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Data Center Cooling Nature's Way

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How would you like an annual electric bill of $7,000,000? That is about what a typical large data center drawing ten megawatts of power pays, even at a negotiated rate of eight cents per kilowatt hour (about half the residential rate in many areas of the country).

Heat is a data center's worst enemy. In many data centers, half or more of the consumed energy is used simply to cool the IT equipment – servers, network devices, storage arrays, consoles, and so forth. Cooling all this equipment not only costs a lot of money, but it also has a significant impact on our environment.

No wonder so many companies are aggressively looking at ways to reduce cooling costs. One successful approach that has been taken is to locate a data center in a cold climate and to simply use the outside air, unconditioned, to cool the data center. Intel has taken this approach to an extreme by locating an experimental data center in the desert – with amazing results.

In this article, we look at the Intel experiment and at several production data centers using Mother Nature's own cooling.[1]

PUE

PUE, the Power Usage Effectiveness factor, is a measure of the energy efficiency of a data center. It is the ratio of the amount of energy consumed by the data center to the amount of energy consumed just by the IT equipment. For instance, if a data center draws ten megawatts of power, and if the IT equipment uses five megawatts of that power, the data center's PUE is 2.0. This is typical for today's data centers.

Air Economizers

The bulk of the energy required for cooling is consumed by compressors. A typical air-conditioning system moves cold air in and about the IT equipment to carry off heat. The resulting hot air passes over coils containing a compressed liquid coolant, evaporating the coolant and cooling the air. The cooled air is then recirculated over the equipment; and the evaporated coolant is recompressed to a liquid by a compressor, which squeezes out the heat to repeat the cycle.

If a free source of cool air can be tapped, the compressor can be eliminated; and only fans, if any, need to be powered. This requires a fraction of the power consumed by the compressor. This

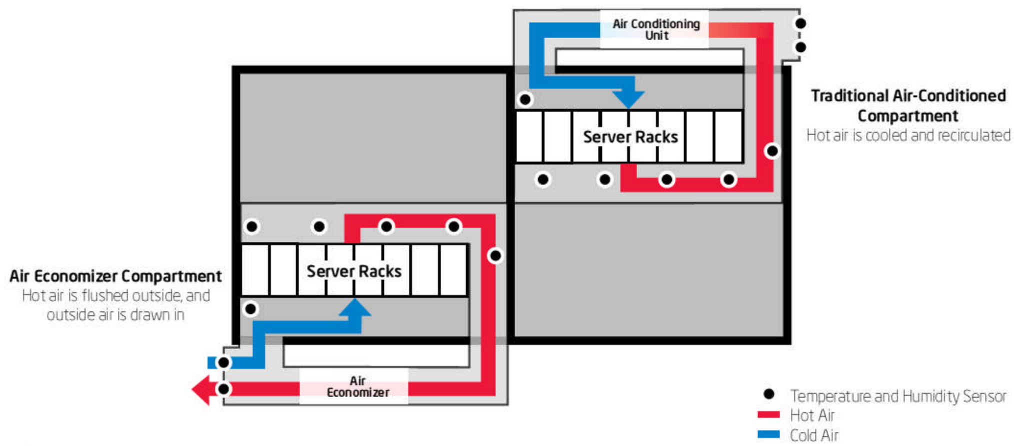
[1] We began this discussion in our November, 2009, article entitled Chillerless Data Centers, available at http://www.availabilitydigest.com/public_articles/0411/chillerless.pdf.

technique is often referred to as an *air economizer* that provides “free cooling.” It has been used to cool buildings for decades and is now being experimented with for data centers.

Intel’s Experimental Air Economizer

In 2008, Intel reported on a very important experiment to determine the effectiveness of an air economizer.[2] It set up a pair of small data centers in a desert environment. One data center used standard air conditioning; and the other used only unconditioned outside air unless the outside air temperature exceeded 90ºF, in which case it reverted to air conditioning. The result – after ten months of operation, including through the heat of the summer, there was little difference in the failure rate of IT equipment.

The test data center was divided into two compartments. Each compartment was 500 square feet in area; and each contained eight racks with 56 blade servers per rack, for a total of 448 blades per compartment. To simulate real conditions, the blades executed applications that created a 90% server utilization rate. The resulting electric load created by the servers was about 100 kilowatts per compartment. The data center was active over a ten-month period, from October to August.



The servers in the economizer compartment were subjected to considerable variation in temperature and humidity. The outside air temperature varied from 65ºF to 90ºF (many manufacturers today specify that their servers can operate up to 98ºF). If the outside air temperature exceeded 90ºF, the compartment’s air conditioning was turned on (the outside air temperature was below 90ºF 91% of the time). If the outside air temperature fell below 65ºF, intake air was heated with excess heat from the IT equipment.

There was no control over humidity. Relative humidity varied from 4% to 90% and changed rapidly at times. Furthermore, the economizer air was only marginally filtered. Standard household filters were used and eliminated only large particles. Smaller desert dust particles were allowed into the compartment.

The servers in the air-conditioned environment were cooled with a well-filtered air supply of 68ºF. The exit temperature of the air was 126ºF. Thus, the air conditioning unit had to cool the circulating air by 58ºF.

Cooling for the air-conditioned compartment required 112 kilowatts of power, giving a PUE of (100+112/100 = 2.12. During economizer operation, power requirement for cooling (just fans) for

[2] Reducing Data Center Cost with an Air Economizer, *IT@Intel Brief*; April 2008.

the economizer compartment required 29 kilowatts, a 76% reduction in power consumption for cooling. This resulted in a PUE of (100+29)/100 = 1.29 for the economizer compartment.

Though the IT equipment in the economizer compartment was covered with a layer of dust at the end of the test, the surprising result was that there was no significant increase in equipment failures. The economizer compartment suffered a 4.46% server failure rate, while the air-conditioned compartment suffered a 3.83% failure rate.

Intel estimates that if this were a ten megawatt data center, almost $3 million in annual electric costs would be saved at eight cents per kilowatt hour (a savings of about 3,500 kilowatt hours per kilowatt consumed). In addition, significant capital expenditures in the air-conditioning equipment could be saved since in high external ambient temperatures, the air only needs to be cooled to 90ºF rather than to 68ºF.

Production Economizers

Several variations of air economizers are now in successful operation to provide "free cooling" in an increasing number of data centers.

HP, Wynyard, England

HP has recently opened the first phase of a 360,000 square-foot data center in Wynyard, which is near Stockton on Tees in Northern England.[3] Wynyard is on the eastern sea coast of England, eight miles north of the North Sea.

HP's new data center has four data halls. It is designed to be a secure, hardware-agnostic data center to compete with companies such as IBM for IT services and management contracts.

Eight large 2.1 meter (about seven feet) plastic and stainless steel fans draw glacial-cooled coastal air thorough filters and pass the air to a twelve-foot high plenum area beneath its data center halls. From there, the cool air rises through the server racks and is exhausted back into the open air.

The data center also collects and filters rain water. If the air is too dry, this water is sprayed in a fine mist to increase the humidity of the intake air.

As an added energy-conserving innovation, all of the server racks are light-colored. This reduces the lighting requirements for the data center by 40%

HP expects that it will have to run its air conditioners only about three days per year. It estimates a PUE of 1.2 for the data center, saving about $1.4 million dollars per year per hall for an anticipated energy savings of 40% compared to other data centers.

Google, Saint-Ghislain, Belgium

In late 2008, Google opened a prototype air economizer data center in Saint-Ghislain, Belgium.[4] Saint-Ghislain is 30 miles southwest of Brussels, which puts it about 70 miles southeast of the English Channel.

The average summer temperature in Saint-Ghislain is between 66 to 71 degrees Fahrenheit. Google uses this outside air to keep its data center at temperatures below 80ºF. Google estimates that it will have to power up its air conditioning system only about seven days per year.

[3] HP Opens New Wind-Cooled Data Center in Northern UK, *The Whir*; February 10, 2010.
[4] Google's Chiller-less Data Center, *Data Center Knowledge*; July 15, 2009.

During these periods, Google will turn off IT equipment as needed and shift processing load to other data centers to maintain equipment temperatures within allowable ranges.

Free cooling makes local weather forecasting a large factor in data-center management. Google has developed automated tools to provide advance weather forecasts to help it decide when to distribute workloads. These tools can also rapidly redistribute computing workloads during an unanticipated thermal event.

Google reports a PUE for this data center at slightly less than 1.1.

Yahoo!, Lockport, New York, U.S.

Yahoo's planned chillerless data center[5] is to be located in Lockport, New York, northeast of Buffalo and ten miles south of Lake Ontario. Not only will this data center use hydroelectric power generated by Niagara Falls to the east, but it will use the winds off Lake Ontario for free cooling of its IT equipment.

The data center will comprise a set of independent modules. Each module will be a prefabricated metal structure 120 feet by 60 feet. Louvers built into the sides of each module will allow cold air to enter the computing area. The modules are angled to take advantage of the prevailing winds off Lake Ontario so that the winds will blow directly into the louver system.

Thermal convection normally moves the air through the modules, even eliminating the power requirements for fans. Each module has a peaked roof with a "penthouse" on top that manages the release of waste heat from the hot isle in the module into the outside air.

A module will house five megawatts of equipment. Initially, five modules will be built, though the site has room for more.

On days that are warmer than 80º F, the module cooling system will be augmented with evaporative cooling. It is expected that this may be required about nine days per year. The result is an estimated annualized PUE of 1.1, meaning that 90% of the energy consumed by the data center goes to power its IT equipment.

Yahoo! already operates green data centers in Washington State. The data centers use wind and hydroelectric power with free cooling for most of the year.

Associated Bank, Green Bay, Wisconsin, U.S.

In Green Bay, Wisconsin, it is cold. However, the Associated Bank was running its data-center air conditioners even in the dead of winter.

When faced with the need to expand its data center, the bank decided to take advantage of the cold outdoors.[6] Aided by a grant from Focus on Energy, a Wisconsin agency that runs Wisconsin's energy efficiency and renewable energy program, the bank installed a glycol-based "free cooling" system at its two new data centers.

Glycol is the cooling agent. Hot air from the servers is circulated over coils containing glycol liquid. The glycol absorbs the heat, and the cool air is recirculated back over the IT equipment.

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[5] Yahoo's 'Chicken Coop' Data Center Design, *Data Center Knowledge*; June 30, 2009.
[6] Data Center Cooling From the Frozen Tundra, *Information Management*; March 30, 2010.

However, unlike a standard air conditioner, during the winter months the glycol is circulated to the outside air to be cooled. No compressors are necessary. Compressors are used to liquefy the glycol only if the outside temperature rises above 40ºF.

The Associated Bank estimates that it saves about 1.4 million kilowatt hours of electricity annually, enough to provide a payback from the new system in three years.

Mauritius Eco-Park, Mauritius

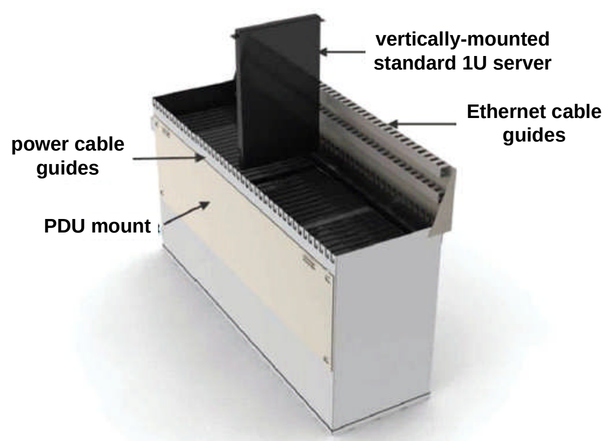
Eco-Park[7] is a project of Mauritius, a small island off the coast of Madagascar. Mauritius lies in the path of a deep-sea current. The water temperature at about 5,000 meters from shore at a depth of 1,000 meters is a fairly constant 5ºC (41ºF).

Seawater will be pumped from this depth to cool intake air for a large data center that Mauritius is building. Mauritius is positioned at the crossroads of Africa, Asia, and Australia and has become a major financial and telecommunications hub for the area. It plans for its Sea Water Air Conditioning system (SWAC) to be a competitive offering to attract outsourcing contracts and to be used as a disaster-recovery center.

SWAC has also been used in other locations such as hotels in Hawaii and Curaçao.

Submersion

Yes. Submersion. If you don't have cool outside air, but you want to avoid the energy consumption of a compressor, why not simply dunk the entire rack into a cooling fluid and dissipate the heat from the bath? That is an approach that Green Revolution Cooling (GRC) of Austin, Texas, U.S., is taking. Its system looks like a 42U rack tipped over into a bath of mineral oil.[8]



The GRC system allows servers to be operated without a raised floor or an air conditioner. The cooling fluid is similar to mineral oil in that it is non-hazardous, transfers heat almost as well as water, and does not conduct an electrical charge. It can support heat loads up to 100 kilowatts for a 42U rack. Cooling a 5,000 watt rack requires about 40 watts of cooling power (a PUE less than 1.01).

The system can be used with standard blades from several manufacturers. Despite being immersed in fluid, the system is said to be easy to maintain. A GRC video shows a blade being drained and ready for servicing within sixty seconds.

GRC plans to shortly install its first units at the Texas Advanced Computing Center.

Spraying

Another similar path is being pursued by SprayCool of Liberty Lake, Washington, in the U.S. In its system, a module is attached directly to a microprocessor chip and sprays a fine mist of coolant

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[7] Sea Water Data Center Cooling promoted at Mauritius data center conference, *Data Center Journal*; September 14, 2009.
[8] Submerged Servers: Green Revolution Cooling, *Data Center Knowledge*; March 17, 2010.

onto a cold plate surrounding the chip.[9] SprayCool claims that with its technology, it only takes 175 watts to cool 11 kilowatts (this would lead to a PUE of 1.02).

HP is reportedly pursuing a similar strategy using ink-jet spray heads from its printer division.

Summary

Data-center power consumption accounted for 1.5% of all worldwide power consumption in 2009, and it is rapidly growing. Half of this energy is used simply to cool the data centers heated by the millions of megawatts consumed by the IT equipment. Data-center cooling is not only costly, but it is also a major factor in CO_2 emissions.

To cut the amount of energy required to cool data centers, efforts are being made by the server vendors to reduce the power consumption of their servers. On another front, many data centers are experimenting with "free cooling" – using nature's own environment to cool IT equipment without massive uses of power.

Whatever the solution, the U.S. Environmental Protection Agency (EPA) has set a 2011 goal for new data centers to achieve a PUE (Power Utilization Effectiveness) of 1.12, down from today's typical PUE of 2.0. This means that only about 12% of data-center power utilization will be used for other than the operation of the IT equipment itself.

[9] New Cooling Technologies Tackle Data Center Heat, *Information Week;* September 26, 2006.
SprayCool – Reliable Green Computing, *SprayCool Data Sheet*.