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LEAN, CLEAN & GREEN

KyotoCooling

Analysis of the KyotoCooling Process: Introduction to the New KPN CyberCenters

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The KyotoCooling system uses an industrial heat wheel to move the heat generated by IT equipment to the ambient (outside) air. Under ordinary circumstances no refrigeration is involved in the dissipation of this heat, making KyotoCooling a very efficient system. This paper presents the results of an evaluation of the KyotoCooling process as employed at their demonstration site in Amersfoort, the Netherlands. The evaluation included an understanding of the physics of the technique, the design of the installation, and the performance of the system in its ability to meet the system claims made by the inventors and developers.

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Introduction

The Royal Dutch Telephone Company, KPN, is branching into the business of housing and hosting data centers. Because they plan to implement the new KyotoCooling process in their new CyberCenters, KPN recently contracted with Uptime Institute to perform an evaluation of the process. This evaluation took place over a number of visits to the KyotoCooling demonstration site in Amersfoort, the Netherlands, in 2008 and early 2009. The evaluation included an understanding of the physics of the technique, the design of the installation, and the performance of the system in its ability to meet the system claims made by the inventors and developers.

The KyotoCooling system uses an industrial heat wheel to move the heat generated by the computer equipment to the ambient (outside) air. Under ordinary circumstances no refrigeration process is involved in the dissipation of this heat, making this technique a very efficient process.

The KyotoCooling process is a newly developed data center cooling technique that uses a heat wheel to extract heat from the computer room and dissipate it to the ambient (outside) environment. The heat wheel process is not a new technology, having been used as an energy recovery device in building air conditioning systems and industrial applications for many decades. In normal operation the heat wheel uses conditioned air being exhausted from a building to precondition the incoming air, thereby making the air conditioning or heating system operate more efficiently.

The most advanced heat wheels use an aluminum honeycomb material to absorb energy from one air stream and deposit it in another.

When applied to a data center, the heat wheel system is "plumbed wrong." Air is not drawn in from the outside, circulated through the computer room, and then expelled to the outside. Instead there are two recirculating airflows patterns. The hot air from the computer room circulates through the wheel, gets cooled, and returns to the computer room to again cool the computer equipment. On the ambient (outside) chambers of the KyotoCooling cell, the ambient air circulates through the wheel and dissipates the computer room heat out of the building. In this way there is very little transfer of ambient air and computer room air (only <0.3 percent of the computer room airflow volume). Such a small exchange of ambient and computer room air insulates the computer room and equipment from particulate and gaseous pollutants in the ambient air. It also insulates the computer room from low and high moisture contents in the ambient air, minimizing the need to humidify or dehumidify the room, a tremendous efficiency-improving factor.

Under extreme conditions computer room air can be used to exclude unconditioned outside air from entering the computer room. This is applicable if the outside air is too dry, moist, or polluted. The excess leakage of computer room air is made up through the building air handling unit (AHU), where the air can be both filtered and conditioned for temperature and moisture content.

A well-managed chilled water cooling system that does not use any waterside economizing typically has an overall efficiency of 0.60—that is, it takes 60 kW of cooling energy to dissipate 100 kW of computer equipment heat load. With waterside economizing, this efficiency can be reduced to below 0.30. The typical airside economizing technique will have an efficiency of 0.15 to 0.20, if the need to humidify is avoided. Low supply air relative humidity increases the efficiency numbers to 0.30 to 0.70 due to the energy put into humidification. This situation usually requires the airside economizing system to revert to the supplemental refrigeration cooling system, which reduces the hours of free cooling available to the data center.

With all free cooling systems, supplemental (refrigeration-based) cooling systems must be used when the ambient temperature gets too hot for the system to efficiently dissipate the computer room heat. In other free cooling techniques this is a situation where the free cooling is turned off and the supplemental cooling supports the full computer room load. The KyotoCooling system can maintain improved efficiency to higher temperatures by mixing free and supplemental cooling for at least 10°C beyond the other free cooling systems. This situation will be reviewed in detail in a later section of this report.

KyotoCooling, at a demonstration site in the Amsterdam area, has a measured efficiency as low as 0.08, meaning only 8 kW of mechanical energy is required to dissipate 100 kW of computer equipment load. This data will be displayed in table form in the body of the report. The demonstration site is a single cell installation. The impact of redundant capacity can improve this efficiency to as low as 0.02 to 0.04. The details will be reviewed in a later section of this report.

With the minimal exposure to pollutants and/or out of specification moisture content in the ambient environment, as well as the amazing efficiency of this mechanical system, the only drawbacks that can be identified are

- it is a new technology to the very conservative data processing industry
- it takes a unique physical configuration to the data center to accommodate the system. The architecture of the building must be such that the KyotoCooling cell is immediately adjacent to the computer room, either beside the computer room or above it on the roof.

KPN has made a commitment to use KyotoCooling, which negates the first drawback and they are designing their new data centers to accommodate the KyotoCooling cells immediately adjacent to the computer rooms, which addresses the second.

KyotoCooling International BV also produces a series of package units that are self-contained modules with cooling capacities of 150 kW to 300 kW, depending on the size of the heat wheel installed. These units are packaged in self-contained modules that can be installed on the roof of a data center or outside the building.

When installed in groups of three, 300 kW units can provide 600 kW of redundant cooling. In the same configuration 200 kW units can provide 400 kW of redundant cooling capacity.

History of the heat wheel and how it works

The use of heat wheels in energy recovery systems has existed for decades. Heat recovery wheels attain high levels of efficiency by transferring heat or enthalpy between two air streams. The heat wheel rotates through the two air streams and transfers the energy from the air being exhausted from the building to the incoming air stream.

In the example illustrated in Figure 1, during the summer the air exhausted by the building air conditioning (AC) system is cooler than the outdoor air and is used to cool the hot incoming air stream from 35°C (95°F) to 27°C (81°F), thereby minimizing the energy required of the AC refrigeration system to bring the temperature down to the required level for summer cooling. In winter the warm exhaust air preheats the incoming air from -14°C (7°F) to 12°C (53°F), thereby minimizing the heating energy required to warm the building. Additional moisture must be added to the air when it is heated to maintain an acceptable humidity level in the building in the winter time. This can be accomplished using a desiccant-treated wheel or an adiabatic humidification system.

Typical Heat Wheel Application

Cooling in Summer • Heating in Winter

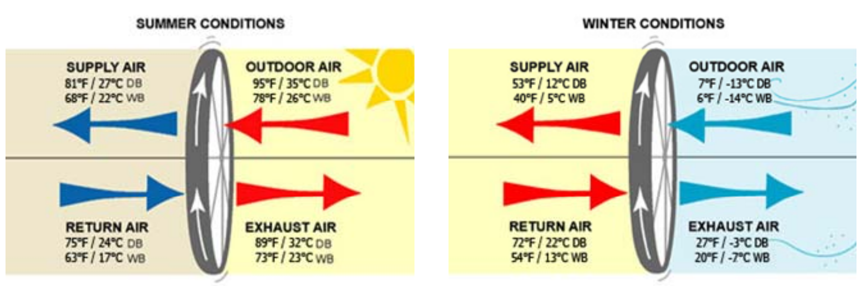

Figure 1. Heat wheel in normal configuration.

There are a number of materials used in heat wheels; the most prevalent is a honeycomb aluminum structure. For sensible heat transfer, which is used in the KyotoCooling application, thin aluminum foil is treated with an epoxy coating to avoid oxidation of the foil surface. If it is necessary and/or desirable to transfer moisture in addition to heat, a desiccant material is used to coat the surface of the aluminum foil.

Adaptation of the heat wheel to the KyotoCooling process

In the normal heat wheel configuration air enters the building, passes through the wheel (where it is further conditioned by the building's heating, ventilating, and air conditioning [HVAC] system), then circulates throughout the facility and is exhausted out of the building through the wheel.

The installation, called a cell, is divided into four chambers: exhaust air and supply air on the computer room side, and ambient air and exhaust on the ambient side. With the new configuration used to dissipate the heat produced in the computer room, there are two separate recirculation cycles. The first recirculates hot exhaust air from the computer room, carrying the heat from the computer equipment through the heat wheel and back to the supply side of the computer room. The second circulates ambient air through the wheel to dissipate the computer room heat by exhausting the air outside the facility (see Figure 2).

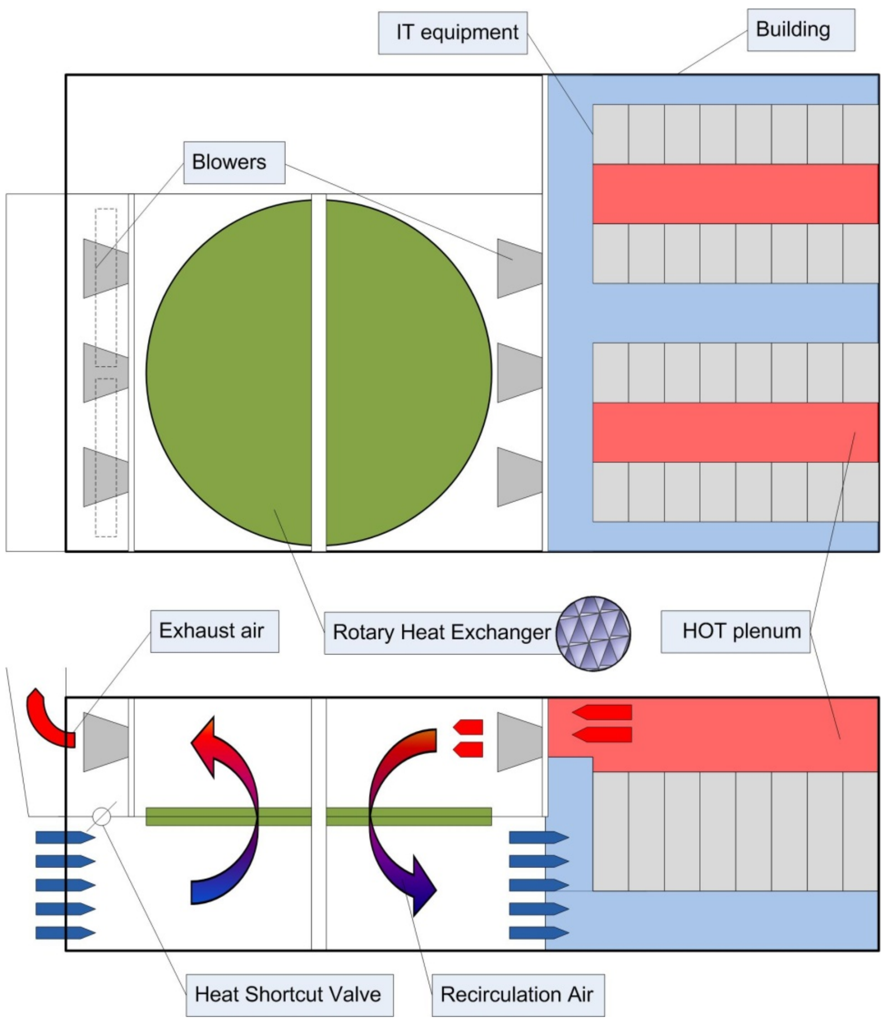

Figure 2. The plan (top) and elevation (bottom) views of the system illustrate the airflow movement on the ambient and computer room side of the heat wheel cooling system, as well as the computer room cabinet layout.

The hot exhaust air from the computer room is circulated back to the heat wheel by a set of three ventilators (fans). The airflow volume of these ventilators is controlled by the specified temperature drop across the heat wheel and the power being dissipated in the computer room, both of which are monitored by the controls system. The air is then supplied to the computer room either from under the raised floor, through a perforated wall between the heat wheel cell and the computer room, or a combination of the two. For cleanliness purposes, the static pressure in the computer room is monitored to ensure that positive pressure (in relation to the ambient pressure) is maintained at all times. The static pressure difference between the cold and hot aisles is also monitored to ensure a sufficient volume of air is being supplied to satisfy the IT equipment's cooling demands.

wheel by three ventilators and returns to the computer room, either under a raised floor and/or through a perforated wall between the KyotoCooling cell and the computer room.

In addition the airflows counter-rotate to each other, with the outside airflow rotating clockwise and the computer room airflow rotating counterclockwise. This creates a situation in which the wheel is self-cleaning. Any object that gets into the wheel will be blown out in the adjacent chamber.

The rotational speed of the wheel and the volume of ambient air being circulated through the wheel are variable and controlled to maintain the preset supply air temperature being fed into the computer room.

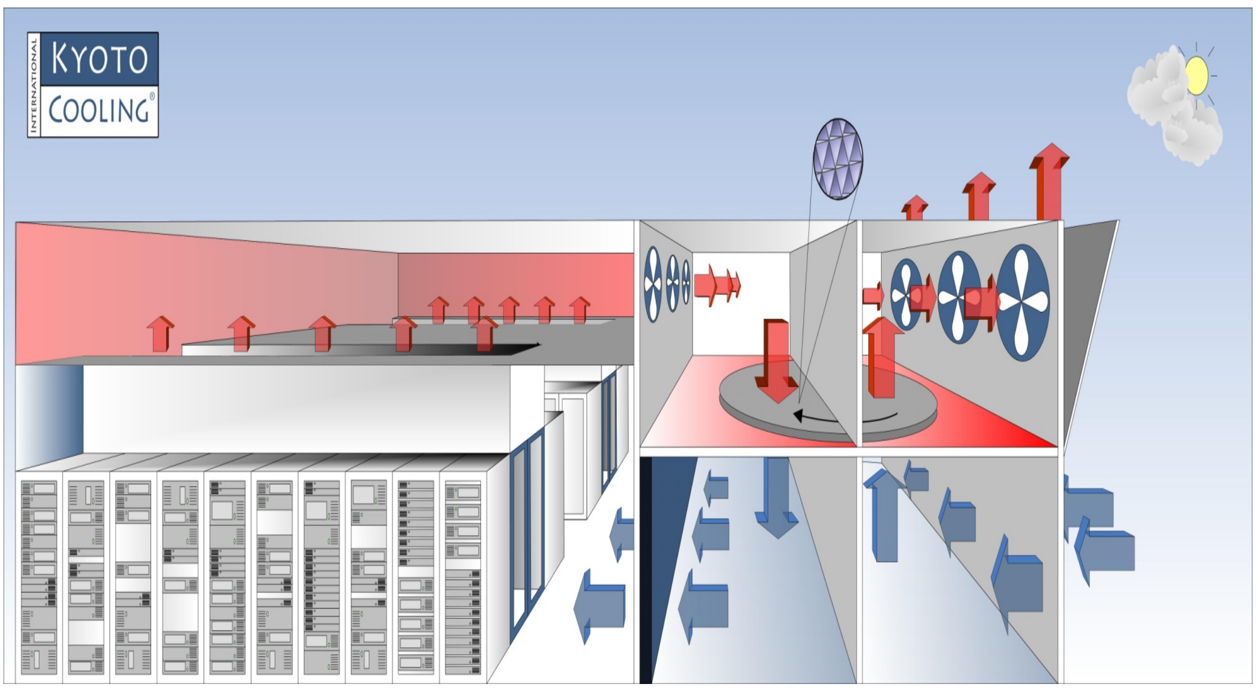

Figure 3. A general overview of the KyotoCooling installation and airflow patterns.

Ambient cold air is drawn into the lower chamber on the ambient side of the wheel, cools the wheel, and then is exhausted back to the outside by a set of three ventilators. To ensure the exhaust air does not recirculate into the air intake, a chimney system is used to exhaust this air above the roof line of the building. On the computer room side the hot exhaust air from the servers is drawn back to the

The rotational speed of the wheel and the volume of ambient air being circulated through the wheel are variable and controlled to maintain the preset supply air temperature being fed into the computer room.

For this new cooling system to function effectively, especially at the high loads it is capable of handling, the hot air exhausted from the computer equipment is isolated from the cold air in the computer room. This is accomplished through hot aisle containment. The hot aisles are physically sealed so the hot exhaust air rises into the dropped ceiling space and is carried back to the computer room chamber of the heat wheel cell. Another alternative in the isolation process is to use cabinets that have sealed back covers and chimneys that duct the hot exhaust air directly to the dropped ceiling space.

The hot air isolation system also requires that blanking plates be used in all unused areas of the equipment cabinets to avoid recirculation of hot air to the air intake of the servers within the computer cabinets.

The cold air coming off the heat wheel is allowed to flood the computer room, filling the cold aisles and satisfying the airflow needs of the servers installed in the room. This flooding technique can be accomplished with the air introduced into the computer room from under a raised floor, through overhead ducting, or with the air through a perforated wall between the KyotoCooling cell and the computer room. As long as there is sufficient air introduced into the computer room to satisfy the airflow demands of the server fans all the heat loads installed in the room can be cooled, even if there are significantly varying heat loads in adjacent cabinets.

The heat wheel is driven by a 1.5 hp motor with a V-belt wrapped around the perimeter of the wheel. Wheel rotation can be varied from 0.1 RPM to 10 RPM. Under normal conditions maximum efficiency is achieved at 6 RPM. To minimize the air exchange through the wheel the maximum speed of the wheel is limited to 3 RPM or less.

The speed of the wheel controls the exchange of ambient air into the computer room and that of computer room air exhausted to the outside. As the wheel rotates from one side to the other, a volume of air is carried with it. The volume of the exchange is determined by the size of the wheel, diameter and thickness, and the speed at which the wheel is turning. With a maximum speed of 3 RPM on the 6-meter wheel, the exchange is less than 0.3 percent of the airflow volume circulated through the wheel. In comparison the leakage through the seals around the wheel and other places in the computer room are insignificant.

The exchange of air by the rotation of the wheel is not a problem under normal circumstances. If the ambient air is polluted, too humid, or too dry it can be purged from the wheel between the upper computer room chamber and the lower ambient chamber and will not enter the computer room. A small amount of hot computer room air is used to blow the ambient air caught in the wheel back to the ambient side of the cell. The loss of this air from the computer room side of the cell is made up by increasing the air introduced into the computer room through the building AHU.

This second source of outside air coming into the computer room is through the small building AHU that is used to maintain a positive static pressure in the room, as well as the proper moisture content. This AHU recirculates computer room air from the return chamber of the computer room side of the wheel, injects just enough ambient air to maintain a positive pressure of 5 to 6 pascals (Pa) (0.01 to 0.02 inches of water gauge), and returns the air to the cold side of the computer room. A cold coil and steam generator are used for dehumidification and humidification to control the moisture content of the air.

In the demonstration installation only the static pressure and moisture content are controlled, not the air temperature. This allows warm air to be introduced back into the computer room, which can disrupt the uniform supply air temperature to the server cabinets.

Both moisture content and temperature should be controlled in full-scale data center installations. This can be done in two ways. The first is to draw the recirculated air from the supply chamber on the computer room side of the wheel. The second is to continue to recirculate air from the return side of the wheel but reintroduce it into the air stream in the return chamber so it can be properly cooled when passing through the wheel. This makes humidification more efficient because warm air more readily absorbs moisture yet still allows the air to be cooled after humidification.

Supplemental cooling system for the KyotoCooling system

In most installations using a free cooling system, a supplemental refrigeration-based cooling system must be installed. This is to ensure continuous operation of the data center at high temperatures and/or low or high dew point ambient conditions. For the KyotoCooling system the supplemental cooling is provided by either a modular compressor-based direct expansion (DX) system located in the KyotoCooling cell or by chilled water using an existing chiller-based system installed in the facility. Both of these systems provide efficient supplemental cooling through evaporator coils installed at the computer room wall on the supply side of the wheel. With the locally placed modular DX units the condenser coil is located on the exhaust side of the ambient airflow path. Such placement of the evaporator and condenser coils creates very short refrigeration piping paths that minimize the installation cost of the modular DX system.

In areas with consistently moderate climates and a computer operation that does not require 24 by forever availability, the supplemental cooling system may not be required.

Control of the KyotoCooling system

Control of the system is automatically handled by proprietary software with only a minimum number of inputs. The inputs include the temperature drop (ΔT) through the wheel in the computer room chamber, the supply air temperature to the computer room, and the electrical power delivered to the computer equipment. The control system continuously monitors the heat load being dissipated in the room and controls the computer room airflow volume to match the load and the desired ΔT of the system. The speed of the wheel and the ambient airflow volume are then modulated to control the computer room supply air temperature.

The positive static pressure is maintained by both the building AHU and the computer room fans to ensure there is sufficient cool air flowing into the room to satisfy the cooling fans of the installed IT equipment. If the server fan The positive static pressure is maintained by both the building AHU and the computer room fans to ensure there is sufficient cool air flowing into the room to satisfy the cooling fans of the installed IT equipment. If the server fan airflow volumes change or the installed equipment is modified, the cooling airflow will adjust automatically to maintain sufficient cool air supply to cool the servers.

As computer room load and ambient temperatures vary, so do the operating conditions. At temperatures below 10°C (50°F), the recirculation louvers between the two chambers (see Figure 4) on the ambient side of the cell are opened to allow warm air to recirculate to the intake chamber to maintain a 10°C (50°F) face temperature on the wheel. From 10°C (50°F) and 23°C (73°F), ambient temperatures the speed of the wheel and the ambient airflow volume increase with increasing ambient temperature, maintaining the preset temperature of the supply air to the computer room. For a supply air temperature of 25°C (77°F) supplemental cooling is required when the ambient temperature exceeds 23°C (74°F).

Above 23°C (73°F), chilled water or DX supplemental cooling is brought on in 50 to 100 kW increments. As each increment of DX cooling is added, the wheel slows down so the DX compressors operate at 100 percent capacity. As the ambient temperature continues to rise the wheel again speeds up until the next increment of supplemental cooling is required. This process repeats itself until the cooling system is on 100 percent sensible

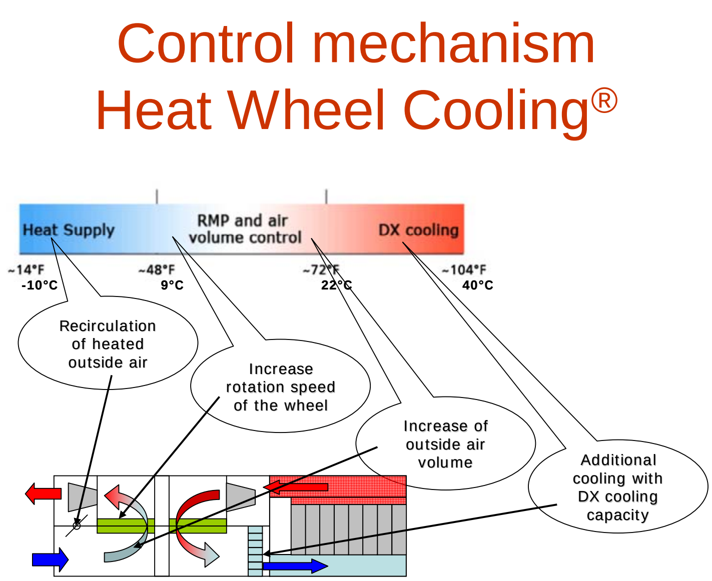

Figure 4. Illustration of the KyotoCooling control system.

cooling, usually between 32°C (90°F) and 34°C (93°F) at which time the wheel is stopped (see Figure 4).

The ambient temperature at which supplemental cooling is required can be raised by employing adiabatic pre-cooling of the ambient air. In one proposed installation in a very dry (low dew point) climate, adiabatic cooling will extend the exclusive use of the heat wheel cooling system to 36°C (96°F) for a supply temperature of 25°C (77°F). With the American Society of Heating, Refrigerating, and Air Conditioning Engineers- (ASHRAE-) recommended guidelines extended to 27°C (81°F) the adiabatic cooling system would allow this installation to operate without supplemental cooling up to 38°C (100°F) ambient temperature.

Evaluation of the flooded system of cooling the computer

The measurement of cooling performance for this evaluation will be the input air temperatures to the four rows of eight cabinets in the computer room of the demonstration site in Amersfoort, the Netherlands. One row contains IT servers and storage modules. The load in this row of cabinets is less than 4 kW per cabinet. Cabinets in the other three rows are populated with 2 kW load banks with fans attached. These cabinets can dissipate from 4 kW to 28 kW depending on how many load banks are activated. This layout is depicted in the plan view of Figure 2. In addition a Chatsworth Products Inc. (CPI) chimney cabinet has been added at one end of the room. Five 20 kW load banks are installed in this cabinet, but for this evaluation only 40 kW was activated.

Liquid crystal temperature strips were installed at the top and bottom of each of the 33 cabinets. Temperature variations were monitored from top to bottom of each cabinet, between the first cabinet and the last cabinet in the row, and from row to row.

For ambient conditions less than 22°C (72°F), the temperature variations are dependent on the amount of heat load in the room. With a heat load of just 150 kW (1500 W/m² or 150 W/ft²), the airflow through the wheel in the computer room chambers is quite low, 38K m³/hr (23K cubic feet per minute, or CFM). With these low airflows the variation from top to bottom of cabinets and from the first cabinet to the last cabinet was less than 1°C (2°F). However, from Row 1 to Row 4 the variation was 5°C (9°F).

The row to row variation is the result of a temperature difference of the heat wheel as it rotates through the computer room portion of the cell. It is very cold when it enters and warms as it absorbs heat from the computer room. This variation across the computer room can be minimized by mixing the air in the supply chamber of the computer room side of the cell with louvers, which will increase the airflow through the computer room side of the cell.

When the heat load in the computer room increases to 550 kW the airflow volume through the computer room increases to 140K m³/hr (85K CFM) and the temperature differences in the computer room are minimized. Top to bottom and front to back are less that 1°C (2°F), and from Row 1 to Row 4 the variation is also 1°C (2°F). .

Other performance highlights include the verification that cabinet input air temperature of 25°C (77°F) can be maintained up to an ambient temperature of 23°C (73°F). Another test demonstrated that the system can deliver 21°C (70°F) air to the computer room with a heat load of 550 kW and a ΔT across the wheel of 28°C (50°F) at an ambient temperature of 20°C (68°F). With these last results it shows the heat wheel can easily handle blade server and other high density loads that produce high ΔT values through the servers.

With a ΔT across the wheel of 20°C (36°F) to 25°C (45°F), the efficiency of the KyotoCooling system is 0.02, even at a heat load of 550 kW.

Comparison of efficiency three free cooling systems

There are two established free cooling / economizer systems, waterside and airside. The efficiency of both of these systems will be compared with that of the KyotoCooling system. Values used for waterside and airside will be taken from a report by Lawrence Berkeley National Laboratory (LBNL) that compared the two systems.[1] The KyotoCooling data was developed at the test site in Amersfoort, the Netherlands. The chilled water refrigeration system data has come from surveys of numerous computer rooms.

The measurement of efficiency used to characterize this installation is a modified version of the Green Grid's power utilization efficiency (PUE).[2] Since the measurements being made only reference the mechanical energy used to

1 "KyotoCooling Design & Features – Basic Design." Marcel van Dijk, March 16, 2009

2 Uptime Institute Charrette—Track 2 Executive Summary. Robert Sullivan, December 17, 2007

Critical Load kW	Wheel ΔT °C / °F	Supply Temp °C / °F	Outside Temp °C / °F	PUEm Single cell	PUEm 1 cell + 1 redundant	PUEm 4 cells + 1 redundant
150	12 / 22	22 / 72	20 / 72	0.05	0.02	0.03
150	12 / 22	25 / 77	20 / 72	0.05	0.02	0.03
350	12 / 22	22 / 72	20 / 72	0.13	0.04	0.09
350	12 / 22	25 / 77	20 / 72	0.09	0.03	0.06
350	20 / 36	22 / 72	20 / 72	0.05	0.02	0.03
350	20 / 36	25 / 77	20 / 72	0.04	0.02	0.03
550	12 / 22	22 / 72	20 / 72	0.21	0.06	0.14
550	12 / 22	25 / 77	20 / 72	0.15	0.04	0.10
550	20 / 36	22 / 72	20 / 72	0.07	0.02	0.05
550	20 / 36	25 / 77	20 / 72	0.05	0.02	0.03
550	28 / 50	25 / 77	10 / 50	0.03	0.01	0.02

Table 1. KyotoCooling PUEm for a variety of operating conditions.

cool the computer room heat load, a Mechanical PUE (PUEm) will be used. PUEm compares the computer equipment load (referred to as the “Critical Load”) to the mechanical load required to cool the critical load.

PUEm = Mechanical Load / Critical Load

The first table illustrates measurements made at the KyotoCooling Amersfoort demonstration site for a varietyof critical loads and ΔTs. In addition, calculations are made reflecting the system’s efficiency when redundant cells are included in the data center configuration. The redundant numbers are lower because the major energy usage for this system is the computer room and outside air ventilators (fans). When redundant units are included in the design the ventilators run at a slower speed because there are more of them operating.

The energy the ventilators consume is related to the cube of the speed, so slower speeds means significantly less energy

The efficiency values in Table 1 illustrate key factors to improved efficiency are lower power loads and higher ΔTs, as well as lower ventilator speeds. Other data collected also showed that lower ambient temperatures improved the efficiency. The lower efficiencies are directly related to the amount of air circulating on the computer room side and ambient side of the wheel. Since the energy consumed by the ventilators is related to the cube of the fan speed, situations requiring less airflow results in lower energy draw and therefore greater efficiency. That is why lower loads, higher ΔTs, and lower ambient temperatures result in greater efficiencies.

Another factor to consider along these lines is the influence of redundancy. If one cell is required and two are installed for redundancy, the power used to dissipate the same load under the same ΔT and ambient conditions is reduced to 25 percent that of a single cell operating. As the number of cells required increases and the ratio of necessary cells to redundant cells increases, the operating savings is not as great. But even with four cells required and one redundant the energy usage is reduced to 64 percent of the non-redundant level.

Cooling Type	Hot & Dry	Cold & Dry	Marine	Hot & Damp
Refrigeration process (baseline)	0.60	0.60	0.60	0.60
Baseline with airside economizing	0.22	0.15	0.15	0.23
Baseline with water-free cooling	0.23	0.23	0.23	0.26
Heat wheel—single cell	0.22	0.08	0.10	0.17
Heat wheel—4 cells + 1 redundant	0.14	0.05	0.07	0.11

Table 2. Comparison of PUEm for the three free / economizer cooling techniques, with a normal chilled water system as a base. In this measurement small values indicate increased efficiency.

Table 2 compiles the efficiencies of the three free cooling / economizer techniques for various generic climates. Hot and dry might be Phoenix, AZ; cold and dry, Minneapolis, MN; marine, Seattle, WA or Amsterdam, the Netherlands; and hot and wet Houston, TX. For comparison purposes a standard refrigeration cooling system is also listed.

As can be seen from the data, airside economizers and KyotoCooling are better than the chilled water. This is related to the fact that the chilled water free cooling is usually limited to an ambient environment below 10°C (50°F).

The classic exposures for the airside economizing technique is contamination because of the very large volumes of air brought into the computer room and more specifically, the exposure to episodic contamination events that have been known to plug the intake air filters or set off fire alarms. Both of these situations will cause the computer room to overheat, the first due to a lack of airflow into the facility and the second due to the airflow system shutting down. To avoid these problems a sophisticated monitoring system and automatic controls are required to shut down the ambient airflow and bring the supplemental cooling system on line. Few installations have such a system and many are not manned 24 by forever, exposing the computer systems to potential unscheduled system outages.

Another disadvantage to the airside economizing technique is the need to control the humidity or moisture content (dew point) level within the computer room. Even with the new ASHRAE-recommended moisture content guidelines of a lower limit of 5.5°C (43°F) dew point in many dry climates, there will still be a need to humidify for extended periods of the year. The alternative for this technique is to limit the number of hours per year free cooling is available and use the supplemental cooling system when it is too hot and too dry. This is actually a more economical strategy than to humidify the air.

Another measurement of efficiency is the average annual power used by the computer equipment compared to the average annual power used by the cooling system.

EER-A = Annual Energy (Critical Load) / Annual Mechanical Energy

Cooling Type	Hot & Dry	Cold & Dry	Marine	Hot & Damp
Refrigeration process (baseline)	3.56	3.62	3.55	3.61
Baseline with airside economizing	4.55	6.67	6.67	4.35
Baseline with water-free cooling	4.35	4.35	4.35	3.85
Heat wheel—single cell	4.55	12.5	10.00	5.88
Heat wheel—4 cells + 1 redundant	7.14	20.00	14.30	9.09

Table 3. Comparison of EER-A for the three free / economizer cooling techniques, with a normal chilled water system as a base. In this measurement large values indicate increased efficiency.

Both of these efficiency measurements illustrate the benefit of KyotoCooling not requiring large volumes of ambient air to be introduced into the computer room and its ability to provide free cooling at higher ambient temperatures.

Unique applications for the KyotoCooling process

The use of the heat wheel, with the isolated hot aisle, has been shown to easily cool 28 kW and 40 kW per cabinet.

Computational fluid dynamics (CFD) modeling has shown the ability to cool more than 70 kW per cabinet. With the proper airflow through a cabinet and the correct cooling fans in the servers, is there a limit to the amount of heat that can be dissipated in a cabinet?

In addition to the high heat loads, KyotoCooling has demonstrated the ability to handle a variety of heat loads in proximity to each other. Four kW, 24 kW, and 40 kW in cabinets in close proximity are all cooled properly with less than a 1°C (2°F) variation in input air temperatures.

It should be pointed out that the data center operations requirement is to provide the proper environment at the face (air intake) of the server. It is up to the manufacturer to properly use this air to cool the equipment.

The ability to handle high heat loads and high ΔTs has also been demonstrated. A heat load of 550 kW (5500 W/m² or 550 W/ft²) and a ΔT of 28°C (50°F) has been demonstrated, requiring just 17 kW of power for the mechanical system at an ambient temperature of 10°C (50°F). This yields a PUEm of 0.03.

Modeling has also shown that if the ΔT across the wheel is increased from 12°C (22°F) to 20°C (36°F), the cooling capacity of the cell would be 1 MW of power.

Unique requirements for the KyotoCooling system

The two unique requirements for the KyotoCooling system are the architectural layout of the data center for the full capacity wheel installed in a cell and/or a location to install the modular units on the roof or beside the building.

With the full capacity system and the 6-meter diameter wheel, the cell is located immediately adjacent to the computer room. This allows for the most efficient circulation of hot exhaust air from the computer room to flow through the heat wheel and be returned to the computer room in a low pressure / low velocity flow.

The cell typically measures 8 m wide, 12 m deep, and 8 m high. Depending on the heat density of the computer room one cell can support up to 500 m² (5,000 ft²) at a density of 1,000 W/m² (100 W/ft²) to 100 m² (1,000 ft²) at a density of 5,000 W/m² (500 W/ft²).

Conclusion

KyotoCooling is a unique application of an existing technology that has demonstrated its capability to dissipate heat reliably over an extended period of time. The application of the heat wheel technology to the data center provides efficient and effective cooling with minimal ambient airflow into the computer room. It has the capability of cooling both low and high density loads, both on a per cabinet basis as well as throughout the computer room. Easily going from 4 kW to 40 kW in a cabinet and 1,000 W/m² (100 W/ft²) to 5,000 W/m² (500 W/ft²).

Because it can to prevent ambient airflow exchange with the computer room, problems associated with contamination and humidity control are non-existent. The system allows airside economizing without air transfer.

Part of the control system employs sensors to detect ambient air filters becoming clogged and/or the introduction of contaminate gasses infiltrating the ambient side of the cell, and low or high moisture situations in the ambient air. As a last resort the ambient air can be shut off and supplemental cooling used to dissipate the load until the situation is cleared.

Maintenance of the system is minimal and does not take especially skilled technicians. The belt driving the heat wheel should be inspected, lubricated, and changed as necessary. At the demonstration site in Amersfoort, the Netherlands, vibration sensors have been attached to each of the ventilators to identify potential bearing problems long before they become critical. This allow maintenance procedures to be conducted on a scheduled basis, rather than under crisis conditions.

Overall this is an amazing new cooling technique with great efficiency that can be installed in a wide area of the world because of its wide operating temperature range. Even if the heat wheel can only be used 50 percent of the time or less, it is still beneficial to the annual energy consumption of the cooling system. KPN’s analysis indicates the installation cost (capital expenditure) is not greater than a standard chilled water system. Therefore an operational savings will immediately provide an increase on a data center’s return on investment and total cost of operation.

About the Author

Dr. Robert Sullivan, or Dr. Bob, as he is commonly known within the IT industry, joined Upsite Technologies, a leading designer and manufacturer of optimizing solutions for the data center, in 2000 after a 32-year career with IBM's Storage Systems Division in San Jose, CA.

Dr. Bob is one of the original inventors of the pervasive KoldLok Grommets, an innovative raised-floor sealing solution that eliminates up to 100 percent bypass airflow in computer rooms. As Upsite continues to develop and manufacture optimizing data center solutions, including HotLok Blanking Panels for the server cabinet and KoldWorks diagnostic and remediation services for data centers, Dr. Bob participates as an esteemed member of the product development team, consulting on mechanical engineering issues.

He currently represents Upsite Technologies worldwide as a speaker on data center cooling optimization, and contributes to Upsite’s studies and white papers.

Dr. Bob is a recognized expert in the areas of computer room environments, hardware installation, computer room layout, power and power distribution, grounding, cooling, and airflow plus contamination identification and remediation.

About KyotoCooling

In 2005 Mees Lodder started UpTime Technology in Holland, an only-data center technical infrastructure consulting company. UpTime is currently consulting for top 500 Dutch companies. Activities vary from basic design, project management during built, audits in existing data centers and incident mapping, problem solving unexpected incidents.

Since the start of UpTime, KyotoCooling® was step by step discovered and developed. During this process KPN became interested and involved. This resulted in the built of a full size KyotoCooling test facility in Amersfoort, where we demonstrate at 6,000 Watt/m2 and 100 kWatt in one cabinet how efficient KyotoCooling can cool IT hardware. Occurring PUE at in the range of 1,02–1,06. In the Dutch climate a year over PUE of < 1,10 was derived and reported.

In 2008 KyotoCooling International was formed to market KyotoCooling to the world. KyotoCooling is presented to the market as a total solution. KyotoCooling International will supply all necessary mechanical and electrical hardware as well with the process controller. All parts are fully tested at the test site. The process controller is designed and tested to meet the highest standards in continuity.

KyotoCooling International BV owns all the IP, patents and know-how regarding KyotoCooling. For more information on KyotoCooling, contact R.M. Lodder at m.lodder@uptimetechnology.nl.

About the Uptime Institute

Uptime Institute is a leading global authority on data centers. Since 1993, it has provided education, consulting, knowledge networks, and expert advisory for data center Facilities and IT organizations interested in maximizing site infrastructure uptime availability. It has pioneered numerous industry innovations, including the Tier Classification System for data center availability, which serves as a de facto industry standard. Site Uptime Network is a private knowledge network with 100 global corporate and government members, mostly at the scale of Fortune 100-sized organizations in North America and EMEA. In 2008, the Institute launched an individual Institute membership program. For the industry as a whole, the Institute certifies data center Tier level and site resiliency, provides site sustainability assessments, and assists data center owners in planning and justifying data center projects. It publishes papers and reports, offers seminars, and produces an annual Green Enterprise IT Symposium, the premier event in the field focused primarily on improving enterprise IT and data center computing energy efficiency. It also sponsors the annual Green Enterprise IT Awards and the Global Green 100 programs. The Institute conducts custom surveys, research and product certifications for industry manufacturers.

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