VERTIV WHITE PAPER

Evaluating Precision Chillers for the Data Center

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As the data center landscape shifts toward larger, often hyperscale, core facilities at the center of hybrid networks with a more robust edge, cooling strategies are evolving to meet the needs of these large environments. Direct expansion systems with chillers remain an effective choice for high-capacity data centers, but these systems exist on a spectrum. The chosen system will have a significant impact on the cooling and energy efficiency of the facility.

A chiller cools water using an internal direct expansion circuit made up of compressors (the largest energy consumer), refrigerant, expansion valves, condenser coils and evaporators (heat exchanger between refrigerant and water). To evaluate a chiller and make the proper choice for a specific data center, operators should consider efficiency, communication, refrigerants, control and energy savings (indirect free-cooling and adiabatic coil) and weigh these criteria appropriately. The conclusions will vary depending on many criteria specific to a given data center. Let's look at each independently:

EC Fans

High performance EC-Fans with die-cast aluminum blades statically and dynamically balanced. Availability of 900 mm and 800 mm model to meet different noise request.

Microchannel condenser

Microchannel condenser in multiple "V" design. This allows to minimize the weight of the unit (-10%), increase the heat transfer and reduce the quantity of refrigerant. The freecooling version use a traditional Finned coil.

Electrical Panel

Is highly configurable to adapt to different customer needs, possibility to have dual power supply, ATS, power factor capacitor, energy meter.

The electrical panel is divided in two sections (power and control) for an easy maintenance. Protection IP54.

Shell & Evaporator

in seamless carbon steel with internally finned copper tube. Externally insulated with closed cell elastomer to reduce heat losses.

- **Standard**
- **Freecooling**
- **Adiabatic**

Compressor

- Inverter Screw
- Screw
- Scroll

Other options

- Dual power supply
- Fast start ramp
- Power meter
- Supersaver
- Ultra low noise
- Teamwork

Electronic Expansion Valve

to ensure an accurate control of superheating of the gas under all conditions. Optimized part load operation to reduce energy operating costs.

Figure 1. Main components of a data center (precision) chiller. To what is evidently observable, the embedded software specially designed for the application must be added.

Efficiency

A chiller cools water that is then used to extract heat from the environment to be cooled. However, environments and applications are different. What we would consider comfort chillers designed for office buildings or supermarkets are not the same as those designed for industrial environments prone to high pollution, vibrations, corrosion, and poor power quality. Efficiency is dependent on the type of chiller and its application.

For data centers, efficiency is a priority and the precision chillers used in those facilities are designed accordingly. Water is used at high temperatures (>20°C) to maintain optimal operating conditions (with temperature and humidity regulation on cabinet doors) and deliver high reliability and efficiency. In fact, a precision chiller for data centers is most efficient at high water temperatures – higher than many comfort or industrial chillers can accommodate. This is all part of the design that allows precision chillers to maintain the appropriate conditions for the sensitive equipment in a data center.

Change one of the variables, however – by lowering the water temperature, for example – and the precision chiller will not be as efficient as the comfort or industrial chiller. The point is simple: Different chillers are designed for different applications and optimizing the efficiency of the system requires matching the right chiller to the right application.

Communication

In the data center, communication between the chiller and the indoor units or water handlers (CRAH) is central to optimizing operation. Here again, the difference between the types of chillers is significant. Comfort and industrial chillers often aren't designed for such communication or can't perform it because those chillers and the indoor units are different brands, lacking the ability to share information.

Precision chillers, including those from Vertiv (called "Super Saver"), enable communication between chillers and indoor units. The indoor units near the critical equipment feed information to the chillers, and the two systems in tandem define the actions to be carried out depending on conditions on the server floor – specifically, temperature and the percentage of load in use.

Here's what that means in practice: Since there is always redundancy in chillers and drivers, and all data centers operate at less than 90%, the water valves of the CRAH can be opened wide and the water temperature increased, leading to higher efficiency. This likewise reduces the percentage of the chillers' operation by lowering the workload of the compressors. If ambient temperature conditions allow it, this will increase indirect free cooling.

All of this provides great energy savings. It also is unique to the types of precision chillers used in the data center, because they have the control cards and embedded software needed. Comfort and industrial chillers, by contrast, require external controllers, additional adaptations or extra programming to perform the same functions.

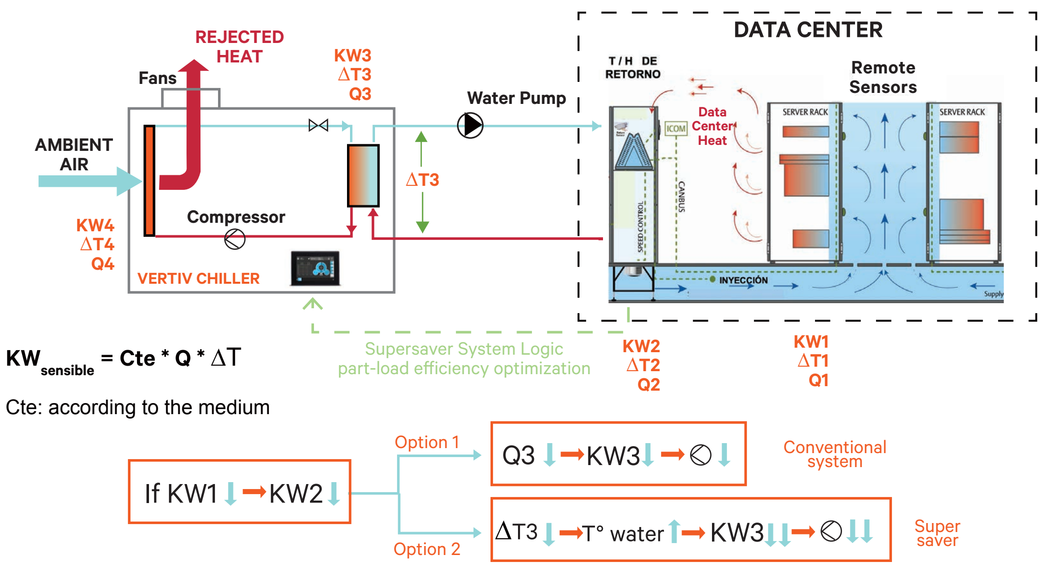


Figure 2. Supersaver is more effective as it can increase the temperature of the water and open the water valves to operate the compressors at a lower percentage, versus always cooling the water to the same temperature and regulating the valves.

CONFRONTATION:

- Standard system HPC freecooling chiller + PCW
- Same system with Supersaver

COMMON DESIGN CONDITIONS:

- Freecooling chiller in/out water temperatures at full load: 15-10˚C
- PCW set-point: 24˚C, with return air control

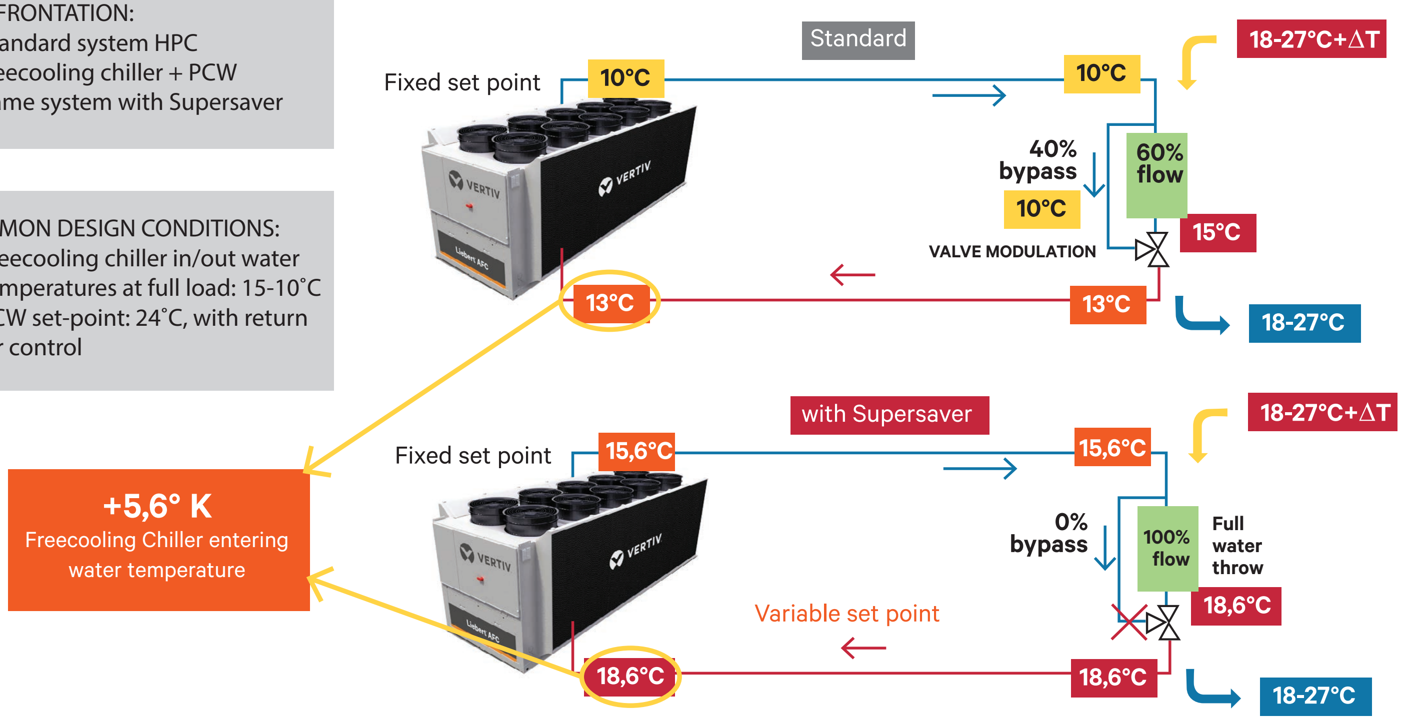


Figure 3. Example of a case with Supersaver at 60% load. This communication occurs between the chiller and the indoor units, and the control is automatic. By increasing the TD, the cooling capacity improves and if free-cooling is available, it is enhanced.

		Design operation percentage	**90%**
		Redundancy R	**1**
Number N	**Redundancy R**	**Total amount**	**% of operation per unit**
1	0	1	90.0%
1	1	2	45.0%
2	1	3	60.0%
3	1	4	67.5%
4	1	5	72.0%
5	1	6	75.0%
6	1	7	77.1%

		Design operation percentage	**95%**
		Redundancy R	**1**
Number N	**Redundancy R**	**Total amount**	**% of operation per unit**
1	0	1	95.0%
1	1	2	47.5%
2	1	3	63.3%
3	1	4	71.3%
4	1	5	76.0%
5	1	6	79.2%
6	1	7	81.4%

Figure 4. Actual percentage of chiller operation in redundancy. Operating simultaneously allows more energy to be saved (increased water temperature and greater efficiency in the case of inverters) and faster response in the event of a sudden shutdown of one of the units.

Refrigerants

The data center industry is in the process of transitioning to refrigerants with low global warming potential (GWP), increasingly at the behest of various regulatory bodies around the world. Europe is mandating migration low-GWP refrigerants, and R410, R407 and R134, among others, will be discontinued by 2025. Thus, precision chillers are now offered with new low-GWP refrigerant options such as R513 and R1234. Similar regulatory steps elsewhere are pending or likely in the coming years.

Description	R22	R407C	R410A	R134A	R32	R513A	R454B	R515B	R1234ZE
Damages ozone layer	Yes	No	No	No	No	No	No	No	No
GWP (Global Warming Potential)	1800	1774	1740	1430	675	573	466	299	7
Flammable (ASHRAE Safety Designation)	No (A1)	No (A1)	No (A1)	No (A1)	Low (A2L)	No (A1)	Low (A2L)	No (A1)	Low (A2L)

Figure 5. Comparative table of refrigerants typically used in data centers. The target GWP is less than 750. Those in red would not meet the target. Those in green would be the replacements.

Control

Precision chillers come with all the electronics, communication capabilities, and measurement and control components to operate effectively in a data center. Communication between units can optimize energy savings based on the automatic control of water temperature, rotation of the units for redundancy, or operation tailored to full or partial loads. For example: If one unit requires maintenance or fails, the others automatically increase their workload to compensate for the absence. All of this can happen automatically per operating parameters, and every machine can be monitored from a single unit.

That built-in intelligence and control doesn't exist in comfort or basic industrial chillers. Those systems usually require additional external elements, such as a PLC, and various sensors or control and monitoring modules for integrating different units to work in concert. These various external components represent points of failure and typically produce results inferior to those seen with precision chillers.

For cloud and colocation provider, the business is the data center itself. Therefore, cooling being the great consumer of energy in these facilities (more than 35% of all consumption) and the most expensive to acquire in terms of infrastructure, energy efficiency in those systems is vital. The cost of operation and equipment lifespan also contributes to the total cost of ownership and should not be discounted.

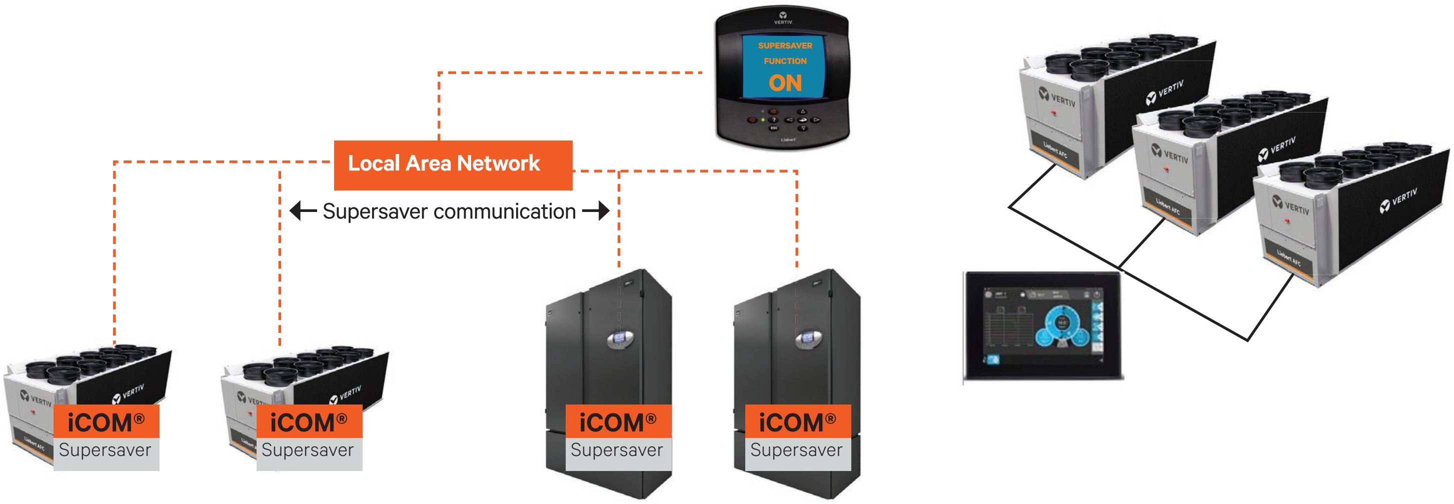


Figure 6. Vertiv precision chillers incorporate control and management focused on the optimal operation of the data center without the need for additional external equipment or programming.

Energy Saving

Energy efficiency features are important, but their full contributions depend on how they are configured and used. In the chiller market, EC-fans are practically the market standard, and inverters and magnetic gears are common across many systems. All are capable of reducing energy use, but their true impact depends on correct configuration and use.

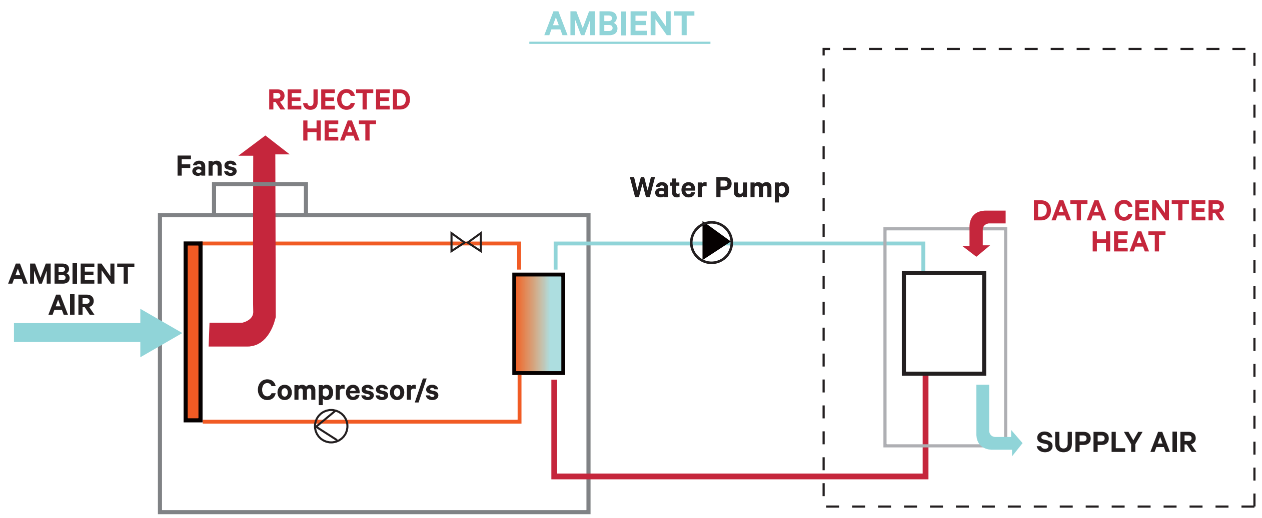
Beyond the standard incorporated technology, chillers can be configured with certain accessories that enhance efficiency. These include the free-cooling coil and the adiabatic coil, based on the principle of temperature difference (TD). The greater the difference, the greater the heat evacuation capacity, and by extension, the greater the energy savings. Operators can increase the temperature difference by increasing the temperature of the water and "lowering" the temperature of the air surrounding the chiller.

For example, if the air is 10°C and the water is 15°C, the temperature difference is 5°C. Raising the temperature of the water to 20°C immediately doubles the difference (10°C). Therefore, the capacity grows, and the workload of the compressors drops, reducing the energy required for operation.

In the case of the adiabatic coil, a normally black coil is wet with water like a sponge. As air at high temperature passes through this humid coil, cooler, more humid air comes into contact with the water pipes. This increases the temperature difference and the ability to evacuate the heat from the liquid, effectively reducing its temperature and the workload of the compressors – again reducing the energy consumed.

ONE operating mode:

- Mechanical cooling («**DX**» direct expansion)



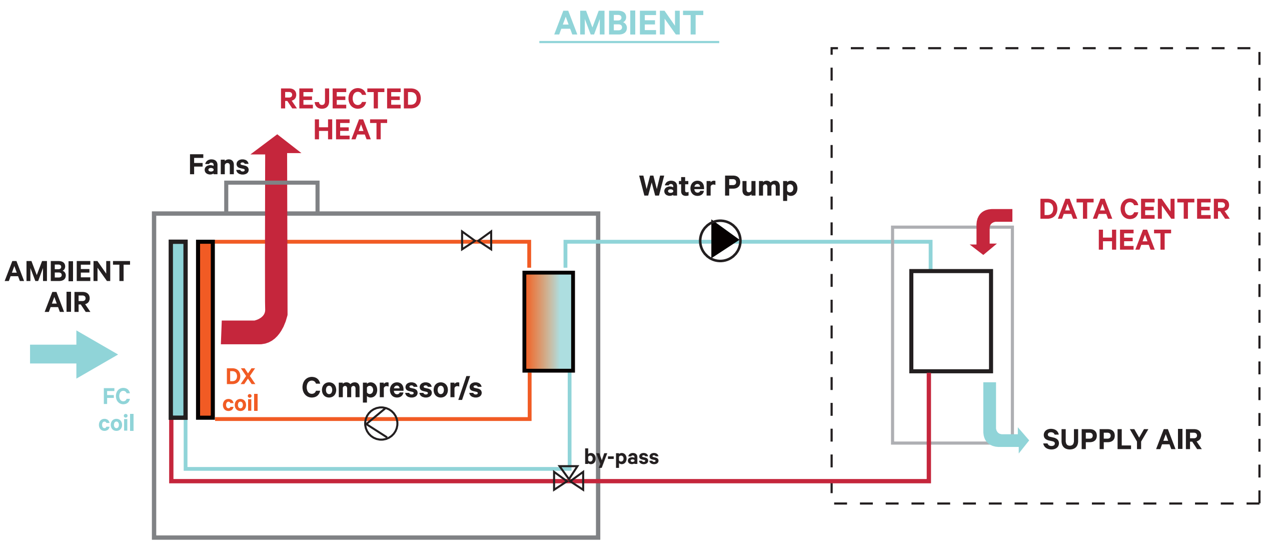
Typical applications:

- **Comfort** application or **legacy data centers** with low water regimes (i.e. **12 - 7°C**)
- Very **warm countries** where Freecooling is still not popular (but the trend is changing)
- As **backup for systems with drycooler or cooling towers**

Figure 7. Conventional chiller operation, single coil

THREE operating modes:

- Mechanical cooling («**DX**» direct expansion)
- Freecooling «**FC**»
- Mixed mode «**FC**+**DX**» freecooling + backup compressors



Typical **applications**:

- Data centers with medium/high water regime (**15 - 10°C → 26 - 20°C, ASHRAE**)
- Traditionally used in **cold countries**
- New trend also in warm countries (ASHRAE, Adiabatic)

Figure 8. Chiller with free-cooling. Note the detail of the additional FC coil that allows heat to be evacuated by taking advantage of the low ambient temperatures and the temperature difference generated to reduce the workload of the compressors.

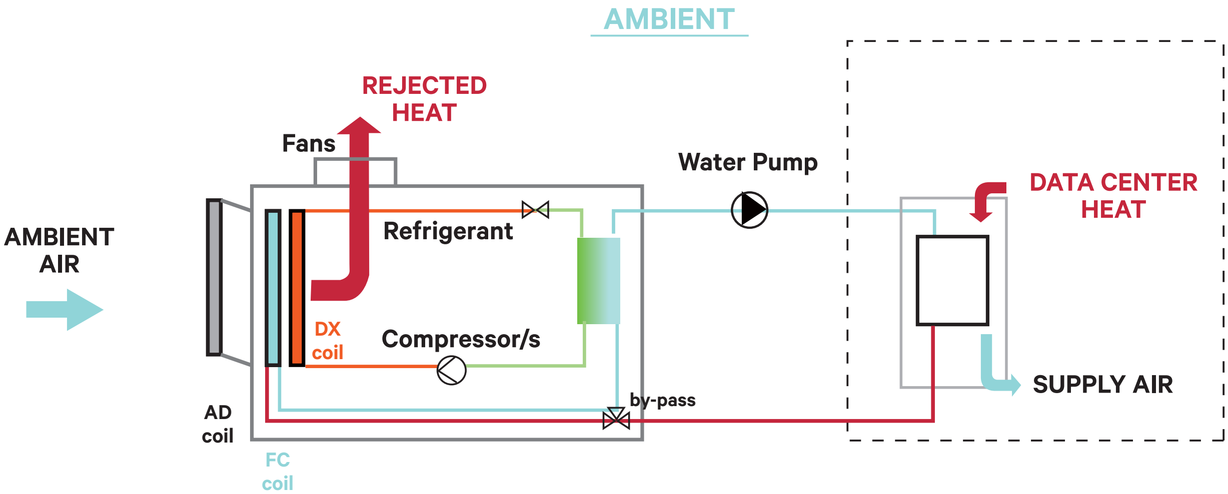
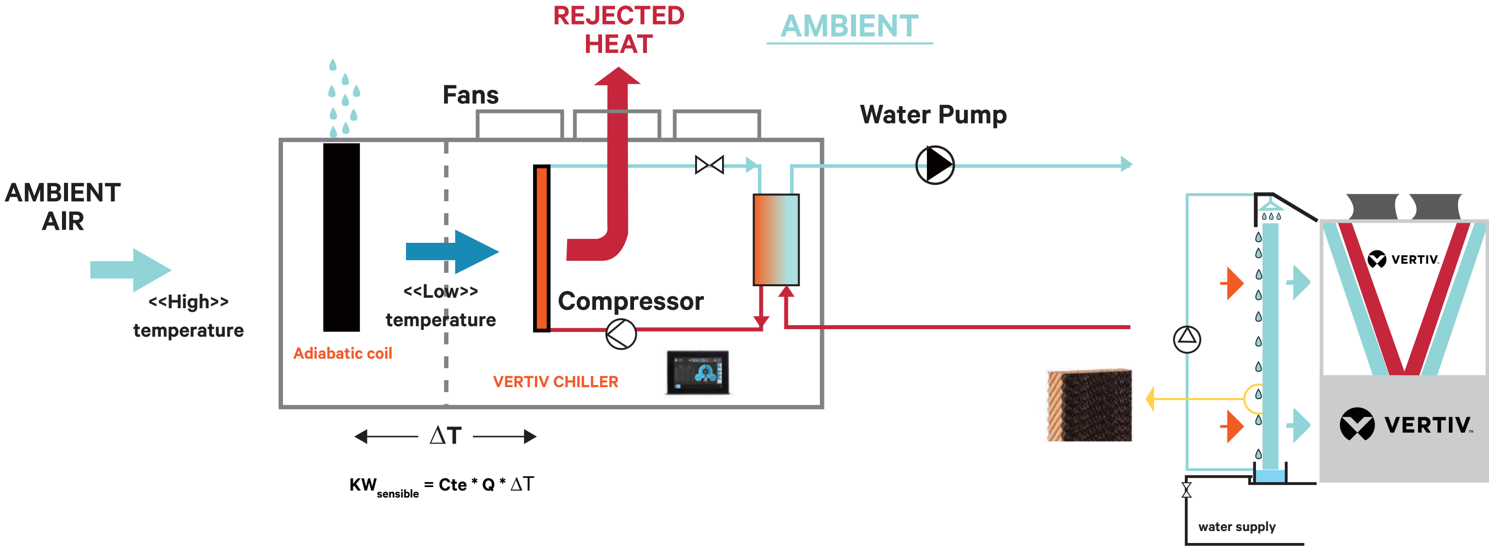


Figure 9. Adiabatic coil to lower the temperature and raise the ambient humidity



Ambient air passes through the wet pads (AD)

Adiabatic transformation:

- Humidity increases
- Dry Bulb temperature decreases

Figure 10. Adiabatic coil to lower the temperature and raise the ambient humidity.

Air temperature before PAD (°C)	Air Condition after PAD															
	Tdb (°C)	RH (%)	Tdb (°C)	RH (%)	Tdb (°C)	RH (%)	Tdb (°C)	RH (%)	Tdb (°C)	RH (%)	Tdb (°C)	RH (%)	Tdb (°C)	RH (%)	Tdb (°C)	RH (%)
50	30,6	56	34,3	65	37,2	72										
48	29,6	56	32,8	65	35,5	72										
46	28,3	56	31,3	65	33,9	72	36,3	78								
44	27	57	29,8	65	32,3	72	34,5	78								
42	25,7	57	28,4	65	30,7	72	32,8	78	34,7	83						
40	24,4	58	26,9	66	29,1	72	31,1	78	32,9	83	34,6	87				
38	23,1	58	25,4	66	27,5	73	29,4	78	31,2	83	32,8	87	34,2	91		
36	21,8	59	24,0	66	26,0	73	27,8	78	29,4	83	30,9	87	32,3	91	33,7	94
34	20,4	59	22,5	67	24,4	73	26,1	78	27,7	83	29,1	87	30,5	91	31,7	94
32	19,1	60	21,0	67	22,8	73	24,4	78	25,9	83	27,3	87	28,6	91	29,8	94
30	17,8	60	19,6	67	21,2	73	22,8	78	24,2	83	25,5	87	26,7	91	27,9	94
28	16,4	61	18,1	68	19,7	73	21,1	79	22,4	83	23,7	87	24,9	91	26,0	94
26	15,1	61	16,6	68	18,1	74	19,4	79	20,7	83	21,9	87	23,0	91	24,0	94
24	13,7	62	15,2	68	16,5	74	17,8	79	18,9	83	20,1	87	21,1	91	22,1	94
22	12,3	62	13,7	69	14,9	74	16,1	79	17,2	83	18,3	87	19,3	91	20,2	94
20	11,0	63	12,2	69	13,3	74	14,4	79	15,5	83	16,5	87	17,4	91	18,3	94
18	9,8	63	10,8	69	11,7	74	12,7	79	13,7	83	14,7	87	15,5	91	16,4	94
16	8,4	64	9,3	69	10,1	74	11,0	79	12,0	83	12,9	87	13,7	91	14,4	94
14	7,1	64	7,8	70	8,6	75	9,4	79	10,2	83	11,1	87	11,8	91	12,5	94
12	5,8	65	6,3	70	7,0	75	7,7	79	8,5	83	9,2	87	9,9	91	10,6	94
10	4,4	65	4,9	70	5,4	75	6,0	79	6,7	83	7,4	87	8,1	91	8,7	94
8	3,1	66	3,4	71	3,8	75	4,3	80	5,0	83	5,6	87	6,2	91	6,7	94
6	1,8	66	1,9	71	2,2	75	2,7	80	3,2	83	3,8	87	4,3	91	4,8	94
5	1,1	66	1,2	71	1,4	75	1,8	80	2,3	83	2,9	87	3,4	91	3,8	94
Air R.H. before PAD (%)	10		20		30		40		50		60		70		80	

LEGEND
T out > 35°C
30°C < T out < 35°C
25°C < T out < 30°C
20°C < T out < 25°C
15°C < T out < 20°C
7°C < T out < 15°C
Freezing risk!

Figure 11. Effect of passing the surrounding air to the chiller through the adiabatic coil. Depending on the initial conditions, the improvement is significant (air with high temperature and low humidity are perfect for this application).

Figure 12. Vertiv Liebert AFC chillers with adiabatic coils (black).

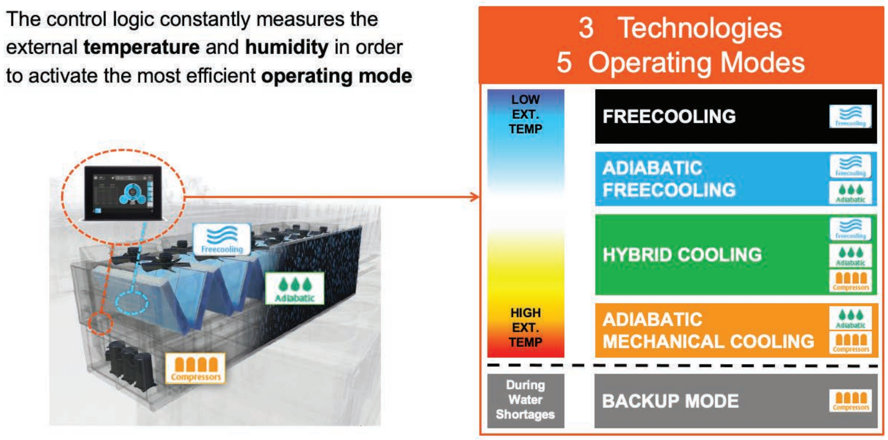


Figure 13. All energy saving options depending on ambient temperature.

Conclusion

Chillers are designed and configured to meet the needs of specific applications. Data center operators too often make purchasing decisions without this understanding and before considering the technical and performance specifications of various solutions. The initial purchase price of these systems is a small part of their total cost of ownership and must be weighed against the clear design advantages precision chillers offer in data center environments.

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