Increasing energy efficiency in data centers

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Datacom (data centers and communications facilities) energy use and efficiency has moved to the forefront of public policy, the IT (information technology) industry, and data center operator discussions. This focus has been driven by a convergence of concerns:

- Rising energy costs and increased energy supply and security concerns worldwide have generated a public policy focus on increasing the efficient use of energy in national economies;
- Climate change concerns are driving a focus on energy conservation as a means to reduce energy use and CO2 emissions;
- High density computer equipment are exceeding the power and cooling capacity of current data centers and driving significant increases in data center power use; and
- Use levels of 10% to 20% in some server and storage products are recognized as driving unproductive power consumption in the data center.

Without intervention, these data center trends are likely to become more pronounced. Jonathan Koomey reported that server electrical use alone represents 1.2% of U.S. electrical use, suggesting overall data center use would be close to 2%. (1) He estimated that server electrical use has doubled from 2000 to 2005 and will grow by 15% annually from 2006 to 2010. Other articles and references have detailed similar growth rates at individual firms. (2) This rapid increase in energy use is attracting the attention of environmental agencies in the U.S., European Union, China and other countries.

The U.S. Environmental Protection Agency (EPA) ENERGY STAR[R] initiative has targeted the development of ENERGY STAR specifications for IT equipment and data center energy use. For IT equipment the EPA's initial focus is on servers. The EPA has stated that they intend to propose specifications for power supply efficiencies for selected classes of servers by the end of 2007 and power workload performance benchmarks by the end of 2008. (3) These specifications will drive manufacturers of IT equipment and data center operators to achieve advances in power and workload

management, greater energy use, improved integration of facilities, and implementation of recognized best practices.

The European Union has initiated discussion to establish a data center code of conduct which will establish best practices to which data center operators subscribe to improve the energy efficiency of their operations. Many jurisdictions are establishing energy.efficiency programs, which may require companies to develop energy.efficiency plans, (4) utilities to supply demand growth through energy. efficiency projects, and carbon dioxide emission allocations, (5) which require companies to reduce their energy use over time to operate within their emission allocation. It is expected that there will be extensive implementation of these types of programs as countries establish climate change/ energy policies and actions.

Significant opportunities exist to improve data center energy use and efficiency through the implementation of best practices and leading edge engineering design strategies. It is estimated that data centers can reduce their energy use by 10% to 40% through the application of these practices and strategies. (6) ASHRAE Technical Committee 9.9, Mission Critical Facilities, Technology Spaces, and Electronic Equipment, is uniquely positioned to provide the resources needed by data center operators to improve and optimize energy use in their operations.

Overview of ASHRAE TC 9.9

With the increased power trends of the IT equipment and need to provide important information about the data center infrastructure to data center operators, owners, CIO's, consultants and others, key technical experts of the major IT manufacturers recognized that power and cooling capacities were becoming increasingly more challenging for the industry. Further, they saw no vendor.neutral professional society holistically addressing the technical aspects of the data center industry, and they were seeing increasing need for the collaboration and coordination of the IT industry and the facilities industry.

Due to ASHRAE's major international presence, leadership, long history (started in 1894), and major publishing infrastructure (including model codes, standards, guidelines, courses, etc.), the IT manufacturers saw ASHRAE as the source to publish unbiased information. Because no other vendor neutral, nonprofit organization existed for data center facilities, the committee was organized and its members carefully selected to address the broadest possible scope. For example, the committee title, "Mission Critical Facilities, Technology Spaces, and Electronic Equipment," reflects a broad perspective.

TC 9.9 members include experts from the IT manufacturers, as well as the facility design, construction, and operation areas. The committee also includes members from

many countries to help provide a broader perspective. Many committee members are not members of ASHRAE and are not thermal engineers.

The focus of the committee is to identify informational and technical needs of the data center industry and to meet those needs. Where the committee does not have the full range of resources or expertise, resources are sought and added to the team. These needs in some cases are not HVAC based, so the committee and ASHRAE's publishing capabilities are used as a means of meeting the industry's needs. To summarize, TC 9.9 has the following major objectives:

- Produce unbiased technical material on data center HVAC;
- Provide unbiased training on data center HVAC; and
- Provide a forum for publishing unbiased technical material on subjects other than HVAC that relate to the data center.

TC 9.9 Datacom Book Series

The Datacom Book Series is ASHRAE TC 9.9's primary means to meet the informational needs of the data center industry. The content is intended to provide value to technical and non.technical readers.

At the time of this publication, the following six books were published with two bookssoon to be completed.Thermal Guidelines for Data Processing Environments (2004) Datacom Equipment Power Trends and Cooling Applications (2005) Design Considerations for Datacom Equipment Centers (2006) Liquid Cooling Design Guidelines for Datacom Equipment Centers (2006) Structural and Vibration Guidelines for Datacom Equipment Centers (2007) Best Practices for Datacom Facility Energy Efficiency (2007) High Density Data Centers..Case Studies and Best Practices (forthcoming) Contamination and Economizers in Datacom Facilities (forthcoming)

Book 1: Thermal Guidelines for Data Processing Environments. This book is a framework for improved alignment among IT equipment hardware manufacturers (including manufacturers of servers, and storage products), data center designers, and facility operators and managers.

This guide covers four primary areas: equipment operating environment specifications (four classes defined), facility temperature and humidity measurement (to evaluate data center health), equipment placement and airflow patterns (a hot aisle/ cold aisle layout is recommended), and equipment manufacturers' heat load and airflow reporting requirements.

Book 2: Datacom Equipment Power Trends and Cooling Applications. Datacom equipment technology is advancing at a rapid pace, resulting in an increased frequency of datacom equipment upgrades. Since datacom facilities are composed of components that are typically built to have longer life cycles

than datacom equipment, any modern datacom facility design needs to seamlessly accommodate the multiple datacom equipment deployments it will experience during its lifetime. This book provides new and expanded datacom equipment power trend charts to allow the datacom facility designer to more accurately predict the datacom equipment loads that their facility can expect to accommodate in the future, as well as providing ways of applying the trend information to datacom facility designs today. The trends projected to 2014 are based on the latest information from all the leading datacom equipment manufactures.

Book 3: Design Considerations for Datacom Equipment Centers. The design of computer rooms and telecommunications facilities is different in fundamental ways from the design of facilities used primarily for human occupancy. ASHRAE has not, until now, published a basic reference text to provide an overview of the special design needs of datacom facilities.

This book is divided into two parts. Part 1, Datacom Facility Basics, includes chapters on datacom design criteria (temperature, temperature rate of change, relative humidity, dew point, and filtration), HVAC load, computer room cooling (includes both air and liquid cooling), and air distribution. Part 2, Other Considerations, includes chapters on ancillary spaces (battery plants, emergency generator rooms, burn.in rooms and test labs, and spare parts rooms), contamination, acoustical noise emissions, structural and seismic design and testing, fire detection and suppression, commissioning, availability and redundancy, and energy efficiency.

Book 4: Liquid Cooling Guidelines for Datacom Equipment Centers. Data center IT equipment today is predominantly air cooled. However, with rack heat loads steadily climbing, the ability for many data centers to deliver either adequate airflow rates or sufficient chilled air is now being stretched to the limit.

IBM Server Model 520 - Rack Mounted Drawer

Configuration	Condition								
	Typical Heat Release (Voltage 110 V)	Airflow				Weight		Overall System Dimensions[b] (W x D x H)	
		Nominal[a]		Maximum at 35°C					
	watts	cfm	(m³/h)	cfm	(m³/h)	lbs	kg	in	mm
Minimum	420	26	44	40	68	117	53	25 x 37 x 23	639 x 933 x 584
Full	600	30	51	45	76	117	53	25 x 37 x 23	639 x 933 x 584
Typical	450	26	44	40	68	117	53	25 x 37 x 23	639 x 933 x 584

ASHRAE Class 3	Airflow Diagram Rack-mount Cooling scheme F-R	Configuration	
		Description	Model
		Minimum	1-way, 1.5 GHz processor, 16 GB memory
		Full	2-way, 1.65 GHz processor, maximum memory
	Front to Rear F-R	Typical	1-way, 1.65 GHz processor, 16 GB memory

a. The airflow values are for an air density of 1.2 kg/m³ (0.075 lb/ft³). This corresponds to air at 20°C (68°F), 101.3 kPA (14.7 psia), & 50% relative humidity
b. Footprint does not include service clearance or cable management, which is zero on the sides, 48 in. (1168 mm) in front, & 40 in. (1016 mm) in the rear.

Figure 1: Datacom manufacturer's thermal report.

The overall goals of the liquid implementations include aspects such as transferring as much waste heat to the facility liquid cooling loop as possible, reducing the overall volume of airflow needed by the racks, and reducing processor temperatures such that increased compute performance can be achieved. This book describes the liquid systems and their interface requirements.

- The datacom equipment itself is becoming heavier; and
- The facility is able to house more datacom equipment and therefore becomes increasingly important to the owner. This may result in the need for increased structural resistance against the potential threats of high wind, snow, seismic and physical assault.

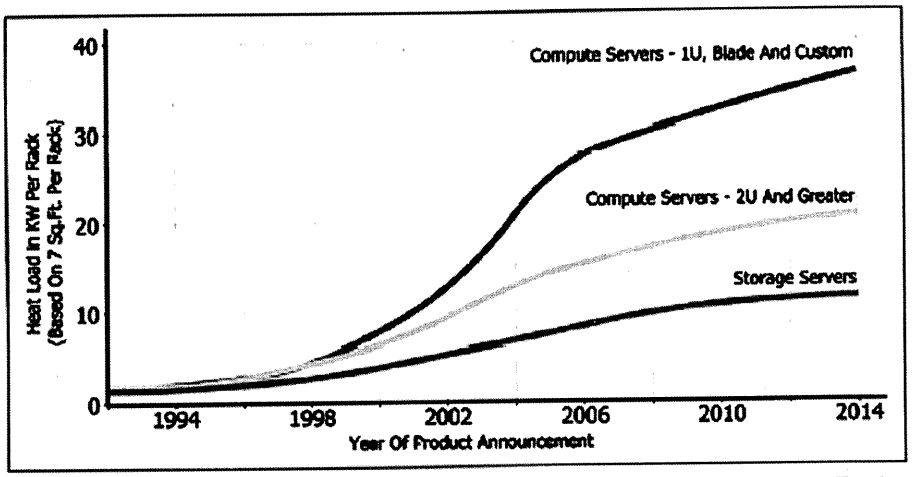

***Figure 2: ASHRAE power trend chart (based on 7 ft² per rack). (Source:* Datacom Equipment Power Trends & Cooling Applications.)**

Book 5: Structural and Vibration Guidelines for Datacom Equipment Centers. Datacom equipment centers require a focus on the structural and vibration performance of the facility, the building infrastructure, and the contents (e.g., datacom equipment).

As the datacom equipment density continues to increase (compaction), the requirements of the datacom facility continue to evolve because:

- The power and cooling infrastructure is becoming larger, heavier and inherently more structurally challenging;

This book, as part of the ongoing ASHRAE Datacom Series, provides the reader with critical information about structure and vibration in datacom facilities. The book includes best practices, building structure, building infrastructure (power, cooling, flooring, and ceiling systems), and datacom equipment or IT equipment (servers, storage, tape drives, network equipment, etc.).

Book 6: Best Practices for Datacom Facility Energy Efficiency. Sustainable design, global warming, depleting fuel reserves, energy use and operating cost are becoming

increasingly more important. These issues are even more important in datacom equipment centers for reasons such as:

- Large, concentrated use of energy (can be 100 times the watts per square foot of an office building); and
- 24/7 operations have about three times the annual operating hours as other commercial properties.
- The intent of this publication is to provide the reader with detailed information on the design of datacom facilities that will aid in minimizing the life.cycle cost to the client, maximize energy efficiency in a facility, and align with ASHRAE's stated direction (from the 2006 Strategic Plan) to "lead the advancement of sustainable building design and operations."

This book covers many aspects of datacom facility energy efficiency, and includes chapters on the topics of environmental criteria, mechanical equipment and systems, economizer cycles, airflow distribution, HVAC controls and energy management, electrical distribution equipment, datacom equipment efficiency, liquid cooling, total cost of ownership, and emerging technologies. There are also appendices on such topics as facility commissioning, operations and maintenance, and the telecom facility experiences.

Using Book 1 to Save Energy

The first book in the datacom series, Thermal Guidelines, was a major contributor

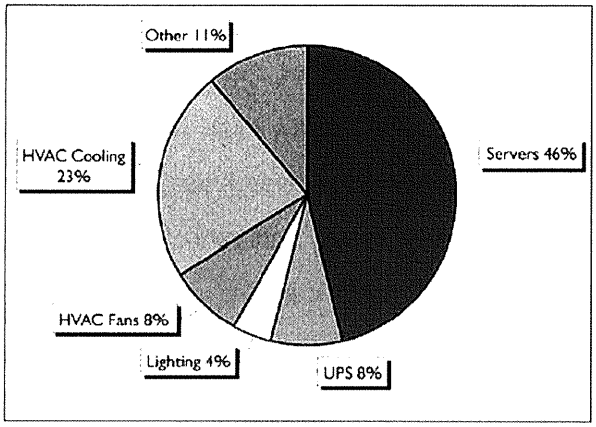

Figure 3: Average data center power application.

to developing energy.efficient solutions. This book addresses the need for temperature and humidity standardization. This is particularly critical in a multiple IT vendor environment.

Book 1 establishes a much wider range of recommended temperatures (68[degrees] F to 77[degrees]F [20[degrees]C to 25 [degrees] C]) and relative humidity (40% to 55%) than the industry had been using. This creates the opportunity for broader [DELTA]Ts and increases the annual hours where economizers potentially can be used. In addition to the recommended temperatures and humidities, allowable values are given that provide an even broader range.

The impact of an extended temperature range is further improved by the book's definition of where the temperature is measured. Prior to this book, there was no industry standard regarding where temperatures should be measured. The book clearly identifies that the required temperature range is measured at the air inlet to the datacom equipment. Another opportunity for savings was created

in the book by developing an accurate method of establishing the load. Previous to Book 1, the IT load often was established by applying a derating factor to the nameplate data. This led to significant inaccuracies resulting in the cooling system and equipment not being right.sized. The book establishes a thermal report that is used by the datacom manufacturers to report measured load (heat release) as well as airflow (Figure 1).

Finally, the book identifies the airflow protocols for datacom equipment. This is further enhanced by clearly describing the hot aisle/cold aisle concept, which reduces the badly distributed air that occurs in a mixed aisle architect.

Using Book 2 to Save Energy

Book 1 provides pivotal information regarding designing an energy.efficient facility to meet today's needs through environmental conditions, temperature measurement, accurate heat release information, equipment airflow, and datacom equipment row architecture.

A critical challenge is that the datacom equipment often is upgraded or replaced multiple times, while the basic facility and cooling system are not replaced or significantly upgraded. As a result, it is important to gain a basic understanding of what the datacom equipment cooling needs will be across the lifetime of the facilities cooling system.

Book 2, Datacom Equipment Power Trends, projects the load growth through 2014 (Figure 2). These curves show the worst.case scenario for a given type of equipment. For equipment that is not fully configured a derating factor is needed.

Using Book 6 to Save Energy

To perform a serious analysis of energy efficiency, the first step is benchmarking existing energy consumption. Lawrence Berkeley National Labs (LBNL) initiated a benchmarking study of data centers in 2001, a study that eventually examined energy use in 22 data centers. Average power allocation was difficult to assess because of variations in site characteristics, but an approximate average allocation of 12 of the 22 data centers benchmarked is shown in Figure 3.

This breakdown of power distribution within the data center serves as a structure for the book, that is, each chapter describes the technologies for each area shown in the figure followed by best practices for that area that results in reduced energy use. For example, a best practice for HVAC cooling is using central humidity control that can eliminate one of the historical causes of wasteful energy use. Another is to use variable speed control for pumps and motors. These and many others are described in the eleven chapters of the book.

Summary

ASHRAE Technical Committee 9.9 was formed in 2001 and will have published six datacom books by the end of 2007 (with two more due soon) focusing on data center environmental guidelines, power trends, design considerations in the data center, liquid cooling, structural vibration, and energy efficiency. All of these can be purchased in print or downloadable versions from www.ashrae.org/bookstore. Significant energy improvements of up to 50% energy savings in a data center can be achieved by using the energy saving management techniques and solutions described in Books 1, 2 and 6.

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