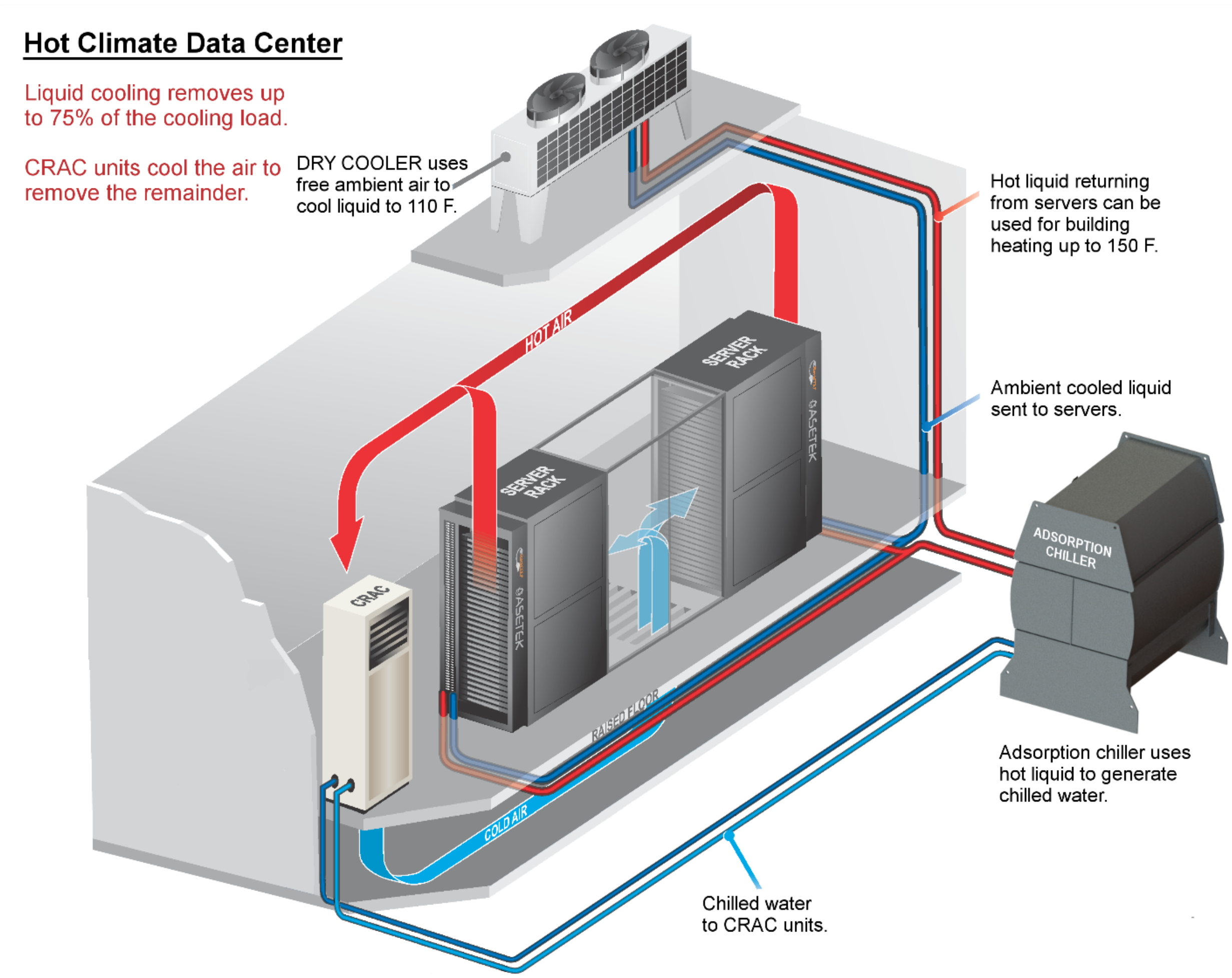
The Self-Cooled Data Center



NEW LIQUID COOLED SERVERS WITH ADSORPTION CHILLERS RAISE EFFICIENCY AND REDUCE FOOTPRINT

BY WES LIVINGSTON, P.E.

Microprocessors are incredible marvels of modern technology. But from a thermal perspective, they're just small heating elements. Electricity flows in. If all goes well, the heat flows out. Due to thermal resistance, the temperature will rise until a stable temperature is achieved where the heat output equals the energy input. If the temperature is too high, the performance and life span of the processor will be reduced. Typically, the air space around a server is cooled below ambient temperatures to provide a sufficient temperature gradient across the processor to prevent it from overheating. Cooling requires energy input, especially in hot and humid climates where mechanical refrigeration is required to create an artificially cool and dry space. As server racks become more densely packed with heating elements, the problem of rejecting that heat becomes more difficult.

Successful thermal management has typically focused on removing the heat from the electronics. However, why not step back with a holistic view of the building and harness the heat for something beneficial? With new advancements in HVAC, it is now possible to use a heat pump to efficiently convert low grade thermal energy into useful cooling energy. By extracting the heat with a thermal fluid directly at the source, it is possible to safely raise the temperature of the fluid up to 150 F without compromising the processor. Then that fluid can be put to work with a solid desiccant adsorption chiller to produce chilled water for supplemental building cooling demands. According to the EPA, the amount of energy consumed by data centers in the US approaches 2.5% of national consumption. The savings that could result from harvesting the heat could be in the range of 1.5 to 3 gigawatts of capacity.

Multiple companies offer their own version of liquid cooling solutions including Asetek, Chilldyne, Clustered Systems, CoolIT Systems, Green Revolution Cooling, and IBM. The majority utilize a design where water-cooled heat exchangers directly touch the CPU, extracting heat at the source. In contrast, Clustered Systems Co. utilizes two-phase R-134a refrigerant as the circulating fluid, which migrates naturally due to heat transfer, thus eliminating the circulating pump. Lastly, Green Revolution Cooling submerges the entire server in a bath of circulating mineral oil. Of these manufacturers, Asetek is known to be able to provide fluid temperatures sufficient for the operation of heat driven chillers.

Adsorption chillers are a new type of machine that are quite different from the previous generation of liquid desiccant absorption chillers. With solid desiccant adsorbers, the desiccant never moves and never changes phase. It is always a solid. There are very few moving parts and no chemicals. In fact, the refrigerant used is regular tap water with no additional additives. The unique property of adsorption machines is their ability to operate at reduced hot water temperatures as low as 130 F. Two manufacturers lead the world in commercial scale products. These include the American-manufactured ECO-MAX brand offered by Power Partners and the AdRef models offered by Mayekawa of Japan. These machines are inherently reliable due to their lack of a compressor or other moving parts. The desiccant operates in a closed system with no contaminants. Estimated life expectancies are 25 years or more in most cases. Capacities up to 330 tons (1,155 kW of cooling) are available from single chillers.

Adsorption chillers work in a two-step process. First, a solid desiccant such as silica gel or zeolite is used to adsorb water vapor as the refrigerant inside the vessel. Since all air has previously been removed from the inside of the machine, the adsorption process creates a low pressure region. This vacuum causes liquid water in the evaporator to change phase to a vapor, which creates a cooling effect of 1,000 BTU's per pound of water evaporated. The cooled refrigerant drips over copper chilled water tubes, thus chilling the chilled water flowing inside the tubes. The chilled water is circulated throughout the building in parallel with traditional mechanically driven chillers. After a few minutes of adsorption, the solid desiccant's bonding sites become saturated with water vapor, and the adsorption process slows. At this time, internal vapor valves close to isolate the bed of desiccant from the evaporator. Next, water-side control valves allow hot water from the server racks to pass through heat exchangers placed into the bed of desiccant inside the chiller. The solid desiccant heats up and releases the water vapor which move to the condenser section. In the condenser, the refrigerant water vapor changes phase from vapor to liquid and gives off its heat of vaporization to the copper condenser tube bundle, which is kept at 85 F by circulating water connected to a cooling tower outside. Since the adsorption and desorption process is not continuous, two chambers of desiccant are required. One chamber operates in adsorption mode while the other operates in desorption mode. Then they swap modes simultaneously. This creates a continuous cooling process and increases the efficiency of the machine.

With most data centers, the thermal load requires removal from the servers by passing air over it. The energy transferred to the air is then moved to the chilled water loop via the chilled water coil heat exchanger inside the computer room air handlers (CRAH's). Then the heat is extracted from the chilled water loop by large centrifugal chillers operating on a refrigeration process to move heat from a cold body to a warmer body. The heat is moved to the cooling water loop at 95 F where it is ultimately rejected to the atmosphere in an evaporative cooling tower. In all, the thermal energy moves from the processor to the room air, chilled water, refrigerant in the chiller, cooling water, cooling tower, and ultimately ambient air fluid. That is five fluids that must be moved around just to reject thermal energy from the processor to the air outside the building envelope. These fluids require energy input from the server fan, CRAH fan, chilled water pump, centrifugal chiller compressor, cooling water pump, and cooling tower fan. Overall, that requires an electrical input of about 1.4 kW per ton of cooling energy rejected (or 0.398 kW electric input per kW of cooling). Therefore, the cooling load adds 0.398 unwanted points to the PUE score.

By using the direct-to-chip fluid cooler and adsorption chiller, the energy consumption will be reduced to 0.425 kW per ton of cooling. This reduces the HVAC components from 0.398 to 0.120 for a savings of 0.277 PUE. Even if the data center itself does not require cooling, the chilled water can be used for other parts of the building that do require cooling. Or in the winter, the heat can be used to heat the building. In hot climates like Miami and Tokyo, a chiller may need to operate twelve months out of the year. In mixed use buildings even in colder climates such as New York City, the chiller may run 8 to 10 months per year to cool core interior spaces, even when temperatures outside dip below freezing. Or in the winter, the high grade heat can be used to warm perimeter spaces, providing even more savings.

Since most of the heat produced by the server is removed directly with the thermal fluid, the chilled water cooling load is reduced significantly. Most of the remaining load can be handled by the adsorption chiller. The higher server density drastically reduces the footprint from the servers. These systems are usually applied where space is a concern or the equipment simply cannot be cooled with a conventional system due to the high thermal density. Payback times are typically less than three years due to energy savings and the avoided capital costs achieved by eliminating conventional chilling and CRAH equipment. Additional savings are obtained by eliminating much of the electrical supply and backup generation systems associated with conventional chilled water and CRAH equipment. For example, by eliminating 80% of the cooling load, the associated emergency generators and electrical supply required to operate the cooling equipment can also be downsized by 80% in addition to the 80% reduction in the mechanical cooling system itself. Lastly, the environmental savings from the system are noticeable. A small system that saves just 100 tons (350 kW) of cooling capacity will reduce carbon dioxide emissions by about 480,000 pounds per year.

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