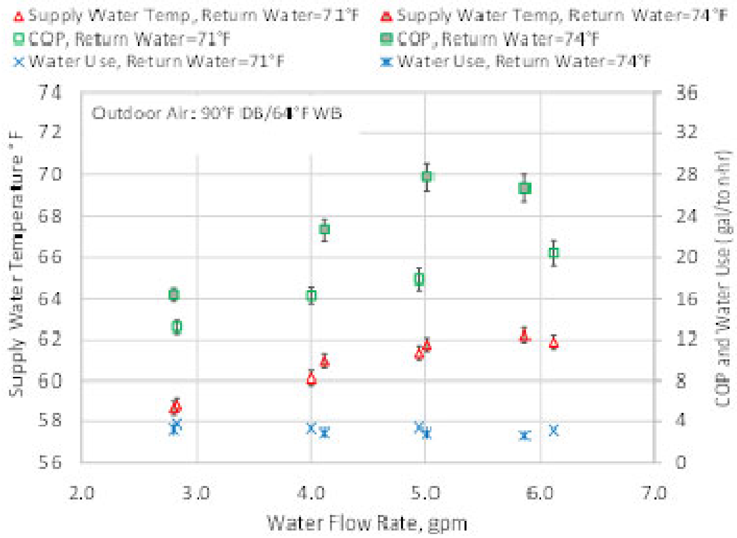

Figure 5. Nexajoule SWEC: Chiller performance metrics versus water flow rate

Figure 6 illustrates the effect of air flow variation on the supply water temperature. One series of four tests was run at a constant return water temperature of 71°F and constant water flow rate of 4 gpm. The outdoor air conditions for the tests were held constant at 90°F dry-bulb and 64°F wet-bulb. As the air flow rate was increased, the supply water temperature decreased. Increasing the air flow rate from 900 cfm to 1400 cfm reduced the supply water temperature by 2°F and slightly improved the overall cooling COP. At airflow rates greater than 1400 cfm, further reductions in supply water temperature occurred along with reduced cooling COP due to fan power consumption. Water use

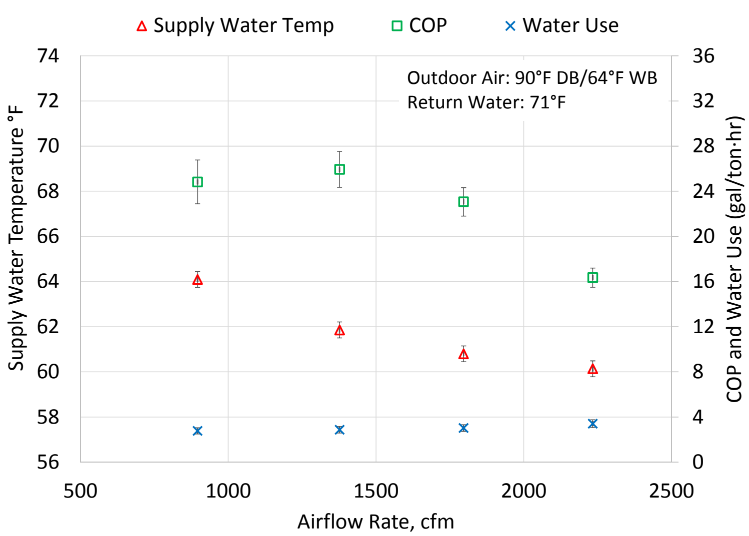

Figure 6. Nexajoule SWEC: Chiller performance metrics versus airflow rate

was slightly greater at higher airflow rates. This is likely due to the fact that the plate heat exchangers are less effective at heat recovery at higher airflow rates, so cooler air is exhausted, which results in wasted cooling.

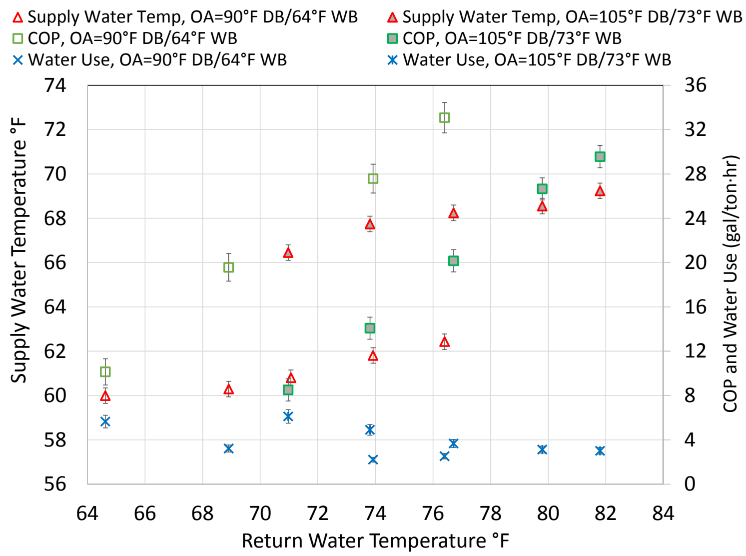

Figure 7. Nexajoule SWEC: Chiller performance metrics versus return water temperature

Figure 7 (left) shows the results for supply water temperature versus the return water temperature. There are two sets of tests shown where outdoor air conditions were held constant at 90°F dry-bulb and 64°F wet-bulb (5 tests) and 105°F dry-bulb and 73°F wet-bulb (4 tests). For all tests the water flow rate was 4 gpm and the air flow rate was 1800 cfm. The data shows that the SWEC produced a lower supply water temperature at lower return water temperatures. However, this was at the expense of reduced cooling efficiency and increased water consumption. In most cases, reducing the supply water temperature of a few degrees may be worth the tradeoff of additional water and electricity consumption, because colder chilled water temperatures will reduce the heat exchange surface area needed for a radiant or fan coil distribution system. Interestingly though, for the 90°F outdoor air temperature test, reducing the return water temperature from 69°F to 65°F reduced the supply water temperature by only 0.3°F, while reducing the COP by 50% and increasing the water use rate by more than 50%, illustrating that the relationships are non-linear and there are some practical bounds to consider in operating the equipment.

Tsinghua SWEC Results

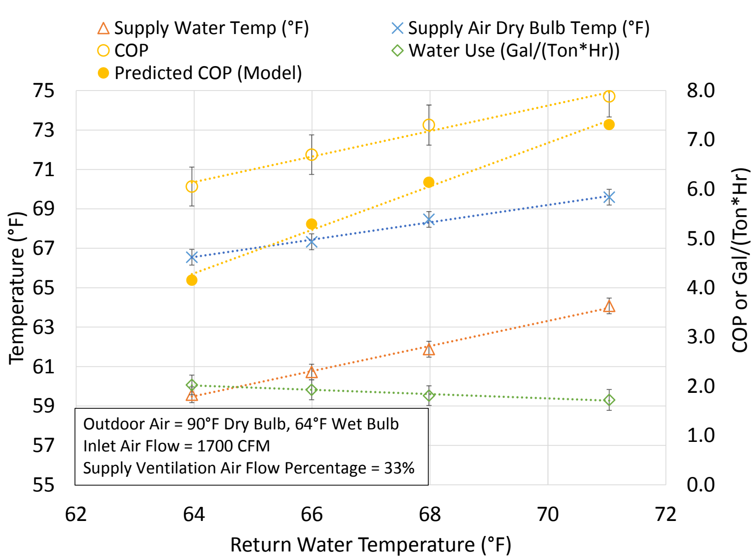

Figure 8. Tsinghua SWEC: Chiller performance metrics versus return water temperature

Figure 8-10 illustrate the effects of varying parameters on the chiller efficiency and supply water temperatures. **Error! Reference source not found.**8 shows the effects of varying the return water temperature on performance of the chiller. The tests were conducted at constant air inlet properties, 1700 CFM total air flow, and 33% ventilation air fraction. In all cases the chiller supplied water at or below the wet-bulb temperature of the air. Increased return water temperature increased ventilation air temperature, supply water temperature, system cooling efficiency, and water use efficiency (meaning, gallons used per ton·hr of cooling delivered decreased). The temperature differential between the return water temperature and supply water temperature increased as the return water temperature increased.

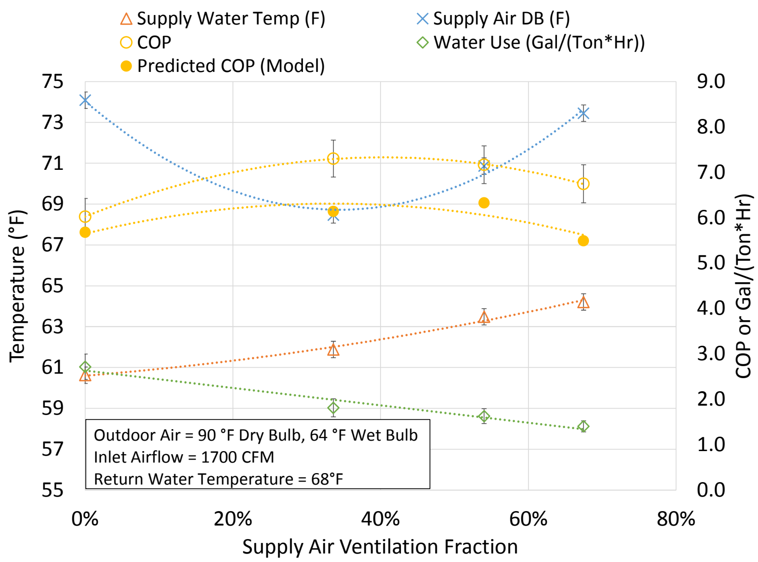

Figure 9. Tsinghua SWEC: Chiller performance metrics versus supply air ventilation fraction

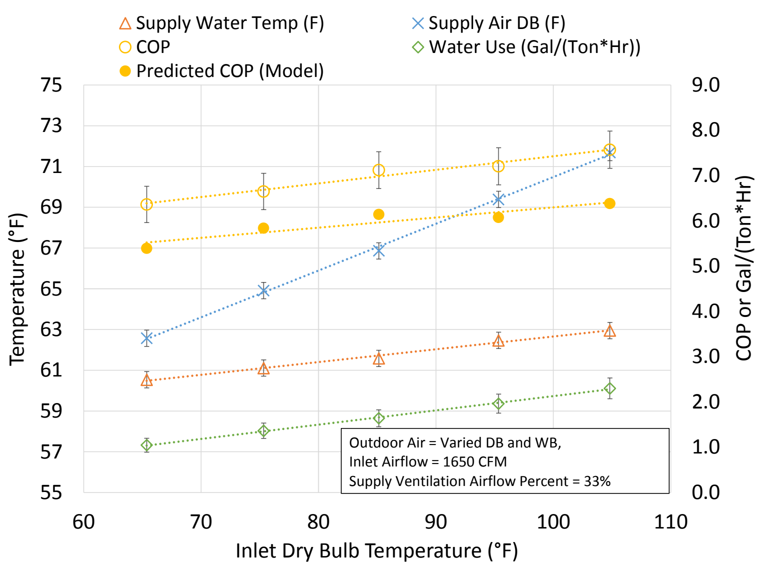

Figure 10. Tsinghua SWEC: Chiller performance metrics versus inlet dry bulb temperature

The measured efficiency of the chiller was significantly better than predicted by the model. This is likely due to an assumption in the evaporative media performance component of the model that calculates the water and air temperatures leaving the evaporative media. In this model, the saturation curve is linearized over a small temperature range in order to simplify the calculation (Jiang and Xie 2010). This may influence the result, especially the last stage of the outlet water temperature, which will influence the total cooling energy and COP significantly.

Figure 9 illustrates the effect of increasing the percentage of the outdoor air that is used for ventilation. In all tests, the total outdoor air flow rate and outdoor air conditions are fixed. At 0% supply air fraction, no ventilation air is supplied and all air is used for water chilling. The results show that the chiller efficiency peaked at approximately a 33% supply air fraction. This was the design condition for the chiller to achieve optimal efficiency, so the experimental results validate the recommended operating condition of 33% ventilation air fraction. All remaining tests were completed at a 33% ventilation air fraction.

Figure 10 shows the effects of varying ambient dry-bulb temperature while keeping the dew-point (46.9°F) and return water temperature (68°F) constant. The supply ventilation air temperature is more sensitive to the change in ambient dry-bulb temperature than the supply water temperature. Increasing the outdoor air temperature from 65°F to 105°F increased the supply water temperature from 60.5°F to 63°F while the supply ventilation air temperature increased from 63°F to 72°F. The chiller COP increased with increased ambient dry-bulb, however, the water use increased substantially with dry-bulb temperature (56% increase with 20°F increase in dry-bulb temperature). As shown previously, the measured efficiency of the chiller was significantly better than predicted by the model.

Discussion and Conclusions

The performance of the tested SWEC chillers illustrates a large energy savings potential in hot dry climates. The results also reveal that, under a wide range of weather conditions, the SWEC technology can produce chilled water at temperatures between 60 to 66°F, which is desirable for serving a radiant cooling system with efficiencies much higher than vapor compressor air conditioning systems.

In order to understand the comparison between the Tsinghua chiller and the Nexajoule chiller it is important to reiterate the differences in design. The major differences are the capacity, the maximum design air flow, the maximum design water flow, and the fact that the Nexajoule SWEC only provides chilled water, whereas the Tsinghua SWEC provides chilled water and ventilation air. Given these differences in operation, Table 2 highlights the performance of the two chillers under similar external parameters, including inlet air conditions and return water temperature.

Table 2: Comparison of SWEC performance

	Comparison 1		Comparison 2	
	Tsinghua	Nexajoule	Tsinghua	Nexajoule
Inlet DB (°F)	90.0	90.0	105.2	104.7
Inlet DP (°F)	47.2	47.2	55.2	56.2
Air Flow CFM	1694	1797	1744	1793
Ventilation Air	553	0	595	0
Water Flow GPM	9.3	4.1	9.2	4.0
Return Water Temp (°F)	71.0	71.1	70.0	71.0
Supply Water Temp (°F)	64.1	60.8	66.0	66.4
Ventilation Supply Air Temp (°F)	69.6	-	73.9	-
Capacity Tons	3.7	1.7	3.2	0.8
Evaporation Gal/(Ton*Hr)	1.7	3.7	2.5	7.4
COP	7.9	23.1	6.8	8.5
COP (Adjusted to remove air handler power from Tsinghua SWEC)	9.0	23.1	7.8	8.5

The first comparison is at an ambient condition of 90°F dry-bulb and 64°F wet-bulb, with both units operating at design air and water flow conditions (Table 2). The comparison shows that the Tsinghua SWEC is able to provide a larger capacity, however the Nexajoule SWEC provides chilled water that is a few degrees cooler than the Tsinghua SWEC. This is partially due to an additional plate heat exchanger in the Tsinghua SWEC that separates chiller water loop from the building water loop. In the Nexajoule SWEC, the water returned to the building was supplied directly to the SWEC. The COP of the Tsinghua SWEC is lower than Nexajoule SWEC, however the Tsinghua SWEC includes the ventilation fan power to supply cool air to the building. In order to adjust for this, the power consumption of a typical air handler was considered according to AHRI standard 340/360, and subtracted from the total power use of the Tsinghua SWEC. The adjusted COP is still lower than the Nexajoule SWEC, but is more representative of the actual difference that would exist in an installation. Finally, the water use per ton-hour of cooling is significantly lower (less than half) for the Tsinghua SWEC than for the Nexajoule SWEC.

The second comparison is at an ambient condition of 105°F dry-bulb and 73°F wet-bulb. The flow rates for the two units are near their ideal values, and the return water temperatures were closely matched. In this comparison, the Nexajoule SWEC produced a slightly larger drop in water temperature. The COP of the Nexajoule SWEC unit was slightly better. The Tsinghua SWEC significantly outperforms the Nexajoule SWEC in terms of water evaporation losses per ton-hour.

The comparison shows that both sub-wet-bulb chillers have benefits and drawbacks. The Tsinghua SWEC that was tested for this project is capable of a higher capacity, can provide chilled ventilation air, and accomplishes more cooling while consuming less water per unit of cooling. The Nexajoule SWEC is favorable for its higher efficiency, and slightly lower chilled water temperatures. Additionally, the Nexajoule SWEC unit is smaller, lighter, and would perhaps be better adapted for smaller residential applications than the Tsinghua SWEC.

As with any evaporative cooling unit, there are additional complications associated with running the SWEC, compared to a standard compressor based system. The main concern is regular maintenance of the system in order to prevent corrosion or scale deposits. Current methods to accomplish this include continuous water bleeds to reduce mineral concentration and replacing the evaporative media every one to three years, depending on water hardness.

Field demonstration of the technology will provide information regarding maintenance requirements, usability, and longevity. The Nexajoule SWEC technology was demonstrated in a residential home in the US Department of Energy’s Solar Decathlon competition in Irvine, CA. Two long-term field demonstrations are planned in residential homes in Davis, CA as replacements for split-system compressor-based air conditioners.

The Tsinghua SWEC tested in the laboratory will be installed to provide cooling in a mixed-used laboratory and office building leased by UC Davis. The building has an existing radiant floor that is used only for heating and cooling is provided by air handlers and split-system compressor-based air conditioners. Field verification and monitoring of both installations will be completed to validate the performance of the systems in actual installations.

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