Thermal Management in Telecommunications Central Offices: The Next Steps

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***Abstract* - Besides new energy intensive network equipment, more electronic equipment of the type typically found in data centers is finding its way into telecom central offices. Servers generally have higher heat dissipation compared to traditional network equipment. This change leads to challenges in terms of equipment cooling and network reliability.**

In 2001, Telcordia provided the leadership by developing GR-3028-CORE (GR-3028) *Thermal Management in Telecom Central Offices* which included a new common language and new concepts as well as a flexible procedure to cope with high heat dissipation. The ideas in the requirements document have been widely adopted by related industry guidelines.

Since the introduction of GR-3028, however, not only has the equipment and the equipment environment evolved but there are now new knowledge, technologies, and tools available to develop improved thermal guidelines. Although the document focuses on thermal issues, energy management and thermal management are today so tightly linked that they need to be addressed simultaneously. GR-3028 is due for an update.

First, it is desirable to include revised targets for equipment heat dissipation, based on current best practice shelf-, rack-, and room-level thermal design. The targets in GR-63 are much lower than commonly encountered in new installations.

Key to optimal room thermal management is to supply cold air where it is needed and extract hot air without mixing with the ambient air. There are recent technology developments that take air management to new levels.

Today, there are a number of top-level metrics and associated software available for evaluating the environment. The U.S. Department of Energy (DOE) is currently developing a software suite called DC Pro to help evaluate the thermal and energy status of equipment facilities.

Economizers have been used in many central offices for decades and are increasingly being used in data centers. There are currently no guidelines in GR-3028 to address the use of economizers to reduce cooling expenses.

Finally, there are training issues that need to be addressed. Significant knowledge and skills are required to accurately assess equipment facilities. To this end, DOE has launched a Certified Energy Practitioner program (DC-CEP).

This paper outlines these new resources for an improved holistic approach to thermal/energy management in telecom equipment rooms. They should be considered for the next revision of GR-3028—the next steps in thermal management.

I. Background

Besides new energy intensive network equipment, more electronic equipment of the type typically found in data centers (servers) is finding its way into telecom central offices. Servers generally have higher heat dissipation when compared to traditional network equipment. This overall transformation leads to complications in terms of equipment cooling and physical network reliability.

Managing this diverse and dynamic environment is an increasing challenge. For years the industry relied on equipment requirements contained in GR-63-CORE (GR-63) *NEBS™ Requirements: Physical Protection*. GR-63 contains requirements for many topics of environmental performance for equipment to be deployed in telecommunications central offices. These topics include not only operating temperature and humidity, but also fire, shock and vibration resistance. As telecommunications products continued to evolve, it became clear that a document focused strictly on heat dissipation and equipment cooling was needed. This new document would target not only equipment aspects, but also facility design and operation. In 2001, Telcordia provided the initial leadership by developing GR-3028 *Thermal Management in Telecom Central Offices* which included a new common language and new concepts as well as a flexible procedure to cope with higher equipment heat dissipation. The ideas in the requirements document have been widely accepted and adopted by related industry guidelines such as ASHRAE and BICSI.

Since the introduction of GR-3028, however, not only has the equipment and the equipment environment evolved but there are now new knowledge, technologies, and tools available to develop improved and up-to-date thermal and energy guidelines. Although GR-3028 focuses on thermal management, energy management and thermal management are today so intertwined that they need to be addressed in tandem. GR-3028 is poised for an update.

II. GR-63-CORE

The traditional guidelines for thermal management are contained in GR-63. It contains required and desirable features for network equipment to assure they operate reliably in a central office environment. In 2006, GR-63 was updated for the first time in ten years. Among the topics addressed in the update, were key aspects of thermal management. However, the operating temperature and humidity guidelines were left essentially unchanged. The maximum short-term temperature remained at 50°C for aisle ambient, and 55°C for individual shelves. However, based on the experience with GR-3028 over the previous years, a number of key aspects of GR-3028 were directly adopted by GR-63.

The rapid temperature rise test specified in GR-3028 was incorporated into the operating temperature and humidity test regime. This test provides for a rapid temperature rise from a normal ambient of 23°C to 50°C in 17 minutes. The sequence simulates the heating that could occur in a telecom environment if a loss of space cooling were to occur. The test protocol includes a 4 hour dwell at 50°C, followed by a more controlled return to normal ambient.

The GR-3028 objectives for equipment airflow schemes were also incorporated into the GR-63 as objectives. These preferred airflow schemes had been discussed for years within the industry prior to their introduction in GR-3028, and there was general agreement within the update forum that the schemes would be useful in GR-63. The objectives play an important role in managing room airflow with minimal mixing of supply and return air.

In the early 1970's, when the NEBS requirements were developed, it was implicit to the HVAC and equipment designers that cooling air would be supplied to the front of equipment and exhausted from the rear. As equipment designs left the control of the Bell System, this unwritten rule was forgotten, and equipment designs with a myriad of airflow patterns were placed into service. The problems became apparent as front air exhaust equipment was placed across aisle from equipment with front air intakes. Other equipment, perhaps first designed for wall mounting, was provided with side-to-side airflow. This airflow scheme is not suitable when equipment is installed in lineups where other racks and cable management systems can block the side-to-side airflow. Furthermore, hot exhaust air may be drawn into nearby equipment.

While there is some flexibility regarding the exact airflow scheme, the preference is inlet at the lower front and exhaust at the upper rear (Figure 1). Side, bottom, and front exhausts are discouraged in both GR-3028 and GR-63.

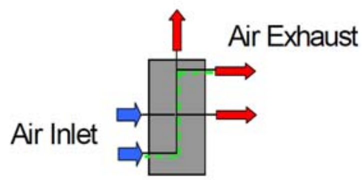

Figure 1. Conforming equipment airflow schemes; dashed path is preferred.

In addition to the criteria ported over from GR-3028, several new requirements were developed by the GR-63 update forum to address specific thermal issues. One issue was the now nearly universal reliance on fans for equipment cooling. The use of cooling fans should not negatively impact system availability. For this reason, it is now a GR-63 requirement that fan cooled systems should be able to operate with an aisle ambient of 40°C with any single fan failed for up to 96 hours. This gives the service technician an opportunity to change a fan before service is impacted or equipment is damaged.

For the same reason, it is required that products provide remote alarming when a fan fails. There is a new objective in GR-63 that equipment fans be hot swappable, so that when they fail, they can be replaced with no interruption in service. If fans are not hot swappable, the time required to change a fan is to be documented. These requirements and objectives came as a direct result of carrier experiences with prematurely failing fans, buried deep within products that required service outages to repair.

Heat dissipation limits of GR-63 were not revised in the last update. These limits include a system or room average of 80 Watt/ft^2. There has long been a widespread acknowledgement that the objective limits for heat dissipation in GR-63 are much lower than commonly experienced in new equipment installations. While removal of the limits completely was considered, it was decided instead to maintain the limits as historically accurate guidelines, as they still describe the heat removal capabilities of the majority of telecom central offices. Included along with the historical objective limits is a reference to GR-3028 for more information on room and equipment cooling.

III. GR-3028-CORE

GR-3028-was developed in 2001 with the goal of helping carriers cope with increasing heat loads produced by more capable telecom hardware. Where GR-63 is directed primarily towards the network hardware features, GR-3028 contains improvements that can be applied to facilities and operation. Having incorporated many of the equipment innovations of GR-3028 into GR-63, there now exists an opportunity to provide further enhancements in these GRs. GR-3028 is scheduled for re-issue in 2010. The recent focus of the telecom industry on energy efficiency warrants a return to the GR-3028 to evaluate the requirements and guidelines to see how they could be tailored to the industry's current demands. Considered for update in GR-3028 are the following topics:

- Target heat dissipation – It is desirable to have revised targets for rack- and shelf-level heat dissipation, based on improved room-level thermal management. The heat release would be considerably higher than that currently in GR-63, and would aid the integration of higher heat dissipating equipment into equipment spaces. There is no value specified in GR-3028, but having a reasonable target would allow for easier space planning and equipment deployment.

- Equipment design guidelines – Equipment design guidelines must account for the long-term operating temperature range, high and low temperature limits, humidity, altitude, and rates of temperature change specified in GR-63. Design guidelines and thermal modeling techniques are detailed in Section IV.

- Room-level air management – Key to optimal thermal and energy management is to supply cold air where it is needed and extract hot air without mixing with the ambient. There are recent technology developments that take air management to new levels. Correcting poor air management can often save 70-80% on fan energy and 15-25% on chiller energy. Air management is addressed in Section V.

- Rack cooling effectiveness – The most important aspect of a telecom central office facility is to provide a physical environment that ensures reliable operation of the equipment. And, the equipment intake air temperatures characterize the thermal environment, not the aisle ambient. A relevant metric for equipment intake temperatures should be used to gauge the thermal environment. Such a metric and two related air management metrics are addressed in Section V.

- Guidelines for the use of economizers – There are currently no guidelines in GR-3028 to address the use of economizers to reduce cooling expenses. Economizers have been used in many traditional central offices for years and are increasingly being used in data centers as well. Two main types are available to reduce the need and energy costs of mechanical cooling. Section VII addresses economizers.

IV. Equipment Design Guidelines

GR-3028 does not address shelf-level thermal design. However, high heat producing shelves are the building blocks of high density racks. Concerns with the increased difficulty to provide effective room level thermal management has led carriers such as Verizon to compile their own purchasing requirements addressing thermal design at the shelf, circuit pack, and component levels. These requirements strive to reduce equipment energy consumption by reducing the heat generation through the use of thermally efficient designs, while simultaneously maintaining high reliability through a stringent examination of component temperatures at various operating conditions.

The Verizon approach requires a multi-level examination of thermal management. The following are the main aspects of equipment thermal design specified in *Verizon NEBS™ Compliance: Thermal Management Requirements for Improved Energy Efficiency of Telecommunications Equipment*:

1. Components and plastics used in the product must be suitable and thermally stable over the temperature range expected in service.

2. A maximum component ambient (50°C for central office), and a maximum component surface or case temperature (85°C) are specified.

3. A maximum “hot spot” surface temperature and a maximum average surface temperature of the circuit pack laminate are specified.

4. The worst case heat dissipation of a fully equipped system must be specified by the supplier and verified via independent testing. Based on this heat release value, the supplier shall provide an enclosure resulting in a heat density not to exceed 200 Watt/ft^3.

5. System airflow must be designed to cool the worst case heat dissipation under conditions of a 40°C aisle ambient and a maximum air temperature rise within the enclosure of 10°C.

The goal is to have an enclosure with low airflow resistance and fans operating at high efficiency while satisfying all thermal constraints. To cost effectively optimize the myriad of system variables, a systematic approach is required. It is expected that suppliers will use computational fluid dynamics (CFD) modeling to optimize board layout and shelf designs prior to prototyping. Conformance to the purchasing requirements then becomes a straightforward review of the thermal model and verification of its accuracy via laboratory measurements. This iterative approach allows for cost effective design modifications before prototyping, with better system level results when completed. Verizon purchasing requirements, going into effect in 2010, are the first attempt to formalize this approach across the industry.

Consideration of carrier specific design requirements and thermal modeling techniques for inclusion in GR-3028 can further help carrier efforts to better manage shelf-, rack-, and room-level heat dissipation.

V. Room-Level Air Management

Key to optimal thermal and energy management is to supply cold air where it is needed and extract hot air without mixing with the ambient air - in short air management. There are recent technology developments that take air management to new levels. There is a strong trend to shorten the air-loop by bringing the cooling closer to the heat load (rack-level cooling and in-row-cooling). Most of these solutions are characterized as liquid-cooled solutions. Another increasingly common method relies on enclosure technologies whereby physical barriers funnel the cold air directly to the electronic equipment without mixing with the ambient air. Again, correcting poor air management can often save 70-80% of fan energy and 15-25% of chiller energy.

Three issues need to be addressed to understand the effects of room-level air management: Thermal management of the electronic equipment, by-pass and recirculation air, and overall energy implications. Three top-level metrics will be discussed for these purposes.

The Rack Cooling Index (RCI) is a measure of how well the equipment is cooled within specifications based on vendor and/or industry guidelines. Since a thermal guideline becomes truly useful when there is an unbiased and objective way of determining the operating compliance with the guideline, the RCI index is included in the ASHRAE Thermal Guideline (ASHRAE 2009) for purposes of showing compliance. The Return Temperature Index (RTI) is a measure of the overall performance of the air-management system. Finally, Data Center infrastructure Efficiency (DCiE) is a metric used to determine the overall energy efficiency of a data or telecom center. The three metrics reduce a great amount of data to understandable numbers that can easily be trended and analyzed.

A. Rack Cooling Index (RCI)™

The most important aspect of a data center or telecom central office facility is to provide a physical environment that ensures reliable operation of the data processing equipment. The equipment intake air temperatures characterize the thermal environment. A number of industry standards provide recommended and allowable intake temperatures to protect the equipment and cap facility cooling costs.

A relevant metric for equipment intake temperatures should be used to gauge the thermal environment. The Rack Cooling Index (RCI) is a measure of how effectively equipment racks are cooled within a given thermal guideline, both at the high end and at the low end of the temperature range (Herrlin 2005). Specifically, the RCI is a performance metric explicitly designed to quantify the compliance with the thermal guidelines of ASHRAE (2008) and NEBS (Telcordia 2001, 2006) for a given data center. The index is included in the ASHRAE Thermal Guideline for purposes of showing compliance.

Both industry guidelines specify recommended and allowable ranges. The recommended intake temperature range is a statement of reliability (facility operation) whereas the allowable range is a statement of functionality (equipment testing). The numerical values of the recommended and allowable ranges depend on the applied guideline. Table 1 shows a comparison between ASHRAE and NEBS.

Note that the ASHRAE Thermal Guideline is referring to intake temperatures whereas GR-63 is using aisle ambient. GR-3028 also refers to intake temperatures. GR-63 should follow by simply changing "aisle ambient" to "intake" temperature.

TABLE 1: ASHRAE AND NEBS TEMPERATURE GUIDELINES

(@ Equipment Intake)	Min and Max Recommended	Min and Max Allowable (Long-Term)
Temperature (°C) Data Centers ASHRAE Telecom NEBS	 18° – 27°C 18.33° – 26.67°C	 15° – 32°C 5° – 40°C
Temperature (°F) Data Centers ASHRAE Telecom NEBS	 64.40° – 80.60°F 65° – 80°F	 59° – 89.60°F 41° – 104°F

Over-temperature conditions exist once one or more intake temperatures exceed the maximum recommended temperature. Similarly, under-temperature conditions exist when intake temperatures drop below the minimum recommended. The RCI compresses the equipment intake temperatures into two numbers: RCI_{HI} and RCI_{LO}. RCI_{HI}=100% mean no intake temperatures above the max recommended whereas RCI_{LO}=100% mean no temperatures below the min recommended. Both numbers equal to 100% signify absolute compliance, i.e., all temperatures are within the recommended range. The lower the percentage, the greater probability (risk) intake temperatures are above the maximum allowable and below the minimum allowable, respectively.

TABLE 2. PROPOSED RATING OF RCI

Proposed Rating	RCI
Ideal	100%
Good	≥95%
Acceptable	≥90%
Poor	<90%

Figure 2 provides a graphical representation of the RCI_{HI} (the RCI_{LO} is analogous). The bold curve is the intake temperature distribution for all N air intakes; the temperatures have been arranged in order of increasing temperature. The Total Over-Temperature represents a summation of all over-temperatures (triangular area). The Maximum Allowable Over-Temperature is also defined in the figure (rectangular area). The definition of RCI_{HI} is as follows:

$$RCI_{HI} = \left[1 - \frac{\text{Total Over-Temp}}{\text{Max Allowable Over-Temp}}\right] 100\ \%$$

The index value for the intake temperatures shown in Figure 2 is RCI_{HI} = 95%. The Rack Cooling Index (RCI) Software (ANCIS 2010) automates the task of calculating the RCI metric for temperature data stored in Excel spreadsheets (see Section VI).

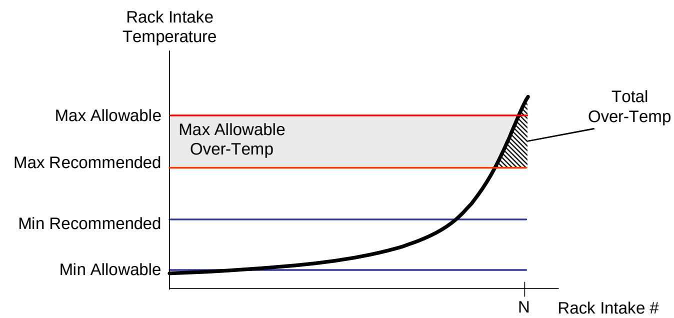

Figure 2. Graphical Representation of RCI_{HI}

The RCI is the key metric to consider for incorporating into the next revision of GR-3028-CORE. Its numerical value may be based on Table 2. Besides used as a standards requirement, there are a number of applications of RCI related to telecom facilities.

- Design Equipment Environments: The RCI combined with CFD modeling provides a standardized way of evaluating and reporting the effectiveness of cooling solutions, see Quirk and Herrlin (2009).
- Provide Design Specifications: Operators now have the opportunity to specify a certain level of thermal performance in a standardized way, e.g., RCI ≥ 95%.
- Assess Equipment Environments: Temporary or permanent monitoring of the environment is feasible by using temperature sensors that mimic the overall intake conditions.

B. Return Temperature Index (RTI) ™

To understand room-level air management, there is a need for another top-level metric. The Return Temperature Index (RTI) is a measure of the net level of by-pass air or net level of recirculation air in the equipment room (Herrlin 2008). Both effects are detrimental to the overall thermal and energy performance of the space. By-pass air does not contribute to the cooling of the equipment, and it depresses the return air temperature. Recirculation, on the other hand, is one of the main reasons for hot spots or areas with significantly hotter intake temperatures.

The RTI is a measure of the performance of the air-management system and how well it controls by-pass and recirculation air. Deviations from 100% are generally an indication of declining performance. The index is defined as follows:

$$RTI = \Delta T_{AHU}/\Delta T_{Equip} = V_{Equip}/V_{AHU}$$

Where

RTI	Return Temperature Index
ΔT_{AHU}	Temperature drop across air handlers
ΔT_{Equip}	Temperature rise across equipment
V_{AHU}	Total airflow through air handlers
V_{Equip}	Total airflow through equipment

Since the temperature rise across the electronic equipment provides the potential for high return temperatures, it makes sense to normalize the RTI with regard to this entity. In other words, the RTI provides a measure of the actual utilization of the available temperature differential. Consequently, a low return air temperature is not necessarily a sign of poor air management. If the equipment only provides a modest temperature rise, the return air temperature cannot be expected to be high. Many legacy systems have a temperature rise of only 10°F (6°C) whereas blade servers can have a differential of 50°F (28°C).

The RTI equation above shows the intrinsic link between energy and thermal management, since the RTI is also the ratio of total airflow through the equipment to the total airflow through the air handlers. The interpretation of the index is now straight forward (see Table 3): A value above 100% suggests net recirculation air, which elevates the return air temperature. Unfortunately, this also means elevated equipment intake temperatures. A value below 100% suggests net by-pass air; cold air by-passes the electronic equipment and is returned directly to the air handler, reducing the return temperature. This may happen when the supply airflow is increased to combat hotspots or if there are leaks in the supply air plenum.

TABLE 3: Interpretation Of Rti

Interpretation	RTI
Balanced	100%
Net Recirculation Air	>100%
Net By-Pass Air	<100%

There might be a number of legitimate reasons to operate below or above 100%. For example, some air-distribution schemes are designed to provide a certain level of air mixing (recirculation) to provide an even equipment intake temperature. Some overhead air-distribution systems commonly find in telecom facilities are designed to operate this way. Data centers with raised-floor cooling, on the other hand, often need some excess air to function adequately. Target levels of RTI can be specified and incorporated into GR-3028-CORE.

It should be noted that saving on energy costs through air management depend on the ability to reduce the system airflow rate. Variable frequency drives (VFD) are the preferred way of modulating the airflow. Means of reducing the airflow should be specified in GR-3028.

C. Data Center Infrastructure Efficiency (DCiE)

The RCI analysis should be accompanied by an energy analysis. Improving the RCI can lead to an energy penalty. The RTI and the DCiE can help evaluate how severe such a penalty may be.

Data Center Infrastructure Efficiency (DCiE) and the Power Usage Effectiveness (PUE) have become commonly used metrics for data center energy efficiency. The PUE is essentially the reciprocal of DCiE. These metrics were developed by members of the Green Grid, which is an industry group focused on data center energy efficiency. One benefit of using the DCiE rather than the PUE is that it has an easily understood scale of 0-100% (Green Grid 2008).

$$DCiE = \left[\frac{\text{Equipment Power}}{\text{Total Facility Power}}\right] 100\ \%$$

Standard guidelines for using and reporting of these metrics have been developed by the Green Grid. All DCiE measurements should be reported with subscripts that identify (1) the accuracy of the measurements (2) the averaging period of the measurements (e.g., yearly, monthly, weekly, daily), and (3) the frequency of the measurement (e.g., monthly, weekly, daily, continuous).

Table 1 shows consensus ratings of the DCiE. A value of 100% simply indicates 100% efficiency, i.e., all energy is used by the electronic equipment (ideal). However, a typical value is only 50%. State-of-the-art installations have values around 85%.

TABLE 4. RATING OF DCiE

Rating	DCiE
Ideal (maximum)	100
State-of-the-Art	85
Best Practice	70
Improved Operations	60
Current Trend	55
Typical (average)	50

The DCiE allows data center operators to quickly estimate the energy efficiency of their data centers and determine whether any energy efficiency improvements need to be made. Target levels can be specified and incorporated as Requirements or Objectives in GR-3028-CORE.

VI. SOFTWARE TOOLS

The Rack Cooling Index (RCI) Software (ANCIS, 2010) is an easy way to show conformance with thermal industry standards without manually calculating the RCI metric. The Software automates the task for intake temperature data stored in Excel spreadsheets. The Software also plots the temperature distribution and calculates key temperature distribution statistics. This information provides additional data for analyzing and optimizing the thermal equipment environment.

The U.S. Department of Energy (DOE) is in the process of developing a software suite (DC Pro) to help evaluate the thermal and energy status in equipment facilities (DOE, 2009a). These tools use metrics to gauge the quality of an environment. Since the most important aspect of a telecom facility is to provide a physical environment that ensures reliable operation of the electronic equipment, the RCI has been included to determine how effectively rack mounted equipment is cooled. The two other performance metrics discussed above are also used in DC Pro.

Companies can use DC Pro to identify and evaluate thermal and energy efficiency opportunities in equipment rooms. The suite features a Profiling Tool and a set of System Assessment Tools to perform assessments on specific system areas.

The DC Pro is intended for facility owners and operators who want to diagnose how energy is used by their facilities and determine ways to save energy and money. Using the online Profiling Tool as the first step to identify potential savings and to reduce environmental emissions associated with facility energy use. In addition to the DC Pro Profiling Tool, the following Excel-based tools can be used to conduct a more accurate assessment of energy efficiency opportunities for major equipment room systems. The Air-Management tool is intended mainly for raised-floor cooling with hot/cold equipment aisles. The Electrical tool helps assess the savings from efficiency actions in the power chain.

Software and manuals can be accessed through a dedicated DOE website (DOE 2009a). A DC Pro fact sheet is also available (DOE 2009b).

VII. ECONOMIZERS

Two main economizer types are available to reduce the costs of mechanical cooling. The first type is a water-side economizer. In many traditional data centers, heat is removed from the chiller refrigerant by tower water passing through the chiller condenser. The warmed condenser water is then cooled in an evaporative cooling tower. When the outdoor wet-bulb is lower than the chilled water set-point, the exiting cooling tower water temperature will be low enough to allow it to cool the chiller water via a heat exchanger. In this operating mode, the chilled water is cooled without operating the chiller compressor, resulting in energy savings.

The second type is an air-side economizer. It is even more efficient and less complicated than a water-side economizer. An air-side economizer relies on outdoor air directly for equipment cooling when outdoor conditions are favorable. The economizer evaluates the enthalpy of each airstream (outdoor, supply, and return) and determines which airstream or combination thereof can cool the equipment space with the least amount of mechanical cooling.

In cooler climates, the economizer can nearly always be utilized. Even in warmer climates, the 24-hour operation of the telecommunications facilities and cooler nights provide an opportunity for savings from economizer operation. Air-side economizers are more efficient, but water-side economizers may be useful under limited conditions where the cooling plant and building design do not permit 100% outdoor air introduction into the air handler.

VIII. STAFF TRAINING

Besides the technical aspects, there are also training and educational issues that need to be addressed. The U.S. Department of Energy (DOE) has launched a Certified Energy Practitioner (DC-CEP) program. Significant knowledge, training, and skills are required to perform accurate assessments in equipment facilities. The objective of the DC-CEP Program is to provide training and a certification process leading to practitioners best qualified to evaluate the thermal and energy status as well as efficiency opportunities in equipment facilities. The ultimate goal of the program is to accelerate energy savings in the energy-intensive marketplace of data centers and telecom central offices.

There are two program tracks: Training Diploma track (training only) or Certification track (training + exam). The Certification track requires that a candidate meets both prequalification and training requirements and passes exams. In addition, the program has two levels. The Level 1 Practitioners ("generalists") will be expected to have a good understanding of all data and telecom center disciplines, including HVAC, air management, electrical, and electronic equipment, for providing broad recommendations based on the DC Pro Profiling Tool. The Level 2 Practitioners ("specialists") address energy opportunities using one or several of the in-depth DC Pro System Assessment Tools covering the same four disciplines.

The pre-qualifications to take the training and exams have been structured to allow a wide range of practical and academic experiences. For Level 1 of the Certification track, there is an optional 1-day training including the DC Pro Profiling Tool and a case study. This training is obligatory for the training Diploma track. For Level 2 of both tracks, there is an obligatory 2-day training including applicable DC Pro Assessment Tools. A study guide with study references is available, including a reference to a Process Manual. This manual provides administrative step-by-step instructions for conducting a complete assessment including steps to be taken before, during, and after the on-site evaluation of the facility.

Candidates who have completed the required prequalification and training may enroll for the four-hour written exams at either level. Participants who pass the exams will be designated DC-CEP at Level 1 or Level 2. Their names and contact information will be posted on a DOE website. Recertification every three years is required to cover changing technologies, which is especially critical in this fast-moving industry. A detailed description of the Program and sign-up forms are available from DOE (DOE 2009c).

SUMMARY

This paper has outlined key new resources for creating an improved holistic approach to thermal and energy management in telecommunications equipment rooms. These resources are being considered for the next revision of GR-3028. Technical guidelines and standards incorporating equipment thermal design, room-level air management, top-level thermal and energy metrics, related software tools, thermal and energy technologies, and staff training form a strong foundation for successful design and management of equipment and equipment environments—the next steps in thermal management.

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