scalable design

creating data center efficiencies using closed coupled design

abstract

Current data center trends are focused on delivery of service and reliability. However, up till now, there has been little incentive for data center managers to optimize the efficiency of their data center. Data center managers are primarily concerned about capital costs related to their data center's capacity and reliability. In most cases the energy costs are either hidden among other operating costs, or just absorbed as a cost of doing business. A study by IDCTM shows that for every $1.00 of new server spend in 2005, $0.48 was spent on power and cooling. This is a sharp increase from 2000; when the ratio was $0.21 per $1.00 of server spend. This ratio is expected to increase even further. Thus the immediate demand to create more efficient data centers will be at the forefront of most company's cost saving initiatives.

Currently 40% of the cool air that is supplied from air-conditioning units in a typical data center is wasted. This white paper provides information to help achieve greater efficiencies within the data center by making use of systems that reduce wasted conditioned air while driving up air conditioner efficiency.

Written by:
Brent Goren, P. Eng.
Wright Line LLC April 2008

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legacy data center design issues

A legacy data center typically has the following characteristics:

- A free open air system that delivers cold air at about 55° Fahrenheit via overhead ducting or a raised floor plenum .
- Perforated tiles (in a raised floor environment) used to channel the cold air from beneath the raised floor plenum into the data center.
- Rows of enclosures orientated 180° from alternate rows to create a hot aisle and cold aisle room design.
- Minimum of four feet separation between cold aisles and three feet between hot aisles.[1]
- Precision computer room air conditioning units (CRACs) located at the ends of each hot aisle.

In practice, the airflow in the legacy data center is very unpredictable, and has numerous inefficiencies, which are proliferated as power densities increase.

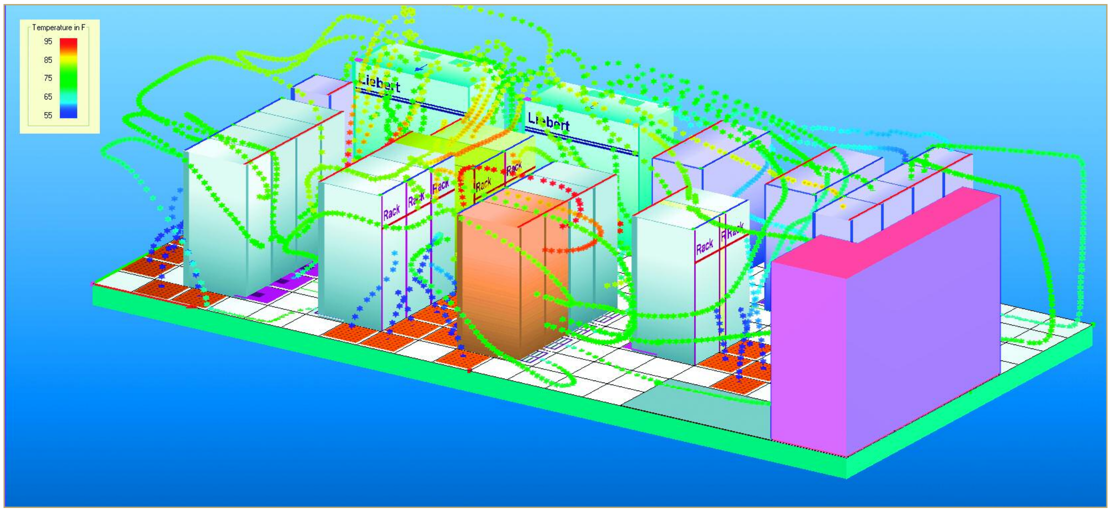


Figure 1

This is shown in great detail in Figure 1 where bypass air, recirculation and air stratification are the dominate airflow characteristics throughout the data center.

bypass airflow

Bypass airflow is defined as conditioned air that does not reach computer equipment[2]. The most common form of bypass air, is when air supplied from the precision air conditioning units is delivered directly back to the air conditioner's intake. Examples of this include leakage areas such as air penetrating through cable cut-outs, holes under enclosures, or misplaced perforated tiles that blow air directly back to the air conditioners intake. Other examples of bypass airflow include air that escapes through holes in the computer room perimeter walls and nonsealed doors.

A recent study completed by engineers from Upsite Technologies, Inc.™ and the Uptime Institute, Inc® concluded that in conventional legacy data centers only 60% of the air delivered from precision air conditioning units makes its way to cool the existing IT equipment. This not only amounts to a tremendous waste in energy, but also an excessive and unnecessary operational expense.

[1] Recommendations as per ANSI/TIA/EIA-942 April 2005

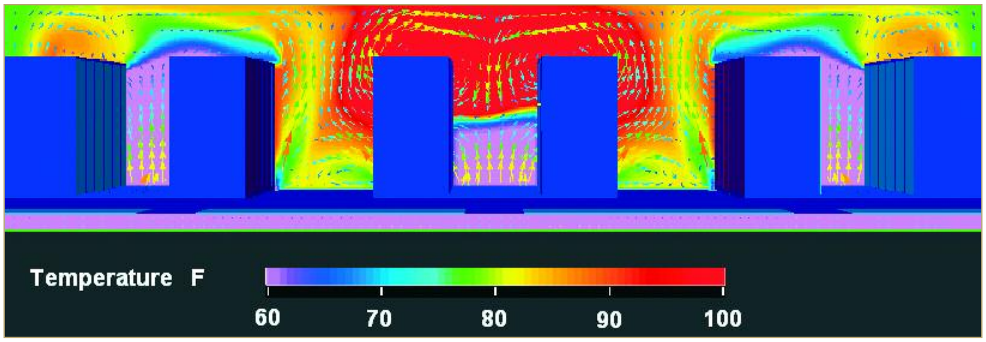
[2] Reducing Bypass Airflow Is Essential for Eliminating Hotspots By Robert F. Sullivan, Ph.D.

recirculation

Recirculation occurs when the hot air exhausted from the rack-mounted computing device is fed back into its own intake. This principally occurs in servers located at the highest points of a high density enclosure. This is illustrated in Figure 2 by the large area shown in red. Recirculation can result in potential overheating and damage to computing equipment and as a result may cause disruption to mission-critical services in the data center.

hot and cold air remixing and stratification

Air stratification in the data center is defined as the layering effect of temperature gradients from the bottom to the top of the enclosure.



In general in a raised floor environment, air is delivered at approximately 55° Fahrenheit from under the floor through perforated tiles. The temperature, as the air first penetrates the perforated tile, remains the same as the supply temperature, but as the air moves vertically up the enclosure, air temperatures gradually increase. In high density enclosures, it is not uncommon for temperatures to exceed 90° at the server intakes mounted at the highest point of the enclosure. However the recommended temperature range for server intakes as stated by ASHRAE Technical Committee 9.9, Mission Critical Facilities is between 68° and 77° Fahrenheit[3]. Thus, in a legacy data center design we are essentially over cooling the computer room by sending extremely cold air under the raised floor because there is a lack of temperature control as the air moves upward through the front of the enclosure.

data center heat source

processor performance – need for speed

In our modern economy the fact remains that companies need to maintain growth and profitability which demands delivery of better, faster, richer and more reliable products and services to remain competitive. Thus, "the need for speed" reflects a modern day business compulsion to consume increasing levels of computing performance to attain a competitive advantage. However, until recently most information technology departments never associated this exponential growth of processing power with power consumption. The fact is the ratio of processor performance, with respect to power, has increased significantly over the last several years. In other words, the processor manufacturers have made some significant technology breakthroughs to increase the performance of the processor while consuming less power. The actual culprit of the power consumption issue is related to the exponential growth in power densities. Processor manufactures such as Intel Corporation® and Advanced Micro Devices®, Inc. are making the processors smaller and denser, so that server manufacturers can incorporate greater numbers of processors in a smaller footprint. Data collected by Intel has shown that current processor technology consumes 24% of the power consumption to execute the same workload, in roughly the same time period, as the processor technology that was used in 1999. However, the power density has increased by a factor of 16 times since 1999.

[3] Thermal Guidelines for Data Processing Environments, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Technical Committee 9.9 "Mission Critical Facilities, Technology Spaces and Electronic Equipment ISBN 1-931862-43-5 2004

processor performance – need for speed – continued

Practically every server on the market today is equipped with an internal fan system to take in cool air from the front and exhaust it out the back. How much airflow is required to effectively cool a server? This question is typically answered using the following formula, where the airflow required to cool the equipment is related to the power consumed by the device.

$$CFM = 3.16 \times Watts / \Delta T$$

CFM = Quantity of Airflow
Watts = Heat dissipated or Power Consumed[4]
ΔT = Difference in temperature in degrees Fahrenheit between the server exhaust and supply air entering the server intake.

This would normally seem quite straight forward, however the one thing that is important to note is that CFM is only generally related to power consumption. The actual fan speed in the server is controlled by internal temperature sensors within the server. When higher temperatures are detected at the sever intake, the fan speed will increase regardless of how much power is consumed. Thus, power efficiencies can be achieved by maintaining server intake temperatures at recommended operating range levels.

Hewlett Packard®, Sun Microsystems Inc.®, Dell Inc.® and IBM Corp.® publish specific environmental operating requirements that the end user must meet to ensure their devices will function properly and be covered under warranty. These conditions include a minimum and maximum operating temperature at the server intake, a relative humidity range and the quantity of airflow measured in CFM required at the server's intake.

closed coupled heat containment

What is a closed coupled design?

The legacy data center is an open system where air is allowed to move freely throughout the data center. A closed coupled design is a solution where all the air that is supplied by the computer room air conditioners is delivered to the intakes of the rack-mounted computing equipment and all the hot air exhaust is delivered directly back to the intake of the air conditioning system.

There are essentially two current methods available for achieving a closed coupled design.

1. Cold Air Containment
   A cold air containment system is one where the cold air supply from the computer room air conditioning unit is isolated, and the hot air is allowed to move freely throughout the room. This can be done by completely isolating the cold aisle in the data center or using a ducted enclosed channel attached to the front of the enclosure that draws cold air directly to the server intakes.

2. Heat Containment
   Heat containment is achieved by capturing all the hot air that is exhausted from the rack-mounted computing equipment and directing it to the intake of the CRACU without any cold air contamination. This can be accomplished by enclosing the hot aisle, or enclosures, and having a heat rejection system pump the heat from these contained units out of the data center. A ducting system that directs the hot air from the rear of the enclosure to the air-conditioner intake can also be employed.

Heat containment is the more dominant solution in high-density deployments because it allows for a far more comfortable working environment. With cold air containment the hot air is allowed to move freely throughout the room, thus promoting uncomfortable operating conditions where 100° plus temperatures can be reached.

[4] The inference of using watts consumed as part of the heat transfer equation is that every watt of power consumed in the server is converted to heat.

closed coupled heat containment solutions

Closed coupled design is an adaptive concept that is built on the premise of providing customers with ease of deployment that integrates with existing infrastructure. Not unlike Lego™ building blocks, once the foundation is created all the other pieces fit together. Once an adaptable enclosure frame is installed there are several solutions available to the customer. Each solution has its benefits.

<u>Passive Exhaust System</u>
The Passive Exhaust Heat Containment System incorporates a chimney that is attached to the back of an adaptable frame enclosure. In this case the chimney is designed over the rear corner of the enclosure to ensure access to overhead cable management such as ladder trays. The heat containment system relies on all the hot air exhaust to be directed through the chimney, thus much attention has been placed on minimizing any air leaks in the enclosure. The enclosure must be deployed with a sealed solid back door and cover other exposed areas to ensure the air exhaust does not leak outside the enclosure. The passive system is dependent on computing equipment exhaust fans to deliver enough volume of airflow to pass through the chimney. Thus in a passive exhaust system configuration, it is essential to remove all congestion behind the server exhaust fans such as cable management arms.

<u>Assisted Exhaust System</u>
An Assisted Exhaust Heat Containment System uses fans within the attached enclosure chimney to assist the airflow through the ducted vent. This system should be used in conjunction with a fan speed controller to optimize the airflow volume within the enclosure. One of the advantages of the assisted system is the ability to control the flow of air. If the airflow exhaust from the servers is too large there will be an increase of pressure buildup within the enclosure and the hot air will escape through unintended parts of the enclosure including the bottom of the enclosure and extraneous cable pass through holes. If the server exhaust is not strong enough, cold air from the surrounding room can enter into the rear of the enclosure causing remixing. The key strategy in using an assisted exhaust based system is to control the flow of air such that there is a slight negative pressure at the very top of the enclosure and a zero static pressure throughout the rest of the rear portion of the enclosure. This strategy will optimize air flow performance to ensure the heat is exhausted correctly without cold air contamination.

application of heat containment system

Closed coupled heat containment solutions are designed to adapt to existing infrastructures as well as provide a solution for greenfield applications. The application of heat containment systems increase efficiencies within the data center by reducing bypass airflow and recirculation, thus allowing the heat to flow directly to the air-conditioner's intake.

To achieve heat containment with the active or passive ducted exhaust option, the hot air exhaust that flows through the enclosure's chimney attachment must be used in conjunction with other building systems to continue the flow directly back to the precision air conditioner intake without remixing. There are effectively two methods to achieve this task.

1. Extend the adaptable enclosure's rear duct to a plenum ceiling
   A closed loop system can be attained by extending the rear duct from the back of the frame to a drop ceiling plenum and adding a ducted return from the ceiling plenum back to the air conditioner's intake. If a drop ceiling is in place, it minimizes the cost of building out a completely dedicated ducted heat return.

2. Direct Ducted Exhaust Return
   If no plenum ceiling exists, it may be possible to duct the hot air exhaust directly back to the air conditioner intakes. This provides a more controlled HVAC environment since the air path is 100% dedicated for the purpose of heat containment.

quantifying closed coupled efficiencies

Recent articles make generalizations about an enclosure's ability to cool based on power densities within the enclosure. Specifically, the enclosure is essentially a passive device[5] that does not provide any cooling whatsoever. Thermally, the function of the enclosure is to ensure that adequate airflow can be provided to computing equipment intakes and the heat generated from the equipment is not trapped within the enclosure.

However with the recent increase in power densities and data center energy costs the enclosure has evolved as a critical piece in the data center. The enclosure needs to be a part of an integrated strategy towards achieving greater efficiencies in the data center.

The foundations of closed coupled design efficiency savings can be established by optimizing four conditions.

1. Provide consistent air temperature between 68° and 77° Fahrenheit to all the computing equipment in the data center.
2. Ensure the temperature of air leaving the server exhaust matches as closely as possible the intake temperature of the computer room air conditioner.
3. Make certain there is sufficient air flowing to the intakes of all the computing equipment.
4. Ensure the computer room is sealed as much as possible and avoid air leakages wherever they occur.

In current legacy infrastructures cold air is supplied from the precision air conditioners at very cold temperatures in the range of 55° Fahrenheit. The reason the air is supplied at such cold temperatures is to counter the effects of high temperatures detected at the top of many enclosures caused by hot and cold air remixing. However if the heat can be contained and not remixed with the cold air, there is no reason to supply such cold temperatures under the raised floor. Studies have shown that by increasing the chilled water supply temperature from 45° to 55° or raising the air supply temperature to 65 degrees that you will achieve a 25% energy savings from the chiller[6].

In part, the losses in cooling efficiency can be derived by comparing the Delta T values between the computing devices and the air conditioner. In other words, if all the heat that is exhausted from the computing equipment is delivered directly back to air conditioners without remixing and all the cold air supplied from air conditioners is fed to the intakes of the computing equipment, then the Delta T values should practically be identical.

This is the ideal situation for creating optimal efficiency using forced air as a medium for cooling. In a legacy data center it is not uncommon to detect air conditioner Delta T values at around 15° Fahrenheit with the average Delta T per device in the range of 27°-35° Fahrenheit. This inefficiency is attributed to by-pass airflow, but also represents a waste of valuable supply air in CFM that should have been delivered to the computing equipment intakes. Thus close containment of the heat exhaust and delivery of the heat directly back to the air conditioner is one of the most important strategies that can be used to meet server manufacturer's air intake requirements. More importantly, it will optimize the airflow dynamics within your data center to drive up its efficiency.

Wright Line, a global leader in the design and manufacture of consoles, enclosures, office and other specialty furniture, has been serving the data center, office, call center, electronic laboratory and high-tech manufacturing environments for nearly 75 years. Our innovative designs are manufactured to the highest quality and safety standards.

[5] With the exceptions of enclosures that include internal heat exchangers.

[6] A Strategic Approach to Datacenter Cooling Dr. James Fulton, Associate Professor of Mathematics Suffolk County Community College – Selden, New York April 2008