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Technical article from
24.02.2017

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Data centre cooling using hybrid dry coolers

Before deciding on the optimal technology to invest in for data centre cooling, a careful review of the local climate and the internal requirements is performed. Cooling technologies are available that differ in terms of how they work, however operating costs can also be saved simply by changing operating parameters and using intelligent system technology.

Optimal temperature control in a data centre is a balancing act, with the commercial considerations of keeping the power usage effectiveness value (PUE = quota of all energy consumption and that of IT) as low as possible on one side, and the need to provide optimal working conditions for the server technology on the other. Ultimately, on average 50 percent of power consumption in data centres is attributable to air-conditioning, heat dissipation and ensuring an uninterruptible power supply (UPS).

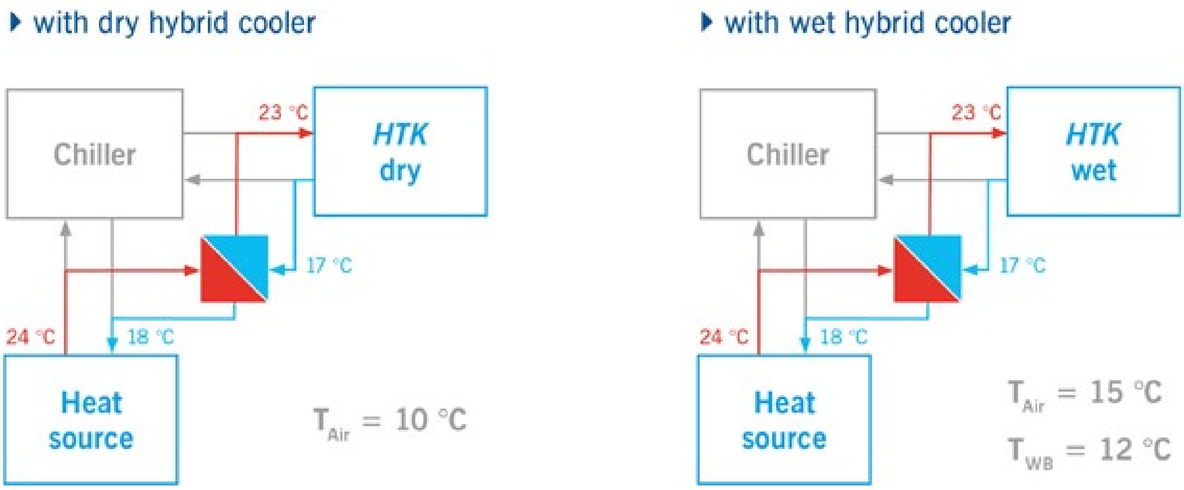
The ASHRAE TC9.9 guidelines (recommendations and guide values for room air temperature and humidity) provide a good guide to achieving an optimal server room climate. In addition to budgetary restrictions on investment and operating costs as well as building regulations, it is in principle the technical specifications applicable to the supply and exhaust air and the local climate that decide the optimal cooling technology for computer centres.

Six different cooling technologies

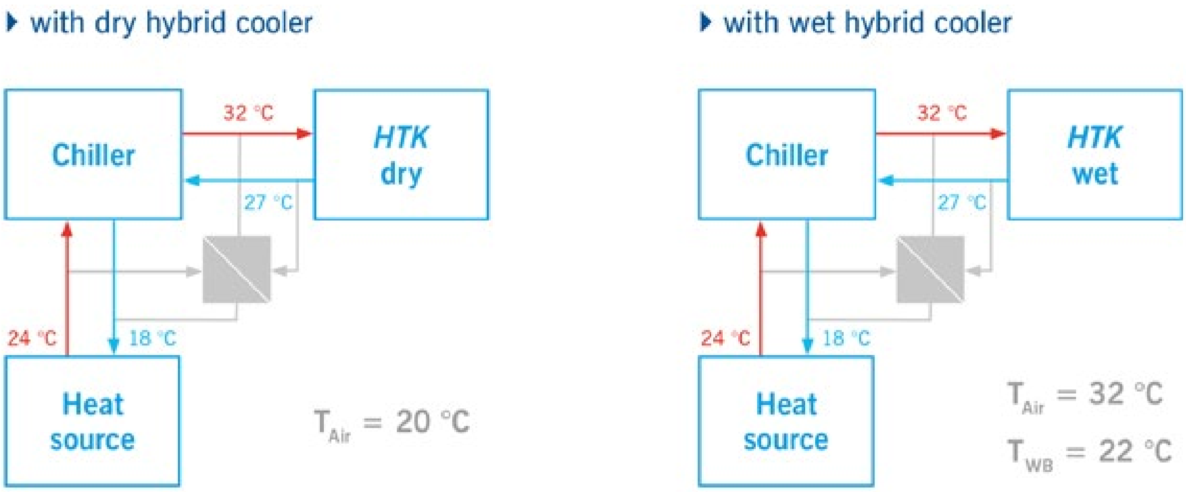
Theoretically, there are six different cooling technologies to choose from: dry, sprayed, adiabatic and hybrid dry coolers as well as closed and open cooling towers – the technical range thus extends from dry to purely „wet“ cooling.

In air-cooled cooling systems, physical limits are defined for the return temperatures. For dry systems, a cooling limit interval of approx. 6 to 8 K is still considered economical, meaning that at an ambient air temperature of 34 °C a return temperature of around 40 °C can be realised. Wet cooling towers however incur high operating costs.

It is significantly more efficient to combine free cooling, when external temperatures rise, with the use of evaporative cold, in particular to prolong the free cooling operation. This technical alternative is made more and more interesting by the further development of IT server hardware, as nowadays this can tolerate supply air temperatures of up to 32 °C; temperatures of 18 – 27 °C are recommended for server rooms in the 2011 ASHRAE Handbook. With that, depending on the system technology, cold water temperatures of only approx. 24 °C would be necessary.



Picture 1:
Free cooling mode at low external temperatures without chiller operation in dry and wet operation



Picture 2:
Chiller operation mode at high external temperatures in dry and wet operation

In contrast, very low temperatures in data centres are not economically sensible, as these cause enormous demand for cooling and the dissipation of heat from the server room into the environment.
Additionally, if one minimises or eliminates temperature differences for free cooling operation, for example at the plate heat exchanger for system separation between the water cycles of the computer centre/cooling, the potential of free cooling is further improved and, in otherwise unfavourable climatic conditions, free cooling is actually made possible. Under certain circumstances, and given suitable climate prerequisites, it is thus possible to dispense entirely with the installation of a compression refrigeration chiller.

Careful needs analysis

Within the framework of project planning and preparation, comprehensive calculations are first performed with respect to the performance of the systems. The external conditions, i.e. the climatic influences at the planned location, are recorded using statistical data, namely temperature ranges and the number of hours at defined dry bulb and wet bulb temperatures.

Using the required or desired temperatures in the data centre, various alternative system technologies can then be proposed and the corresponding resource consumption and operating costs calculated. In Europe, it is often customary for data centres to have cooling systems with a water-cooled refrigeration chiller and system separation for the refrigeration chiller/free cooling operation.

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Modern chillers have an energy efficiency ratio (EER) at full load of 5 to 10. As the consumer circulation pumps and dry coolers must also be taken into consideration in order to improve the efficiency of a cooling system, this configuration theoretically yields three „adjusting screws“:

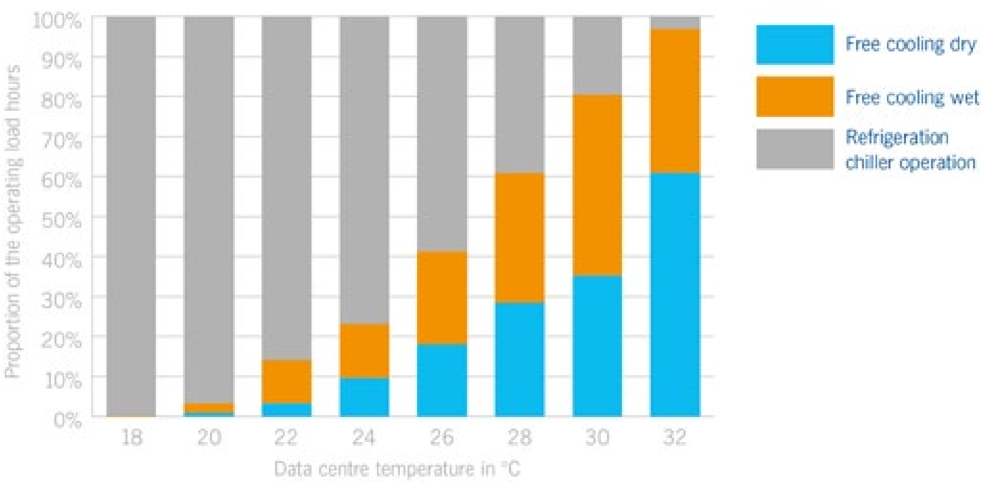
1. The condensation temperature and thus the cooling water temperature are designed to be as low as possible. As a guide value, one can assume that for each 1 K that the condensation temperature is lowered, a saving on electrical power consumption of approx. 3 % is made at the refrigeration chiller‘s motor. At cooling water temperatures of 35/30 °C, an EER of 5 is thus achieved for a refrigeration chiller, or at 1,000 kW refrigerating capacity, a motor power of 200 kW. If for this machine, however, the cooling water temperature is lowered by 5 K to a level of 30/25 °C, the EER is 6, and for 1,000 kW refrigeration capacity a motor power of 167 kW is required. This difference of 33 kW also reduces the quantity of heat that needs to be supplied at the dry cooler.
2. The evaporation temperature and thus the inlet temperature of the cold water to the server room‘s heat exchanger are set as high as possible, which is made easy by new IT technology.
3. At low external temperatures, the cold water is provided via free cooling, so that the refrigeration chiller remains switched off or can be run in low partial load operation.

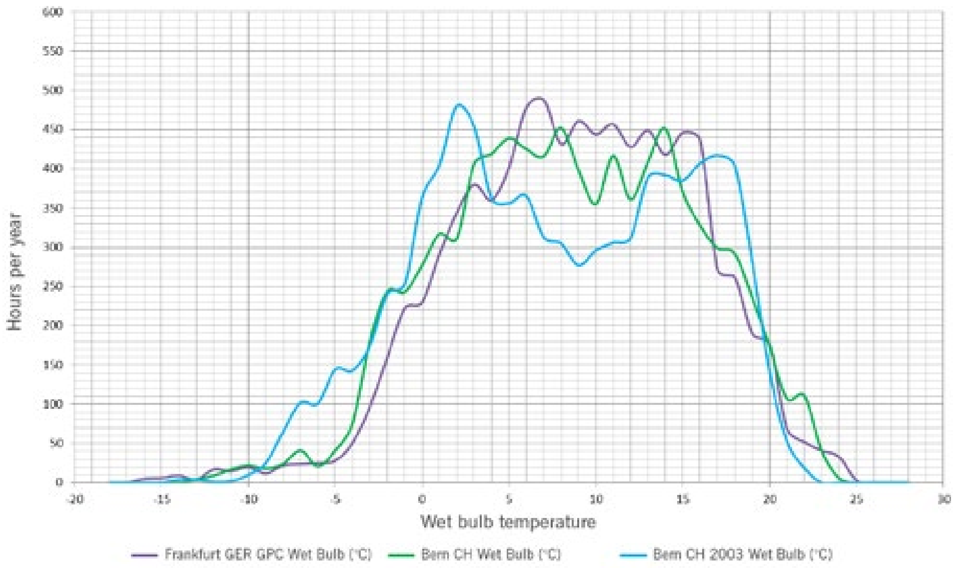
Hybrid dry cooling

The tried and trusted free cooling technology can be made significantly more efficient by using hybrid dry coolers, as these combine the advantages of dry and water-cooled cooling thus conserving valuable resources. With a corresponding system set-up, the cooler can, at low ambient temperatures, directly take over cooling the cold water from 20 °C to 15 °C. The refrigeration chiller remains switched off for this. In dry mode, this is possible up to an ambient temperature of approx. 7 °C, wetted up to a wet bulb temperature of around 9.5 °C (15 °C at relative humidity of 49 %).

The power requirement reduces with this mode of operation to the electricity demand for the dry cooler. If both the air temperature of the server room supply air and the cold water temperature required for this are raised at the same time, this yields significantly longer operating times in free cooling mode than in purely dry free cooling operation. At a data centre temperature of +32 °C, the efficient free cooling mode can be used at external temperatures of up to +25 °C.

Picture 3:
As the temperature level rises in the server room, the potential of free and hybrid cooling rises too – while operating costs fall.





Picture 4:
Climate data comparison of Frankfurt and Bern (statistical and the year 2003)

For energy-efficient operation, an intelligent controller which independently regulates the desired system temperature level and performs the required wetting water management, is indispensable. The controller must assume, on the one hand, the monitoring of the wetting water circuit and, on the other, the output regulation of the dry cooler. Safer operation and the economical use of water and electricity throughout the entire cooling circuit are likewise significant. The task of the controller is to determine the relevant optimal operating point from the initially contradictory requirements. Furthermore, it should be possible to exchange operating data, error messages and approvals or floating setpoints via defined interfaces (bus connection, contacts) with a superordinate building management system.

Comparison of wet and hybrid cooling

In order to compare the efficiency of a hybrid cooler with that of a wet cooling tower, two systems were examined at the place of installation in Frankfurt/Main. The first is a production plant which requires a room temperature in a workshop of 18 °C around the clock. A traditional wet cooling tower is used here. The second is a hybrid dry cooler that dissipates the heat of a data centre which, at external temperatures of over 34 °C, sets its server rooms to a room temperature on a sliding scale up to max. 32 °C. A year-round constant cooling load of 1,000 kW was assumed as a basis.

Thanks to the hybrid dry cooling, the water consumption for the hybrid dry cooler from JAEGGI was reduced by more than 90 percent compared to the wet cooling tower. The temperature „increase“ in the data centre to maximum +32 °C compared to +18 °C in the production hall resulted in free cooling only having to be used for just short of three quarters of the year. This reduced the number of operating hours of the refrigeration chiller thus lowering the operating costs of the hybrid dry cooler to 44 % of the wet cooling tower reference taken as a comparison.

At another data centre that was studied, in Scandinavia, the refrigeration chiller only runs at 2 % in sole operation. In this cooling system, hybrid dry coolers were connected in series with air-cooled refrigeration chillers and the system was operated at almost 60 % exclusively through free cooling. During the rest of the time, the hybrid dry coolers cool the process fluid beforehand and the refrigeration chiller cools it afterwards, back down to the required temperature level.

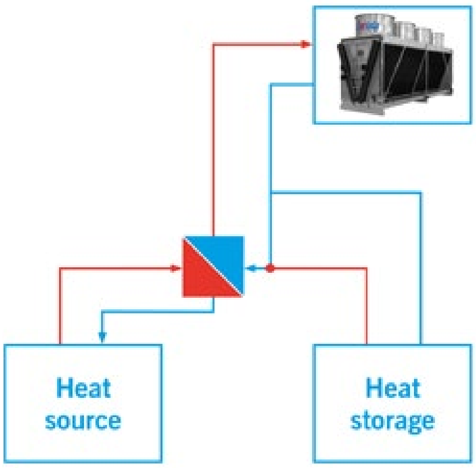
Dispensing with the cold water generator

In order to maximise the operating time of the free cooling operation, the required temperature level must be shifted in order to minimise losses at the data centre/dry cooler system separation at the plate heat exchanger. At a data centre near Bern, this project was successfully implemented and the data centre works without a central refrigeration chiller. In the planning phase, the climatic conditions were not considered on the basis of statistical long-term data – as is standard practice. Instead, the system was dimensioned on the basis of the temperature data from 2003 with maximum summer heat. This year featured a significant shift of average temperatures into the higher temperature ranges, compared to the statistical average year. With this additional underlying climatic deviation, an additional redundancy was built into the design and thus the operational reliability was further improved. We can also assume from this that this concept can be transferred without difficulty to the climatic conditions in Germany.

Geothermal cold reservoir

Another means of dispensing with a central refrigeration chiller is to use a natural cold sink. In the Netherlands, for example, it is possible to use groundwater aquifers as geothermal reservoirs. Using this natural reservoir, the peak loads are shifted into times of the day or year when conventional cooling is possible, or put another way: coldness is harvested at climatically favourable times and stored geothermally. As statutory provisions demand an even thermal balance of the reservoir, the system is cooled at low external temperatures (1.5 °C) through free cooling and the thermal reservoir is „charged“ with coldness.

Where technically possible, the hybrid coolers pre-cool the fluid between external temperatures of 14 to 25 °C, and the difference with respect to the desired temperature level is compensated via the low media temperature of the thermal reservoir. If the external temperatures rise above 25 °C, the thermal reservoir alone serves as the cold reservoir.



Picture 5:
Sketch of a system with thermal reservoir

Mode of operation of hybrid dry coolers

Hybrid dry coolers from JAEGGI are optimised for the energy-efficient and cost-efficient operation of the overall system. Due to their large finned heat exchanger, they can be operated for most of the year without water and evaporation, purely as a dry cooler. The operating costs of cooling are limited during dry operation to the energy consumption of the fans, media pumps and the control technology. Efficient fans whose speed is controlled via frequency converters are used to regulate the output of the hybrid cooler.

By wetting the robust fins made from hard-rolled aluminium and fitted with louvres, the output of the hybrid cooler can be increased enormously at high external temperatures. As a result, when used in accordance with the specifications, the JAEGGI type HTK hybrid coolers meet the hygiene requirements of the German VDI guideline 2047-2 and also comply fully with ACOP L8 and HSG274 Part 1 and thus also fulfil the strict requirements of sensitive sectors and applications.

