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Energy Management Subcommittee

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SCTE 274 2021

Cable Operator Critical Facility Air Containment Operational Practice

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1. Introduction

1.1. Executive Summary

This operational practice will address how airflow containment can be an effective strategy leading to increased critical facility efficiency, availability, and energy reduction. Airflow containment is the practice of controlling the flow of air in one or more ways such as hot aisle/cold aisle rack arrangement or other means that will be discussed in this operational practice. This document will expand on the topic introduced in SCTE 219. Also, SCTE 253 provides background information on setpoint management where airflow containment will help optimize that setpoint practice.

1.2. Scope

This document will explore the various types of air containment: hot aisle, cold aisle, chimney cabinets (which are another method of hot aisle containment) and associated systems. It will provide guidance on which methods to use for various scenarios faced daily by cable operators, for both legacy sites and new building design.

1.3. Benefits

All cable operators, telco providers, and data center managers are faced with keeping their electronic equipment environments in strict compliance with acceptable temperature ranges according to industry standards, codes and Service Level Agreements (SLAs). In addition, as energy use becomes a primary social and business consideration, the efficiency of cooling systems has become a major area of focus. There are a variety of ways to achieve this compliance through air conditioning via mechanical cooling as well as free airside economization where geographically feasible.

The operational benefits of containment are improved efficiency, increased cooling capacity, and more homogeneous distribution of cold supply air to the intake or inlet of IT equipment. The results from these benefits are, respectively: lower energy consumption, fewer cooling units required, and more effective control of the space. This applies regardless of the type of containment, whether hot aisle or cold aisles are contained.

1.4. Intended Audience

Facility design engineers and facility managers

1.5. Areas for Further Investigation or to be Added in Future Versions

Beyond containment the topic of rear door heat exchangers to remove heat directly at the rack is in a separate category to be considered. Heat removal using liquid or immersion cooling are possible in the near future as air cooling reaches its limitations. Future development of a selection matrix of solutions and kW heat removal required.

2. Normative References

The following documents contain provisions which, through reference in this text, constitute provisions of this document. The editions indicated were valid at the time of subcommittee approval. All documents are subject to revision and, while parties to any agreement based on this document are encouraged to investigate the possibility of applying the most recent editions of the documents listed below, they are reminded that newer editions of those documents might not be compatible with the referenced version.

2.1. SCTE References

No normative references are applicable.

2.2. Standards from Other Organizations

No normative references are applicable.

2.3. Published Materials

No normative references are applicable.

3. Informative References

The following documents might provide valuable information to the reader but are not required when complying with this document.

3.1. SCTE References

[SCTE 184] SCTE 184 2015: SCTE Energy Management Operational Practices for Cable Facilities

[SCTE 186] ANSI/SCTE 186 2012: Product Environmental Requirements for Cable Telecommunications Facilities

[SCTE 203] ANSI/SCTE 203 2014: Product Environmental Requirements for Cable Telecommunications Facilities —Test Methods

[SCTE 210] SCTE 210 2015: Performance Metrics for Energy Efficiency & Functional Density of Cable Data Generation, Storage, Routing, and Transport Equipment

[SCTE 211] SCTE 211 2015: Energy Metrics for Cable Operator Access Networks

[SCTE 212] ANSI/SCTE 212 2015: Cable Operator Energy Audit Framework and Establishment of Energy Baseline

[SCTE 213] ANSI/SCTE 213 2015: Edge and Core Facilities Energy Metrics

[SCTE 219] SCTE 219 2015: Technical Facility Climate Optimization Methodology

[SCTE 253] SCTE 253 2019: Cable Technical Facility Climate Optimization, Operational Practice: Understanding Set Point Values, Part 1

3.2. Standards from Other Organizations

[ISO] ISO 50001:2011 Energy Management Systems – Requirements with guidance for use. http://www.iso.org/iso/home/standards/management-standards/iso50001.htm

[BICISI] ANSI/BICSI 002-2014, Data Center Design and Implementation Best Practices https://www.bicsi.org/book_details.aspx?Book=BICSI-002-CM-14-v5&d=0

[NFPA] NFPA 76 – 2020: Standard for the Fire Protection of Telecommunications Facilities

3.3. Published Materials

No informative references are applicable.

4. Compliance Notation

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shall not	This phrase means that the item is an absolute prohibition of this document.
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may	This word or the adjective "*optional*" means that this item is truly optional. One vendor may choose to include the item because a marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.
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5. Abbreviations and Definitions

5.1. Abbreviations

AHJ	Authority Having Jurisdiction
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
BICSI	Building Industry Consulting Service International
CAC	cold aisle containment
CRAC	computer room air conditioner
CFD	computational fluid dynamics
HAC	hot aisle containment
IT	Information Technology
kW	kilowatt, measure of power
MSO	multiple system operator
NSenCOP	net sensible coefficient of performance
RAT	return air temperature
SCTE	Society of Cable Telecommunications Engineers
ΔT	delta temperature – temperature differential

5.2. Definitions

appliance	IT Equipment
classroom style rack layout	The racks are all oriented with equipment cool air intake or inlets facing the same direction resulting in equipment hot air exhaust outlets facing the next row’s equipment inlet.
cold aisle	Air that is provided by a cooling unit supply air system with a temperature determined by room operating design conditions. This provides equipment inlet temperatures that are typically 65°F(18°C) – 80°F(27°C)
hot aisle	Air that is provided to the cooling unit return air system. This return air is provided by equipment outlets with temperatures that may reach on the order of 90°F (38°C) or greater
hot spots	Areas where the IT intake or inlet air temperature is too high caused by the mixing of cold supply air with hot return air, resulting in high temperature alarm on the IT equipment.
information technology equipment	Servers, optical transmitters or other devices that are supported at any facility addressed in this document
ton	ton of refrigeration, approximately 12,000 BTU/h or 3.5 kW
wrap around	With respect to air flow, and exhaust air pathway returning the hot exhaust air to the IT Equipment inlet

6. Air Flow Management

When implementing containment, it is useful to assess the existing air management in the space. If the room has underlying air flow problems, then these should be dealt with first to maximize the benefit of adding containment. Good air management practice applies to the overall room as well as the space internal to the rack. SCTE 219 Technical Facility Climate Optimization Methodology provides guidance for identifying air management challenges and remedial steps for improvement in the room and inside the IT rack.

Common problems in the space are created by items such as architectural characteristics of the room (columns, for example), suboptimal placement of cooling units and perforated tiles, and IT equipment rows that are not properly aligned to make optimum use of the supply and return air streams. Air leaking out of the raised floor plenum (around cutouts for conduits and piping, for instance) contributes to losses as well. While the solutions to some of these problems are complicated and prohibitively expensive, others can be solved with rather simple measures. Equipment cannot be easily moved but floor tiles can be rearranged, upgraded, and retrofitted with air flow management options.

Air flow management inside the rack is just as important as room management. If hot air discharge cannot escape a cabinet due to a cluster of cables blocking the flow, then all the other remedial measures outside the rack will not help. Blanking plates and cable management are often overlooked since they are usually outside the scope of an installing contractor or a facility manager.

6.1. Air Containment

Air containment enhances the benefits of a hot aisle / cold aisle room layout, which is well-documented in the industry.

Aisle containment can be thought of as providing a physical boundary between cool equipment inlet air and warm or equipment exhaust air. A containment strategy ensures that appropriately conditioned air reaches the air inlet or intake of the IT equipment and that the exhaust air of the IT equipment is returned directly to the computer room air conditioners (CRAC's). Containment also enables the deployment of high-performance computing equipment using traditional best practices in room design without requiring exotic supplemental cooling methods. Another case can be made for remedial treatment of an existing space that has sufficient cooling but is struggling to keep up due to less than optimum room configuration.

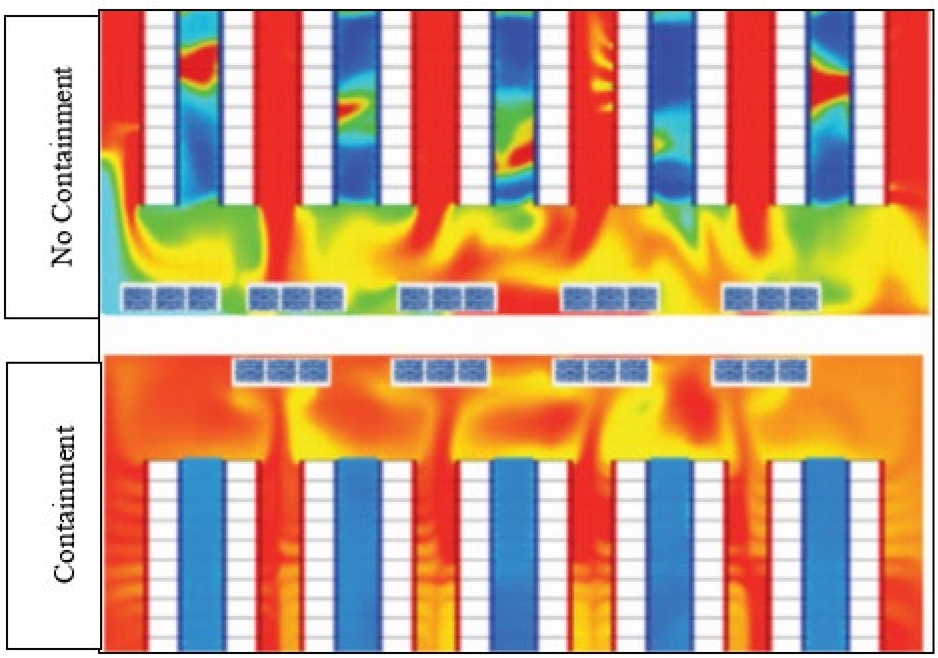

Figure 1 - Containment comparison - without containment (above, top) and with cold aisle containment (above, bottom)

6.1.1. Improved Efficiency

Separating hot and cold air streams results in higher return air temperatures which in turn increases the efficiency of the cooling unit. For example, if a nominal 30-ton (105kW) rated air-cooled system is deployed at a traditional return air temperature (RAT) of 72°F (22°C), then the resulting NSenCOP (Net Sensible Coefficient of Performance) is 1.70 at full load assuming a 95°F (35°C) ambient. If containment can be used to raise the RAT to 85°F (29°C) then the resulting NSenCOP is 2.28, a 34% increase in efficiency.

6.1.2. Increased Capacity

In the example above, the 30-ton system provides a sensible cooling capacity of 72kW at the lower RAT (72°F, 22°C), and when return air increases to 85°F (29°C) the resulting cooling capacity is 99.8kW, a

39% improvement. This could result in a similar proportional capital savings, for instance in a deployment of 5 units without containment the unit count could be reduced to 3 with airflow containment.

6.1.3. Improved climate control

When hot or cold aisle containment is deployed the reduced mixing of the cold supply air and the warmer return air results in a more uniform temperature gradient. Hot spots (areas where the IT intake or inlet air temperature is too high caused by the mixing of cold supply air with hot return air, resulting in high temperature alarms on the IT equipment) can be eliminated or at least minimized, depending on the scope and scale of containment achieved. This improvement in air management helps to capture stranded capacity, eliminate hot spots, and results in more effective cooling with a homogenous cold supply air temperature in the cold aisle.

6.2. Airflow Containment: Applicability

Applying containment enables the deployment of higher density IT hardware, either pre-configured in the engineering phase of a project or often after the fact as a remedial solution to an air flow management problem. Every situation is different, depending on the layout, architectural obstructions, distribution of the heat load, rack dimensions and the general room configuration to name a few of the potential challenges. Add to this that containment does not necessarily need to be an all-encompassing room solution but alternately it may be applied selectively to hot zone areas within a space.

When considering aisle containment, users and designers often ask: at what minimum heat load should containment be considered? In a rapidly changing IT environment, what is considered “high density?” Conventional wisdom varies on what constitutes a high-density load, but clearly the heat load density in racks is trending upward. Closer examination indicates that high density is a relative term. For instance, in a poorly designed room with ineffective air management, relatively low densities may be a challenge for the cooling system, even if the cooling capacity is properly matched to the heat load. But a room with optimal layout and ideal air management can be equipped to handle a range from 15 to 20kW per rack. Hence, when deciding about applying containment based on heat density it is probably best to think of a range rather than an absolute threshold.

Heat load in a facility is typically not evenly distributed. Racks in one area may have noticeably higher heat loads and may benefit from containment, while all other racks are at much lower heat levels. In these cases, partial containment may be a good solution. A number of factors need to be considered before making the decision on the most appropriate approach.

Another reason to consider partial containment is in cases that would require significant modifications to the fire suppression system if full containment were to be used. For instance, a completely enclosed cold aisle enclosed at the ends of the aisle plus containment across the tops of the racks would require the fire suppression system to extend into the contained space. But a partial containment at the ends of aisles without containment across the tops of the racks or with only partial top containment, as shown in Figure 2, could be deployed without extensive changes to the fire suppression system. The containment shown in Figure 3 which completely contains the sides and top, *would* require fire suppression changes.

Partial containment can be useful as an economical first step in the process of deploying an effective containment system in a heavily loaded room, or perhaps as an end in itself in a moderately loaded space.

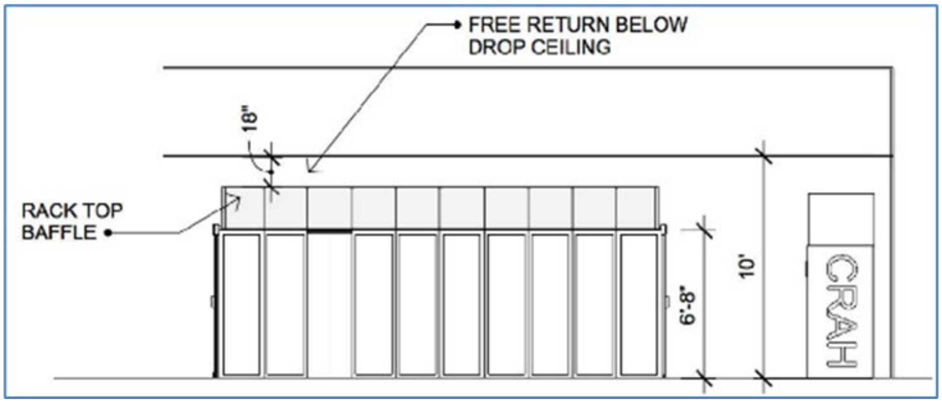

Figure 2 - Partial Containment with top curtain

Figure 3 - Complete Containment

IT space is generally designed with a raised floor or a non-raised floor (slab). Containment installation variations including complete fabricated enclosures typically consisting of clear containment panels, strip curtains, aisle containment doors or partial containment.

6.3. Preparing for Containment

Planning and preparing for deploying containment are tasks that can vary in complexity and detail depending on the requirements of the project. A full-blown CFD (computational fluid dynamic) model can predict air flow patterns, temperature mapping, and pressure gradients throughout the space. If there is an SLA in place, then a rigorous study may be required. On the other hand, if an existing space needs some improvement in air management then a more intuitive and experimental approach may be sufficient.

As a prerequisite, hot aisle / cold aisle configuration is basic to any successful containment strategy. There are some appliances (IT equipment) that do not comply with the standard front-to-back air flow convention, and for these devices there are usually some creative solutions to treat these separately or even some in-rack solutions to assist with redirecting air.

All efforts need to be made to ensure appliance air flow is all in the same direction, from cold aisle to hot aisle.

Physical rack size – Rarely are rack heights perfectly aligned, and containment needs to have the flexibility to accommodate various rack dimensions.

Space under the rack – IT racks can include feet that leave a gap underneath the rack. This space usually falls outside the scope of a containment system and can be treated with other available options.

Architecture of the room – Generally speaking, raised floors lend themselves to cold aisle containment, slab floors are more amenable to hot aisle containment.

Chimney racks, a form of hot aisle containment – some IT rack manufacturers provide an option for extending a plenum, or chimney, that can carry the hot exhaust air into a ceiling plenum directly routed into the plenum which provides an effective return air path to the cooling units. If there is no return air ceiling plenum, the chimney can still provide the advantage of stratification, exhausting the hot air into the highest point in the room to minimize mixing.

Doors, ceilings, curtains – determine what type of containment works best for the situation. Doors at the ends of aisles are often the least costly, least disruptive, and most effective treatment. CFD studies demonstrate that most of the hot air that escapes into the cold aisle occurs at the ends of aisles.

Curtains are easily implemented if it is determined that hard containment is not required.

Containment systems require consideration of fire suppression systems and local fire codes, see section 7.

6.4. Where Not to Use Containment

There are three layouts that will not benefit from containment:

1. Classroom style rack layouts (all oriented with equipment cool air intake or inlets facing the same direction resulting in equipment hot air exhaust outlets facing the next row’s equipment inlet.)
2. Locations where the equipment layout is random.
3. Locations which are 1500 square feet and/or 50 racks or less, and typically use cooling units mounted a wall.

6.5. Cold Aisle Containment

Cold aisle containment (CAC) provides a boundary to manage the cool supply air flow to the intake of the rack-mounted IT loads. Containment doors or curtains at either end of a cold aisle can create a “bathtub” effect, allowing the cold air to “fill up” the cold aisle with cool supply air and minimizing the wrap-around effect of hot air short-circuiting around the ends of the aisles. Adding ceiling containment across the top of the racks can further enhance air management by preventing hot air from encroaching into the cold aisle over the tops of racks.

6.5.1. Issues with Cold Aisle Containment

While there are benefits to this arrangement, there are also drawbacks. The main hurdle when implementing a CAC system is attempting to closely match airflow requirements between the CRAC supply and the IT demand. When CAC is used, supplying positive pressure into the cold aisle is essential to prevent the influx of warmer air. A nominal amount of positive pressure in the cold aisle will safeguard against recirculation or mixing air streams.

If the aisle is excessively positively pressurized, conditioned air may leak into the hot aisle and reduce the RAT to the CRAC unit. This will decrease the capacity and efficiency of the CRAC units.

In the case of a retrofit system, challenges include architectural obstacles such as columns, and overhead obstructions such as cable trays or ductwork. In a new construction facility, many of these challenges can be avoided or accommodated by a thoughtful layout of the equipment in the space.

Another challenge when applying cold aisle containment is the perception that the room is too warm. The air outside the CAC is subject to the influence of a mix of the hot air exhaust from the IT racks and whatever leakage is escaping from the cold aisle, and the resulting temperature in the hot aisle space is often warmer than a typical work environment. This elevated temperature is essential to providing the key benefits of containment: greater cooling capacity and higher efficiency. The perception to those unfamiliar with aisle containment in the IT facility may be that the warm environment presents a risk to the critical IT equipment in the space.

Some additional points for consideration include:

- Different rack heights make installation more complicated.
- The remainder of room can become a hot aisle possibly affecting return air efficiency, temperature and air flow negatively.
- In a cold aisle containment retro fit project, it is important to recognize the airflow implications to the balance of the data center or cable headend. The return air from the containment aisle (exhaust) needs to be managed correctly in that this elevated temperature can affect the intake conditions to servers that are not in a contained aisle. Airflow management is therefore critical in this “hybrid” type of room configuration.
- See Section 7 for fire detection and suppression considerations.

6.6. Hot Aisle Containment

Hot aisle containment (HAC) installations use virtually the same structures as CAC, with the objective of containing the hot air exhaust and directing it to the return air stream of the cooling equipment. In the HAC deployment, the environment outside the contained area is, essentially, the cold aisle. Temperatures inside the HAC can be uncomfortably warm for people working in the space.

HAC can be doors and walls built around the hot aisle in a facility that is designed with an intake / exhaust (hot aisle / cold aisle) arrangement. For a HAC design, the supply air is distributed to the cold aisle through air distribution tiles in the case of a raised floor environment or supplied via the ambient space in the case of a non-raised floor design. In both cases, the contained warm exhaust air is then sent directly back to the CRAC unit through ducting or a plenum with the intent of not mixing with the cold supply air to the critical equipment avoiding adverse effects of mixed cold and hot are at IT inlets or intakes.

6.6.1. Benefits of Hot Aisle Containment

The benefits of HAC are similar to those associated with the CAC arrangement. These include isolated return air flow paths, increased capacity of CRAC units and overall improved energy efficiency, by raising the temperature of the return air. HAC is isolating the hot exhaust air and allowing the laws of physics (hot air rises) to assist in keeping the space in compliance of the design parameters. The HAC approach is generally most effective when down-flow CRACs are deployed that utilize the space above a suspended ceiling as a return plenum.

6.6.2. *Issues with Hot Aisle Containment*

Working conditions within HAC may require evaluation and temporary remediations for the protection of workers and to comply with work environmental conditions due to OSHA requirements.

7. Fire Detection and Suppression

Because fire suppression systems are based on square footage and protected space volume any use of any form of containment will require an evaluation of the suppression system capacity and compliance to local authority having jurisdiction regulations (AHJ).

Fire Detection and Suppression changes may be required and the NFPA 76 is suggested to provide guidance in this area.

As always AHJ engagement is recommended.

8. Containment – Temperature Controlling and Monitoring Overview

8.1. Supply Air Temperature Control

As critical computer room spaces have evolved from room cooling to more targeted hot and cold aisle separation, the evolution of an effective control strategy for cooling units has fallen behind the physical changes. The need for more effective adaptation to hot/cold environments is even more pronounced when containment is added into the design. In legacy rooms, the average room temperature was a relevant control metric and the accepted practice was to use the RAT as the reference point for feedback to the control. But as rooms have evolved, load densities have increased and RAT to the CRAC has come to be defined as the hot aisle temperature, and the average room air temperature is no longer a practical control input. The more useful feedback metric is the cold aisle temperature which, after all, is the key parameter for maintaining proper temperature to the racks.

As a control metric, the hot aisle RAT is not useful as a direct feedback value. Some have tried to adapt by building in an offset value into the cold aisle set point, but this is an inexact science at best and requires constant minding to ensure that the cold aisle is maintaining the correct temperature.

In a supply air temperature control algorithm, remote temperature sensors provide feedback to the control processor and automatic adjustments are made based on maintaining the supply air temperature. Some hysteresis or deadband should be built into the algorithm so that the feedback loop between the control module and the CRAC doesn’t create a short-cycle oscillation between modes of operation.

Another control method in contained environments is to use a differential pressure sensor to maintain constant static pressure between the cold and hot aisles. This method is better suited to manufactured ‘low leakage’ containment. Temperature monitoring is important to ensure cold aisle temperatures. In fact, temperature sensors can be incorporated in a hybrid temperature/pressure control scheme.

9. Measuring Success of Containment

Air containment is implemented for a number of reasons including to improve thermal conditions, reduce cooling energy costs and to allow for increased IT load while maximizing cooling utilization. As indicated in previous sections, free flowing air in a hot aisle cold aisle configuration can meet the needs of rack heat loads equal to or less than 5-kW IT load. Beyond that some form of containment should be considered.

The decision to add containment can be driven by one or a combination of the following factors:

a) create more consistent thermal conditions throughout the critical facility
b) eliminate rack inlet hot spots
c) reduce cooling energy costs and increase efficiency of cooling systems by increasing ΔT
d) ability to add more IT load to a site without physical site expansion or addition of cooling equating to the deferral of expenditure on additional cooling systems

Determining the success of containment to attain any of the above goal requires some form of measurement.

If creating a better thermal environment and removing hot spots are the goals, then thermal monitoring on the racks would be appropriate prior to and post containment implementation. Continuous monitoring over at least a two-week period and ideally longer would establish the baseline conditions and a similar monitoring period post containment would provide the data to identify changes.

If the objective is to reduce cooling energy costs and improve efficiency of cooling systems, then energy metering on the cooling units should be done over a period of at least a month or longer. If the critical facility is in a weather zone where ambient temperature can have significant influence on cooling systems operation, then a longer metering period would be recommended. Keep in mind the installation of containment on its own will have a limited impact on reducing cooling energy. The higher RAT should result in the cooling units operating more efficiently however additional steps will need to be taken to maximize energy reduction. These could include reconfiguration of perforated tiles in a raised floor site, increasing RAT and possibly modifying humidity control points.

If the desire is to add more IT load to a site without physical expansion or addition of cooling, then a more thorough analysis on cooling efficiency and energy use is required. Increasing RAT not only enables the cooling unit to use less energy but also increases the cooling capacity of the unit. As noted in section 6.1.2 this can be 35% or more added cooling capacity. Translating the added cooling capacity into additional IT load requires a site to be fully optimized from an air flow perspective. The improved cooling efficiency can mean deferral of capital for cooling and ensure that N+1 cooling capacity is available.

Maintaining the optimized conditions of a site is a challenge unless there is continuous monitoring of thermal conditions and energy metering. The addition of higher density IT equipment can have a significant impact and unless these changes can be identified the eventual result will be a significant deterioration in site conditions. Real-time monitoring of thermal conditions can identify if cooling systems are beginning to show signs of operational issues which could result in higher rack inlet temperatures or equipment failure. Continuous energy metering of cooling systems will provide the data to determine how efficient cooling units are running, the level of cooling utilization and available cooling capacity. These all add up to knowing when more cooling capacity is needed and avoiding the issue of capital expense for unnecessary cooling.