THERMAL MANAGEMENT INNOVATION by knürr

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Effectively Transfer Heat With Water

Innovative Thermal Management High-Performance With "Proven-In-Practice" and Fail-Safe Technology

knürr
environments for electronics

Knürr is a leading manufacturer
and supplier of rack platforms
for electronic applications.

Better Knürr!

Our customers set the requirements. We respond with quality, flexibility, speed and perfect service.
Worldwide, we are recognised as a reliable partner in the areas of telecommunications and data communication, server and network technology, medical technology and, of course, security, automation and traffic control technology.

The product diversity and quality provided by Knürr has been setting traditionally recognised high standards for several decades.
Innovative technologies are the mirror image of our engineering know-how, which characterises and provides the impetus for the markets where we operate.

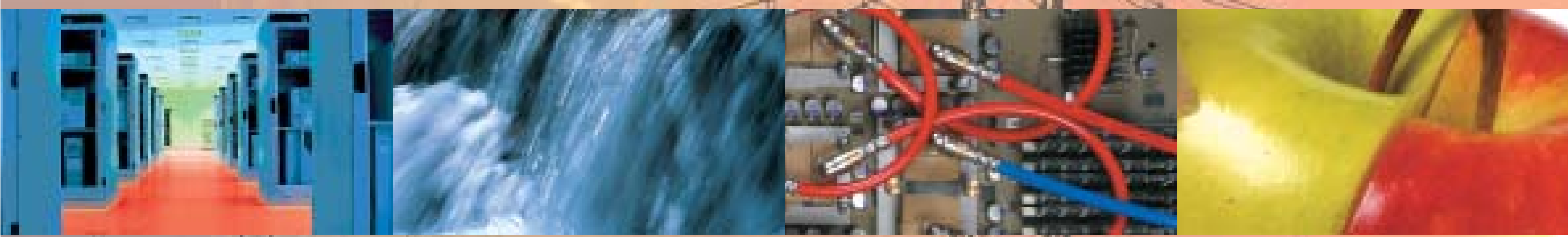
Knürr's profound depth of knowledge and proven capabilities, with, for example, every single requirement of a professional thermal management, qualify Knürr as a leading manufacturer of high grade equipment.

Where energy flows, heat accumulates – a law of physics that rack manufacturers and computer centres battle now more than ever before.

The ever-increasing computing performance of servers causes a parallel increase in their heat release.

But it is particularly in computer networks that the thermal management used thus far has not been able to cope with the rising thermal loads of high-performance CPUs for quite some time now, which is why innovative cooling systems such as those produced by Knürr have become indispensable. And that's because they are the only ones that enable the necessary performance increase in processor technology to be used efficiently.

Thermal Management From Knürr is Revolutionary!



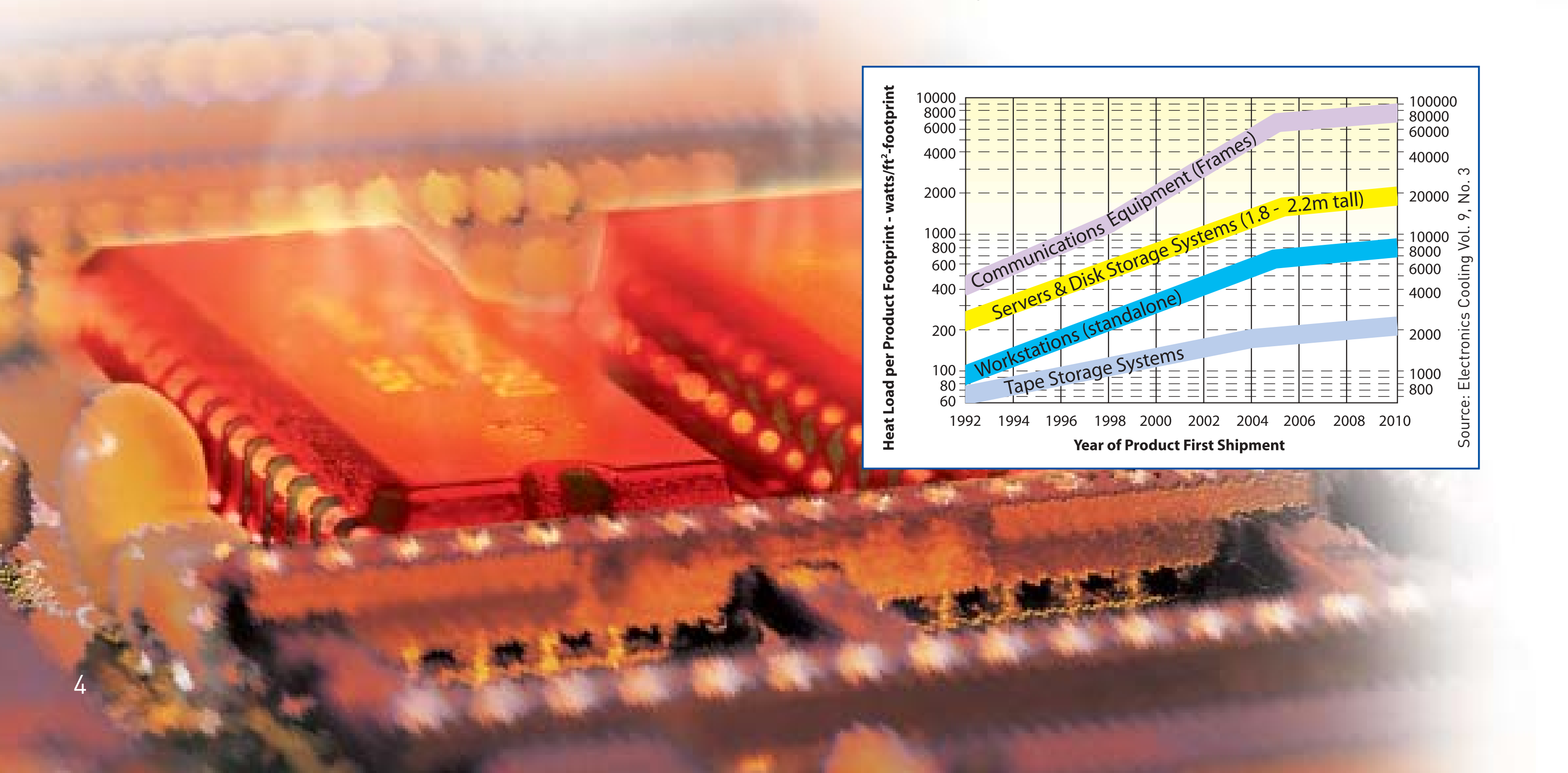
Thermal loads rise with the CPU performance capacity and the packing density. Existing computer centre thermal management is no longer sufficient.

Serious Problem: Heat!

With the constantly increasing performance of the CPU, and therefore of PCs and servers, their heat releases also appear to be soaring to unstoppable limits.
The difficulties of diverting the released heat accumulations within the available space, further limit performance compression in servers and computer centres. Add to this the fact that the expenses for the heat transfer systems (air conditioning equipment etc.) consume a good deal of the overall investment and operating costs of a computer centre.
To make things a little clearer: Large computer centres already consume several megawatts of power, which ultimately must be completely diverted as dissipated heat to the surrounding environment. According to a study carried out by the US Department of Energy, in the mid nineteen-nineties in the United States, more than ten percent of the power was already being consumed by IT systems.

The previous customary way of cooling servers and complete computer centres with air, consequently reaches its limit at both ends of the transport route of dissipated heat:

The performance limits of air cooling have long been reached or already passed directly at the source of the heat, the CPU.
High-performance processors today already attain power losses that can only be diverted with very expensive and voluminous cooling equipment. With 70–100 W on approx. 10 cm^2 rack surface, processors beat any hotplate in the "heat flow density" discipline.
The roadmaps of manufacturers are forecasting a further increase to over 150 W. CPUs with some 130 W dissipated heat will already be on the market in 2005.
And it is above all in the current highly compact construction form of servers (Pizzabox, Blade) that the cooling surfaces for the air cooling can no longer be accommodated. Cooling therefore appears to be the limiting factor for a further performance compression!



Cooling Computer Centres

Even in the most modern conventional air-conditioned computer centres, a theoretical value of 1,500 W/m² cooling power, in relation to the room surfaces, is never attained in practice. And 1,000 W/m² are only achieved with an enormous constructive and operational expense; air distribution remains problematic and is very difficult to adjust to altered configurations. Thermal problems, in particular for additional servers installed above are on the agenda.
Older computer centres still don't even support far lower cooling loads, some 300 – to 500 W/m².
With an average geometric space requirement of some 3 m² per server rack, 3 - to 4 kW thermal stress must therefore be coped with per rack. This only just suffices today for commercial computer centres, but in scientific areas these values have already been exceeded. In fact computer clusters with up to 100 racks are today operated at 10 kW each - but, however, not with air cooling.
15 kW per rack have since become the planning value for the first commercial computer centres in the banking sector, where ultra-densely packed Blade servers are used with peak values of up to 17 kW per rack. And the predictions for the future are far beyond this in the area between 20,000 and 30,000 watts!

For a densely packed assignment of racks with servers and computer centres with racks, the options of conventional thermal management have long been passed by. Even approaches that attempt to cool each individual rack via air ducts do not enable the required performance density.
The only remaining solution with the assignment of servers and racks is to stay well behind the geometrically possible densities, and therefore, of course, to sacrifice valuable building space.
Or, on the other hand, there is the option of changing over to an essentially new cooling concept?

Build-up of “Hotspots” Through Air-Recirculation.

Water in the computer centre?
Provocative! And yet economical, because water effectively diverts heat ...

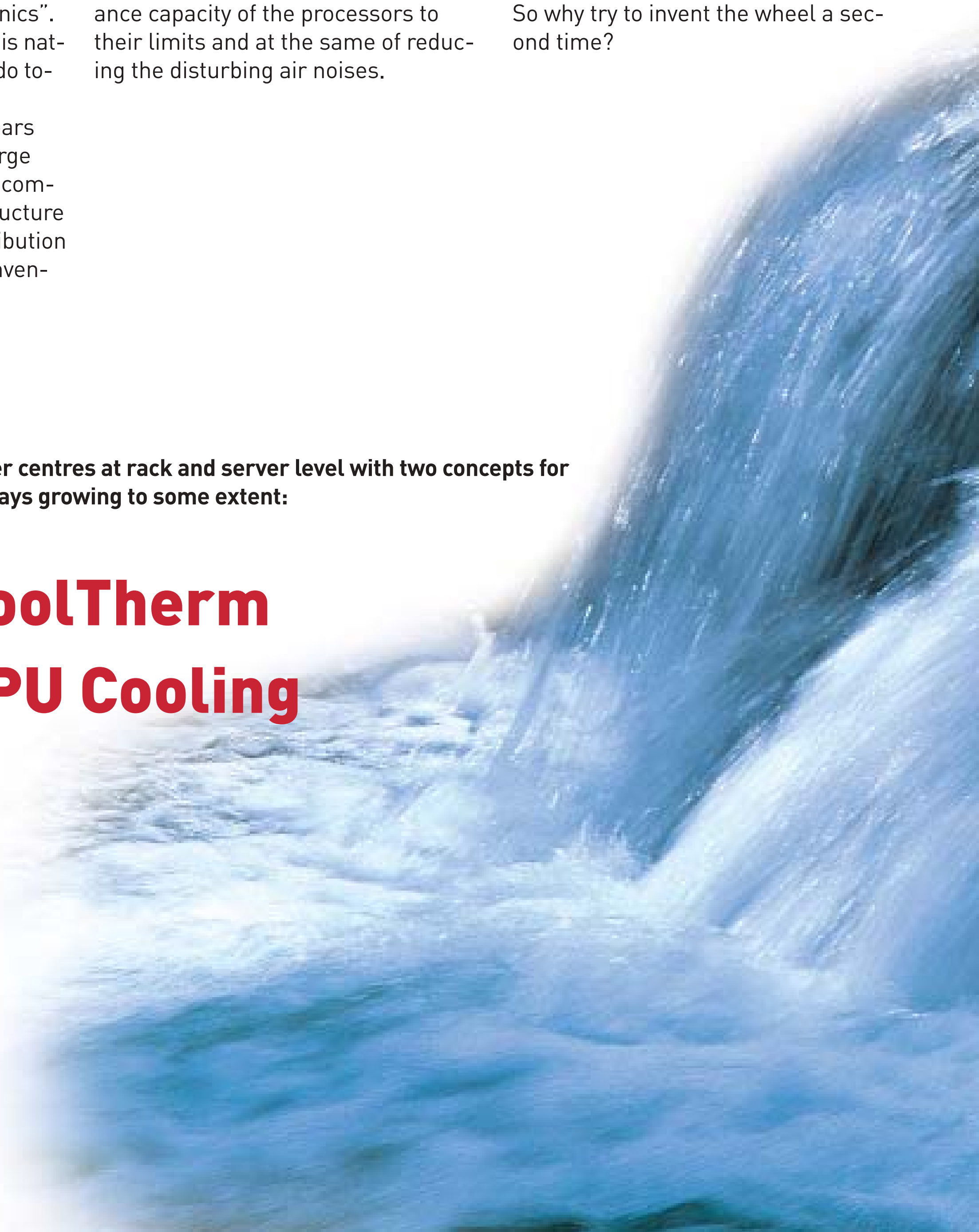
Liquid Cooling, the Solution.

Cooling with water overcomes difficulties, both at computer centre level and at CPU level, and enables a quantum leap for further performance compression. This leads directly to considerable increases in the cost-effectiveness and safety of computer centres.

Water has been considered until now as the "natural enemy of electronics". Only when it is possible to use this natural element in a qualified way, do totally new opportunities arise.
Forgotten already? About ten years ago it was quite usual to cool large computers with water! In many computer centres the same infrastructure is still available today. The distribution of "cold" is made today with conventional high capacity cooling systems using cold water.

Water-cooled CPUs today find widespread use in the high-performance PC area. Various construction kits are available from dealers for this area. And one of the more valued options here is that of extending the performance capacity of the processors to their limits and at the same of reducing the disturbing air noises.

For over a century now, water has been the medium for heating and cooling buildings in equal measure. Innumerable parts and components are produced in industrial amounts and installed on construction sites. Quality, safety and cost-effectiveness have long been guaranteed by industrial-level series production.
So why try to invent the wheel a second time?



Water is used today in computer centres at rack and server level with two concepts for high-performance cooling, always growing to some extent:

✔ Knürr CoolTherm
✔ Knürr CPU Cooling

Water versus air.
Superior heat transport medium?

1 Water can transport far more heat per volume unit than air can. In order to divert 1,000 watts with 10 degree temperature difference, 90 litres of water per hour suffice - compared with 325 cubic metres of air. Volume-related, that's approximately 3,500 times more! A thin water line diverts more heat than a well aired-out complete room.

2 And water only needs about one percent of the surface for transporting heat! A liquid cooling heat sink requires very little transport surface and is scarcely bigger than the processor itself. The size is more dependent on the connections and the mounting on the board than on the cooling capacity.

Liquid-cooled server racks from Knürr:
The Miracel CoolTherm platform provides heat exchangers with
10 kW to 20 kW within a closed cooling system (air-to-water)!

Miracel CoolTherm – up to 20 kW

In comparison with conventional air-cooled server racks, which ensure the maximum amount of air throughput using perforated doors, Knürr CoolTherm racks are completely sealed off from the room air (IP55). The dissipation of the total power loss is made via an air-to-water heat exchanger in the base area or door of the rack, which is connected to the cold water system in the building. Redundant high-performance fans drive a closed cold air circulation in the rack's interior. The built-in servers are supplied from the front with air that is brought to the right temperature of about 20–25°C. The warmed air is collected at the rear topside in the rack, pushed down by the heat exchanger and back to the front, to the server front panels. Stopping values for the volume currents are 1 l/s cold water and 4,000 m^3/h of circulated cold air at 20 kW cooling power.
A cold water system with a chiller is required in the building for the operation of the rack. In most bigger computer centres, similar water systems are available, as conventional cooling systems from approx. 150 kW cooling power are also operated via these kinds of systems. Furthermore there are no requirements for room thermal management; the rack system is fully independent from the room air. This allows a highly efficient internal cooling circulation to emerge, which , with the corresponding installation of the heat exchanger and the airflow, meets every requirement that might be encountered. At the moment, water-cooled server racks of up to 20 kW cooling power are available in 2.5 kW increments. The controlled airflow inside a relatively small enclosed space enables the evenly distributed cool air supply for all servers, regardless of their installation position in the rack. The top server is cooled exactly as much as the lowest. The limits for air cooling processors can consequently also be extended that bit more. With this cooling concept, 100 – 120 W dissipation can be managed even better in Pizzabox and Blade servers.
The aim of this concept is to eliminate the restrictions on the packing density of high-performance servers in computer centres; restrictions imposed until now by the previous cooling options.

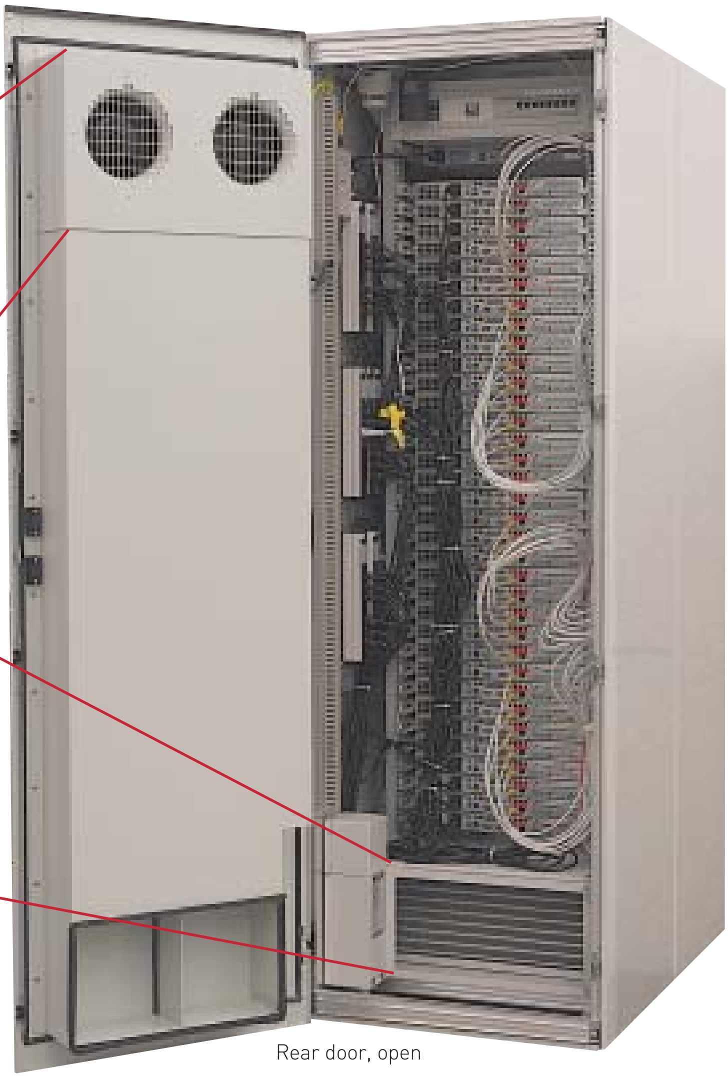
Closed air circulation with air-to-water heat exchanger (cross-section)

The heat exchanger only requires 6 HU per rack, which means that in a 46 HU rack, 40 HU remain for any kind of complete equipping with components. As the previous limits of the air cooling in the room are also done away with, fully-equipped racks can be set up as densely as geometrically possible without any restrictions. In the previous most extreme case made possible with 15 kW power loss per rack, this means a surface area saving of more than factor 3 compared with conventional room thermal management!

Apart from the heat exchanger, the user will find a perfectly normal 19" server rack. This means that there are absolutely no restrictions for installing components. Everything that can be installed in a conventional rack can also be located without change in the Knürr CoolTherm. This is especially true for rack servers that do not require any special preparation, as well as for other heat-emitting components (memory units, TFT drawers, switches, routers, power supplies etc.) and for cabling, and so on. All previously usual access options with reconfiguration, maintenance and repair are possible without any change; the Knürr CoolTherm can also be operated with the doors opened (rear door for only a short period).
A comprehensive safety concept ensures a maximum amount of operational reliability and availability. All relevant components are, of course, operated redundantly and connected to a redundant power supply. Fans, temperatures, door locks,

Ventilation,
temperature-dependent, speed-controlled

Knürr heat exchanger, air-to-water



Rear door, open

smoke accumulation and, optionally, leaking water and fall below the dew point are all monitored in the rack. Because of the way the heat exchanger is constructed, leakages and condensation build-up are ruled out anyway. The heat exchanger is a compact unit with no detachable connections, which is pressured at production end with 32 bars. This value lies well above the operational pressures that can be expected. For the building network there are only two connections that can be detached, which, proven in building technology, also ensure compactness that can be controlled. The position of the heat exchanger right at the bottom of the rack, from where, in the worst case scenario, water cannot get to the server area, provides additional safety.
Should condensation build up in the heat exchanger with fall below the dew point, it is removed from the airflow and diverted because of the structure design. The CTU, which takes over all of the functions of the cold water supply and functions monitoring of a rack suite (5-10 racks), provides the maximum amount of safety possible. In addition to the function of a controlled interface, the option is also available here of completely separating the subsystem from the rest of the water system via a heat exchanger, and consequently ruling out large leakage volumes.
Because the rack interior is well-sealed against the room air, this cooling system provides exceptional protection against the effects of a fire. Smoke, aggressive gases, steam and extinguishing water are safely held back. As long as the cold water supply functions, even significantly increased room air temperatures are no problem. Only very high temperatures or direct flames would be critical; the effects of fires nearby or in adjacent rooms are, however, always dealt with.

Knürr show their innovative superiority:
Cooling with water directly where high-performance CPUs create significant thermal stress as a result of high clock frequencies.

CPU Cooling. We Do It With Water!

Even closer still! With CPU cooling, the coolant water is brought right up to where the heat source is. The dissipated heat of the processors flows through water heat sinks with flowing water directly into the water circulation.
The even distribution of the cooling water on all installed servers is ensured by two vertical distributor pipes, through which water flows after the Tichelmann circuit. Regardless of the installation height of a server, the flow resistance and therefore the flow volumes are always kept the same.
One server per height unit can be connected to the water distributor; the connection is made via high-grade, very flexible plastic pipes. If these (preferably together with the wiring) are routed accordingly, a water-cooled server can even be pulled out from the server rack while operating. As the plastic pipes on the vertical distributors can be quickly and safely released, installation and removal of servers is just as problem-free as with just air cooling.

The integration in the building-own cold water system is made from the raised floor or from the ceiling directly onto the two vertical distributor pipes in the rack. In contrast to the water-cooled server rack, cold water does not have to be available for the cooling. As enclosure temperatures on the CPUs are permitted at almost 70°C, it is sufficient if cooling water at a temperature of about 50°C is available. This temperature is low enough, even in high summer, to be able to cool back with environmental air. A chiller is therefore not required in the cooling water system! This leads to enormous savings in the building infrastructure, both with the investment and with the operating costs.
The option also exists of actively using the accumulating dissipated heat, in, for example, building heating via panel heating or component activation. This opens up further very significant savings potential.

However, with this system not all heat sources on the server board are cooled In addition to the CPUs, there are many other smaller hotspots located here (e.g. power supplies, drives, memory cards, graphic cards, etc.), which cannot all be connected to the water cooling. Some 50% of the dissipated heat must continue to be removed from the servers and racks in the conventional method, which is logically via the conventional air cooling method. The heat load for the cooling system lies here at approximately half compared with purely air cooling; the cooling system and the RLT equipment in the computer centre can therefore be implemented accordingly smaller.
And here also, the performance restrictions of a conventional thermal management system are quickly reached. If more than 6 kW heat is released in a server, that is then, more than 3 kW of this must be diverted with air, the installation

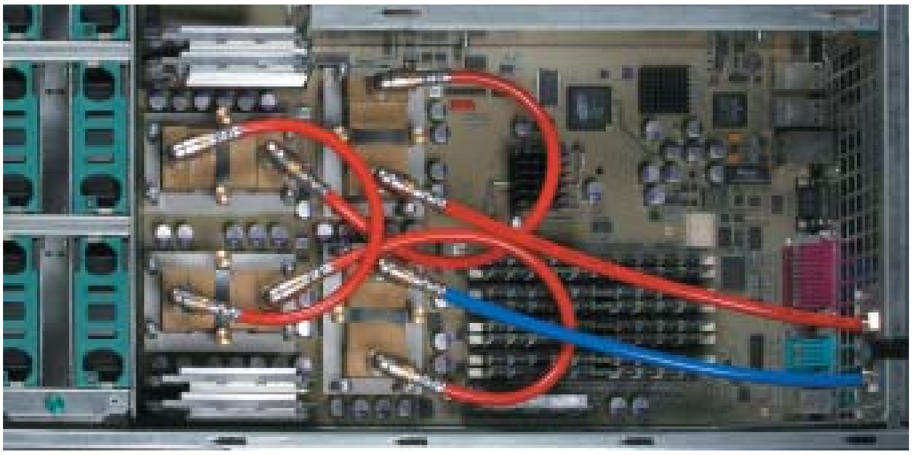
capacity of the server per rack must be reduced with relation to the geometric possibilities.
Assistance is then also possible here again as a result of the additional water cooling of the rack, that is then, the combination of the two concepts described. A TCO study shows that this combination may even represent the ideal solution with regard to cost-related issues.

The primary objective of this solution is to also make it possible to cool high-performance CPUs in the smallest installation space. The direct water cooling of processors also makes it possible to safely deal with 150 W and more per CPU in Pizzabox or Blade servers. Tests of up to 200 W on 10 cm^2 surface area have already proven the capacity of this technology. Ultimately it is all about achieving the highest possible density of the computer power for the total building surface area.
Another until now scarcely discussed potential of this solution is the option of cooling processors to very low temperatures and therefore of being able to operate drives at higher clock frequencies. Special precautions must be taken for this in order to prevent a fall below the dew point and condensation build-up on the boards.

Water-cooled servers can only be developed and put into operation in co-operation with a server manufacturer. The necessary modifications are actually quite low, however the high requirements for safety and reliability rule out later addition solutions. As a standardised interface between water-cooled servers and racks still does not exist, the full compatibility has so far only been guaranteed among the products of one manufacturer. If no cooling water is available in a building, water-cooled servers can also be operated locally on a 19" cool back unit.
Next to it in a rack for CPU cooling, any other kinds of conventionally cooled components can be operated. There are no restrictions with regard to cabling, installation and removal of components.

The reliable and leakage proof version of the liquid system in the servers and racks merits special interest. The huge number of servers and processors brings many more components with just as many connection points into play. Managing everything is only possible with the exclusive use of robust, tested and proven components made in process-safe industrial production. All requirements for redundancy and monitoring will then be appropriately meet.

Another essential safety feature is the HTU, a component that when built into the rack or raised floor takes over the overall cooling water supply and monitoring of a rack suite. In addition to a redundant pump group, various valves, sensors and an electronic control unit, it also contains a controlled interface to the building system. This optionally consists of a well-dimensioned heat exchanger or two magnet valves, to enable independence from the mains should there be malfunction of any kind.



In Black and White:
We don’t make any claims; we make our argument
for a costs/benefits ratio and ensure cost-effectiveness.

Costs – Benefits: Comparison Study TCO

A well-known planning office was commissioned to quantify the advantages of liquid cooling by carrying out a comparison study (Total Cost of Ownership, TCO).
The starting point was a model computer centre designed as it will operate in the high-performance area in the near future. Basis: The CC consists of 2000 1 HU servers each with 2 CPUs at 125 W heat release. Further components release an additional 250 W, each server therefore 500 W. The cooling load of the servers for the entire model computer centre is a total 1 MW. The heat release of further components was not taken into account for the time being.

All investment and operating costs relevant for the cooling were taken into account:

Building:	Computer centre incl. shell, raised floor, floor covering, paint work and gas removal system, refrigeration centre incl. shell, floor covering and paint work
Ventilation technology:	Air circulation refrigeration equipment, air conditioning systems
Refrigeration technology:	Compression refrigeration machines, recooling plants, dry
Electrical engineering:	UPS,mains standby systems, low voltage systems, server racks

Assumed as important technical conditions:

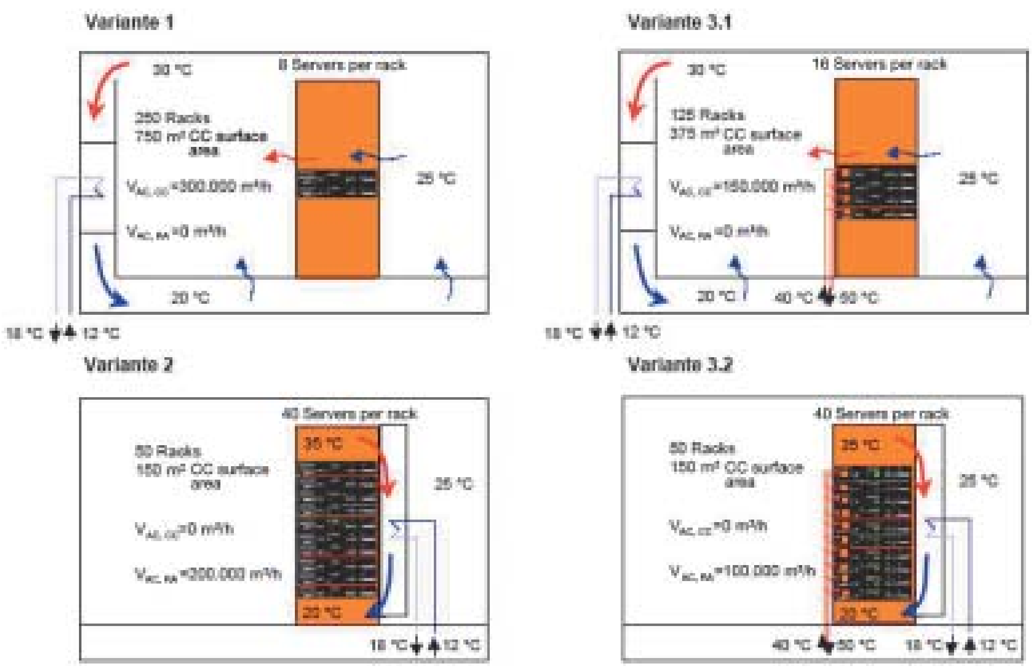
- COP of the compression refrigeration machine: 4.2
- Pressure loss of the air circulation equipment: 400 Pa
- Simultaneity factor of the computer: 0.75
- Proportion of free cooling over the annual operating time: 0.3
- Reference location for seasonal thermal changes: Würzburg
- Power and heating price: 5 ct/kWh

Four different kinds of cooling variants were compared:

1. Conventional air circulation cooling
2. Water-cooled server racks – Knürr CoolTherm

3.1 Water-cooled CPUs / air-cooled racks

3.2 Water-cooled CPUs in water-cooled racks (combination 2. and 3.1)

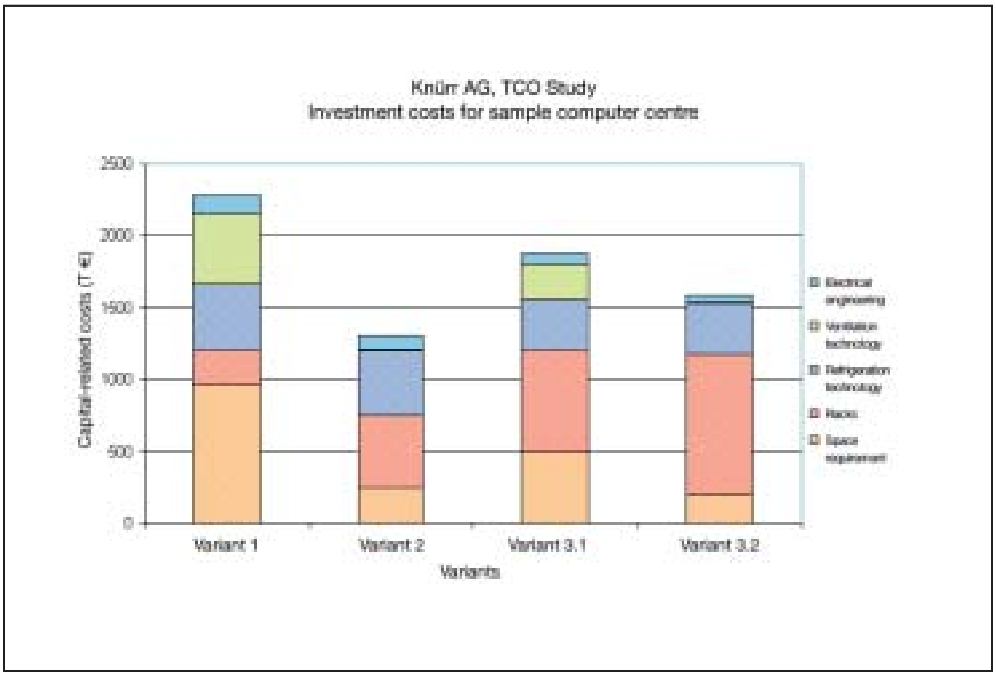


The greatest influence on the results was provided by the surface requirement in the computer centre. In the case of conventional air cooling (**variant 1**) the capacity of the thermal equipment massively restricts the possible density of the servers. Only eight servers can be operated in one rack. Altogether 250 racks were required, which would require approx. 750 m^2 surface, incl. aisles (3 m^2 per rack).

If the racks are cooled with water (**variant 2**), the maximum number of possible servers can be operated in one rack. In a Knürr CoolTherm with 46 HU, 6 height units are required for the heat exchanger, 40 are available for servers. If altogether only 50 racks each with 20 kW heat release are required, the space requirement is still only 150 m^2, that is then, 20% of the initial value.

In the case of purely CPU cooling (**variant 3.1**), half of the accumulating heat must still be diverted with air. The server density is also restricted here accordingly by the cooling power of the thermal management system. 16 Servers can be operated per rack; the space requirement is halved all the same to 375 m^2.

With variant 3.2 (the racks are additionally water-cooled here), the same value is attained as with variant 2.



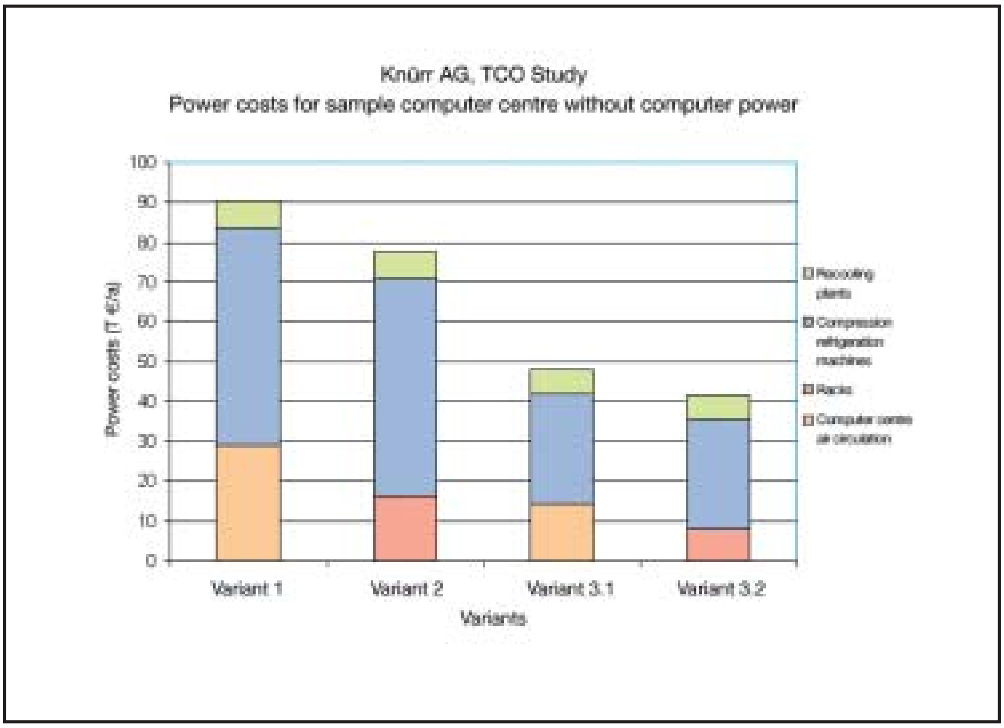
With regard to investment costs, it is quite clear that variant 2 performs best. The comparison-relevant costs are reduced from 2.3 million euro by over 40% to 1.3 million euro. The majority of this are room costs and ventilation engineering, which are completely done away with, apart from a simple basic ventilation. The costs for the racks on the other hand have risen significantly in their individual price as a result of the added expense for the liquid cooling.

With **variant 3.2** (rack cooling combined with CPU cooling), the expense for the racks is the highest, as two different cooling systems have been installed here. The saving with the space requirements is just as big as with variant 2, just as only minimal costs remain for the ventilation technology. The expense for the refrigeration technology is reduced by approx. € 100,000, as the proportion of the processor heat release (50 %) can be given directly at high temperature level to the surroundings The refrigeration machinery can therefore be dimensioned considerably smaller. Variant 3.1 (purely CPU cooling) is the same with the refrigeration technology as variant 3.2; the building costs in accordance with the space requirements are not reduced very much; the costs for the racks are somewhere between variant 2 and variant 3.1. The expense for the ventilation technology is significantly below that of variant 1, however, way above that of variants 2 and 3.2. Of all the solutions with liquid cooling, variant 3.1 provides the lowest saving with the investment costs - as opposed to variant 1, all the same, almost 20%.

Very conservative, i.e., high costs were assumed for liquid-cooled racks in each case. With increasing piece numbers, a very significant reduction of the manufacturing costs can be expected. The comparison of the investment costs then favours the liquid-cooled solutions even more.

Knürr help keep expenses down: Up to 40 percent less investment costs, 20 percent less operating costs!

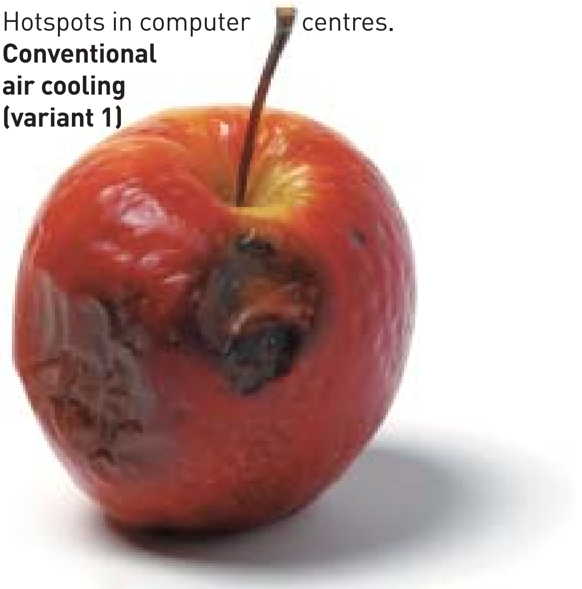
The comparison with the operating costs shows a somewhat different result. The power consumption of the following consumers was taken into account with the comparison: Recooling plants, compression refrigeration machines, racks and air circulation equipment.
The two variants with CPU cooling (**3.1 and 3.2**) perform far better here. The reason for this is that only 50% of the dissipation must be diverted via refrigeration machines, while the dissipated heat of the processors can be given directly via back coolers to the external air.



Less energy is generally used with the same cooling power for the circulation of the cooling air in liquid-cooled racks than for air circulation in the complete room. Therefore **variant 2** is better than **variant 1**, and **3.2** better than **variant 3.1.** In the most beneficial case, the power costs with **variant 3.2** can be more than halved; they fall from about € 90,000 a year to € 41,000. The option additionally exists with **variants 3.1 and 3.2** of saving approx. € 33,000 costs on heating costs by using the dissipated heat for building heating!

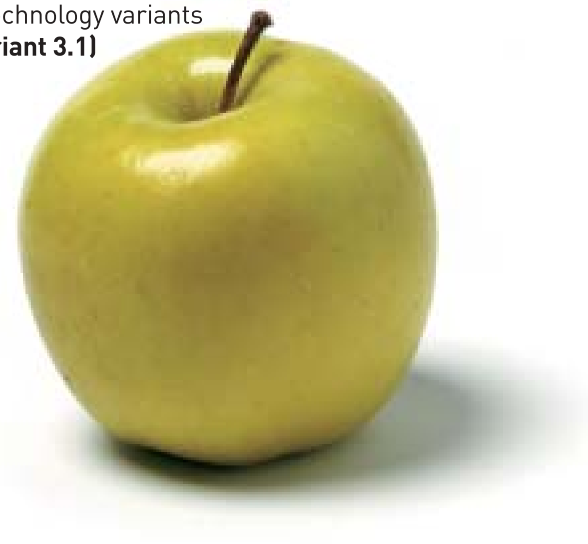
Old-fashioned?

Hotspots in computer centres.
Conventional air cooling (variant 1)

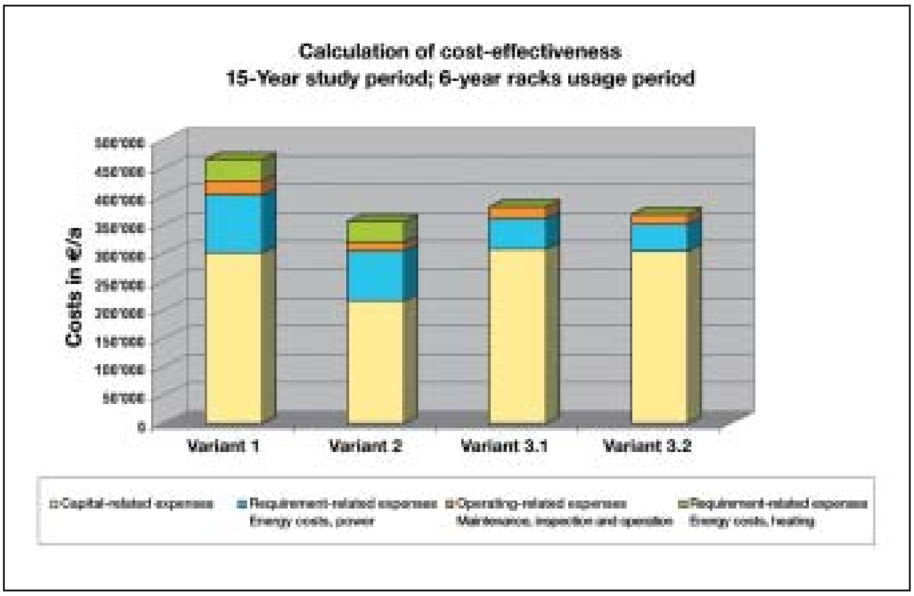


Brilliant Solutions:

Miracel CoolTherm
Rack cooling (variant 2)
Knürr´s latest technology variants
CPU cooling (variant 3.1)



The overall effect is demonstrated by a study of financial considerations in accordance with an annuity method (VDI guideline 2067), which takes costs into consideration with regard to requirements (power), operating (maintenance, inspection, operation) and further requirement-relevant (waste heat usage) costs. management. The costs per year are reduced by some € 100,000. With **variants 1 and 2**, the possible saving of **variants 3.1 and 3.2** through usage of waste heat have been taken into consideration as additional costs (green column). If you do not incorporate the waste heat usage, **variant 2** - Knürr CoolTherm - is even still further in front with this usage period. For longer usage periods of the racks, the comparison tends somewhat more towards **variant 3.2** – particularly if the waste heat can be used.



With a usage period of the racks of six years, all three variants of the liquid cooling easily perform by 20% better than the conventional thermal

It is clear in the final conclusion that an enormous savings potential for surface area is possible for all variants of the liquid-cooled server racks, and consequently for the connected costs, system costs and running operations costs in the computer centre. The "total costs of ownership" (TCO) over the overall usage periods are very significantly below those of the conventional thermal management.
This saving is achieved easiest and with the most effect with liquid-cooled server racks – Knürr CoolTherm. The more expensive CPU cooling is then predominantly used if the direct dissipation of the processors can no longer be managed with air cooling or if the option exists of using the waste heat for heating purposes.

Ideal!
The combination of both technologies
Water-cooled rack with CPU cooling (variant 3.2)

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