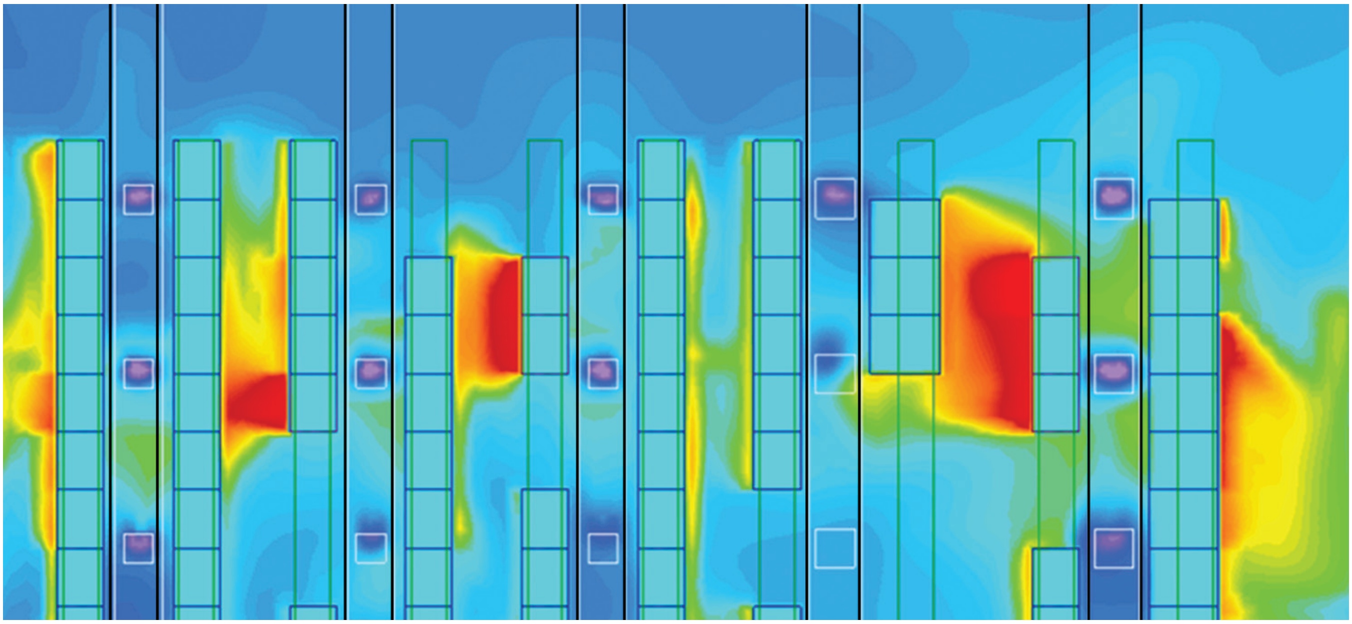

Load Strategies

For Telecom Switching Centers

By David Quirk, P.E., Member ASHRAE; and **Magnus K. Herrlin, Ph.D.,** Member ASHRAE

More electronic equipment of the type historically found only in data centers is finding its way into telecom switching centers. This trend is driven largely by the need to increase speed-to-market for new applications and services driven by customers' thirst for more data services and greater transfer speeds. The result is a shift in technology from switching to IP-based protocols and standardization of hardware platforms most commonly found in data centers. Generally, this equipment has high or very high heat dissipation compared to traditional network gear.

This migration may lead to complications in terms of physical network reliability. Cooling design of network rooms differs significantly from data center design. For example, overhead air delivery is dominant (no raised floor) and equipment facing the same direction is not uncommon. What is applicable to data centers is not necessarily applicable to telecom switching centers. When dealing with telecom facilities, those familiar only with data centers and books such as ASHRAE's *Thermal Guidelines for Data Processing Environments*[1] can benefit from understanding telecom-specific requirements and the principal telecom standards.

Managing the dense, diverse, and evolving network environments is a challenge. The telecom industry must understand cooling options so that new high-density equipment can coexist with legacy gear. Traditionally, Telcordia Technologies provided the leadership and guidance for telecom applications. Its "GR-3028-CORE, Thermal Management in Telecom Central Offices"[2] outlines a

About the Authors

David Quirk, P.E., is a senior engineer at Verizon Wireless in Basking Ridge, N.J. He is a corresponding member of ASHRAE Technical Committee (TC) 9.9, Mission Critical Facilities, Technology Spaces, and Electronic Equipment, and past president of ASHRAE's Akron chapter. **Magnus K. Herrlin, Ph.D.,** is president of ANCIS Incorporated in San Francisco. He is vice chair of TC 9.9.

procedure for determining acceptable overall heat densities of the network equipment through a comprehensive computational method, allowing for high flexibility in maximum equipment heat dissipation. This de-facto standard, however, did little to provide guidance on placing high-density point loads in existing switching centers.

Verizon Wireless took the initiative in 2006 to perform research to better understand the point-load issues by using the advanced modeling services of ANCIS Incorporated, building on the methods developed in GR-3028-CORE. The objective was to develop a strategy for deploying point loads in typical network rooms. The scope of this article is limited to providing an overview of several limitations, issues, and solutions discovered in the research. Although telecom-centric, the computational methods and point-load strategies are also applicable to many traditional data centers.

Background

Most existing network environments operate with a relatively uniform and low heat density of 50 W/ft^2 (540 W/m^2) or less, which generally means an average cabinet heat dissipation of less than 1 kW. However, equipment cabinets are available with power densities of 20 kW or greater. For this article, high-density cabinets are defined as greater than 5 kW.

It is common for high-density equipment to be deployed in existing low-density network environments. This is the result of two key events:

- The exponential increase in power density of network equipment; and
- Widespread industry network upgrades driven by market forces.

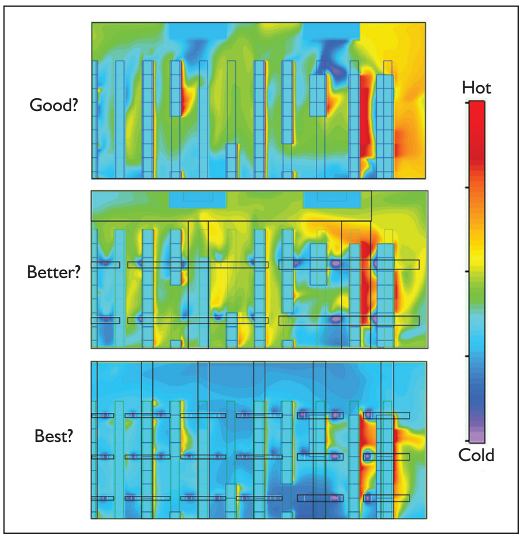

Figure 1: Temperature CFD data for three equipment environments (plan view).

Consequently, another challenge has presented itself; high-density point loads placed in low-density environments. A point load may be a single cabinet or a cluster of cabinets with a significantly higher heat density than the typical average density in the equipment room. It is more common for equipment operators to deploy new high-density equipment in their existing buildings, rather than to build a new high-density network equipment center. It may seem surprising that point loads and their impact on the existing network environment have not been better studied by the industry.

Limitations

There are many physical limitations in existing network facilities. Two of the major limitations are addressed in this section.

Low Design Heat Densities. Most existing network facilities were designed for heat densities below 50 W/ft^2 (540 W/m^2). Introducing high-density cabinets in these environments will not go smoothly without an effective implementation plan. For example, a number of 8 kW cabinets may result in a local density of 400+ W/ft^2 (4300+ W/m^2). Getting enough cool air to such a density may be a tremendous challenge. However, a clever duct design and some basic rules for placement of point loads go a long way. Although not widely accepted, supplemental liquid-cooled solutions may also provide benefits over conventional ducted overhead air.

Poor Separation of Hot and Cold Air. Although alternating hot and cold equipment aisles are the preferred scheme of organizing the equipment, many telecom network rooms are not organized this way. It is not uncommon that the equipment is lined up front to back, meaning that all equipment is facing the same direction. And, network gear often has intakes or exhausts on both sides of the equipment. Consequently, cold air needs to be supplied in all aisles. The lack of separation of hot and cold air results in air mixing that leads to poor energy efficiency. This arrangement also leads to complications with placing the point loads. Specifically, introducing a point load may affect the intake temperature to equipment located directly behind the point load.

Since all equipment in network facilities is air cooled, cool air needs to enter and hot air needs to leave the cabinet. The equipment-cooling (EC) class describes where on the equipment envelope the air enters and exits.[2] Optimal classes, including front-to-rear ventilated equipment, work in concert with the hot- and cold-aisle arrangement. Such equipment (including most point-load equipment) does not necessarily work well in network facilities. However, there are some effective work-arounds.

Issues

In addition to the physical limitations in existing network facilities, there are a number of issues with representing and analyzing the conditions.

The Concept of "Ambient" Conditions. The thermal equipment environment is defined by the temperature of the air drawn into the air-cooled electronic equipment, which is the temperature the electronics depend on for reliable cooling and operation. The exhaust temperature or the temperature in the middle of the aisle, for example, has little to do with the rack cooling effectiveness. This also holds true for the ambient temperature specified by "GR-63-CORE, NEBS™ Requirements: Physical Protection"[3] of 1.50 m (59 in.) above the floor and 0.38 m (15 in.) in front of the equipment. In the historically mixed environments with a fairly uniform space temperature, this ambient made sense but not in today's more organized environments. Environmental specifications and sensor placement should reflect the intake conditions. The flawed idea of ambient conditions has long hampered an organized approach of analyzing modern telecom switching centers.

No Tool for Analyzing the Conditions. After realizing that the intake temperature is the important temperature for air-cooled equipment, an organized approach to thermal management finally emerged. GR-3028-CORE[2] was an important first step in that direction. It presented a cohesive and holistic picture of the thermal network environment; it spelled out the importance of harmony between equipment cooling and space cooling. It went on providing a framework for a common language, as well as estimating the maximum heat density in various typical network environments by using computational fluid dynamics (CFD) modeling. Several of the concepts developed in GR-3028-CORE were subsequently used in *Thermal Guidelines for Data Processing Environments*.[1]

Rating	RCI
Ideal	100%
Good	≥96%
Acceptable	91%–95%
Poor	≤90%

Table 1: Suggested RCI quality ratings using ASHRAE Class 1 environment.

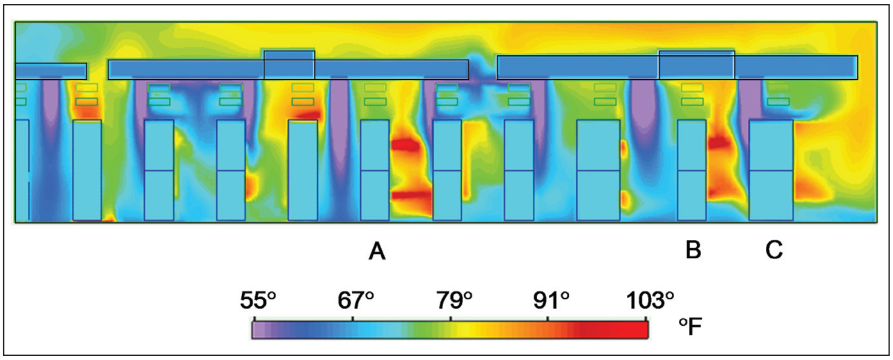

Figure 2: Point loads on perimeter aisle, lineup C (section view).

Still, an effective tool was yet to emerge to compress unwieldy CFD (or measured) data. Although such modeling provides a wealth of information, sorting things out is often a tremendous challenge. *Figure 1* demonstrates the difficulties.

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Solutions

Having discussed a few major limitations and issues, some effective solutions are needed for developing strategies dealing with point loads in existing network facilities.

Metric for Analyzing the Conditions. Since the thermal network environment is defined by the equipment intake temperatures, compliance with intake specifications is the ultimate cooling performance metric. The Rack Cooling Index (RCI)[4] metric has been adopted for the Data Center Assessment Protocol developed by Lawrence Berkeley National Laboratory for the U.S. Department of Energy (DOE).

In the research, the cooling effectiveness was gauged by the RCI when point loads were introduced. By using CFD modeling in tandem with this metric, a tremendous amount of data could be processed and presented in an understandable, objective, and standardized way. The use of the RCI allowed the ideas from GR-3028-CORE to be further developed and refined. Other relevant applications of the RCI are outlined in Reference 5.

Specifically, the RCI_{HI} is a measure of the absence of over-temperatures. RCI_{HI} = 100% mean ideal conditions; all intake temperatures are below the recommended maximum temperature (i.e., total absence of over-temperatures). The RCI_{HI} is a quantitative measure of the equipment environment at the high end of the temperature range. Although an analogous index (RCI_{LO}) is defined at the low end, the RCI_{HI} generally takes precedence.

The definition of RCI_{HI} is as follows (the calculation can easily be automated):

$$RCI_{HI} = \left[1 - \frac{\sum_{x=1}^{n} (T_x - T_{max-rec})}{(T_{max-all} - T_{max-rec})n} \right] 100\% \quad (\text{for } T_x > T_{max-rec})$$

where

Tx = Temperature at equipment intake x

n = Total number of intakes

$T_{max-rec}$ = Maximum recommended intake temperature (e.g., NEBS or ASHRAE)

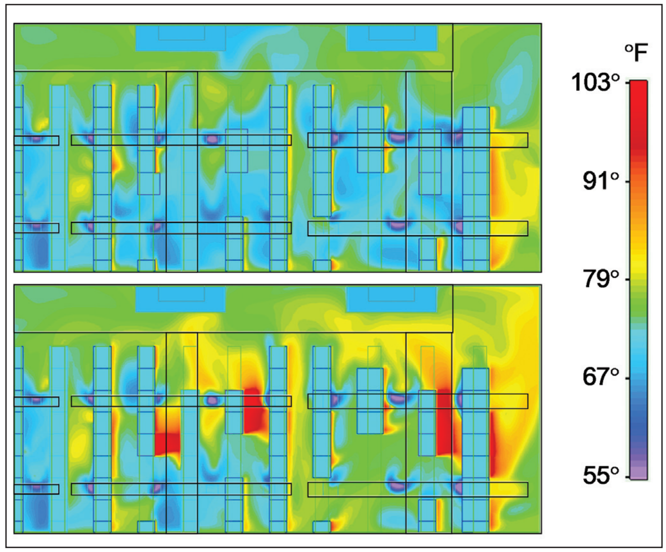
$T_{max-all}$ = Maximum allowable intake temperature (e.g., NEBS or ASHRAE)

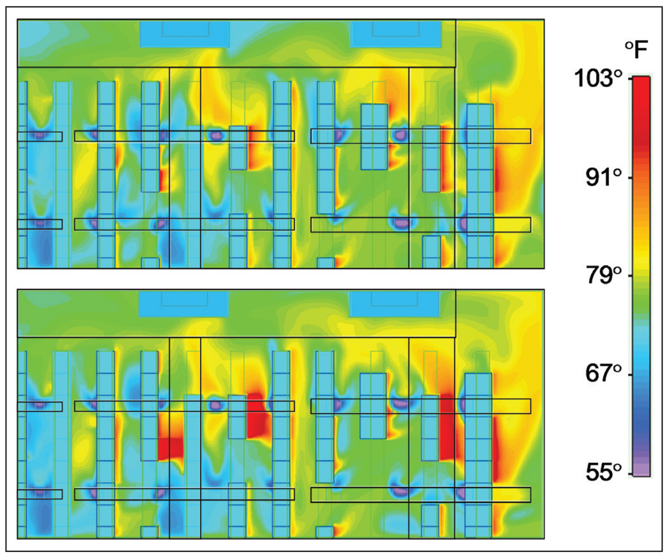
Table 1 lists RCI_{HI} and RCI_{LO} quality ratings based on numerous modeling studies using the *Thermal Guidelines'* Class 1 recommended and allowable environments of 20°C − 25°C (68°F − 77°F) and 15°C − 32°C (59°F − 90°F), respectively.

Placement Strategies for Point Loads. The research suggests that there are preferred placement strategies for front-to-rear ventilated point loads in network rooms with all equipment facing the same direction to ensure that proper intake temperatures are maintained for adjoining equipment. Given the high temperature of the exhaust air from modern network gear, directing that air away from other equipment intakes is imperative. This is especially important if that equipment has not undergone and passed NEBS testing. There is also the occasional HVAC outage condition that must be considered. Intake temperatures will often rise dramatically, resulting in higher exhaust temperatures.

Some key strategies for neutralizing the impact of hot exhaust air include the following four solutions:

- Place point loads on the *perimeter aisles* and direct the exhaust airflow toward perimeter walls where the elevated temperature will not directly be captured by other equipment. The drawback to this solution is that it may not always be workable; space may not be available, or the point loads may need to be placed close to other related gear.
- In *Figure 2,* lineups A, B, and C have 8 kW point loads. Lineup C exhausts air toward the perimeter wall where it can be returned safely to the (central) air handler via high-elevation wall returns without significantly impacting other equipment. However, lineups A and B exhaust hot air directly toward the intakes of the opposite lineups.
- Provide *supplement cooling* to neutralize the hot exhaust air prior to entering other equipment. *Figure 3* shows the impact of using liquid-cooled rear-door heat exchangers. Note the absence of hot air behind the point loads, which results in an ideal RCI value of 100% (i.e., no intake temperatures above the maximum recommended). Benefits include room-load reduction, a modular/scalable solution, and marginal need for valuable floor space. Drawbacks include protrusion outside standard frame dimensions and water or refrigerant piping. In typical telecom environments with concrete floors, an engineered solution is required.





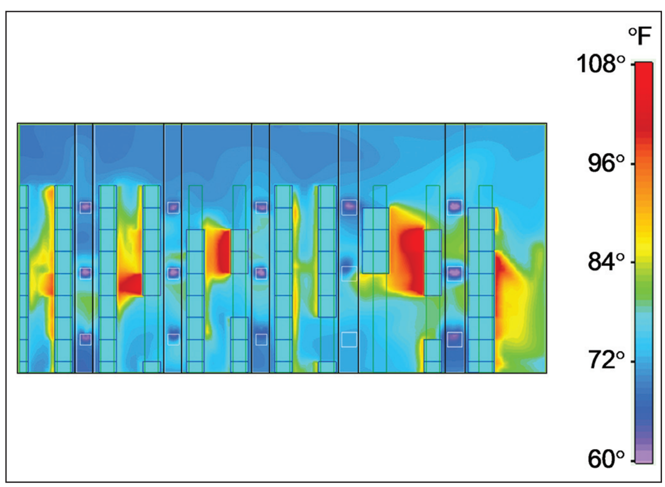


Figure 3 (top): With (RCI$_{HI}$ = 100%) and without (RCI$_{HI}$ = 95%) rear-door heat exchangers (plan view). Figure 4 (middle): With (RCI$_{HI}$ = 99%) and without (RCI$_{HI}$ = 95%) exhaust deflection devices (plan view). Figure 5 (bottom): Organized front-to-front (RCI$_{HI}$ = 99%) layout (plan view).

- Provide *exhaust deflection devices* to direct hot exhaust air upwards toward the ceiling and the return air path. It is a passive device in that no cooling is involved. Benefits include an inexpensive and robust solution that does not require any infrastructure changes and little, if any, maintenance. The thermal effectiveness is remarkable; the RCI improves to 99% (*Figure 4*). Drawbacks include no room-load reduction, no reduction in HVAC airflows, and no reduction in air ducting.
- Migrate to highly *organized equipment environments* with alternating hot and cold aisles using only optimal EC-Class equipment. *Figure 5* shows equipment lined up front-to-front with hot and cold aisles. Besides numerous other benefits, including thermal and energy, organizing the environment this way creates a striking physical simplicity of the overhead ductwork. This configuration should be the long-term goal, and it can readily be phased in when new network equipment is installed. Minor hot-air recirculation and an elevated design supply temperature (55°F → 60°F [13°C → 16°C]) contribute to an RCI below the ideal of 100%.

Conclusions

Although the long-term goal is to migrate the network room to an organized environment with alternating hot and cold equipment aisles and optimized EC-Classes, measures that are readily available in many existing network rooms are more modest. Understanding how to address equipment and infrastructure issues is imperative when new high-density equipment arrives at the loading dock. Improper placement of point loads within the existing environment can greatly reduce the reliability of the network under normal operation and cooling outage situations. A well considered plan for the analysis and placement of high-density equipment is critical to ensure network availability and reliability. Today, tools are readily available to develop key placement strategies similar to those outlined in this article.

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