



DOE FEMP First Thursday Seminar
***Achieving Energy Efficient Data Centers
with New ASHRAE Thermal Guidelines***

Learner Guide

Core Competency Areas Addressed in the Training

Energy/Sustainability Managers and Facility Managers

- Building Cooling Systems
- Building Technologies
- Operations and Maintenance

Operating Engineers/Building Technicians

- Building Cooling Systems
- Operations and Maintenance

Expected Results for Those Completing this Training

Develop plans for and implement processes to control temperature and air volume in high-intensity data centers based on new ASHRAE TC 9.9 information.

ASHRAE TC 9.9 Guidelines and General Energy Efficiency in Data Center Resources

To learn more about data center energy efficiency, check these resources.

FEMP: Data Center Energy Efficiency

http://www1.eere.energy.gov/femp/program/data_center.html

ASHRAE Technical Committee 9.9

<http://tc99.ashraetcs.org/>

2011 Thermal Guidelines for Data Processing Environments – Expanded Data Center Classes and Usage Guidance

http://www.eni.com/green-data-center/it_IT/static/pdf/ASHRAE_1.pdf

FEMP Training for Data Centers

Labs, Data Centers, and High-Tech Facilities First Thursday Seminar:

http://apps1.eere.energy.gov/femp/training/course_detail_ondemand.cfm/CourseId=56

There are multiple opportunities for you to view the Data Center Profiler (DCPro) Tool Training Webinar. Check <http://apps1.eere.energy.gov/femp/training/index.cfm#results> for dates and times.

Glossary of Lighting Technology Terms

ACAE - Air Conditioning Airflow Efficiency, the amount of heat removed per standard cubic foot of airflow per minute.

AHU - Air Handling Unit.

Air Mixing - The unintended mixing of cold and hot air.

Airside Economizer - A device consisting of fans, ducting and a control which utilizes outside air directly to cool the data center when environmental conditions allow. Air is typically filtered, brought into existing distribution system and then exhausted back to the atmosphere.

Aisle - The open space between rows of racks. Best-practice dictates racks should be arranged with consistent orientation of front and back to create 'cold' and 'hot' aisles.

ASHRAE - American Society of Heating, Refrigerating and Air-Conditioning Engineers founded in 1894, is a building technology society with more than 50,000 members worldwide. The Society and its members focus on building systems, energy efficiency, indoor air quality and sustainability within the industry. Through research, standards writing, publishing and continuing education, ASHRAE shapes tomorrow's built environment today.

Blanking Panel - A device mounted in unused U spaces in a rack that restricts recirculation airflow, also called blanking or filler plates.

BMS - Building Management System, synonymous with BAS, AMS and other computer-based control systems installed in buildings to control and monitor the building's mechanical and electrical equipment.

Bypass Airflow - Conditioned air that does not reach computer equipment. With fixed speed fans (common in DX equipment), some bypass air is inevitable and without containment, some bypass air is prudent. Unintended bypass air can occur by escaping through cable cut-outs, holes under cabinets, misplaced perforated tiles or holes in the computer room perimeter walls.

CAC - Cold Aisle Containment system that directs cooled air from air conditioning equipment to the inlet side of racks in a highly efficient manner.

CADE - Corporate Average Data Center Efficiency.

Conditioned Air - Air controlled in terms of temperature, humidity, and particles per thousand.

CFD - Computational Fluid Dynamics, a numerical analysis technique commonly used in the analysis of airflow in data centers.

Chilled beams - Units which, by natural convection from a finned heat exchanger, cool the air in a room.

Chiller - A unit consisting of a compressor, a condensing section and an expansion section. The condensing and expansion sections nearly always have water or glycol as the heat transfer agent to the rest of the system; primary water/glycol on the condensing side and secondary water on the expansion side.

Class A1 - –Used to classify IT Equipment that is suitable for deployment within a data center with tightly controlled environmental parameters (dew point, temperature, and relative humidity) and mission critical operations; types of products typically designed for this environment are enterprise servers and storage products.

Class A2 - Used to classify IT Equipment that is suitable for deployment within an information technology space or office or lab environment with some control of environmental parameters (dew point, temperature, and relative humidity); types of products typically designed for this environment are volume servers, storage products, personal computers, and workstations.

Class A3/A4 - Used to classify IT Equipment that is suitable for deployment within an information technology space or office or lab environment with some control of environmental parameters (dew point, temperature, and relative humidity); types of products typically designed for this environment are volume servers, storage products, personal computers, and workstations.

Class B - Used to classify IT Equipment that is suitable for deployment within an office, home, or transportable environment with minimal control of environmental parameters (temperature only); types of products typically designed for this environment are personal computers, workstations, laptops, and printers.

Class C - Used to classify IT Equipment that is suitable for deployment within a point-of-sale or light industrial or factory environment with weather protection, sufficient winter heating and ventilation; types of products typically designed for this environment are point-of-sale equipment, ruggedized controllers, or computers and PDAs.

Close-Coupled Cooling - Cooling technology that is installed adjacent to server racks, minimizing the path that air must flow from the cooling unit through the IT equipment and back to the cooling unit.

Cold Aisle - An aisle where rack fronts face into the aisle. Supply (cold) airflow is directed into this aisle so that it can then more readily enter the fronts of the racks.

Cold Spot - An area where ambient air temperature is below desired levels. Typically caused by ineffective airflow management necessitating a temperature set point lower than that which would be required with proper airflow management.

Constant Air Volume (CAV) Systems - the temperature of the air supplied to the building can vary, but the air flow rate is kept constant.

Cooling panels - Cold water flows through an aluminum plate, which transfers heat from the air to the cold water. The panel cools the warm room air and also cools the room's surfaces by low-temperature radiation.

Cooling Tower - A device which cools water via the direct evaporation of some of the water. Water is pumped into the top of the cooling tower and allowed to run down over the fill, typically pads or strips into a sump at the bottom of the cooling tower. Air is drawn in from the sides over the fill by fans in the top of the tower, evaporating some of the water, which cools the remaining water. The temperature of the water in the sump is controlled by varying the speed of the fans. The water in the sump is then used to cool the condensing section of a chiller or to cool the secondary loop directly via a heat exchanger (see water side economizer).

CRAC - Computer room air conditioner (pronounced crack), which uses refrigerant and a compressor. Cooling of the air in the data center is accomplished by airflow over the evaporation coils where the refrigerant is being "directly expanded" (see DX).

CRAH - Computer Room Air Handler (pronounced craw) which uses chilled water passing through a heat exchanger to cool air flowing over the heat exchanger.

Critical Load - Computer equipment whose uptime is non-interruptible, typically supported by a UPS.

CSI - Cold Supply Infiltration index, quantifies the amount of hot air mixing with cold inlet air prior to entering the rack.

Cutout - An open area in a raised floor that allows airflow or cable feeds.

DCie - Data Center Infrastructure Efficiency

Dead Band - A control technique which prevents oscillation or unnecessary cycling of a controlled variable. In data center cooling, it typically applies to the action of the CRAC or CRAH relative to the set point. A certain amount of dead band around the set point prevents unnecessary cycling of the compressor or chilled water valve.

Delta T - The difference in temperature across a device. Examples include the temperature difference between the inlet and outlet of piece of IT equipment or between the inlet and outlet of a cooling unit (CRAC or CRAH). Delta T, airflow and thermal dissipation are related: $\text{thermal dissipation} = \text{airflow} \times \text{delta T} \times \text{specific heat of air}$.

Dewpoint - The temperature at which air reaches water vapor saturation. Dewpoint is constant for a specific amount of water in a specific amount of air while relative humidity varies with temperature. The latest ASHRAE TC 9.9 Thermal Guidelines for data center environmental conditions includes an upper limit for humidity based on dewpoint.

D/H - Dehumidifying/Humidifying.

Dry-Bulb Temperature - The temperature of the air measured using a dry-bulb thermometer such that evaporative cooling has no effect. Typically taken in conjunction with a wet-bulb reading which does include the evaporative cooling effect in order to determine relative humidity.

Dry Cooler - A liquid-to-air heat exchanger that is a radiator over which air is blown via fans. Typically used as the heat rejection device for water or glycol cooled condensers, may also be used as the heat rejection device for liquid cooled coils in an AHU under proper environmental conditions.

DX - An abbreviation for direct expansion. This refers to the use of refrigerant directly expanded into evaporation coils in the supply air.

EMCS - Energy Monitoring and Control System

ERE - Energy Reuse Effectiveness. ERE is defined as the ratio of the total energy to run the data center facility minus the reuse energy to the total energy drawn by all IT equipment.

Free Cooling - Used in connection with all-air cooling systems, when the cooling requirement can be met solely without the use of compressors or mechanical refrigeration. Also used to describe the process of utilizing the colder outside air to cool a building instead of operating an air conditioning unit.

HAC - Hot Aisle Containment, system that segregates and channels heated air from the outlet side of racks directly back to air conditioning equipment in a manner that prevents air mixing with the supply air to the data center.

Heat Exchanger - A device used to transfer heat energy from one medium to another. Common uses of heat exchangers are water to air heat exchangers in air handling units, water to water (plate and frame or shell and tube) heat exchangers in water side economizers, etc.

Hot Aisle - An aisle where rack backs face into the aisle. Heated exhaust air from the equipment in the racks enters this aisle and is then directed to the CRAC or CRAH return vents.

HPDC - High-Performance Data Center, a data center with above average kW loading, typically greater than 10kW/rack.

Hot Spot - An area, typically related to a rack or set of racks, where ambient air temperature is above acceptable levels. Typically caused by poor airflow management (insufficient cool air supply or an excess of recirculation).

In-Row Cooling - Cooling technology installed between racks in a row that draws warm air from the hot aisle and delivers cool air to the cold aisle, minimizing the path of the air (see close coupled cooling).

Inlet Air - The air entering the equipment. For air conditioning equipment this is the heated air returning to be cooled, also called return air. For IT equipment (e.g. servers) this is the cooled air entering the equipment.

Latent Cooling - Latent cooling is the process of lowering the temperature of air below its dew point to reduce its moisture content. In a typical HVAC application, latent cooling occurs when air is moved across a "cold" surface, like a cooling coil. In order for latent cooling to occur, the temperature of this "cold" surface must be lower than the dew point of the air. As the air is moved across this "cold" surface, its temperature drops until moisture condenses on the "cold" surface, lowering the moisture content of the air. This is known as latent cooling. Once air reaches a temperature that results in condensation, both sensible and latent cooling will occur simultaneously. .

Latent Cooling Capacity - Cooling capacity related to wet bulb temperature and objects that produce condensation.

Liquid Cooling - A general term used to refer to cooling technology that uses a liquid as the heat transport medium. In data centers, the two prevalent forms of heat evacuation are liquid (chilled water) and refrigerant (DX).

Load - The demand placed on a system, typically used to describe the electrical demand on the electrical supply system or the cooling demand on the cooling system. Units are power such as kW, BTU/hr, Tons, etc.

MAH - Makeup Air Handler, an air handler that conditions and delivers outside air into an occupied space.

Make-Up Air - The conditioned air delivered by a MAU or MAH.

MAU - Makeup Air Unit, synonymous with MAH.

MERV - Minimum Efficiency Reporting Value, ASHRAE 52.2, for air filtration measured in particulate size.

Nominal Cooling Capacity - The total cooling capacity of air conditioning equipment, includes both latent cooling and sensible cooling capacities.

OEM - Original equipment manufacturer

Overcooling - A situation where air is cooled below optimum levels. Typically used in reference to rack inlet temperatures.

PDU - Power Distribution Unit, this typically refers to one of two pieces of equipment in the power delivery chain. One is the combination transformer/breaker panel that is often used between a UPS supplying voltage higher than that used by the IT equipment and the cabinets. The other is the smaller "power strip" like device that is used inside the rack to distribute power to the IT equipment.

Pressure Differential - The difference in pressure between two locations in the data center. Air flows from higher pressure areas to lower pressure areas. Often times, the pressure differential between the under-floor plenum and the above-floor space is controlled by varying the speed of the fans supplying air to the under-floor plenum. This allows the addition of vented floor tiles to occur without affecting the air delivered to existing vented floor tiles so that additional IT load may be placed on the floor without disturbing the tuning of the existing floor.

Plenum - A receiving chamber for air used to direct air flow.

Primary Loop - Refers to the water loop which cools the condenser side of a chiller. This loop is cooled by dry coolers or cooling towers.

PU - Packaged Unit, an air handler that is a complete device shipped ready for use rather than a custom device that is assembled on-site from components.

PUE - Power Usage Effectiveness, a measure of data center efficiency calculated by dividing the total data center energy consumption by the energy consumption of the IT computing equipment.

Rack - Device for holding IT equipment, also called a cabinet when its architecture is enclosed.

RAH - Recirculation Air Handler, a device that circulates air but does not cool the air.

RCI - Rack Cooling Index. RCI measures how effectively equipment racks are cooled according to equipment intake temperature guidelines established by ASHRAE/NEBS

Raised Floor - Metal flooring on stanchions that creates a plenum for airflow and / or cabling, synonymous with RMF.

Recirculation - Air which exits IT equipment and then re-enters either the same IT equipment or another piece of IT equipment without being cooled and therefore increases the burden on the cooling equipment. Typically the result of poor airflow management (e.g. missing blanking panels, gaps in rows, no containment, poor row architecture, insufficient air supply, etc.).

Return Air - The heated air returning to air conditioning equipment.

Rh - Relative Humidity.

RMF - Raised Metal Floor, an alternate term for the more commonly used term 'raised floor'.

RPM - Revolutions per Minute, a unit of angular velocity.

RPP - Remote Power Panel.

RTI - Return Temperature Index. RTI evaluates the energy performance of the air management system.

RTU - Rooftop Unit, an air handler designed for outdoor use mounted on a rooftop.

SCFM - Standard Cubic Feet per Minute, the volumetric flow rate of a gas corrected to standardized conditions of temperature, pressure and relative humidity.

SCADA- Supervisory Control and Data Acquisition

Secondary Loop - Refers to the water which is used to cool the heat exchangers in AHUs and is cooled via the expansion unit in a chiller.

Sensible Cooling - The action of lowering the dry bulb temperature of air without condensation taking place.

Set Point - In a control system, this is the value against which the variable that is being controlled is compared. Temperature and humidity set points are common in the cooling system for a data center.

Short Cycling - Chilled airflow returning to cooling units without passing through IT equipment, also referred to as bypass.

Standby Power - standby power as the power consumed by a product when in the lowest power consuming mode. This typically occurs when the product is switched to "off" or not performing its primary purpose.

Sub-Floor - The open area underneath a raised computer floor, also called a sub-floor plenum.

Supply Air - The cooled airflow emitted from air conditioning equipment.

Total Annual Energy - is calculated as the weighted sum of the annual energy consumption for all energy types serving the data center at the data center boundary.

TCO - Total cost of ownership (capital cost + operating cost over a finite period of time)

Thin Provisioning - Thin Provisioning, in a shared storage environment, is a method for optimizing utilization of available storage. It relies on on-demand allocation of blocks of data versus the traditional method of allocating all the blocks up front. This methodology eliminates almost all whitespace which helps avoid the poor utilization rates, often as low as 10%, that occur in the traditional storage allocation method where large pools of storage capacity are allocated to individual servers but remain unused (not written to). This traditional model is often called "fat" or "thick" provisioning.

UPS - Uninterruptible Power Supply, a device placed in series with the supply of power from the utility which contains internal energy storage such that the supply of power from the UPS is continuous even when the primary supply of power (typically the utility) is removed. While battery-based energy storage is the most common, flywheel-based energy storage is gaining in popularity due to the reduced maintenance cost. The duration of time that the UPS runs using its internal energy source is typically short and intended to span the gap between the primary source of power is removed and either returned or replaced by the secondary source of power (typically an emergency generator).

Velocity - A speed of airflow expressed in Feet Per Minute (FPM).

VFD - Variable Frequency Drive, a device which supplies AC power of varying frequency, typically used to control the speed of induction motors. In the data center, it is common to vary the speed of fans, pumps, and chillers.

Volumetric Air Flow - The volume and speed of air being transported; expressed in Cubic Feet per Minute.

Waterside Economizer - A system which uses a source other than a chiller to cool the secondary loop water used by the AHUs. This typically consists of either a dry cooler or cooling tower, piping, valves and in the case of a cooling tower, it also includes a heat exchanger since the secondary loop water is treated completely differently than the primary loop water and is typically much "better" water.

Wet-Bulb Temperature - The temperature of the air measured using a wet-bulb thermometer, that is, the temperature to which a wet surface can be cooled by evaporation. This temperature is affected by both the dry bulb temperature and the dew point of the air. Drier air has a lower wet bulb temperature. This is a design constraint when utilizing cooling towers or evaporative pads in the cooling process.

Wg - Inches of water column, a unit of pressure based on the height of a column of water supported by the pressure differential between the top and bottom of the column. 1 inch wg = .036 psi.

WPSF - Watts per Square Foot, a unit of power density. In a data center this is a bulk term that refers to the total load in a raised floor space divided by the total area of that raised floor space. This is a design parameter for total capacity of the cooling and power systems and is used in conjunction with point load (the amount of load in a small space such as a rack).