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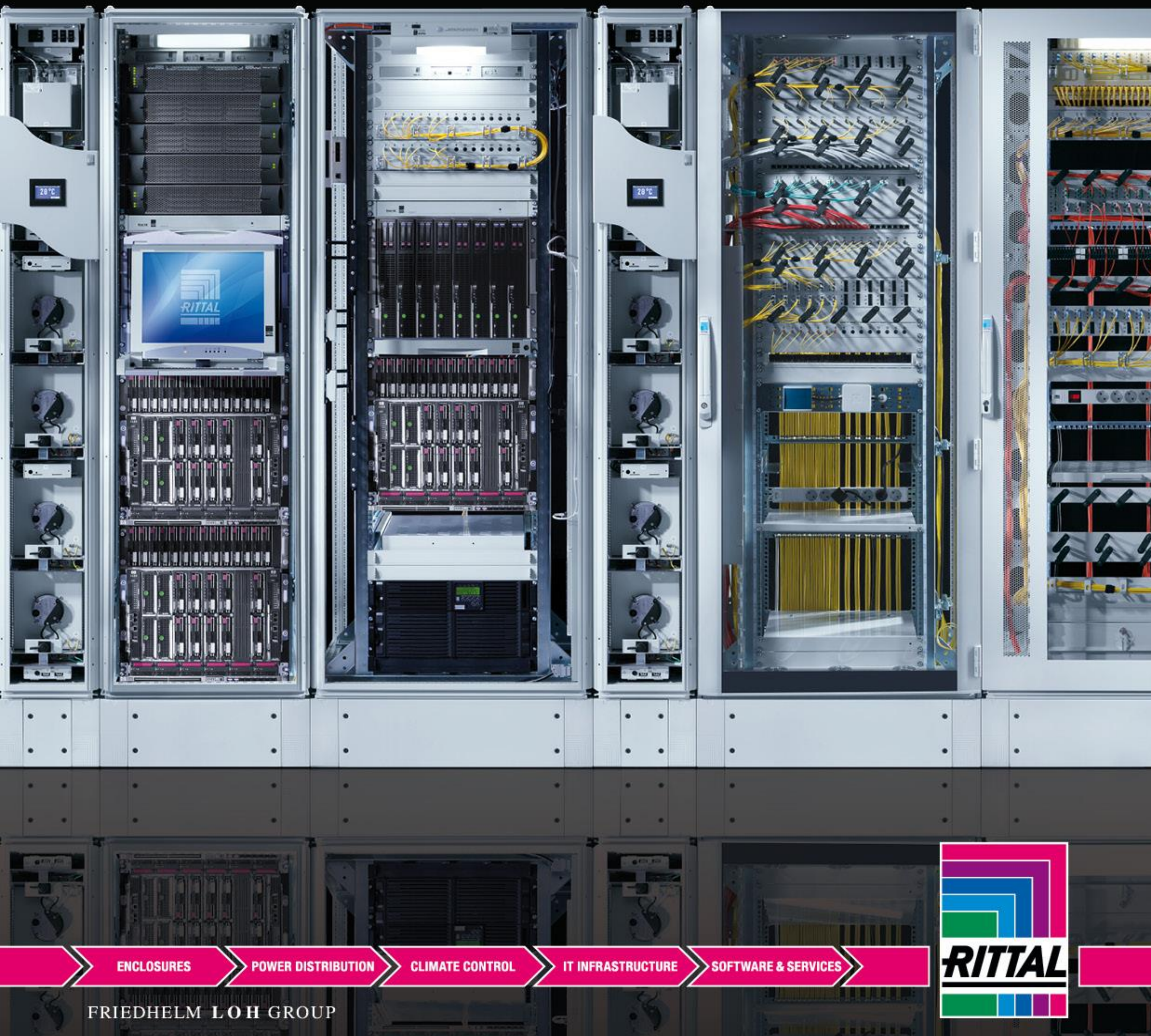
WHITE PAPER — *Data center climate control: An air-to-water exchange provides cooling efficiencies*



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Executive summary

Data Centers are the heart of today's IT environment in nearly all medium-sized and large companies. And, as demand for more computing power increases, so does the number of components involved. Increased component density leads to increased heat and increased concern for cooling at the individual rack level. Rittal's TopTherm Liquid Cooling Package (LCP) system has proven to be an efficient solution to cooling concerns. The different variants in the LCP family offer both row-based and rack-based cooling options.

An LCP uses an air-to-water heat exchange. Water heated by hot air generated by various components is cooled down and recirculated through the system. And, the functions of the LCP can be monitored via PC or a management software package.

The design and control system of the TopTherm LCP range make it particularly energy-efficient. Useful cooling outputs are achieved by using inlet temperatures higher than industry stated norms and making maximum use of indirect free cooling. The result is an effective, energy-efficient climate control solution.

Introduction

Data Centers are at the heart of today's IT environments, especially in medium-size and large companies. With their ever-increasing densities and demands for more capacity, it is in these centers where a company's vital data, records and communications tools are housed.

As data centers expand their footprint they also expand their demand for energy as higher performance components are deployed. And, these components not only require more energy, they generate more heat. Heat is the enemy of all things electronic and if allowed to build up within an enclosure can cause system failures or severely limit the life of the equipment.

A reliable, cost-effective cooling solution is a must in today's IT environment. Rittal's Liquid Cooling Package (LCP) offers several variations to provide high-quality results whether cooling a rack to 10kW or as high as 60kW. Its modular design can accommodate growing cooling demands.

An LCP is bayed to an enclosure and supplies cold water via pipes beneath a raised floor. Employing air-to-water heat exchange technology, an LCP uses cool water to cool the hot air within a rack. This highly efficient technology makes it possible to achieve high cooling output while saving energy and reducing costs – achieving high-efficient cooling at higher temperatures than the industry norm and making use of every free-cooling opportunity.

Objectives and requirements

Floor space is always at a premium so modern data centers are always looking for ways to house massive amounts of computing capacity in the least amount of space. That means more enclosures in smaller rooms and more components in each enclosure. As this density increases so does the heat generated and this heat must be dissipated to prevent overheating and damage to electronic components. Without appropriate external cooling, the air temperature within a data center can rise to extreme levels in a relatively short time – leading to system failures, lost data or worse.

As densities increase more and more powerful cooling options are required to dissipate the excess heat quickly and completely while maintaining a consistent air temperature. It is equally important to provide even, consistent distribution of the cool air. Because hot air is lighter than cool air, it rises and “hot spots” can form within individual racks if the flow of cooling air is not complete. In individual racks, servers at the top levels could be considerably warmer than those at the bottom, for example.

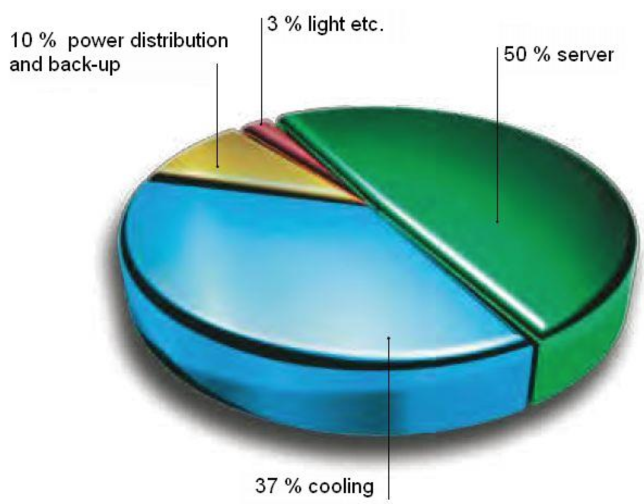


Figure 1: Energy consumption in data centers

The basic infrastructure of a data center, as represented in Figure 1, consumes the same amount of energy as the servers and cooling consumes the most energy after servers (37%). The Environmental Protection Agency (EPA) estimated that in the United States data centers consumed about 61 billion kilowatt-hours (kWh) in 2006. That’s about 1.5 percent of the total U.S. electricity consumed that year. At a cost of approximately $4.5 billion.

Data such as this underlines the need to provide cooling options that not only dissipate heat efficiently and quickly but do it in the most cost-effective way possible.

Room climate control with a CRAC system

In data centers where there are low levels of heat generated by IT components, a Computer Room Air Conditioning (CRAC) system may be suitable. CRAC units are positioned independent of the enclosure rows and cool the entire room's ambient air. Hot air is drawn in just below the ceiling, cooled by the unit and routed to the room's enclosures via a raised floor. It enters each enclosure through perforated front doors. The servers are able to draw in cold air, cool down components and expel the warmer air at the rear of the enclosure. Cool water is used to cool the air within the CRAC itself – a Rittal unit as shown in Figure 2 is plumbed to pipes beneath the raised floor with a pipe bringing in warm water from the room and another dispersing cooled water. Both are routed through an external chiller where water is either cooled mechanically or via cooler ambient air.

Figure 2: CRAC system

Within Rittal's system there's an aisle containment solution for data centers. This configuration can improve cooling efficiency by incorporating mechanical partitions to physically separate the space between two rows of enclosures. The enclosures are then accessed via special doors that have isolated the cold aisle – See Figure 3. Cold air flows through the raised floor into the cold aisle. Hot air from servers is drawn out to the CRAC where it is cooled and returned.

The cold aisle has the benefit of superior efficiency when compared to a more open architecture and provides higher cooling capacity. Without the containment of the aisle structure, hot air would mix with cooler air and increase the overall temperature of the air reaching the servers. Aisle containment keeps hot and cold air separated, increasing the efficiency of the attendant CRAC system while reducing energy consumption.

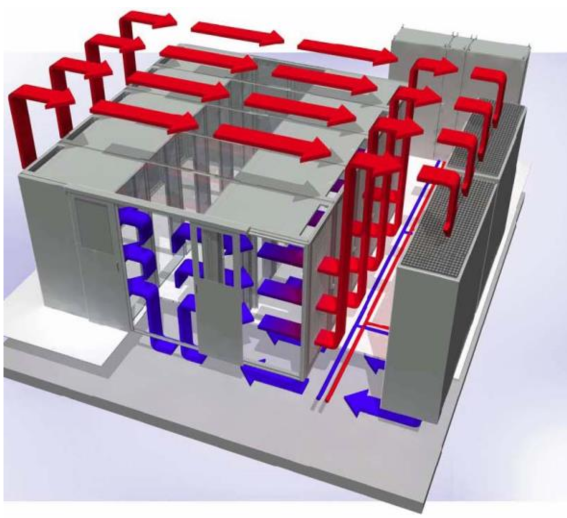
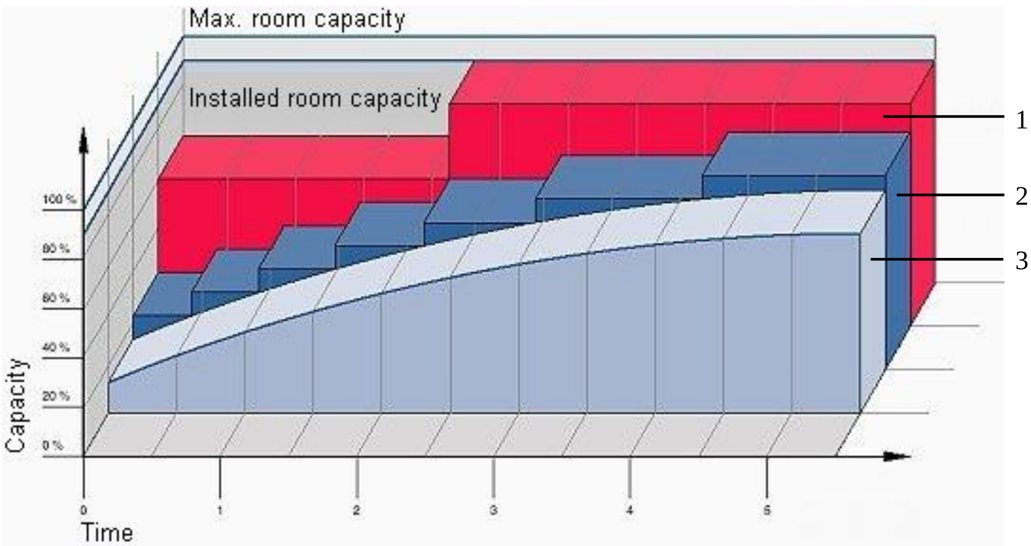


Figure 3: Functional principle of cold aisle containment

The TopTherm Liquid Cooling Package

Rittal's TopTherm Liquid Cooling Package (LCP) offers cooling options capable of dissipating heat at a rate of as much as 60kWper enclosure. Its modular design makes it easier for cooling to be extended as a data center expands and these units can retrofit into existing facilities. The LCP cooling output is flexible and may be adapted to a range of current and future cooling requirments – See Figure 4.



1: Installed excess capacity 2: Capacity adjustment 3: Current power requirements

Figure 4: Adjustment to meet the data center's requirements

Source: Rittal [1]

Unlike a traditional CRAC system, an LCP is not independent of the enclosures and cannot be freely positioned in the room. An LCP is bayed to its related enclosures – making sure that a full 42U in a 2,000mm high enclosure is available for servers and related equipment. Power and water connections are made through lines in the raised floor – each LCP is connected to both a cool and warm water line with the system connected to an appropriate chiller. Based on air-to-water heat exchange technology cool water us used to reduce air temperature within each enclosure – the water circuit is physically separated from all the electronic components and heat is routed out of the enclosure by concentrated air flow. If a malfunction occurs in the water system, there is no threat from escaping water – and leak detection is an integral part of the LCP's security system.

A significant advantage to LCP technology is its even distribution of cold air across the entire height of the rack – all components get an equal amount of cooling air flow, eliminated potential hot spots and prolonging the working life of components.

Compatible with Rittal's extensive line of enclosures, LCP installation – both new and retrofit – can be accomplished quickly and with ease.

Row-based climate control with the TopTherm LCP Inline

The Rittal TopTherm LCP Inline is an integrated climate control system designed to cool an entire row of enclosures. Unlike conventional CRAC cooling, it is not positioned away from the row of enclosures, instead it is bayed in the row with the racks. Figure 5 illustrates the basic principles and configuration of the LCP Inline.

Hot air emitted at the rear of the enclosures is drawn into the LCP where it is cooled by an air-to-water heat exchanger. Cooled air is forced into the aisle in front of the enclosures. With the addition of a closed aisle containment feature, this cool air is captured and readily returned to the enclosures where components are cooled.

An efficient, powerful LCP Inline can provide cooling output of as much as 60 kW while taking up just 12-inches of space between racks – a total footprint of .36m^2. When compared to traditional CRAC options, the LCP Inline has a much higher cooling capacity within a much smaller footprint and is capable of dealing with significantly higher heat losses within an individual enclosure.

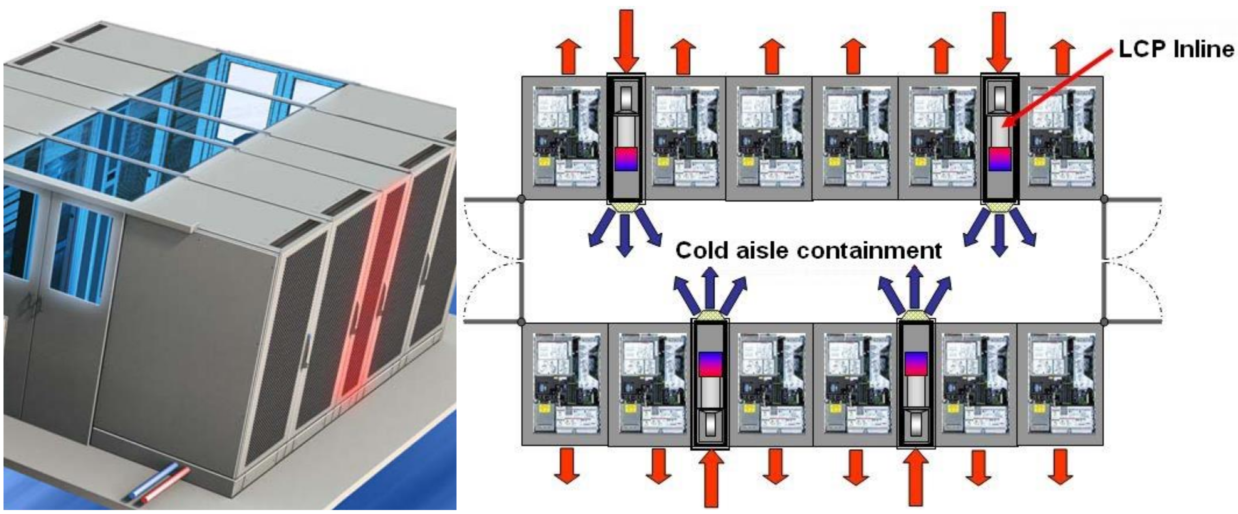


Figure 5: Functional principle of the Rittal TopTherm LCP Inline

The LCP Inline can be integrated into a bayed suite of enclosures in two different ways. It can be mounted flush to the adjoining enclosures (Figure 7) and mounted projecting slightly into the cold aisles (Figure 6). When projecting into the aisle the unit's fans are rotated at a 90-degree angle so that cool air is no longer just released into the aisle, it is blasted directly to the front of the servers. This configuration reduces deflection losses and makes cool air dispersal more efficient because it is directed specifically toward the source of the heat – a "curtain" of cool air forms in front of the enclosures. As an added bonus, when entering the cold aisle, technicians no longer face a blast of cold air hitting them directly in the face.

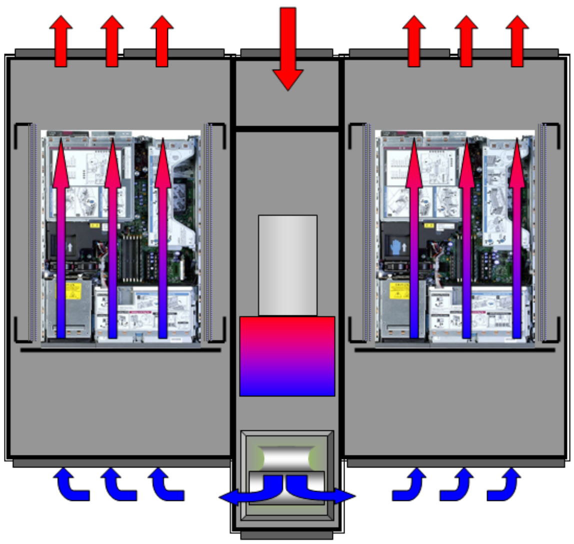


Figure 6: Offset installation of the LCP Inline

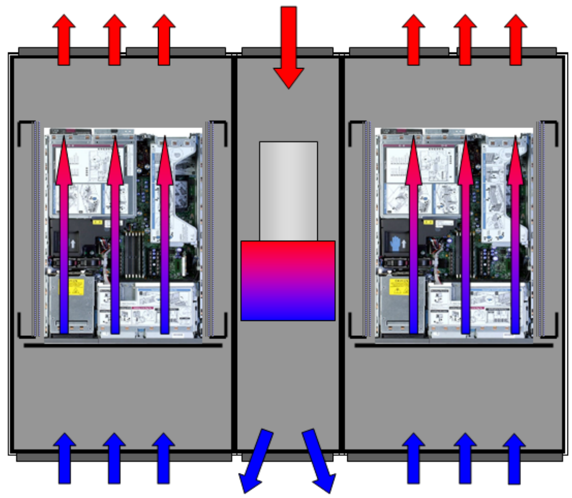


Figure 7: Flush installation of the LCP Inline

Rack-based climate control with the TopTherm LCP Rack

Like most of the Rittal LCP units, the TopTherm LCP Rack can provide up to 60kW of cooling output, but unlike the others a separate air circuit is used to cool components inside the adjacent enclosure and rack. Mounted outside the enclosure, hot air is drawn from the rear of the servers into the side of the LCP sides by high-efficiency fans. Cooling the air via an air-to-water heat exchanger, the unit then blasts cold air back to the front of the servers where operating temperatures are reduced and the cycle continues. (Figure 8 shows the LCP Rack alone)

Figure 8: LCP Rack

Servers are cooled independently from ambient air within the data center so cooling requirements can be adapted to the needs of individual servers or enclosures in a modular fashion. Up to six fan modules may be installed in this configuration to adapt the cooling capacity to a unit's precise requirements – providing for more efficient cooling and energy use. (Figure 9)

A single LCP can be used in conjunction with two racks, with the enclosures mounted on both sides of the LCP module. Both enclosures are cooled simultaneously with the cool air generated by the LCP evenly divided to each rack. In this case, the sum total of heat loss from the two racks must not exceed the cooling capacity of the one LCP.

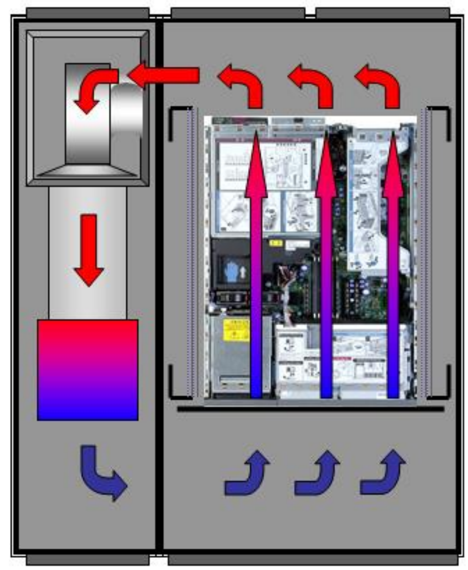


Figure 9: Function of the LCP Rack

Redundant rack cooling with the TopTherm LCP T3+

Unlike other LCP variations that are connected to a single water source, the Rittal CLP T3+ uses a redundant cooling system that makes it highly fault-tolerant and well suited for server installations the experience high thermal loads. It has a useful cooling output of up to 25 kW.

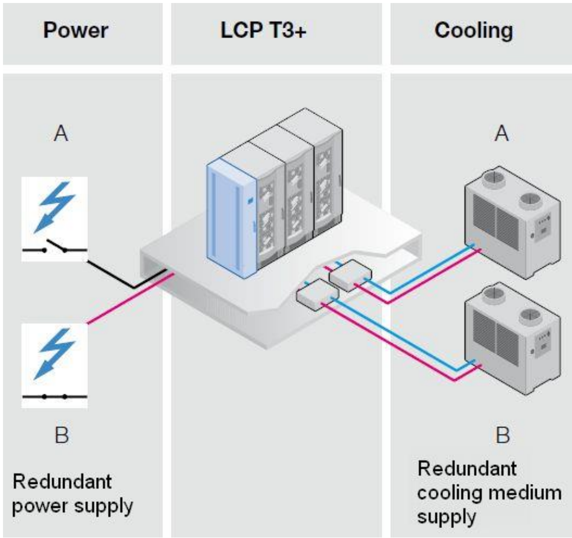


Figure 10: Redundant supply to the LCP T3+

Redundancy is built into the system specifically to provide safeguards under extreme conditions or where highly critical functions must be maintained. Redundancy simply is duplication of functionally identical or equivalent resources not normally required during fault-free operation. With this in mind, the LCP 3+ is equipped with two supply channels – if one channel should fail, the second ensures full, continued operation. Redundancy is possible with other LCP units but they require two LCPs to provide true "2n" redundancy per server enclosure. The LCP T3+ support "2n" redundancy with just one unit connected to two supply channels – two for electricity and two for refrigerant. (See Figure 10)

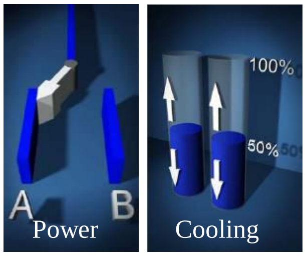


Figure 11: Supply channels

Under normal operating conditions, electricity will be provided by one of the two connections and in an emergency the system automatically switches to the alternate channel. The supply of refrigerant is also divided into two supply channels (See Figure 11) and each can assume full supply of the LCP should the other fail. However, in normal operation, the load is divided evenly between the two. Once an emergency situation is rectified, the controller automatically switches from the one-channel supply back to the dual-circuit operation.

While the controller is extremely fault-tolerant, cooling always receives the top priority should there be a failure among the electronic components – under emergency operation, the unit switches to maximum cooling output. This intelligent control system coupled with redundant supplies not only makes the LCP T3+ reliable and efficient under normal conditions, it makes it suitable for high-MTBF applications.

LCP monitoring options

System-relevant parameters, including incoming and outgoing air temperatures at the servers, cooling output and the water throughput rate are continuously monitored by sensors in the LCP

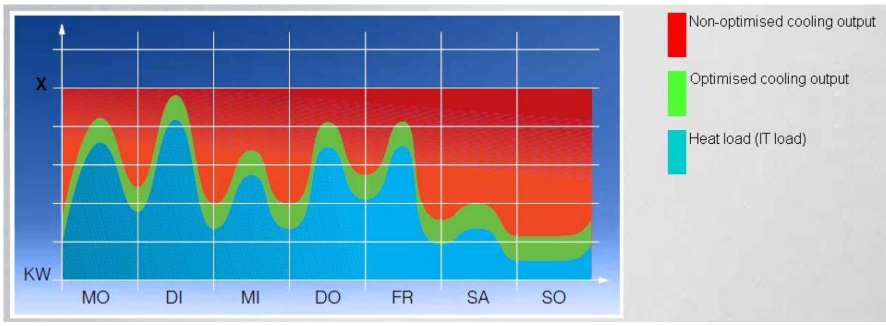


Figure 12: Optimisation of cooling performance with RiZone

Source: Rittal [2]

units. And, an Ethernet interface allows control of the climate control units to be integrated into a company's network – administrators may use the interface to access integral websites on an LCP to monitor readings or edit parameters from their PC workstation.

An LCP may also be incorporated into and monitored via a higher-level network management system via SNMP, including Rittal's RiZone data center management software. This software visualizes the status of a data center and automatically adjusts configuration values as it monitors and controls individual components from enclosure to enclosure and LCPs unit to unit.

Using RiZone it is possible to adapt the cooling output of an LCP or another cooling component (CRAC, recooler, etc.) at the actual cooling load requirements. An intelligent control system allows cooling efficiency (As shown in Figure 12) to be significantly increased with a resulting reduction in energy consumption.

Each LCP is also available with an integral touch-screen display. Its contemporary view shows log files, alarms and additional historical details as well as current readings. Parameters may be set via this display so an LCP can be set on-site as well as from a remote PC. A user-friendly guidance system (See Figure 13) displays basic functions including cooling output, temperature and any alarm or warning messages.

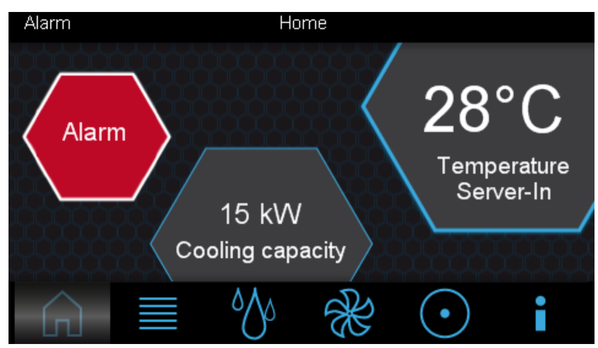


Figure 13: Main display menu with alarm

Energy efficiency

Even without the addition of a higher-level management software system, the LCP is engineered to be energy efficient. At the basis of their efficient design are EC (electrical commutation) fans that are more efficient that standard AC fans. These alone reduce the demand for electrical power. Unlike AC fans, the efficient EC units run at variable speeds rather than a fixed speed. They are infinitely controllable so they have stepless power consumption (See Figure 14) allowing them to precisely adapt to cooling requirements – guarding against having fans continually cutting in and out and eliminating high recurrent start-up currents required to get the fans to maximum speed.

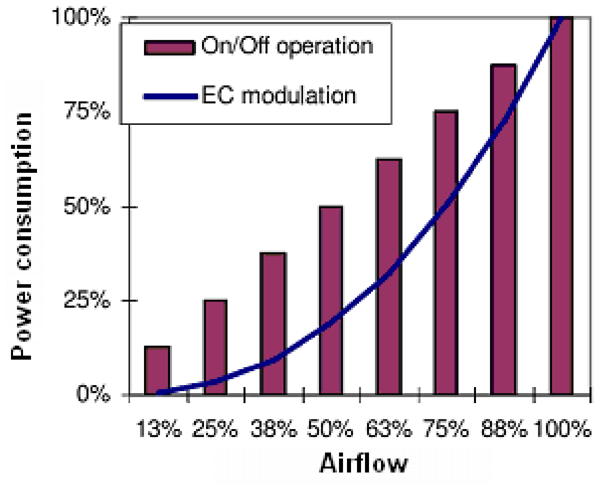


Figure 14: Power consumption of EC and AC fans

In the LCP, fans are installed in the cold air zone rather than the hot air zone – where the air has already been cooled via air-to-water heat exchange – so cool air is drawn in by the fans and moved in front of the servers. This configuration not only moves more cool air to the components, it also puts less stress on the fans which increases their service life.

Rittal LCP units have the advantage of being able to achieve higher useful cooling output temperatures even with high inlet temperatures. This feature increases the benefits available from free cooling systems – systems that use free ambient air to cool the area and are extremely energy efficient, especially when compared to compressors and chillers. In regions where outside air temperatures are regularly cooler than temperatures within a data center, free cooling is an efficient option that can significantly reduce the operating hours of mechanical chillers.

An LCP used in conjunction with a chiller has a significantly higher Energy Efficieny Ratio (ERR) – the ratio between power input in the form of electrical consumption and power output in the form of cooling output. A ratio of 5, for example, indicates that 1 kW of electrical power is needed to produce 5 kW of cooling output. The higher this value, the more efficient the cooling system.

Room climate control with the LCP Passive/Rear Door Heat Exchanger

For specific conditions, Rittal has a unique and economical cooling solution. Its LCP Passive/RDHX stands out because it is fitted at the rear of an enclosure rather than on the door, making it an ideal candidate for retrofit situations. This installation technique eliminates the need to rearrange existing bayed enclosures. However, the LCP Passive/RDHX should be restricted to data centers where ambient temperatures are not excessive and the infrastructure accommodates its installation. (Rittal has published *White Paper: Row-based cooling with LCP Passive* which outlines these requirements in detail.)

Its restrictions are directly linked to the fact that these units are, in fact, a custom rear door with a heat exchanger built in. The heat exchanger is supplied with coolant via pipes in the raised floor but there are no fans installed within the units themselves.

The LCP Passive/RDHX requires no electrical power. Air flow to the heat exchanger is provided by the fans built into servers and other IT components housed in the enclosure.

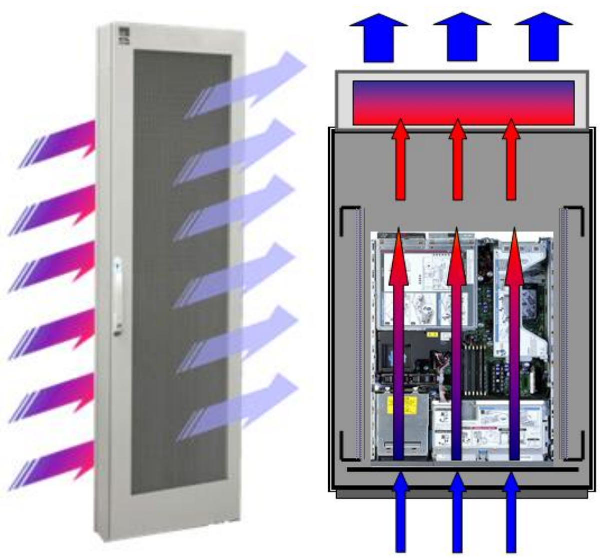


Figure 15: Function of the LCP Passive/RDHX

If all its restrictions are accounted for, an LCP Passive/RDHX unit can cool ambient air that has been drawn through the components. Server fans move air to the unit where it passes through, is cooled and flows back into the room. (Figure 15)

This system allows for cooling capacity of up to 20kW while retaining the 42U of usable space within an enclosure.

With no electrical requirements, the LCP Passive/RDHX is exceptionally energy-efficient and, under the right conditions, can provide significant cooling at very little cost.

Climate control of small systems

The majority of Rittal's LCP options are installed in large data centers where high heat losses are generated by a collection of heavily populated enclosures. In these situations, with a large number of racks, several similar LCP models may be required and they are likely to be connected to a larger recooler.

However, the LCP can be applied to an installation as basic as one enclosure that generates low levels of heat and do not require the more complex infrastructure of plumbing and additional coolers. For small, relatively undemanding installations there's the LCP-DX or the LCP-CW. The DX variation uses a refrigerant (R410a) rather than water – this refrigerant boast a very high level of energy efficiency and supports the use of just one condenser unit (Figure 16). Condensers have smaller dimensions than recoolers. The LCP-CW (Cold Water) uses water instead of refrigerant but operates in the same way.

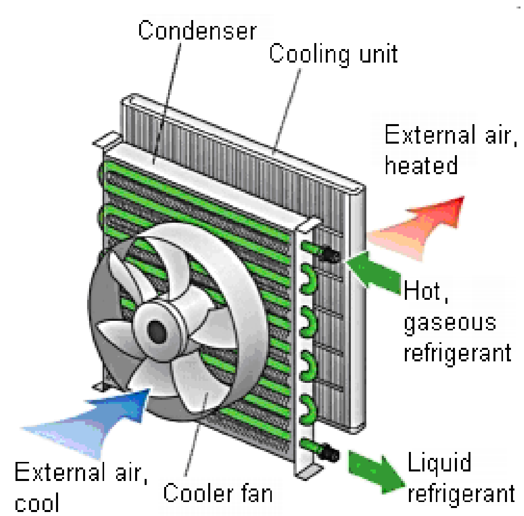


Figure 16: Condenser

Source: KFZtech

The cooling solution reaches the LCP via system pipes where it is heated to above the boiling point. In a gaseous state, it is transported to the condenser where it is compressed and turned back into a liquid – in the process the refrigerant emits heat and is thus cooled. The cooled liquid is then returned to the LCP to cool internal components within the attached enclosure.

Both of these units have useful cooling outputs of up to 10 kW and both are connected to a condenser unit that is located outdoors (Figure 17). Taking advantage of ambient cooling of the condenser from outdoors plus the efficiency of the refrigerants make these units both energy efficient and easy to install.

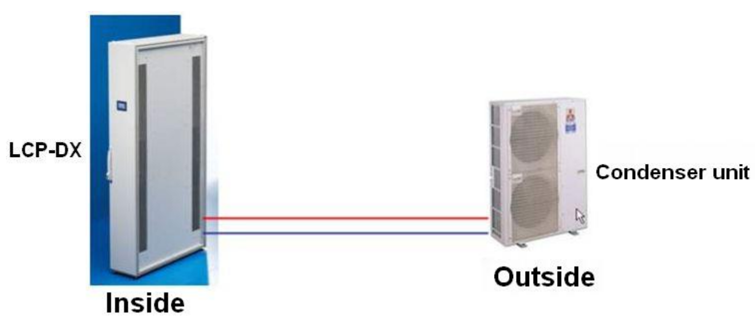


Figure 17: Layout of the LCP DX system

Summary

The enclosures in today's data centers, with their higher densities and higher population, generate more and more heat. Heat that must be dissipated quickly and efficiently. When it comes to systems to provide for this climate control, there is a range of options. Combined with aisle containment, for example, a Computer Room Air Conditioning (CRAC) system is capable of dissipating low to medium levels of heat, but is seldom suitable for newer high-capacity installations. In these situations something more focused on individual enclosures and components is more reliable. Rittal TopTherm Liquid Cooling Package (LCP) is available in several variations for a wide range of these high-intensity applications. Available with useful cooling capacities of up to 60 kW, and using precision air-to-water heat exchange technology, the LCP is cost-effective and reliable.

An LCP is connected to power and water lines beneath a data center's raised floor and can be connected to the center's management network – where the system may be monitored and managed remotely via PC. Optional touch-screen displays provide real-time status and allow units to be set up on-site as well as remotely via a system management program – available through the integral SNMP protocol.

The TopTherm LCP Inline provides the same function as a traditional CRAC system – cooling the air from within the environment and blasting it into the aisle between two rows of racks. But, the LCP Inline units are positioned in series with the enclosures rather than on their own as a CRAC would be. The LCP Rack and LCP 3+ are also installed this way and all three variations can be bayed to the adjoining enclosures. With the Rack and 3+ options, unlike a CRAC unit, each provides climate control for just one or two enclosures rather than the entire room. The LCP 3+ also incorporates fail-safe options with two independent circuits for both electrical and cooling water supplies.

On the other end of the scale, where large recooling units are not necessary, the TopTherm LCP-DX and LCP-CW are appropriate for individual enclosures. Cooling liquids are cooled by an external condenser that eliminates the need for more expensive recooling equipment.

With its various options, the LCP family is flexible and its modular design allows for engineering cooling systems to meet the demands of many different data center challenges. Data center expansions are possible quickly and efficiently using the LCP because of their unique design and minimal footprint – they can be retrofit as needs change.

Efficient use of multispeed fans, the ability to provide optimum cooling at warmer temperatures and the use of readily available free cooling from ambient air all are factors that make the LCP reliable and energy efficient.

References

KFZtech: Climate control system – Coolant circuit / components,
http://www.kfztech.de/kfztechnik/sicherheit/klima/klimazwei.htm, 24.08.2011

Lohr, Dipl.-Ing. Hans-Joachim: Development of an R410A heat pump,
http://www.lohrconsult.de/uploads/media/Entw_R410A_01.pdf, 24.08.2011

Rittal [1]: RimatriX5 system solution,
http://rimatrix5.de/rimatrix5/systemloesung/costs.html, 19.08.2011

Rittal [2]: Rittal – RiZone. Data Center Management Software,
http://www.rittal.de/downloads/PrintMedia/PM5/de/rizone.pdf, 22.08.2011

Umweltbundesamt (Federal Environment Agency): Green IT: Zukünftige Herausforderungen und Chancen (Green IT: Future Challenges and Opportunities),
http://www.umweltdaten.de/publikationen/fpdf-l/3726.pdf, 18.08.2011

Wikipedia: Redundancy (technology),
http://de.wikipedia.org/wiki/Redundanz_%28Technik%29, 22.08.2011

List of abbreviations

AC	-	Alternating current
CW	-	Chilled water
DX	-	Direct expansion
EC	-	Electrical commutation
EER	-	Energy Efficiency Ratio
U	-	Height unit
IT	-	Information technology
kW	-	Kilowatt
LCP	-	Liquid cooling package
PC	-	Personal computer
SNMP	-	Simple Network Management Protocol

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