WEIGEL
MECHANICAL ELECTRICAL PLUMBING & FIRE PROTECTION

Contractor's License 414070
823 San Aleso Avenue
Sunnyvale, CA 94085
Tel: (408) 252-2338
Fax: (408) 252-2780
www.weigelmep.com

GIVING DATA CENTER COOLING SYSTEMS A BOOST

By Gary Storck, PE/CEM/CPE
8/26/02

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Server Density/Heat Transfer Trends

Operators, managers, users, and designers/developers of large Data Centers and Computer Rooms are constantly striving to put as much computer hardware into their available space as they can. This has led to high density, tall, compact, double-density (double-sided) rack systems. At the same time, computing speed is increasing per Moore's law (speed doubles every 18 months) due to the demand for and development of more complex software/interfaces. This typically leads to more heat generation even though there have been advances in energy efficiency. These two factors (server density and heat transfer increases) combined have greatly reduced the effectiveness of traditional cooling systems (Computer Room Air Conditioners – CRACs, Computer Room Air Handlers – CRAHs, In Space Units – ISUs, …)

Traditional Data Center Cooling Systems

Most large Data Centers and Computer Rooms utilize many small packaged Computer Room Air Conditioning or Air Handling systems (CRACs or CRAHs) located atop the raised floor amongst the computer/server equipment. Both of these systems typically pull warm air in at the top (~ 5-6' above the raised floor or from a ceiling plenum), condition the air (per temperature and humidity setpoints), and provide cool air to an underfloor plenum. Air is then passively allowed out of the underfloor plenum through the use of perforated floor tiles.

The heat that is pulled out of the air is then transferred out of each of the CRACs or CRAHs via underfloor Condenser or Chilled Water Piping systems to Cooling Towers, Condensing units, and/or Chillers located outside of the Data Center. Each CRAC or CRAH is also attached to a Condensate Drainage system and, in some climates, Makeup Water piping for humidity control.

Distribution/Stratification Problems with Traditional Data Center Cooling Systems

Since the cool air is passively allowed out of the underfloor plenum, the distance that the air is "thrown" out of the perforated tiles relies on the pressure from the CRACs or CRAHs, the number of perforated tiles, the size/quantity of perforations, and the amount of space served by the CRACs and CRAHs. Another determining factor on the effectiveness of a traditional data center cooling system is the amount/configuration of the underfloor chilled or condenser water piping that serves these CRACs or CRAHs since this piping creates air restrictions to inhibit the flow of air. Since the external static pressure capabilities of the CRACs or CRAHs is typically 0.5" w.c., there can be areas where there is not enough cool air coming out of the underfloor plenum to effectively cool the computer equipment.

With condenser water piping in the underfloor cool air plenum, some of the heat that is in the condenser water piping (up to 125°F) will be reintroduced into the airstreams from the CRACs (typically 60 - 70°F) that are being supported by the condenser water piping instead of being transferred outdoors to its fluid cooler. This can increase the supply temperature through the perforated floor tiles, decrease the effectiveness of the CRAC units, and waste energy.

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Also, since warm air rises and cool air falls, natural convection can overpower the trickle of cool air supplied up through the perforated floor tile. Without active circulation in place (natural or otherwise), the air stratifies into different temperature layers. This results in higher supply and operating temperatures in servers at the tops of the racks (see Figure 1 below). In an effort to resolve this problem, many Facility Managers have been forced into **lowering the supply temperatures from the Data Center cooling plants**. However, the problem with this methodology is that it **wastes energy due to the fact that equipment efficiencies are also reduced at the lower temperatures.** Again, this costs the Data Center owner or client money.

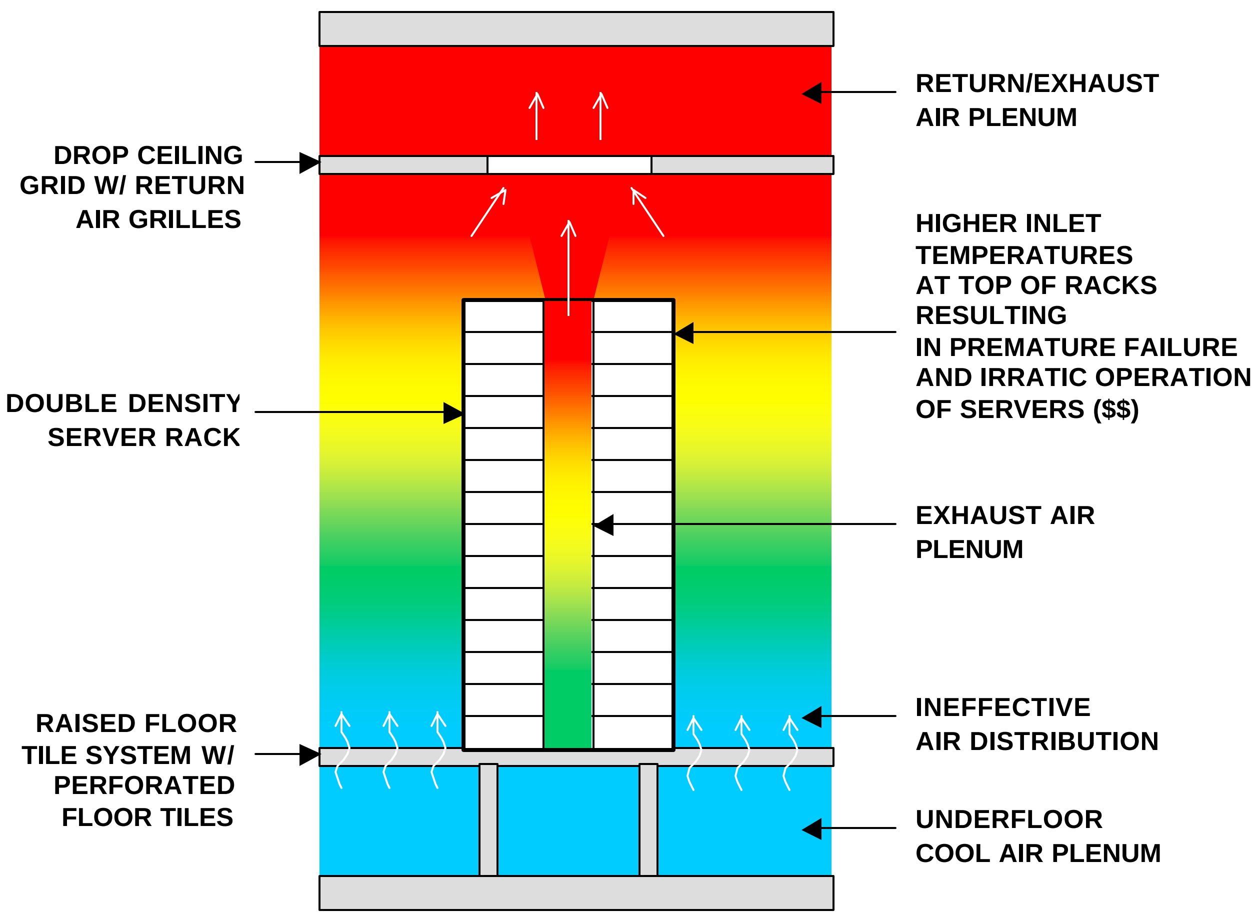

FIG 1: TEMPERATURE STRATIFICATION PROBLEMS

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Discussion on Operating Temperature vs System Reliability

At elevated temperatures, electronic components can fail catastrophically or the electrical characteristics of the chips can undergo intermittent or permanent changes. Manufacturers of processors and other computer components specify a maximum operating temperature for their products. A loaded server/computer with improper cooling can easily experience operating temperatures that exceed these limits. The results of improper cooling can be seen as memory errors, hard disk read-write errors, faulty video, and other problems not commonly recognized as heat related.

There have been many studies by public and private agencies over the years that have found that the life of an electronic device is directly related to its operating temperature. These studies, based on empirical data, were used to create models/standards for determining equipment reliability. (MIL-HDBK-217, Bellcore TR-332, and the Arrhenius equation are examples.)

In applying the Arrhenius equation [1],

$R=Ae^{(-Ea/kT)}$ where

R	Failure or Reaction Rate
A	Empirical Constant
E_a	Activation Energy (eV)
k	Boltzmann's Constant (8.6×10^{-5} eV/K)
T	Temperature in degrees Kelvin

or,

$\text{Log}(R2/R1) = (E_a/2.303k)^* ((T2-T1)/(T1^*T2))$ with an activation energy of 0.4 eV (which is typical for electronic failures)

it can be seen that each 10°C (18°F) temperature rise reduces component life by 50%. Conversely, each 10°C (18°F) temperature reduction increases component life by 100%. Therefore, it is recommended that computer components be kept as cool as possible for maximum reliability, longevity, and Return On Investment (ROI).

InViroPakÔ RAD Solution

To combat this problem, Weigel MEPF, in partnership with First One, Inc. designed and patented (pending) the InViroPak™ RAD (Raised-floor Air Distribution) units. Two basic models (Booster Blower and Fan Coil designs) have been created with multiple options and sizes (1, 1 ½, & 2 ton). The standard Booster Blower units consist of a compact Air Handler to actively pull cool air from the underfloor plenum through a custom 24"x24" Raised Floor Tile with bulkhead fittings into 6 or 8' tall flexible anti-static fabric ductwork (or other air distribution equipment such as supply grilles or registers). This ductwork then directs the cool air equally across the face of all servers on each rack via nozzles or reinforced linear slots. Note that the Booster Blower design can be added to an existing cooling system with CRAC units or it can allow consolidation of cooling equipment into remote (consolidated) Air Conditioners.

[1] Test & Measurement Europe / August – September 2000, "The Effect of Temperature on Failure Rate", Jon Titus

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The Fan Coil design is similar to the Booster Blower; however, it is provided with a Chilled Water Coil to actively cool air from the underfloor space after it has been pulled from the Ceiling Plenum. These units are then tied into an existing Chilled Water system.

The InViroPak™ RAD units, coupled with properly designed Cooling Plants, eliminate heat added to the room and the associated stratification. As seen in the Figure 2, typically 2 units are provided for each double density rack since the intakes for each server are typically on the exterior with an exhaust plenum on the interior of the rack. However, note that the InViroPak™ RAD units can be sized differently to accommodate each application. Also, since some servers pull from a center plenum within a rack, the InViroPak™ RAD units come with optional horizontal discharge ducts. Some of the other optional features include: automatic speed controls (manual speed controls are standard), fan proving switch (for feedback to a Building Automation System), filters with side or top access, lifting handles, filter status switches (for feedback to a Building Automation System), higher floor tile load ratings, colors, tile covering, duct support hardware, registers/grilles (in lieu of the fabric ducts), low velocity anti-static fabric ducts, …

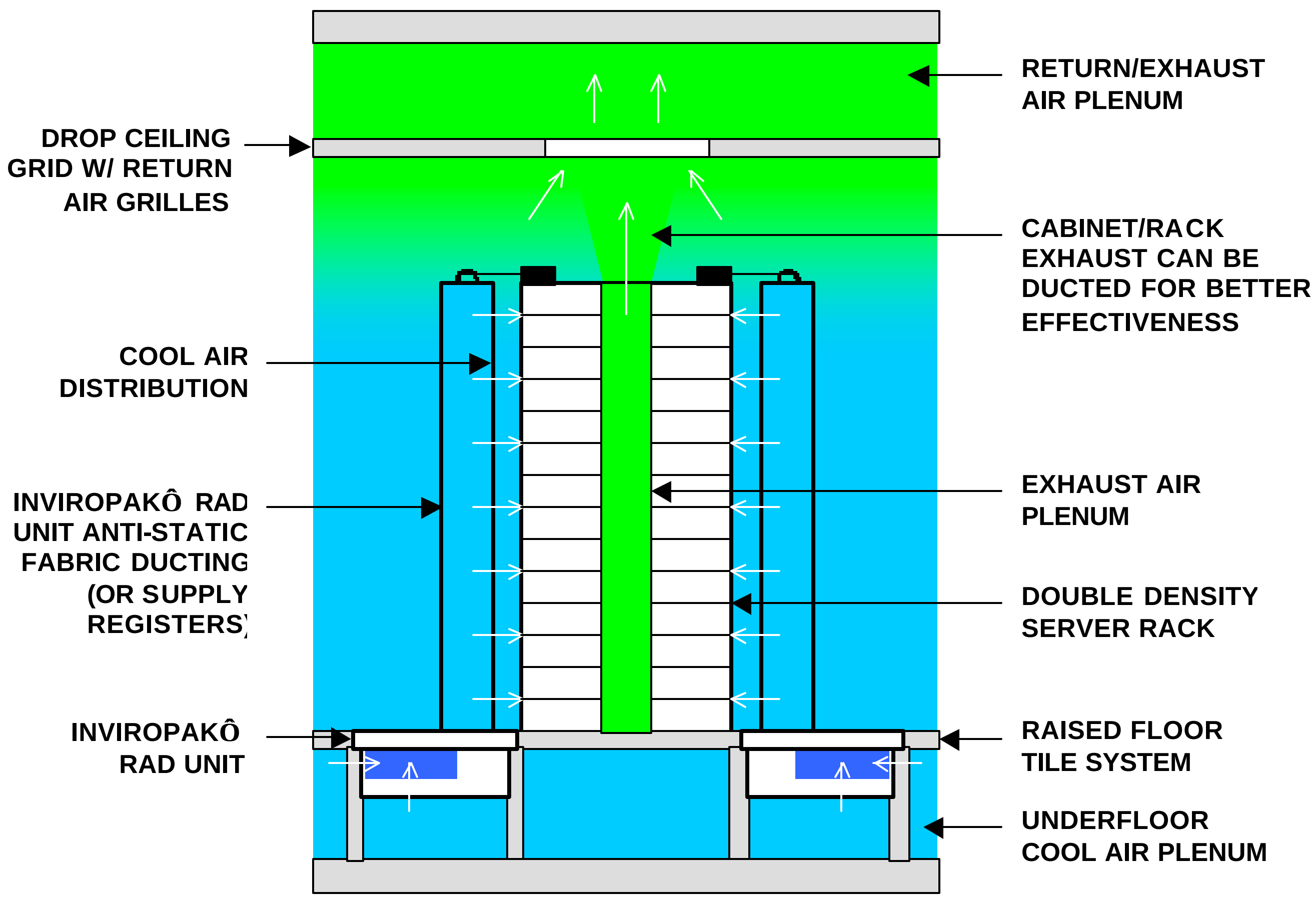

FIGURE 2: INVIROPAK RADÔ SOLUTION

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Server Life Increase

With a traditional Data Center Cooling System, temperatures of 80 to 90°F (***or more***) have been seen at the intake of Servers from the middle to the tops of the racks. This typically leads to a decreased reliability where the servers are either failing prematurely or having operational problems that may seem unrelated to overheating. At a cost of ***$1,000 to $10,000*** per server, the annual cost for Server replacement (not including interruption of service) can add up fast.

As stated previously, each 10°C (18°F) temperature reduction increases component life by 100%. Therefore, with a cooler "ambient" air supply to the servers from the InViroPak™ RAD systems, ***the annual cost*** in a Data Center ***for Server replacement*** (not including interruption of service) ***could be cut in half with a payback period measured in months*** (see assessment below). Note that this savings does not include the implementation of other benefits (as listed in the following sections) or the ***elimination of*** problems from ***customer dissatisfaction*** associated with the equipment overheating issues (which can be more valuable than the replacement costs). Financial losses from possible disruption in service due to overheating would also be reduced.

Existing Server Replacement Costs (w/ traditional Data Center Cooling System):

Data Center Size	10,000 SF
Total number of racks	333 (using 30 SF per rack)
Current Average Replacement rate	2 per rack per 6 months (conservative estimate considering 84 – 1U's per 8' rack)
Server Cost	$2,500 ea (conservative estimate considering some servers cost $10K+)
Current Annual Average Replacement cost	($2,500)*(2)*(333)*(2) = $3,330,000

Projected Savings (w/ InViroPak RAD Cooling System supplementing an existing Cooling System w/o any other changes in the facility – not taking advantage of capability of consolidation (assessment available upon request)):

Extends life of servers failing prematurely due to overheating by 100%

New Annual Average Replacement cost	($2,500)*(2)*(333)*(1) = $1,665,000
Estimated Savings per year	$1,665,000 (not including disruption of service costs)
Estimated cost for InViroPak RAD Units	$599,400 (666 units @ $900 list)
Payback period	($599.4K/$1.665M)*12 = 4.3 months

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Energy

As stated previously, the operation of cooling plant equipment at lower temperatures to compensate for ineffective cooling is accomplished by sacrificing its energy efficiency. Conversely, if the equipment can be run at higher temperatures without sacrificing the reliability of the computer equipment, a real energy savings can be reaped.

Upon reviewing published specifications from leading CRAH manufacturer's, it was seen that by increasing the supply setpoint from 72 to 75°F (3°F delta T) yet keeping the Chilled water parameters constant (at 45°F supply, 10°F temperature rise), smaller CRAHs (with fan motors 30 – 40% smaller) could be used to accomplish the same heat transfer. ***This energy savings can offset and, in some cases, can exceed the additional loads imposed by the incorporation of the InViroPakÔ RAD booster blowers.*** Additionally, the automatic Variable Air Volume controls can save an additional 40 to 60% of the power consumed by the InViroPak™ RAD units by regulating the fan speed to match the demand (versus running at full tilt all of the time).

Real Estate Benefits

Upon incorporating a higher supply setpoint, the CRAHs can be sized 25 – 35% smaller. Since the InViroPak™ RAD units are installed in place of floor tiles in the aisleways between racks/cabinets, they do not require additional space.

For a 10,000 SF Data Center that has 25% of its floorspace occupied by CRACs/CRAHs, the space savings associated with their downsizing equates to approximately ***625 SF of additional floorspace (8.3% increase)***. For a Web Hosting company charging $1,000/SF, this adds up to ***$7,500,000/year in additional revenue***. For a Data Center facility manager looking to save money, this allows for consolidation of facilities, liquidation of assets, and/or additional space that can be devoted to their core business.

Conclusion

The InViroPak™ RAD system is a very cost effective system that can be used to resolve existing fundamental heat transfer problems in Data Centers/Web Hosting Facilities. In addition, owners, operators, and users of Data Centers/Web Hosting Facilities can take advantage of the pressure boosting capabilities of the InViroPak™ RAD system by consolidating their cooling plants remotely (see the White Paper on "Taking Advantage of Booster Blowers in Data Centers.") In either retrofits or new construction, supplementing existing cooling systems or consolidating new cooling systems, ***the InViroPakÔ RAD system will pay for itself many times over***.