NORTEK™
DATA CENTER
COOLING

Solutions to Water and Power Availability

that Challenge the Future of Data Centers

The major challenges facing the data center industry today are finite water and power resources. This is especially true for large scale operations and particularly the ongoing trend toward hyperscale facilities.

Twenty years ago water and power used for cooling wasn't as critical an issue because the data center industry was still in its infancy. However, the data center industry's exponential growth is predicted to tax the planet's future water and power supplies. Increased heat loads from new data uses, such as artificial intelligence, Internet of Things (IoT), machine learning, social media and other new technologies will consume significantly more water and power to cool equipment and keep it operating reliably.

Water and power availability is already affecting different regions of the globe. Short supply is quickly becoming the new normal, instead of the exception. Some countries attempting to develop data center business are realizing this oncoming shortage of resources will dampen their growth or eliminate their participation.

AT A GLANCE

- A new way of data center liquid cooling with unprecedented low PUE and WUE.
- A variety of operational and transitional modes, including economizer, adiabatic and evaporative, are now available from one unit.
- Indirect evaporative cooling using membrane exchangers can reduce liquid cooling's Legionella potential.

Philip Le Poudre,
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Singapore Data Center Water and Power Usage Case Study

The Republic of Singapore is a prime example. Singapore aspires to become a Southeast Asia data center/telecom hub in the next decade. The country will serve as a one of several terminals for MIST1, a planned 11,000-km undersea network of 12-fiber-pair cable that will connect Singapore with Myanmar and India by 2022. Other submarine cable networks already connect Singapore to other Southeast Asia countries.

Consequently, Singapore is setting the stage for its own exponential data center growth. For example, if Singapore had a potential goal of developing a 3-GW IT load, anticipated water and power shortages could curtail the expansion, given the country's current resources. Water, for example, is already a very limited resource. Singapore imports half of its water and another portion is through desalination and reclamation efforts. The country uses approximately 160-billion-gallons/yr of water or 606-million-m3/yr, which is enough water to fill 285,430 Olympic-sized swimming pools. The current dominant method of cooling for Singapore data centers is water cooled chillers (WCC) and conventional cooling towers. If Singapore reaches its near-term goal of a 3-GW IT load, eight to nine percent of its water consumption would be allocated to data centers! That calculates to a comparatively high 1.9-L/kWh water usage effectiveness (WUE) and 51-million-m3/yr of water consumption for a 3-GW IT load cooled with a data center supply air temperature (SAT) of 24°C (75.2°F). At this point, the country continues to rely mostly on WCC for its existing data centers. (See Illustration A)

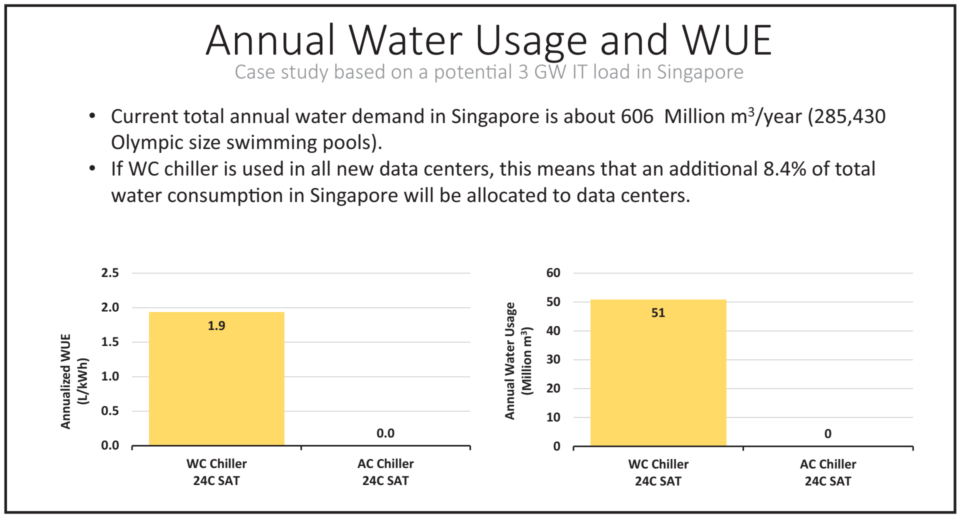


Illustration A

Data center water use is a critical concern, but so is the cost. Data center owners pay approximately $2/m3 (USD) for water, which amounts to a significant percentage of cost.

The power usage effectiveness (PUE) is also exorbitant for Singapore's projected goal of a 3-GW IT load. Singapore pays approximately $0.10/kWh (USD) for power. Singapore's total electric consumption in 2019 was 50-TWh. To reach its goal of cooling a 3-GW IT load, WCC and air cooled chillers (ACC) would require an estimated 6.8 and 9.8-TWh of annual power at a 24°C SAT, respectively, the latter representing nearly 18-percent of the country's total electric consumption. Partial power usage effectiveness (pPUE) would be an estimated 1.3 for WCCs and 1.4 for ACC with SAT at 24°C. (See Illustration B)

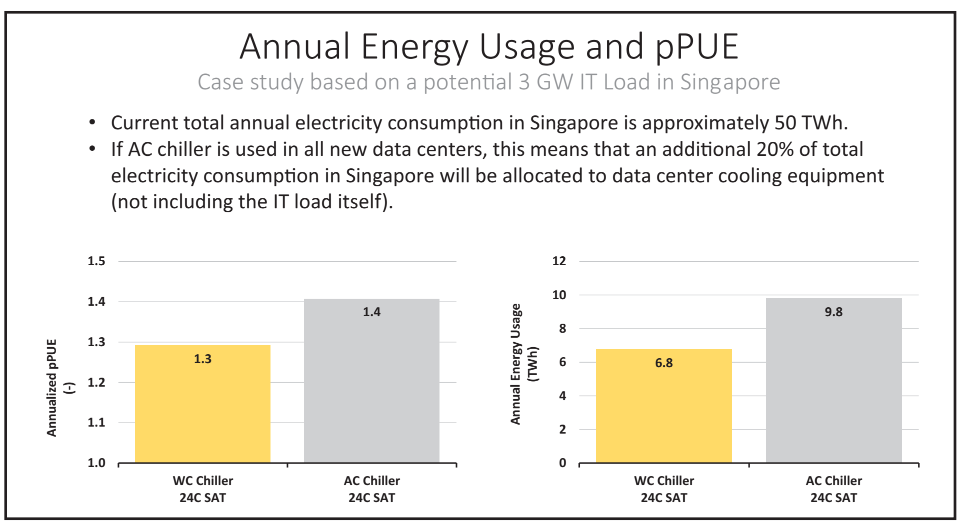


Illustration B

Singapore Data Center Water and Power Usage Case Study

The coefficient of performance (COP) of WCC and ACC, which ranges from 3 to 7 COP in the Singapore case study, is also comparatively lower than other technologies. In 2018 Singapore had a peak electrical power demand of 7,000-MW. Using WCC and ACC to handle the 3-GW IT load at 24°C SAT would consume 800 and 1,147-MW of peak power for the cooling system, respectively, the latter which would account for a significant percentage of the country's peak demand. (See Illustration C)

Singapore officials know that the current status quo of using WCC will have a negative impact on their future stewardship of resources, economy and quest to become a leading player in the Southeast Asia data center market.

Singapore is not alone. Many countries face similar difficulties of finding enough water and power to support fledging data center industries, but without depriving their citizens of natural resources.

More importantly, if the data center industry doesn't curb its power and water usage, there's potential for future government intervention in the form of mandatory conservation, restrictive permits, penalties and rationing that will stunt its expansion, regardless if it's a government or private property. Even with the seemingly unlimited natural resources available for water and power usage in the U.S., some states are considering power rationing to limit global warming. As natural resources dwindle, conservation measures in data centers will only increase.

Large data center users are feeling pressure from local jurisdictions even when they locate facilities in moderate, dry climates. For example, several Silicon Valley corporations and other data center operators built facilities in Prineville, OR, a small community of 10,000 people, located east of a mountain range. Consequently, the area is a high desert with a dry climate that ideally saves significant power when HVAC systems operate in an economizer or evaporative mode. However, the area's water scarcity and the excessive water usage by the facilities have been controversial topics locally. One operator outlaid $8.7 million to help the city build water storage facilities3. Water conservation and the stress on the local water supply have become critical issues. Therefore, it's not just small resource-strapped countries that are balking on the large amount of power and water usage by large data centers.

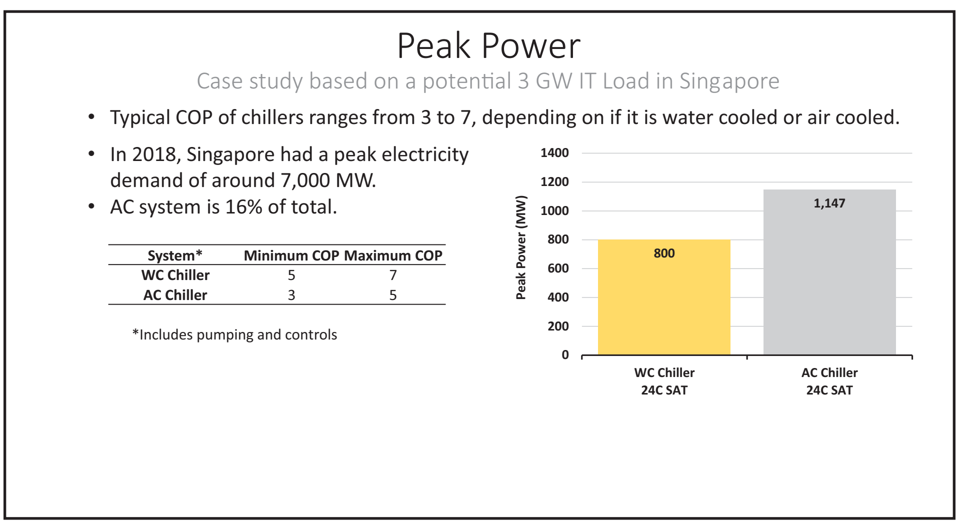


Illustration C

A Data Center Cooling Method that's One of the World's Most Sustainable

The solution is quite simple: use less water and power to cool the same IT load.

Conservation might be easier said than done. However, Nortek Air Solutions has developed a new data center cooling solution called the StatePoint Liquid Cooling (SPLC)4 system that promises both unprecedented PUE and WUE potential. When first initiated in 2015, the SPLC's early development goals were to reduce annual water and power consumption by 20 to 30-percent over the industry's most prevalent method of traditional chiller/cooling tower systems.

However, depending on the climate and the technology type it's compared with, the SPLC system can sometimes record annual water and power reductions of up to 90-percent and 60-percent, respectively. Generally, a 30-percent reduction in water and power is very easily accomplished for the SPLC technology to achieve.

These reductions are illustrated in the aforementioned Singapore example. Using the example again of the 3-GW IT load, Singapore's projected WUE of 1.94-L/kWh and annual water usage of 51-million-m3 with WCCs can be reduced to 1.09-L/kWh and 29-million-m3, respectively, by using SPLC technology for a 32°C (89.6°F) SAT (See Illustration 1).

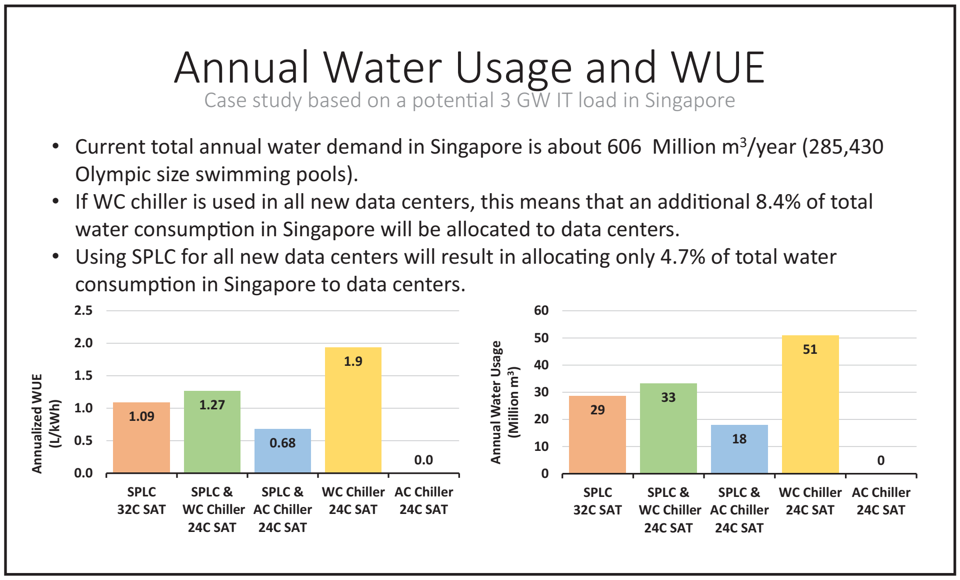


Illustration 1

Power reductions are equally impressive. Singapore's projected pPUE of 1.3 (WCC) and 1.4 (ACC) and annual energy usage of 6.8-TWh (WCC) and 9.8-TWh (ACC) can be reduced to 1.12-pPUE and 2.3-TWh with a SPLC system at 32°C SAT (see Illustration 2).

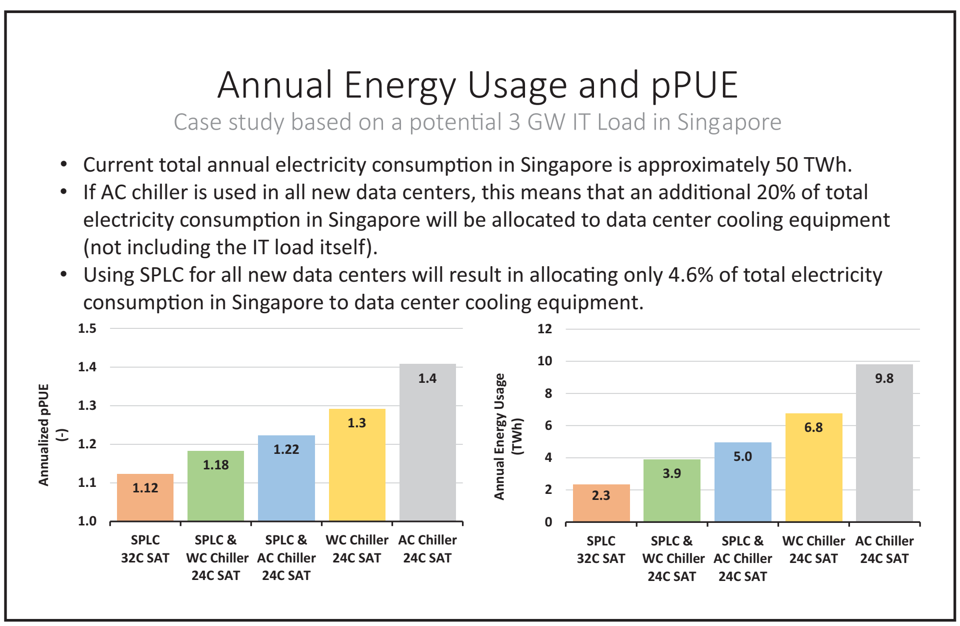


Illustration 2

A Data Center Cooling Method that's One of the World's Most Sustainable

Peak power and COP for the Singapore example is also unprecedented. Using the 3GW IT load example, typical chiller COPs range from 3 to 7, depending on whether its WCC or ACC. The SPLC system can be operating with a fixed 12 to 21-COP year-round, with the majority of operating hours under higher COP. Even if chiller trim cooling is needed in extreme hot, humid weather, the integrated SPLC and chiller system can be operating at a higher overall 6 to 16 COP range than chiller systems. (see Illustration #3) The ACC system in the illustration consumes 16-percent of the total 7,000-MW peak electrical demand Singapore had in 2018. However, the SPLC system would consume only 3.8-percent.

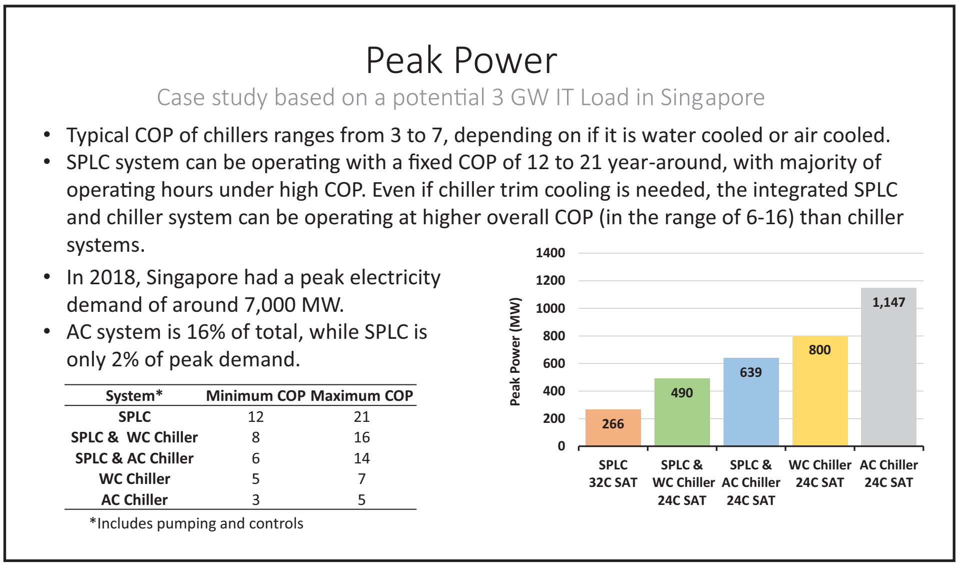


Illustration 3

Additionally, it's important to note that the Singapore example's WCC and ACC as well as SPLC systems with trim chiller cooling, run at a 24°C SAT, whereas the dedicated SPLC system without chillers is run at a higher 32°C (89.6°F) SAT.

Indirect Vs. Direct Evaporative Cooling

The SPLC system uses an unprecedented type of indirect evaporative cooling. Like all evaporative cooling, the SPLC system takes advantage of moderate climates with cool outdoor air temperatures and low humidity. It produces chilled water for distribution to any conventional chilled water delivery component in the data hall.

Unlike some evaporative methods, the SPLC system can operate in most climates under the W2 ASHRAE Water Cooling Class (maximum facility water temperature: 27°C (80.6°F)); and in all climates under the W3 (maximum facility water temperature: 32°C (89.6°F)). Generally, hyperscale/cloud facilities ranging from 13,935 to 92,903+m2 (150,000 to 1 million sq. ft.), which are preferred by companies such as Google, Amazon, Apple and other hyperscale users, provide air cooling temperatures to the data halls between 15 to 32°C (59 to 90°F). Colocation operators with facilities ranging from 46,451 to 92-903-m2 (500,000 to 1 million sq. ft.) such as Equinix, Rackspace Hosting and Digital Reality prefer air cooling temperatures between 18 to 27°C (65 to 80°F).

Today, the trend is swinging away from direct evaporative cooling and toward its indirect evaporative cooling counterpart, especially among Silicon Valley corporate giants. Direct evaporative cooling offers advantages, such as less expensive upfront capital expenditures and operating expenses. However the disadvantages of higher maintenance, the introduction of poor indoor air quality to the data hall, and shorter electronic equipment lifecycles outweigh the pluses. Server lifecycles are shorter in direct evaporative facilities, because outdoor air quality is not always ideal. Furthermore, the indoor air quality during economizer modes can be greatly reduced by outdoor environmental conditions, such as forest fires, inner city vehicle pollution, coastal salt spray and other contaminants that take a toll on sensitive electronic circuitry. For example, less than a decade ago, London data centers were shut down for days due to an Icelandic volcano eruption that polluted the air throughout Northern Europe.

Cleaning the dirty air with carbon gas phase air purification is an option but costly, because media replacement for large facilities with millions of CFMs would be cost-prohibitive. Furthermore, fan energy costs would rise from inherent increased static pressure associated with airflow through carbon media.

Another disadvantage of outdoor air is low humidity. Wintertime outdoor air in northern regions has low absolute humidity, which when heated to the required supply air temperature, often results in relative humidity values below the recommended range for IT equipment, and must be pretreated with humidified air to eliminate static electricity and arcing. This is wasteful to consume water year-round by running a wetted direct evaporative cooling mode during wintertime outdoor temperatures.

These direct evaporative cooling disadvantages have swung many operators toward indirect evaporative cooling, which is a closed circuit method that physically separates the outdoor air from direct contact with the data hall electronics via chilled water delivery loops.

The SPLC system's indirect evaporative cooling uses outdoor air to cool the water, but never comes in direct contact with it. Therefore, it eliminates the maintenance cost associated with outdoor pollution that can contaminate water, as is the case with traditional chiller/cooling tower systems and direct evaporative cooling.

Poorly maintained cooling towers of HVAC systems are also a known cause of Legionnaires Disease5, which is a respiratory condition that infects up to 18,000 people annually just in the U.S. Contaminated cooling tower mist and droplets can affect both building inhabitants as well as people in nearby outdoor public areas. Thus, it's a major health/safety issue building owners must constantly monitor.

Besides safety, water maintenance is also an environmental issue. For example, a country with data center cooling towers consuming 50-million-m3 of water annually presents a major discharge challenge. The mineralized water discharge should be treated, at a considerable cost, before re-entering the municipal water and sewer systems. Furthermore, water treatment facilities may have not been sized to treat the additional water discharge capacity of new data centers coming on line. The SPLC system circumvents these challenges.

The SPLC system is also very flexible in terms of its compatibility with chilled water loop delivery systems. The chilled water can be distributed to virtually the same delivery systems that are common in conventional chiller/cooling tower systems, such as Fan Coil Wall™, cold plate, coolant distribution units (CDU), computer room air handlers (CRAH), rear door heat exchangers, hot aisle enclosure with fan walls and modular data centers. (See Illustration 4)

Indirect Vs. Direct Evaporative Cooling

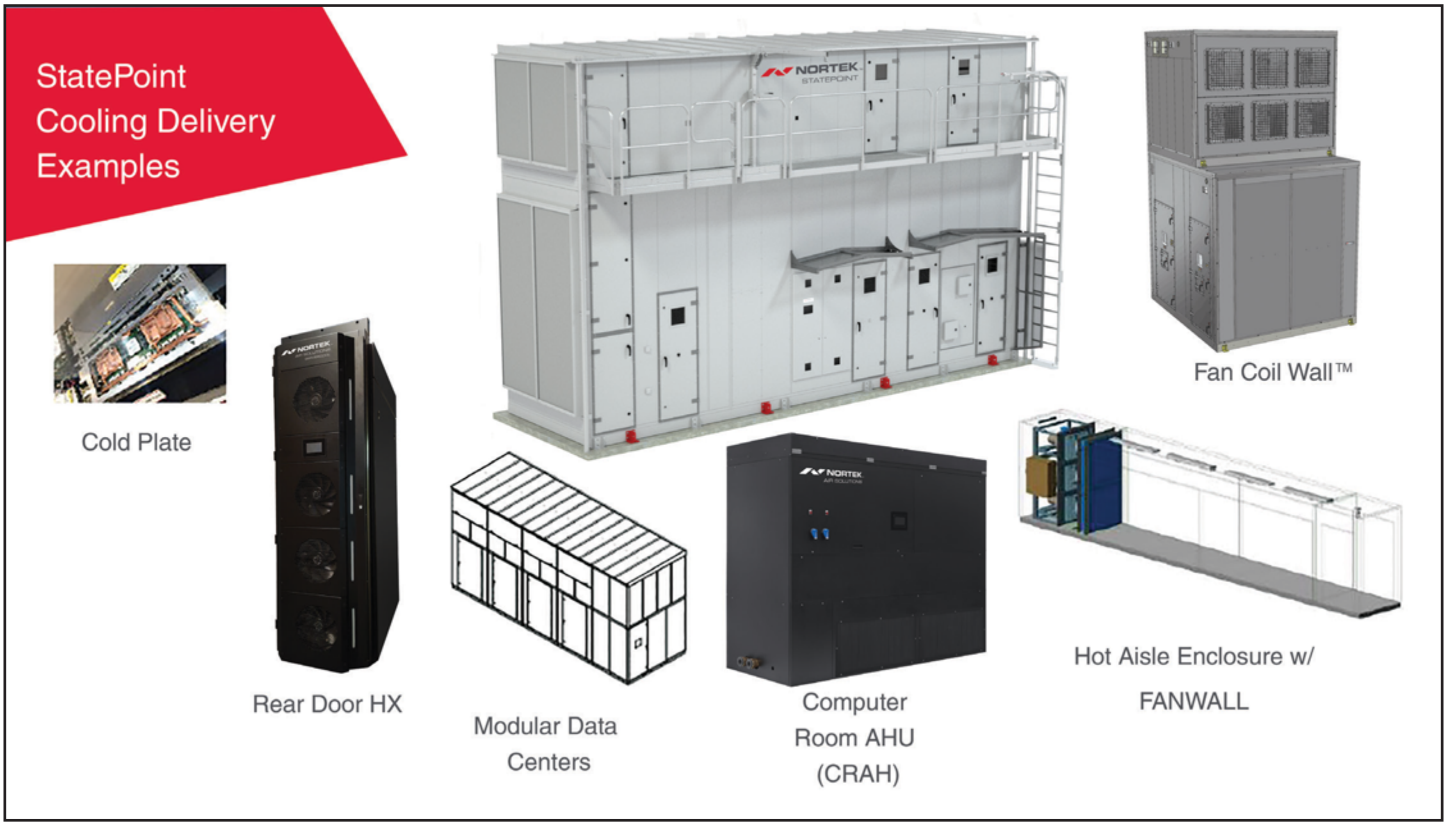


Illustration 4

Furthermore, the SPLC, in most climates, also operates without the use of refrigerant-based mechanical cooling, compressors and chillers. Like other business models, the data center industry has made efforts to decrease its use of refrigerants due to their global warming potential (GWP), leak and maintenance liabilities, governmental regulations, energy costs and general cost of ownership. Trim chiller cooling can be added to SPLC designs when hot, humid days challenge chilled water temperature capacities. However, the chillers are not used exclusively and their designs are significantly downsized compared to 100-percent chiller operations.

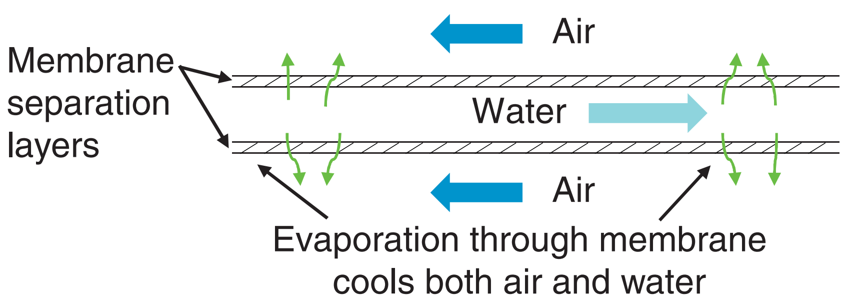
The Secret Component of the SPLC System's Success

The SPLC's unique indirect evaporative cooling method simply consists of a membrane exchanger, a first and primary cooling system, a dry cooling coil, and fans. What separates it from other indirect evaporative cooling technology is a liquid-to-air membrane exchanger strategy that has never been commercialized before in the HVAC industry. This patented microporous membrane heat exchanger, the StatePoint Membrane Exchanger (SPEX), is the "secret sauce" that makes the SPLC totally unique. It's what helps make SPLC system one of the world's most sustainable liquid cooling technologies.

The SPEX consists of a series of stacked water cooling panels separated by air channels. The panels have plates sealed with a hydrophobic membrane, which separate the water and air flow. The membrane is impervious to water, but breathable for water vapor. The membrane functions similar to Gore-Tex clothing material, that sheds rain, but allows the body to breathe.

Nortek Air Solutions invested more than $10 million in its Saskatoon, Saskatchewan, manufacturing plant for modernized and automated equipment to manufacture the SPEX. The rest of the SPLC system is assembled at Nortek Air Solutions' Oklahoma City, Okla. manufacturing plant.

Water flows down the vertical membrane-sealed plates. Outdoor ambient air is drawn across the outside surface of the membrane sheets to cool both water and airflow. The exchanger performs cooling when the warm water flows through the channels, and exchanges heat and vapor to the airstream. Some portion of the water evaporates through the membrane producing latent cooling. Heat is also transferred sensibly through the membrane. This results in a significant amount of cooling from heat transfer in a relatively small exchanger.



The exchanger solves a number of problems for the industry. It eliminates the direct contact of water with the air, which pollutes the water with dust, dirt, pollen and other contaminants that result in a biological sludge. The separation of air and water prevents the air from picking up droplet and aerosol carryover from the water side, which leads to excessive water consumption. It's also the primary transport mechanism for Legionella and other biological contaminants into the environment. Evaporative cooling systems constantly suffer from these challenges, thus they require tremendous maintenance, testing and repair. The SPEX strategy can minimize challenges with ongoing governmental legislation, such as the prohibition of conventional cooling towers in certain designated regions because of Legionella concerns. Also, many local governments prohibit large amounts of dirty water discharges into their municipal sanitation systems.

The SPEX strategy also promises less chilled water loop maintenance. In conventional systems, open cooling tower water is exposed to outdoor air, thus it accumulates a significant amount of dirt, pollen, microorganisms, airborne sand and other contaminants that can turn into a sludge, or worse yet, Legionella. This quick accumulation is a water maintenance challenge for data center facilities. Furthermore, the dirty cooling tower water must be separated from the data center's chilled water loop water via a plate heat exchanger, which decreases system efficiencies, raises equipment costs and increases maintenance. On the other hand, the SPLC's SPEX design of separating the water and air minimizes this challenge. The membrane material blocks particles all the way down to sub-micron sizes, similar to what High Efficiency Particulate Arrestance (HEPA) units do for air filtration. Consequently, SPLC water is kept clean enough to where it can be sent directly into the chilled water loop and the cooling components it supplies.

The system2 does consume some water through evaporation, but because it's a closed circuit, the water usage is significantly less than traditional chiller/cooling tower systems. Furthermore, significantly less water is returned to the municipal sanitation, because it remains cleaner from less filth and fouling.

The SPEX itself also requires less maintenance, because the membranes are hydrophobic, flexible and resistant to the adhesion of contaminants, such as minerals and scale formations that are common among conventional cooling towers and other wetted media.

The Components of the SPLC System

The complete SPLC design differs from conventional cooling towers or evaporative cooling technology. It is a complete cooling plant in a self-contained air handling unit. Everything is built-in to run the cooling system independently, including pumps to drive the data center's entire chilled water loop. Besides the membrane exchanger, the SPLC has a weather and wind-resistant cabinet, intake louvers, air filtration, air bypass damper, hydronic section with a pumping module and water holding tanks, dry cooling tube/fin recovery coil, ECMi FANWALL, fully-integrated control package and an optional pre-cooler, gantry, winter intake, additional filtration, and exhaust fan. (See Illustration 5)

Illustration 5

The control package can operate independently, or in coordination with the facility's building automation system (BAS). The direct digital control (DDC) package controls and monitors operation, mode selection, water flow rate capacities, supply and return water temperatures and dozens of other parameters within the unit.

The SPLC has conventional air handling features, however its heavy-duty, reinforced cabinet dimensions are similar to a small penthouse. It has several pedestrian-sized access doors and ample maintenance accessibility space. These features are unlike conventional cooling towers, which typically have very small access doors, restricted space to perform maintenance, or exposure to outside weather elements. The SPLC system is designed for rooftop locations, however it can also be ground-mounted, stacked on gantries for a multi-story building, or it can be configured for custom applications. Most importantly, it doesn't require interior mechanical room space, which saves the building's footprint for electronic equipment duties and expedites facility construction timelines. The SPLC system is a self-contained unit with single source responsibility that is pre-packaged and inline-tested at the Nortek Air Solutions' factory. Quality control includes leak testing, electrical operation and specification/performance testing in a thermal dynamics laboratory. For example, hyperscale data center operators can review thermal performance test results proving the unit can attain a particular cooling capacity and chilled water temperature and maintain it within a very tight, specified tolerance.

A prepackaged, factory-tested system offers data center operators peace of mind. There are no worries about compatibility, excessive space footprints or contractor installation issues common among systems designed and built from scratch with components from dozens of vendors. Today's data center operators are demanding unprecedented precision capacity from liquid cooling vendors, because they are designing their data halls for very specific temperatures. For example, a chilled water discharge temperature specification might require a tolerance of a fraction of one degree without any variation, regardless whether it's a full IT load and the outdoor temperature/humidity is the 50-year ASHRAE high.

THE SPLC's Operation Modes in Many Climates

Another unique feature of the SPLC system is its multiple operating modes that allow it to react to the planet's constantly changing climate conditions.

The SPLC has three fundamental modes:
1) Economizer Mode;
2) Adiabatic Mode; and
3) Evaporative Cooling Mode, in addition to several transitional and optional modes.

The SPLC system automatically operates under the most optimally efficient mode in response to the inherent real time outdoor temperature and humidity levels.

NOTE: For Full Descriptions of Modes See Nortek Air Solutions.

THE SPLC's Operation Modes in Many Climates

In summary, the SPLC system can operate 100-percent with just the dry coil; or it can partially use the membrane exchanger for pre-cooling that still covers the facility's full IT load with a limited amount of water consumption; or the dry coil and the membrane exchanger can be used together to share the load of the facility. In a climate such as Singapore, the SPLC system may be combined with a trim chiller, for extremely hot and humid days. However, the chiller size, refrigerant amount and the run-times are significantly reduced by up to half compared to 100-percent chiller systems.

Conventional cooling towers don't operate this way. They're continually consuming water through evaporation that amounts to tons of moisture annually. They might react to outdoor elements, but only with fan speed variances to change airflow.

Newer technology, such as hybrid evaporative coolers are able to alternate between dry and wet modes. However, they too have a limited ability to react to weather conditions. The SPLC system is the only evaporative cooling technology on the market that can switch seamlessly between three evaporative modes without chilled water loop temperature variances and still provide efficient power and water consumption.

The SPLC's technology was tested in hundreds of computer modeling studies and exercises that analyzed its total water and power consumption over the course of a year as it reacted to simulated weather conditions across the globe during every hour of the day to provide optimum efficiency. The simulations were used to help develop the SPLC system to react and handle a variety of weather dynamics. Consequently, the modeling simulations can show potential data center users in a particular year-round climate what efficiencies of operation the SPLC can provide their facility. The development of the SPLC was in response to the industry's request for liquid cooling equipment that responded to weather changes to lower WUE and PUE to unprecedented levels.

The SPLC has been successful in that regard and is proving to be the future of data center liquid cooling.

BIOGRAPHY: Philip LePoudre, PhD, P.Eng, Fellow Engineer, is the lead for StatePoint Liquid Cooling technologies at Nortek Air Solutions, St. Louis, Mo. LePoudre joined Nortek's Saskatoon, Saskatchewan, research and development center in 2011. Previously he worked as a professional research associate and lecturer at the University of Saskatchewan (U of S) where he participated in membrane exchanger research. LePoudre has a PhD. from Florida State University, Tallahassee, Fla., in Applied and Computational Mathematics and completed research in Computational Aeroacoustics of turbofan engine noise. He also has an M.Sc. and B.Eng. from U of S in Mechanical Engineering with research in Computational Fluid Dynamics.

References

1. https://www.lightwaveonline.com/network-design/high-speed-networks/article/14074059/ntt-announces-mist-submarine-cable-project
2. https://www.datacenterdynamics.com/en/news/facebook-build-1b-multi-story-data-center-singapore/
3. https://www.oregonlive.com/silicon-forest/2018/12/apple-will-spend-87-million-on-underground-water-storage-in-prineville.html
4. https://www.contractingbusiness.com/commercial-hvac/press-release/20870526/nortek-air-solutions-selected-for-facebooks-singapore-data-center
5. https://en.wikipedia.org/wiki/Legionnaires%27_disease

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