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How XMission Cut Power Costs

By Upgrading Their Data Center Cooling Infrastructure

XMission has recently completed some significant data center energy efficiency improvements. This white paper is intended to educate the public and promote sustainable energy practices. Recent industry trends can help data centers and similar computer facilities dramatically improve energy efficiencies. These best practices upgrades not only make XMission more environmentally friendly but help offset incessant rate hikes by the electrical utility provider. For instance, Rocky Mountain Power's federally mandated incentive program provided XMission with a substantial rebate for performing these energy saving upgrades.

Historical Background

Up until about a decade ago, data center cooling strategies were simple: make computer rooms really cold. Like a meat locker. This approach was a holdover from the telco clean rooms of yesteryear where various, expensive equipment was loosely housed in rows with a multitude of large CRAC (Computer Room Air Conditioning) units circling the perimeter and continually running their compressor motors: the largest energy draw from traditional air conditioning systems.

While all IT equipment had fans, lacking a standard they circulated air in various directions: for instance, networking equipment blew air sideways, or even in the opposite direction, of server fans. Such an approach mixes the heat into the surrounding cooler air, rather than directly removing it, and creates only a slight variance in temperature between the air leaving and eventually re-entering the CRAC units. This practice was horribly inefficient but in the past data centers were relatively small, uncommon, and an insignificant percentage of the total cost of doing business.

Unfortunately, this archaic cooling strategy was deployed at the onset of the dot-com bubble in the late 90s with its exponential data center growth. Things were going too fast to design facilities any differently from how they had been built in the preceeding decades. Over the next 10 years, both server rack density and data center growth dramatically increased, leaving IT companies to not only struggle to cool the equipment but also to pay the exorbitant power bills. Adding ever more CRAC units to server rooms was expensive and often ineffective. Making the room colder didn't effectively pull the heat away from high density server racks either. Often, the servers would recirculate the hot exhaust from the top and sides back around to their own intakes.

Road to Efficiencies

By 2004, IT companies realized that they needed to re-engineer server room cooling efficiencies to more effectively cool their gear and improve energy efficiencies. There also was a growing concern about worldwide data center power consumption and the environmental burden caused by such significant consumption. Change was long overdue and pressing. Among other things, ASHRAE (American Society of Heating and Air-Conditioning Engineers) responded with the first edition of its breakthrough, "Thermal Guidelines for Data Processing Environments" and the EPA worked with IT equipment vendors on Energy Star guidelines for data centers.

Data centers in the US currently consume about 2% of the total electricity generated nationally and that number continues to increase, although not as quickly as it did between 2005-2010. Virtually every query and web site you access from your computers and smartphones depends on equipment housed in data centers, which are scattered across the globe. With electricity being one of the largest operating expenses for these facilities, much work has been done to analyze and improve server and cooling efficiencies.

To best understand cooling optimization in data centers you need to keep two key factors in mind:

Computers don't need to be cool inside; they just need to be able to effectively reject the heat they generate. Internal operating temperatures of 100° - 140°F (38° - 60°C) are absolutely fine for safe, long term operation. Most computing equipment is designed to operate at intake temperatures of up to 95 F (35 C), although ASHRAE recommends ideal intake temperatures to not exceed 80 F (27 C).
Air conditioning doesn't actually need to create cold air but rather only needs to remove enough heat from the facility to sufficiently maintain safe operating temperatures inside of IT equipment. This concept goes against how people traditionally think of air conditioning and can be difficult to grasp. Among other things, this means that the hot aisle can be quite hot.

In other words, the word "cooling" is a misnomer in regards to modern data center HVAC strategies and "heat management" or "heat extraction" more accurately expresses the approach.

XMission Cooling Strategies and Benefits

Since XMission opened its facility in 2001, even with some upgrades along the way including a return hot air plenum, the overall HVAC infrastructure was archaic by 2013 standards. For instance, heat was ejected from the roof using "dry coolers," simple heat exchangers that operate like most car radiators.

Chief among the top changes to XMission's new HVAC deployment include hot/cold aisle containment, VFD (Variable-Frequency Drive) fans, adiabatic humidification, and water/air side economizing. The two key gains from these strategies are significant energy efficiency improvements and more effective cooling. Saving energy is a huge win both for a company's bottom line and our environment. Without the efficiency gains in recent years, global data center power consumption could be as much as twice its current level of 1%. As well, supercomputers and blade servers couldn't be densely populated in racks without the dramatically reinvented approach, which focuses on air flow and heat removal.

The remainder of this document will explain in detail how XMission deployed each of these strategies and how the company now benefits from them.

Why Your Data Center Should Have Aisle Containment

Aisle containment can bring significant power savings of 10-40% and help you more effectively cool densely packed computer systems, like blade servers. In fact, many of the other power saving upgrades require containment to work effectively since controlling air flow is an essential element to cooling efficiency strategies. Hot/Cold aisle containment facilitates air flow efficiencies by limiting the mixing of hot and cold air so that cold air gets to the servers and hot air is ejected outside.

Since data center efficiency gains come from more effectively removing heat, a key vector in attaining those gains relies on the rule that the higher the temperature of the air you send to your CRAH/CRAC ("air handler") units, the easier it is for the system to eject the heat outside.

Hot and Cold Aisles

As mentioned earlier, in the past IT gave little concern about airflow and instead just sought to make the entire computer room cold. In other words, they diluted heat by mixing it with very cool air. This strategy was satisfactory when computer rooms were relatively small and scarce. Once data centers became ubiquitous and computer densities in racks exponentially increased, the archaic approach utterly failed to keep the equipment cool while wasting vast amounts of electricity.

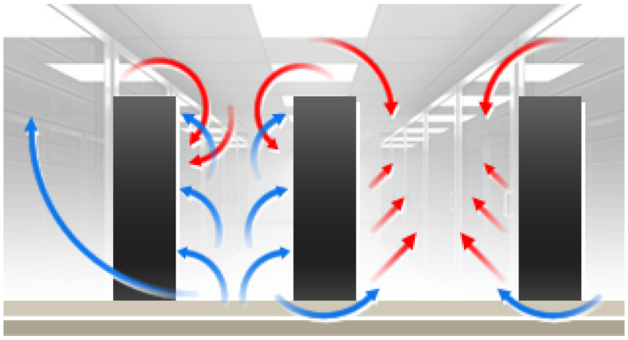
As a first step towards improved cooling efficiency, data centers created separate hot and cold aisles where they pointed computer air intakes to the cold aisle and exhausted the heat into the hot aisles. This prevented the hot exhaust air from one row of servers to vent into the cold air intake of the adjacent row and improved cooling capabilities by ensuring that computers pulled cooler air into them.

Hot Air Return Plenums

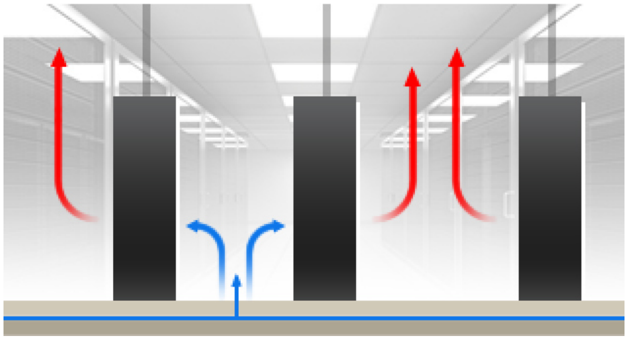
While creating hot and cold aisles somewhat restricted mixing, the warm air would linger in the hot aisles and get pulled back around to server air intakes. It wasn't until facilities built hot air return plenums in their ceilings that cooling efficiencies greatly improved. A plenum is an alternative to ducting. Think of it as a large contained pathway for air to flow through. For example, the raised floor in a computer room is a plenum space. In the same way that the raised floor supplies cool air to where it is needed, a hot air return plenum pulls the warm exhaust from computer equipment back to air handlers.

What does this accomplish? Remember that air conditioning is designed to remove heat. Cold air is simply a by-product of heat removal. In old telco clean rooms, the template followed by early data centers, you had to make the entire room cold enough so that heat would get sufficiently diffused by the cold air.

Unfortunately, when an entire room is cold the air that returns to the air handlers is still relatively cold (typically about 72F/22C), which requires the units to work very hard, including running compressor motors (also referred to as "DX cooling"), to make cold air even colder (~55F/13C). Compressors are the single-most power wasting component in traditional cooling systems. Not only do they require vast quantities of energy to run but, since they're electro-magnetic motors, they cause a big power spike every time they cycle on. Since electrical utilities need to provide enough power to businesses to accommodate for those spikes they add an extra charge for it called a "demand fee" which is often quite substantial.



Uncontained airflow



Airflow with aisle containment

Containment

Based on the same logic that controlling air flow improves cooling efficiencies, containment ultimately proved to bring significant wins and facilitate additional cooling efficiencies. As the illustration above shows, virtually complete control over airflow was finally achieved with full containment.

With the advent of hot/cold aisles, hot air return plenums, and finally containment, noticeably warmer air returns to the air handlers. A higher return air temperature makes it much easier for air handlers to eject the heat outside. Mechanical engineers refer to the temperature differential between return air and cooled air as “Delta T (ΔT)” A heat differential of 20F/11C or more brings significant efficiency gains.

As well, since hot air doesn’t mix with the cooled air before entering servers, the air produced by air handlers doesn’t need to be as cold to still be cool enough to keep computers from overheating inside. By 2008, ASHRAE revised their recommendations, stating that computer intake air could be as high as 80F/27C and the exhaust air returning to air handlers could be as high as 95F/35C. This makes hot aisles slightly uncomfortable for people but it has no negative effect for computers since the exhaust air is effectively pulled back to air handlers. Note that most computer hardware is designed to operate safely at sustained internal temperatures of 140F/60C. When air flow is effectively controlled, the temperature of computer intake air can be quite high.

Containment Implementation

To effectively control mixing of hot and cold air a data center needs to accomplish the following:

- Restrict air flow directly surrounding server cabinets
- Control air flow at the end of hot (or cold) aisles

This is handled by:

- Constructing a wall from the top front of cabinets up to the ceiling
- Building walls with doors at the end of hot (or cold) aisles
- Installing blanking panels in all empty RMU (Rack Mount Units) slots in cabinets

You can see from this photo in XMission’s colocation room the short barrier wall above cabinets that extends around the contained aisle with sliding doors on the end. Blanking panels are installed in the open gaps of all cabinets. This implementation has proven to be very effective for our needs.

Caveats

Properly implemented, aisle containment improves air flow so effectively that higher density power consumption in racks is possible but there are important caveats that must be kept in mind:

- All hardware in cabinets needs to properly ventilate from the front to the back and have working fans. Unfortunately, networking gear is notorious for ventilating side-to-side or even backwards (back-to-front)
- Cabinets must be setup to maximize efficient air flow. For example, you cannot leave gear in the exhaust pathway of other gear (e.g., external HDs). As well, cabling (for networking and power, primarily) must be properly managed to allow exhaust heat to efficiently ventilate out of the cabinet.

Solutions

Hopefully, you already practice good cable management rather than something resembling a spaghetti monster. Move external HDDs and other peripherals towards the front of your cabinets and remove a blanking panel in front of them so they can get sufficient air flow. Unfortunately, network hardware can be the hardest and potentially most costly problem to address. That said, XMission has found that in most cases cabinet air flow pulls heat out sufficiently enough that switching gear still remains within safe operating ranges, which are typically higher than servers. If your networking hardware is consistently and significantly over 140F/60C then check to ensure other hardware is not directly ventilating exhaust heat into it. If so, move gear around as needed. You can also open a blanking panel in front of the networking gear to get it some cooler air, or see if the vendor provides a kit to retrofit the cooling. Note that most new networking gear is designed to work with aisle containment.

Containment in Conjunction With Other Efficiency Strategies

Ultimately, while aisle containment is nothing more than a refining of the hot/cold aisle implementation, facilities that deploy it see vast gains. It further restricts the mixing of hot and cold air, allowing higher operating temperatures for air handlers, thereby reducing if not altogether removing, the need for power hungry compressors. The hotter return air to the air handlers also makes it much easier to reject the heat outside. In fact, when combined with VFD fans in the air handlers and cooling towers on the roof, compressors are no longer needed for most, if not for the entire, year. Such a strategy is called “water side economizing” and it is quickly becoming popular in new and renovated facilities like XMission’s.

Aisle containment can even be used with bleeding edge “air side economizing,” which simply exhausts air from the hot aisles outside and brings in filtered outside air to maintain server operating temperatures. While dust and humidity can potentially shorten the lifetime of equipment used in such an environment, many facilities replace their hardware within three years so it might not be an issue considering the vast potential power savings.

Containment FTW

As part of a complete HVAC efficiency strategy, aisle containment can help bring enormous energy savings for data centers to both lower the bottom line and improve their impact on the environment.

By restricting the mixing of hot and cold air, aisle containment efficiently accomplishes the following:

- Transports chilled air from air handlers more directly to server intake
- Pulls hot exhaust from servers back to air handlers

By attaining those two outcomes, you get these efficiency gains:

- Your chilled air can be warmer
- Your fans don't need to work as hard

The benefits:

- Use less energy to save money and be greener (depending on your current implementation, save 10-40% on your power bill)
- Get more cooling from your infrastructure
- You can have higher power densities in your racks
- If you don't run your own data center, be sure to choose one that does employ these power saving efficiency measures

Data Center Sustainability Improvements Via Free Cooling

Also known as "free cooling," water side economizing provides significant energy efficiencies because it doesn't rely on traditional refrigeration. Water side economizing is a very common strategy in modern data center HVAC (Heating Venting Air Conditioning).

In contrast to traditional, refrigeration-based cooling, water side economizing ejects enough heat outside to reduce, if not entirely eliminate, the need for a chiller. Wet cooling towers, like those atop XMission's data center, provide a much more effective and efficient means of heat exchange in Utah's dry climate as they rely upon evaporation, somewhat like a swamp cooler.

The Two Towers

Why does water side economizing save so much energy? Traditional air conditioning requires a "chiller" to perform refrigeration, which uses compressors (a type of motor) to complete the state-changing processes necessary to remove heat. Motors not only consume vast energy while they're running but their energy use dramatically spikes every time they turn on. In fact, the six-fold spikes are so dramatic that the power company charges businesses with large spikes from motors a special fee called a "demand charge." The demand charge can account for nearly half of the total monthly cost for businesses which rely heavily on motors that often cycle on/off. Since the heat load in data centers is constant throughout the year, facilities that rely entirely on refrigeration incur enormous electrical bills. In fact, many traditionally cooled data centers can pay more money for power to cool than to power the actual computers. Considering how much power these facilities consume, efficiency gains can quickly add up to significant savings and better energy stewardship.

In contrast to traditional, refrigeration-based cooling, water side economizing ejects enough heat outside to reduce, if not entirely eliminate, the need for a chiller. Wet cooling towers, like those atop XMission's data center, provide a much more effective and efficient means of heat exchange in Utah's dry climate as they rely upon evaporation, somewhat like a swamp cooler. Traditional dry coolers, on the other hand, have metal fins wrapped around copper piping similar to your car's radiator and function like the coils behind your refrigerator. While dry cooling towers require less maintenance, they can only facilitate free cooling during the coldest periods of the year (i.e., under about 40F/4C) due to the lower efficiencies of convective heat transfer.

XMission's Cooling Infrastructure

XMission's new water side economizing plant utilizes redundant Evapco water cooling towers on our data center roof with pumps circulating cooled water down to the air handlers inside computer rooms and then returning warmer water from the air handlers back up to the towers. The air handlers are a combination of Liebert CRAC (Computer Room Air Conditioner) units and new CRAH (Computer Room Air Handler) units. The retrofitted CRAC units have fans on VFDs (Variable Frequency Drives) that move the air across a heat exchanging coil, and also include refrigeration chillers, if the water from the towers isn't cool enough on hot days. The new CRAH units are Fan Coil Units (FCU) optimized for water side economizing with oversized heat exchanger coils inside, along with VFD-controlled fans, and don't include chillers.

XMission's aisle containment implementation effectively inhibits the mixing of hot and cool air. The reduced mixing means supplied server intake air doesn't need to be as cold to still be cool enough when it reaches computer racks. This facilitates running the water loop at higher temperatures, thereby reducing energy use and dehumidification problems. Lastly, the warm computer exhaust air from servers returns to the air handlers at higher temperatures, raising the temperature of the water loop as it returns to the roof. Less energy is needed to eject heat from warmer water, especially on hot days.

Since ASHRAE stated that intake temperatures can be as high as 80F/27C. Due to the heterogeneous composition of customer hardware in the facility, including networking gear with sub-optimal airflow configurations, XMission currently maintains computer intake air in the mid-70s. With greater control over airflow, the system more effectively removes heat from cabinets so in many cases servers are slightly cooler inside than before these upgrades. The new cooling strategies also have allowed XMission to increase power usage limits in cabinets to facilitate greater density.

The humidification strategy has also changed dramatically. Previously, XMission ran redundant steam-based humidifiers to maintain 40% RH (Relative Humidity) which not only required 35 kiloWatts each but they ran nearly 50% of the time because the much colder coils in the air handlers were constantly dehumidifying the air. The new adiabatic humidification system requires a fraction of the energy to maintain sufficient moisture to avoid static buildup in the facility. Decoupling from that hopelessly Sisyphean cycle alone saves XMission about 500 kWh (kiloWatt hours) each year.

Turning Dials and Measuring the Effect on Energy Savings

Motors cause big spikes when they turn on but they're also guilty of another energy inefficiency: they use significantly more power when running at 100% speed. In fact, the energy requirements skyrocket on an exponential upwards curve as fan speeds increase past 50%. Since HVAC requires many fans, utilizing VFDs in all fans and then optimizing the system to operate them within a range of 40-80% utilization as much as possible has yielded great savings for XMission.