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White paper

Water cooled racks in data centres – time to look at the economics

Most computer rooms are cooled by conventional precision air conditioning units blowing cold air into the room or under the floor – yet for both capital and running costs, it is nearly always more cost effective to take the point of cooling straight to the rack.

In this paper, we look at a small datacentre project that decided to go for water cooled racks on the basis of the best technical solution, lowest installed cost, lowest running costs and a significant aid to reducing its carbon footprint.

IT equipment, and especially servers, produce a lot of heat. That heat must be removed – if not, it will build up and soon damage or destroy the IT equipment.

Equipment racks typically give off around 3 to 4 kW of heat, although some may only contain passive cabling equipment and give off no heat. Others may be stacked up with blade servers and be producing over 30 kW!

The limiting factors in heat production are how much heat you can take away and how much electricity you can provide to the rack in the first place. In markets where electricity is expensive, reducing electricity consumption is also desirable, as is reducing carbon footprint profiles in all markets.

How much heat can you take away?

If we think about some basic cooling technologies we have:

- **Whole volume cooling**, i.e. pumping cold air into a room and hoping enough of it finds its way to the equipment rack. This is a very inefficient method as around 70% of the cold air produced just goes back to the cooling unit. We can expect an average heat load of about 2 kW per rack possible with this method.
- **Pumping cold air underneath a raised floor** and only letting it escape in front of the air intakes of a rack. This is the very common hot aisle / cold aisle method and will reliably handle an average of about 4 kW per rack – although up to 7 kW may be possible. About 50 to 70% of the cold air produced goes back unused to the cooling unit.

- As above, but **enclosing the aisle** to form either an enclosed cold aisle or an enclosed hot aisle. In the former, the cold air really has nowhere else to go but through the equipment racks. It doesn't greatly improve the cooling capacity, but it does raise the efficiency to about 70 to 90% utilisation of the cold air.
- **In-row cooling**. There are various versions of this, but essentially the cooling units are placed in between some of the racks and produce their cold air directly into the front of the racks or into an enclosed cold aisle. The cooling units have to be connected to the refrigeration system, e.g. chilled water or refrigerant line. It is still an air cooled system so still has the 4 to 7 kW cooling limitations.
- **Water cooled racks**. There are two main variants here. One is the addition of a water cooled rear door to a rack. The hot air produced by the IT equipment passes over a water cooled grid in the rear door and loses all of its heat to it. The other variant places water cooled heat exchangers either side of the racks, takes the hot air from the back of the rack, cools it and then sends it back to the front of the rack again. The main difference with water cooling is that water is thousands of times more efficient than air at picking up heat and this leads to:
  - **Much higher cooling capacities**, e.g. 3 to 45 kW per rack.
  - **Lower energy consumption** because of the greater efficiency of the water in picking up heat. Water cooling also aligns itself very easily to the technology of 'free cooling' when the external temperature is below 17°C/63°F.
  - **Much higher water supply temperature** to the rear coolers (14 to 20°C/57 to 70°F), which leads to greater efficiency and will save up to 40% in energy over conventional CRACs (Computer Room Air Conditioning units).
- There are other, more exotic technologies, such as putting the refrigerant directly into the computer (where the heat is produced) and even using high pressure liquid carbon dioxide for the heat exchange mechanism, but these add cost and complexity without efficiency gains.

How much electricity are you providing to the rack in the first place?

The other limiting factor in heat production is linked to how much electricity one can supply to the rack. Every watt of power and joule of energy that arrives at the rack as electricity turns into heat, one way or another – no exceptions.

Older racks typically had a 16 amp power supply. So, if we take a simplistic expression of power equals voltage times current and use a mains voltage of 230V, then the power available, and hence the heat produced, would be limited to about 3.5 kW.

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More modern installations usually install a 32 amp or 63 amp supply to each rack, hence giving around 7 kW and 14.5 kW of power respectively. Although most racks now have two power supplies for resilience, one is acting as a spare so the expected power consumption generally still isn't above 7 kW and 14 kW.

More often, if you need greater than 7 kW in a rack, then more power supplies have to be laid to the rack – it would then be common to switch over to three phase power distribution at this stage rather than numerous single phase cables; this then allows a single rack to go as high as 27 kW. Many hundreds of racks at many kilowatts each soon add up to thousands of kilowatts – the other limiting factor would then be how much power is available to the whole data centre.

Note that physical space within the rack is now rarely the limiting factor due to the more pressing limitations of cooling and power provision.

Real life design project

A leading data centre design consultancy was recently asked to design and cost a number of options for a university data centre project. A number of computer rooms were to be built around the campus and the basic specification was:

- 100 kVA of UPS power to be available in each computer room.
- A chilled water supply of around 100 kW cooling capacity to each computer room was to be available from the main building supply.
- The IT load would fit within the 100 kVA UPS provision i.e. about 80 kW steady state.
- About 7 kW of background heat was expected from building solar thermal gain, lights, ancillary equipment etc.

As data centres go, 80 kW of IT load is on the small to medium size and so everybody presumed that the usual design techniques of a raised floor with CRAC units arranged around the wall blowing cold air underneath two rows of air cooled racks would be used – i.e. a classic hot aisle/cold aisle approach.

On the expectation that 32 amp air cooled racks could cope with 4 kW per rack running load and 7 kW peak loads, then 20 racks would be needed. The customer also wanted six dedicated communications racks, but with minimal heat load – so 26 racks would be needed in total.

As the cooling depends upon a raised floor to distribute the cold air, then a raised floor has to be built. A floor height of at least 450 mm is required to provide an even air distribution. A ramp is then required to gain access to this new 450 mm level. Even with a 1:12 ramp slope, as required by various Disability Discrimination Acts, we will still lose 7 to 8m^2/23 to 26ft^2 of the floor space just for the ramp area.

All this added up to a floor area of over a $100m^2/328ft^2$, which the university thought excessive for just 80 kW of IT load.

The consultants suggested looking at various forms of water cooled racks to save space. At first the university's IT department thought that water cooled racks were the expensive preserve of large data centres and those looking to build very high density blade server racks.

Blade servers take 4 to 6 kW each, unlike conventional servers which are more likely to be in the 500 to 750 W range, and so a rack full of blade servers would need 16 to 20 kW of cooling (and power). There were also concerns about the widespread use of water around a computer room as leaks are seen as inevitable.

The consultants persuaded the client that several options should be designed and costed; they can be summarised as:

- **Raised floor** with four, 35 kW water cooled CRAC units with 20 server racks and six communications racks in a conventional hot aisle / cold aisle format.
- **Solid floor** with 14 server racks and six in-row cooling units interspersed amongst them, formed in an enclosed cold aisle construction. Six communications racks were placed at the end of the room.
- **Solid floor** with 14 rear-door water-cooled racks. No further enclosure is necessary as the cooling is delivered directly to the rack. Again six communications racks were placed at the end of the room.

The first thing to notice is that the number of racks has gone down to 14 from 20 because the water cooled racks and in-row chillers can handle a higher heat load, here working out to 5.7 kW per rack. The number of racks could be even less as the water cooled racks can easily handle over 10 kW each, but the client felt they needed at least 14 racks to organise their affairs.

Another big difference, of course, is that the client at least has the option of going to higher power consumption per rack with water cooling and could choose to make one or more of the racks a high density cooling area for blade servers, even if the average cooling load of the room was held at 100 kW.

Tapping off chilled water from the main building circuit is not the most usual application in data centre cooling and dedicated chiller units would be more usual, but the technology of water cooled racks can adapt to any source of chilled water.

The pricing for the project came out as shown in the chart on the next page.

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	Option 1. Raised floor, 4 CRAC units*	Option 2. In row cooling**	Option 3. Water cooled rear coolers***
Supply, fit and commission CRAC units	$196,284/£120,000	$0/£0	$0/£0
Raised floor and access ramp	$24,532/£15,000	$0/£0	$0/£0
Equipment racks	$34,345/£21,000	$33,749/£20,667	$33,749/£20,667
Power distribution in each rack	$13,084/£8,000	$9,525/£5,833	$9,525/£5,833
Two main power distribution boards	$26,170/£16,000	$26,128/£16,000	$26,128/£16,000
Power distribution to each rack	$13,084/£8,000	$8,165/£5,000	$8,165/£5,000
Small power provision	$8,995/£5,500	$8,985/£5,500	$8,985/£5,500
Earthing system	$4,362/£2,667	$4,362/£2,667	$4,362/£2,667
Structured cabling system between the racks	$36,960/£22,600	$28,264/£17,300	$28,264/£17,300
Cable containment	$10,903/£6,667	$13,084/£8,000	$13,084/£8,000
BMS connection	$12,101/£7,400	$12,101/£7,400	$12,101/£7,400
Security and access control	$11,942/£7,300	$11,942/£7,300	$11,942/£7,300
In-row cooling units (6)	$0/£0	$136,258/£83,400	$0/£0
Rear door cooling units (14)	$0/£0	$0/£0	$131,372/£80,404
Enclosed cold aisle kit	$0/£0	$17,645/£10,800	$0/£0
Building and pipe work	$9,813/£6,000	$9,802/£6000	$9,802/£6000
Gas fire suppression system	$126,424/£77,300	$126,424/£77,300	$126,424/£77,300
2 x 120 kVA UPS	$95,834/£58,600	$95,834/£58,600	$95,834/£58,600
4 wall mounted A/C units	$0/£0	$9,802/£6000	$0/£0
Power cabling to UPS room	$49,053/£30,000	$49,053/£30,000	$49,053/£30,000
Sub total	$673,441/£412,067	$590,946/£361,767	$576,898/£353,167
Site preliminaries	$32,686/£20,000	$32,686/£20,000	$32,686/£20,000
Provisional sum	$16,335/£10,000	$16,335/£10,000	$16,335/£10,000
Project total	**$722,062/£442,034**	**$639,951/£391,767**	**$617,340/£377,971**
Variance	**+17%**	**+3.6%**	**0%**

*Option 1 26 racks, raised floor, 4 CRAC units. Hot aisle / cold aisle.
**Option 2 20 racks, 14 in an enclosed cold aisle with in-row cooling.
***Option 3 20 racks, 14 with ColdLogik C8 water cooled rear doors.

Both the in-row cooling and the water cooled rack doors required an additional device to act as the interface between the building cold water supply and the local cooling devices.

The in-row cooling still requires some overall room cooling as it is only addressing the cooling load of the 14-rack enclosed cold aisle unit.

Contrary to expectations, the chilled water rear doors, based on the USystems ColdLogik CL20 rear door cooler system, came out as the lowest installed price option when all things were taken into account to achieve the same ends.

In addition to being the lowest overall cost, the ColdLogik system offered:

- The smallest overall footprint to achieve the project goal.
- The only method with the flexibility to upgrade the cooling of each rack (at least 14 kW) to cope with high density heat loads, such as blade servers, at no additional cost.

Each system is based on chilled water so the capacity for leakage problems remains the same for each. However the USystems ColdLogik has as an optional extra a unique leak prevention system. This works by putting the cooling loop under negative pressure. If any water carrying element sustains a leak or damage, then it will actually suck air into the system rather than letting water out. This air would then be vented out elsewhere in the system. The sensors would raise an alarm that a fault had occurred, but meanwhile, the cooling capacity remains unaffected and the IT function can continue.

Running costs

The running costs and electricity consumption were also important factors in product selection.

In the example used here, the source of cold water came from a central supply for all three options – but there is no doubt that the closer the cooling method is placed to the heat source the more efficient the process will be. Rear door cooling will consume the least building supply water to effect the same cooling capacity, followed by the in-row method and then under floor cooling with four CRAC units.

All the systems require pumps and fans to move air and water about. 14 rear door cooling units will take an average of 4 kW in total to manage this. The CRAC unit fans and pumps take about 10 kW each, so presuming three of them would be running to achieve the desired effect, the day-to-day power consumption would be around seven times as much with water cooled CRAC units.

So for a CRAC based solution, with an electrical cost of $0.12/£0.075kW.hr, the yearly running cost is $34,329/£21,000, whereas the ColdLogik solution running cost is $4,576/£2,800, which is 86% less. On a 50% loading factor, water cooled rear coolers save 366,000 kw.hrs over three years – or about $44,867/£27,450 at today's prices.

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Conclusion

On a like for like basis, for an 80 kW IT load in a medium sized computer room, the complete project costs using the USystems ColdLogik water cooled rack system was:

- **3.6% cheaper to install** than an in-row cooled enclosed cold aisle.
- **17% cheaper than conventional CRAC units** on a raised floor in a standard hot aisle/cold aisle layout
- And, in addition, **saved an extra $44,867/£27,450** in electricity costs over three years.

The ColdLogik water cooled rack system also provided the overall lowest floor footprint and also the only method of easy upgrade to high density cooling for blade servers.

- From a capital expenditure point of view, this project managed to remove the myth that water cooling solutions cost more than a CRAC based system and that rear cooling is more expensive than in-row cooling with containment, which patently is not the case.

Unfortunately what the project did not highlight is the amount of financial savings which can be made by adopting the full ColdLogik technology. This project is unusual because the chiller was already in place supporting the building's air-conditioning system and supplying water at a low temperature.

- It is more common to have a dedicated chiller and free cooling module. Had this been the case, the ColdLogik solution would have elevated the energy savings a further 35% – and if the project was based in northern Europe, there would be a combined total of up to 93% savings.

In fact, if a reclaim system was also installed, this figure rises to 98% when compared to a standard CRAC hot aisle cold aisle based solution. It should also be noted that even in hot climates, massive energy savings are possible and with them, a significant reduction in the generation of CO_2.

Please see related documents:
'Energy savings explained'
'Carbon footprint and the datacentre'

For more information:

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