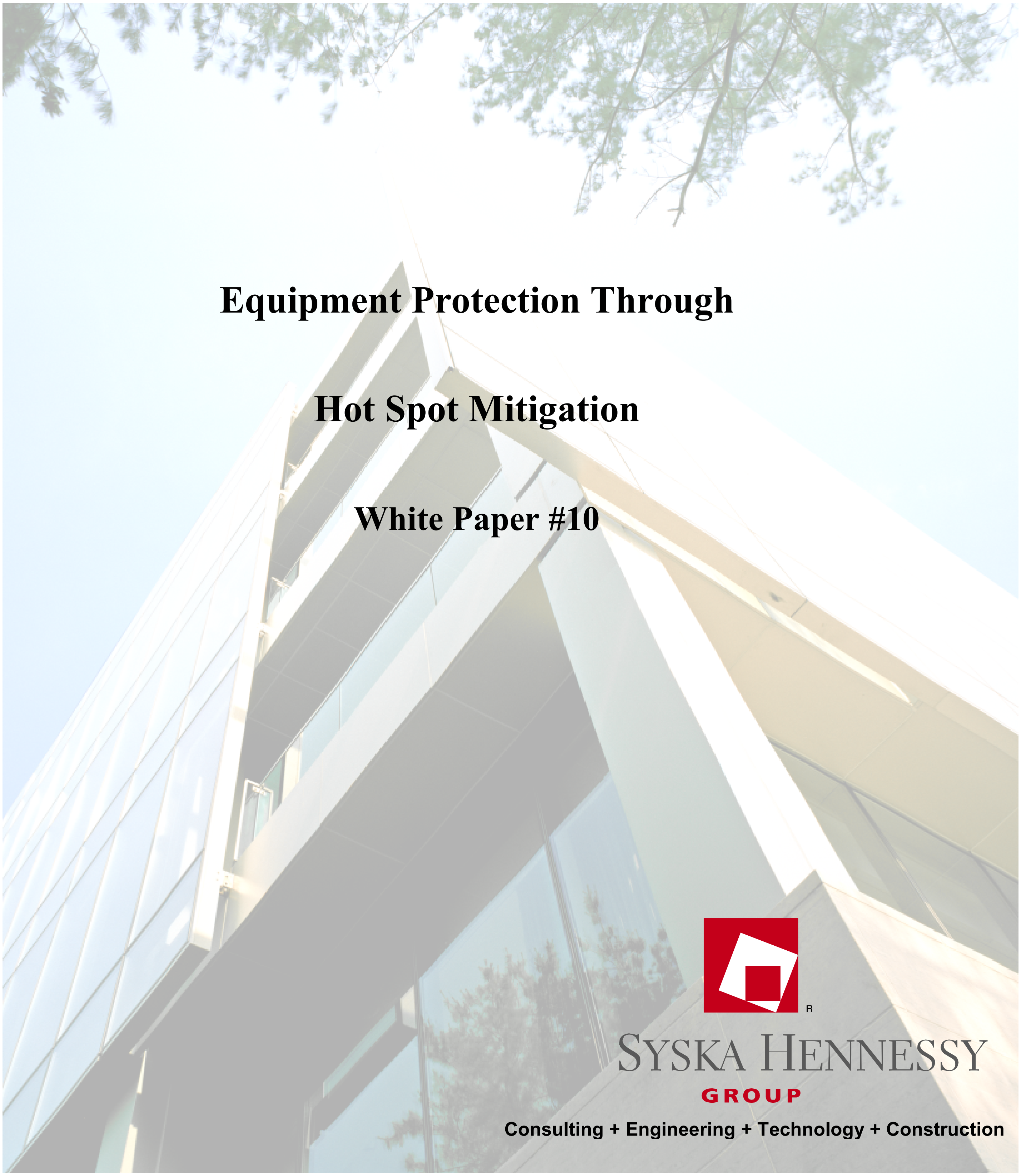

Equipment Protection Through

Hot Spot Mitigation

White Paper #10

SYSKA HENNESSY GROUP

Consulting + Engineering + Technology + Construction

Equipment Protection Through Hot Spot Mitigation
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Pillars of philosophy:

I. Load reconciliation
II. Air distribution evaluation
III. Facility operational & maintenance evaluation

One of the major problems facing critical environments today is a perceived lack of performance from the cooling infrastructure. Data center operators believe they have the installed cooling capacity to support their computer equipment and yet are still witnessing hot spots in their facility. This problem is amplified by the growing power densities of computer equipment that generate large amounts of concentrated heat in the data center.

Hot spots in the data center can be attributed to two main factors: A lack of cooling capacity and a lack of cooling delivery. When evaluating an existing facility with reported hot spots, these two factors should be examined carefully. Either the facility cannot generate enough cooling to compensate for the heat loads being generated on the floor or the cooling cannot be effectively delivered to the target area of control.

Examining the installed cooling capacity of a facility is the first step in this process. Is the heat load being generated in the data center less than what the facility was designed to handle? Is the load infringing on the facility's redundant capacity? How close to the capacity limits is the current loading?

After carefully studying the facility loads and capacities, examining the air distribution is the next step: There could be plenty of water in the well, but it may not be getting to the fire. Physical investigation of the data center can be performed and predictive tools such as computational fluid dynamics (CFD) modeling can be used to evaluate the air distribution performance of the facility. These tools can be used to optimize air flow within the data center, determine optimal CRAC unit placement and simulate equipment loading and failure scenarios.

Tied to both the facility's cooling capacity and air distribution is its operational performance. The equipment capacity may be installed at the data center but the equipment may be underperforming. Any breakdown or inefficiency in the cooling architecture, from the cooling towers to the CRAC unit fans can contribute to the problem of hot spots.

The key point when dealing with hot spots is not to use short-term solutions but rather use a holistic approach, treating the causes and not the symptoms. This approach will not only benefit the operating efficiency of the facility, but it will insure the computer equipment it supports has an optimized and robust infrastructure.

Load Analysis –

A successful load analysis starts with an up to date and accurate computer equipment inventory. IT and data center managers should keep a current manifest of the equipment they have deployed on their raised floor, indicating the equipment type, model number and location. From these data, equipment cut sheets can be cross-referenced for the manufacturer's stated heat rejection load values for the equipment and a heat load per rack can be calculated.

Some may argue that this is not an accurate portrayal of how the equipment operates in a live setting and, for the most part, they would be correct. Most server equipment today is under-utilized and performs well below the published values. The facility UPS and PDU load trending data are also needed in order to temper the calculated values; the load trending will give the accurate amount of power drawn into the data center, the calculated values will tell where and to what density the power is distributed. Branch circuit monitoring can also be used as an accurate gauge of load distribution.

It should be mentioned that as technologies such as virtualization are deployed to increase the utilization of the CPU, the heat loads of this equipment should be expected to creep toward their published values.

Once the total heat loads have been calculated, they can be compared to the facility installed capacity and, more importantly, the room capacity. In some of the cases observed, the client's calculated facility heat load has mushroomed beyond the planned zone cooling capacity and started to infringe on the redundant capacity. If an air conditioning unit in the zone failed, the remaining units would be in danger of failing to meet the load requirements. The load study and a CFD analysis of the space made a compelling argument for the necessity of additional cooling capacity on the raised floor. The CFD analysis helped determine the optimal location for that capacity.

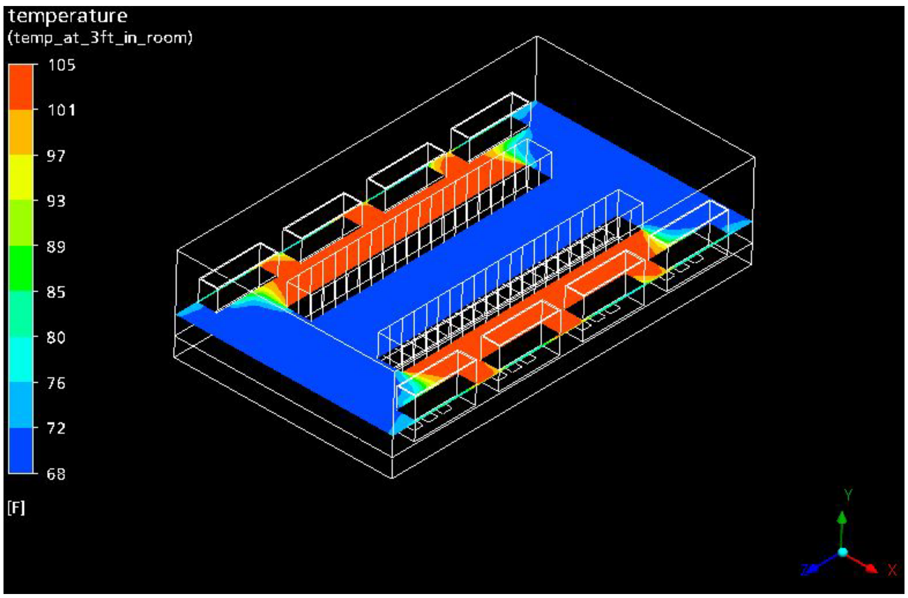
CFD Analysis –

The use CFD has become a popular tool in assessing air flow within the data center in recent years. Using physical data and the heat load analysis, a model of the room can be created to simulate the thermodynamic points of state (temperature, pressure, flows, etc.) throughout the room.

In ASHRAE TC9.9's publication "Thermal Guidelines for Data Processing Environments," (nASHRAE, 2004), the ideal temperature range for computer equipment is defined as 68°F-77°F at the inlet side of the equipment. This is considered as the primary variable in the CFD analysis; as long as this temperature is maintained in the model, specifically at the inlets to the equipment and under all scenarios, the room is functioning successfully.

This model allows for an examination of the temperature and air flow patterns within the data center. Hot spots are identified as areas that exhibit poor cooling air distribution and therefore elevated temperatures at the INLETS to the equipment. (It should be clarified that temperatures above the "Thermal Guidelines" range anywhere in the space other than at the equipment inlets do not qualify as "problem hot spots".) In fact, "hot spots" in the hot aisles indicate that the air distribution system is effective in maintaining a separation between the conditioned air entering the equipment and the hot air leaving the equipment.)

The thermal topography created by the CFD model can identify the location of these hot spots in the cold aisles as well as areas of over-cooling, short cycling of cool air back to the air conditioners and recirculation of air from the hot aisle into the cold aisle.



CFD Model above is typical example of how a raised floor space can be modeled for air flow and temperature gradients.

In one study, the client had wished to expand with higher density computer equipment into an area on the raised floor. The CFD model showed that this particular area was not well suited for this application due to the air conditioning unit arrangement and the path of travel for the rejected heat. It was also determined that a different area was better suited for the high density equipment because of increased cooling air flow and proximity to multiple air conditioning units, making the path of travel for the rejected heat shorter.

HVAC designs can be optimized using the CFD model by running several different scenarios varying the rack loading, air conditioning unit placement, and perforated floor tile placement. Additionally, different air conditioning unit failures on the floor can be modeled and their effect on the cooling air flow are studied, adding another level of confidence to the placement and operation of the air conditioning units.

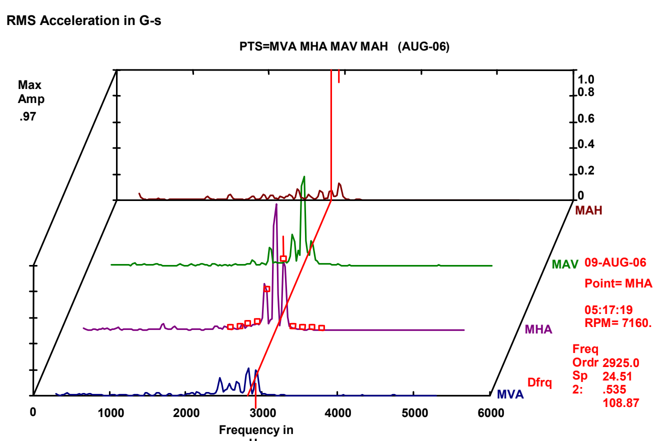
Assessing the existing HVAC equipment –

When considering renovations or other capital investments in a facility's existing cooling infrastructure, it is wise to evaluate the condition of your systems and equipment to make informed decisions on what to keep and what to replace. Fortunately, there are extremely powerful technologies available for just this purpose, referred to as "on-line condition monitoring". When these technologies are used to supplement a maintenance program (by employing baseline data, historical trend data, and pre-determined fault levels), these technologies make up what is known as a "predictive maintenance" program.

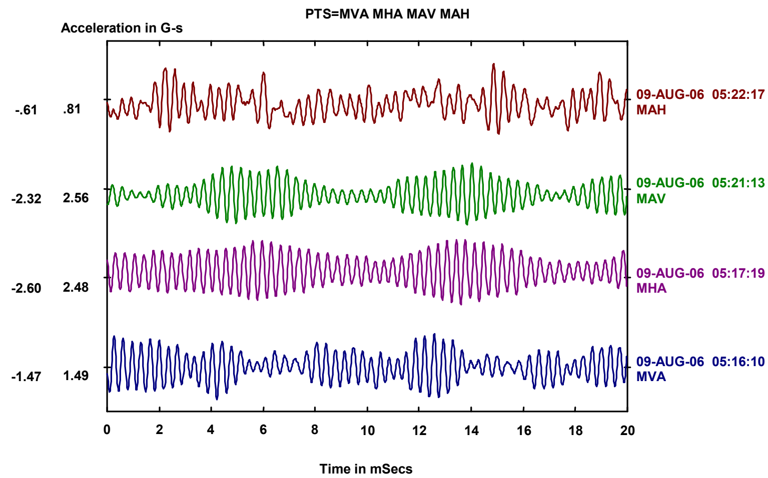
The first and possibly most revealing technology for rotating equipment employs vibration measurement and analysis. The basic concept has been around for many decades, starting with what was known as "shock-pulse" measurements. These sensors could measure a single-value, overall energy level associated with the vibration being measured. It was helpful from a go/no-go standpoint, but did not reveal much about the actual cause of the vibration.

Along with PCs and specialized software programs, today's vibration analysis technologies use accelerometers to feed vibration "signatures" to a PC where the vibration energy is measured across a spectrum of frequencies. The software, using Fast Fourier Transformation (FFT) programs, calculates the energy levels at each frequency and displays the data in graphical format.

By overlaying the operating parameters on the graph, it is easy to identify vibration levels corresponding to the rotation speed (RPM) of the equipment being tested. An astute technician can then identify root-causes of the vibrations such as misalignment, out-of-balance, mechanical looseness, bearing defect, resonance, belt-slap, gear-mesh, coupling defects, impellor defects, broken fan blades, etc. The corresponding value at each frequency can provide accurate data regarding the severity of the cause and, if trended over time, can predict when the problem will reach alarm or failure status.



Full Spectrum test results from a large centrifugal chiller identified high vibrations present at the compressor rotational frequency (about 2900 Hz) with sidebands that were indicative of a potential gear mesh problem resident in the drive gear box.



Vibration waveforms from the same centrifugal chiller and for the same points as shown in the previous figure help the technician analyze the data to determine the most likely root-cause for the high vibration condition.

By employing corrective technologies such as computerized balancing, laser alignment, water and air flow balancing, re-lubrication, and typical maintenance and adjustment procedures, some of the issues identified by the vibration analysis can be easily mitigated.

Another available technology is thermography, also called infra-red scanning. Commonly used by electricians to find loose electrical connections and other potential problems with motor starters, switchgear, etc., this technology can also be informative on HVAC equipment. Thermography can determine bearing problems, especially lubrication issues where bearings operate at elevated temperatures. Thermography can also find motor hot-spots and identify building envelope issues, missing insulation, and other problems that result in temperature variations.

Tribology, commonly known as oil or lubrication analysis, can also provide valuable insight into the operating condition of rotating equipment such as chillers, gensets, and other lubricated equipment. Not only does a lubrication analysis evaluate the condition of the lubricant, it can also identify the nature or source of contamination, which can reveal the root cause. Once the contaminate material is identified, it can be correlated to the source within the equipment, such as bearing material, shafts, housings, impellors, blades, etc.

There are many other aspects of a raised floor environment that should also be inspected for problems that result in loss of cooling capacity. Unsealed wall penetrations, poor vapor barriers, inadequate or poorly configured perforated tile placement, and unsealed tile cuts are familiar examples. Poor IT cable management at the rack level can prevent adequate air flow through racks regardless of how much cooling air is available in front of the rack.

To be consistent with industry standards in identifying “hot spots”, it is essential that measurements be taken consistently and at the appropriate locations. After all, “hot aisles” are supposed to be hot and should not necessarily be considered a problem. For specific, detailed information on how to measure and assess environmental conditions within a data center, refer to the previously noted publication “Thermal Guidelines for Data Processing Environments.” This publication provides standards and best practices for measuring temperature and humidity including floor locations, height and distance from equipment, number of measurements for adequate sampling, etc.

Other checks that should be made to assess HVAC equipment condition and capacity include refrigerant analysis and charge, calibration of sensors and controls, filter cleanliness, air volume and velocity, supply air temperature, chilled water pressure drop across cooling coils, CRAC “fighting”, and unnecessary latent cooling, etc. The goal is to determine if the existing equipment is capable of reliably operating at rated capacity. In many, if not most instances, easily remedied issues will be identified by performing some of these simple inspections.

If the facility was formally commissioned when initially brought on-line, the commissioning documentation can be very valuable in assessing the current operating condition of the cooling infrastructure. The original commissioning data should provide both the manufacturer’s stated capacities and ratings, as well as the baseline operating characteristics including air and water balance reports, pump and system curves, entering and leaving air and water temperatures, underfloor static pressure, etc. Comparisons between the present conditions and the original conditions can reveal obvious discrepancies that can lead to root-cause identification of operational problems.

Design engineers typically assume that installed equipment will provide rated capacities and then compare existing or predicted loads against the rated installed capacity. In many instances, the equipment as installed will not provide rated capacity due to poor setup or commissioning processes. Examples include: adjustable sheaves set incorrectly such that less than rated air flow is provided; clogged strainers, which prevent rated chilled water flow across the cooling coil; un-calibrated sensors, which cause fighting between CRAC units; humidity sensors, which are notoriously difficult to keep in calibration, causing humidification in one CRAC unit and dehumidification (coupled with reheat) in a neighboring CRAC unit; and excessively cold chilled water, which result in dehumidification at the cooling coil with simultaneous humidification by the humidifiers.

All of these examples demonstrate how seemingly healthy equipment can fail to perform to rated capacity, resulting in hot spots and environmental conditions outside of the design specifications. These issues may not be apparent at “day one” loads and may only become visible when the loads increase toward the maximum design rated loads. The lost capacity will result in hot-spots or conditions outside of the “Thermal Guidelines” specifications.

Summary -

To resolve “hot spots” and ensure that data center cooling infrastructure is optimized, the facility operator or engineer should employ a thorough review, evaluation, and assessment process that includes load reconciliation, air distribution evaluation, and systems operational assessment. Hot spots can typically be attributed to either a lack of cooling capacity, or inability to deliver the cooling where it is needed.

Any assessment should start with a load analysis that includes sufficient granularity to identify where the low density as well as the high density loads is located within a space. The next step is to analyze the air distribution performance to determine the air flow characteristics necessary to satisfy the loads for all locations. This should include failure scenarios to ensure adequate redundancy exists to meet the facility's operational risk requirements. Finally, the operator/engineer should assess the actual operational condition of each critical system and component to verify that the infrastructure can perform to rated design capacity.

This should include evaluating the operational parameters and control set points to ensure CRAC "fighting" and unnecessary latent cooling (dehumidification) are avoided. Hopefully, the results of this process will be to eliminate the "hot spots" through the optimization of the existing infrastructure. If not, then the results of the evaluations and analysis should provide valuable insight and direction as to what facility and/or infrastructure modifications or upgrades will best serve the site.

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These white papers are not intended, nor would it be practical to assume it possible, to cover all of the detail considerations that should be addressed related to hypercritical facilities in a particular operational setting, business, market or location. Nor should they be deemed to constitute legal advice ad to how organizations meet their respective obligations in this challenging and varied area of concern. For further specifics items of information that might be of interests or concern to the reader, one is encouraged to contact Syska Hennessey Group directly, or to visit the firm's website at *www.syska.com*. There is found on the website a link to our "ask the experts" feature for questions related to critical operations and hypercritical facilities.