Low Cost Direct Free Cooling in Existing Datacenters

1.0 Introduction:

As companies cram more watts into every square foot of datacenter space, the opportunities for free cooling increase almost exponentially. In a high density environment, Direct Free Cooling (DFC) combined with Hot Aisle Containment and a Return Air Plenum can be the least expensive method of increasing the efficiency of an existing data center. This article discusses the advantages of installing DFC and shows the cost savings that can be achieved.

2.0 Data Center Implementation:

The model data center for this article is located outside of Philadelphia, Pennsylvania. It consumes approximately 180kW in server load. Including the cooling, lighting, and UPS loads the datacenter consumes about 320kW of electricity. The cost of electricity in this area is near $.10 per kW. That means that over the course of a given year datacenter electricity costs in excess of $280,000. Cooling makes up almost 40% of that.

The data center cooling currently consists of DX CRAC (Direct eXpansion Computer Room Air Conditioner) units, a raised floor, cold aisle containment, and a return air plenum ceiling. The raised floor delivers cold air from the DX CRAC units to the cold aisles. Curtains at either end of each cold aisle separate the warm air in the room from the cool air in the aisle. The return air plenum is a space above the raised ceiling that pulls air from the hot aisles and returns it to the DX CRAC units. Put together, these elements ensure that the air in the cold aisle is cold and the air in the hot aisle is very hot. This makes this space nearly perfect for implementation of DFC.

The other main consideration for DFC is the location of the data center. Ideal locations are generally cool, moderately dry climates that experience very little temperature change throughout the year. However, most environments in the United States benefit from DFC for most of the year, if only because datacenters run 24x7 and the temperatures are cooler at night. In the case of the Philadelphia area, the DFC can be run at least 30% of the hours of the year to provide energy savings. In certain types of datacenter applications that number could be as high as 50%.

3.0 Implementation:

Many methods of DFC were investigated to decrease cooling costs. The largest payback was found to be installation of DFC using two supply fans and two exhaust fans. The exhaust fans are located above the hot aisles and the supply fans are located above the CRAC units. The Return air plenum is used as a mixing box between the outside air and the return air from the servers. The air from the supply fans mixes with the hot air in the return plenum to reach the proper temperature before being pulled through the DX CRAC units and introduced into the raised floor. All of the fans are controlled by Variable Frequency Drives (VFD). A VFD changes the speed of the fans to control the airflow into and out of the data center. If the outside air is very cold, dry, or humid, the fans slow down pulling in less air. If the outside air is very hot, cold, humid, or dry, the fans will shut off. This implementation of DFC is simple to install, control, and maintain yet still offers cost savings on par with more complicated systems.

The simplicity of DFC is key to its effectiveness. The exhaust fans simply expel the hot return air from the datacenter. Meanwhile, cooler air from the outside is introduced by the supply fans. If the temperature of the outside air is colder than the requirements for the IT equipment, the outside air is mixed with the warm air from the datacenter, bringing it to the proper temperature. Using the return plenum as a mixing space requires minimal ductwork to be installed. Because the CRAC units use their own independent controls, the logic for the DFC control system remains simple. The goal is to introduce air that is below the setpoint of the CRAC so that the compressors stop running. This means that the CRAC operates only to move, and humidify or dehumidify the air. In normal circumstances, running the compressors and the associated condensers uses about 70% of the CRAC power. If the CRAC compressor does not engage then a 70% savings can be achieved.

The performance of the DFC centers on cold aisle containment. By separating the cold aisle from the hot aisle, the temperature of the return air greatly increases. This in turn increases the effectiveness of the DFC. The Temperature Differential (TD) between the exhaust air and the supply air is roughly proportional to heat rejection of the DFC because the outside air does not have any relationship to the exhaust air. For example, suppose the outside air is 60°F DB (Dry Bulb temperature) with roughly the same dew point as the exhaust air, 40°F. No humidification or dehumidification is required. If the exhaust air is 70°F DB, there is a 10°F TD between exhaust air and supply air. If the exhaust air is 80°F DB, the TD is 20°F. By doubling the exhaust temperature, the system rejects roughly twice the heat yet uses about the same amount of fan energy. Therefore any increase in TD realizes huge savings in energy costs.

This is of course a simplification. Many other factors come into play such as differences in humidity between exhaust and supply air and mixture between exhaust and supply air. These all tend to reduce the efficiency of the system. This does not reduce the importance of TD, however. Even in situations where the outside air humidity is very different from the exhaust air humidity, a large TD greatly increases efficiency.

The last and perhaps most important piece of the DFC is the control system that dictates the mixture of air needed to supply the proper temperature and humidity to the datacenter. Ideally the DFC will only run when the enthalpy (total energy of air including temperature and humidity) in the outside air is significantly lower than the enthalpy of the exhaust air. This enthalpy difference should be greater than the amount of energy it takes to run the DFC. The temperature and humidity must also be monitored at the inlets to the servers to ensure that they are within the range of "2008 ASHRAE Environmental Guidelines for Datacom Equipment." If the enthalpy difference is not met or if the datacenter environment is outside of parameters then the DFC will not run. By carefully modulating these factors it is possible to increase the amount of time that the DFC runs throughout the year and therefore increase the payback on the initial installation.

DFC is an appealing method of datacenter cooling, but there are some drawbacks. In data centers where temperature and humidity are tightly controlled, the variations introduced by DFC may be outside of the required specification or SLA. Also, DFC may introduce a slightly higher amount of particulate intrusion from the outside air such as dust or pollen. These will mostly be filtered by the supply fans but some intrusion will occur. In a data center where intrusion must be kept to an absolute minimum, the costs of a true HEPA filtration may outweigh the savings of the DFC. For most data centers though, these infiltration and environmental variations are not a concern.

4.0 Conclusion:

Even for a smaller data center such as this, the savings from the DFC add up. The cost of equipment for this design is quite low, requiring only two exhaust fans, two supply fans, four VFD and one control system. The installation cost is likewise quite low because of the minimal ductwork and electrical work required. The design and engineering are simple and inexpensive. As for the savings, we expect based on our analysis that the DFC could save 32% or more in datacenter cooling costs. This reduces the Power Usage Effectiveness (PUE, a measure of datacenter efficiency) from 1.77 to 1.52 making the data center substantially more economical and greener in the process. In all, the expected ROI for this installation is about two and a half years. It is possible that the ROI could be faster given an increase in TD. More detailed numbers will be available after the first year of operation.

Although other methods of DFC exist, this installation was by far the least expensive and offered better ROI than any other. The major pre-requisite for DFC effectiveness is a significant temperature differential between the supply and exhaust air. Because the return air plenum and cold aisle containment increased that temperature differential, the DFC operates at a high efficiency in this data center. Even in existing spaces such as this, Direct Free Cooling dramatically reduces datacenter cooling costs.