ENERGY STANDARD FOR DATA CENTERS 90.4

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ASHRAE SSPC 90.4 will publish an updated version of Standard 90.4, *Energy Standard for Data Centers*, this year as ANSI/ASHRAE Standard 90.4-2022. This standard is incorporated into Standard 90.1 as an Alternate Compliance Path, so it is important for anyone dealing with data center design to be familiar with it. What, then, is Standard 90.4, how did it come about and how do you use it?

Standard 90.4 is a companion document to Standard 90.1. Rather than duplicate the noncritical aspects of data center facilities that are already covered by Standard 90.1, Standard 90.4 requires data center facilities to comply with Standard 90.1 for typical building aspects such as building envelope, service water heating and lighting. However, because meeting certain aspects of Standard 90.1 have potentially deleterious effects on data center reliability, Standard 90.1 allows the use of Standard 90.4 as an "alternative compliance path" for facilities that have data center spaces. As such, Standard 90.4's Title, Purpose and Scope are very important

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in establishing the overarching boundaries and limitations of when the standard applies and when it does not.

The Title is obvious: Energy Standard for Data Centers. The Purpose is stated as "…this standard is to establish the minimum energy efficiency requirements of data centers for

a. design, construction, and a plan for operation and maintenance; and

b. use of on-site or off-site renewable energy resources."

The purpose of 90.4, therefore, is to establish a "design" standard and a "plan" for operations and maintenance, allowing for consideration of renewable energy sources to meet the efficiency requirements. It does *not* include any requirement that the constructed facility be verified as operating efficiently—only that it be engineered and designed to be capable of efficient operation, and that this capability be demonstratable to an authority having jurisdiction (AHJ). There is neither a requirement for owners or end users to use all the capabilities, nor is there a requirement for an AHJ to inspect and verify that the facility is meeting the intended efficiencies.

Simply stated, Standard 90.4 is a design standard meant to make efficiency compliance realistic for both the engineers and the AHJ without impairing the reliability and availability of mission critical facilities. Owners wanting to verify operational compliance can turn to other sources.

However, the design must still include a "plan for operations and maintenance." Even if no mechanism exists to enforce operations compliance, it still requires the design team to provide information to the owner as to how the design should be used to realize the efficiencies provided by the design. This aspect takes on high importance with data centers due to the typical need for redundant systems and equipment to provide the required reliability. This, in turn, results in excess capacities and, therefore, less than maximum efficiencies.

Complying with Standard 90.4 ensures that, even with these redundancies, a high level of efficiency is still realized. Further, since data centers typically have day-one loads much smaller than their ultimate design capacity ratings, opportunities exist to optimize mechanical energy efficiencies by applying the affinity laws (energy used is proportional to the cube of rotational speed) by spreading loads across redundant systems and equipment. Likewise on the electrical side, operating electrical equipment at low load conditions, particularly uninterruptible power supplies (UPSes) typically results in reduced efficiency. Therefore, finding the "sweet spot," both electrically and mechanically, may require strategies and operating plans that optimize infrastructure efficiency based on variable load profiles. Since these variables must be addressed to meet the Standard 90.4 requirements, it is only right that apprising the owner of

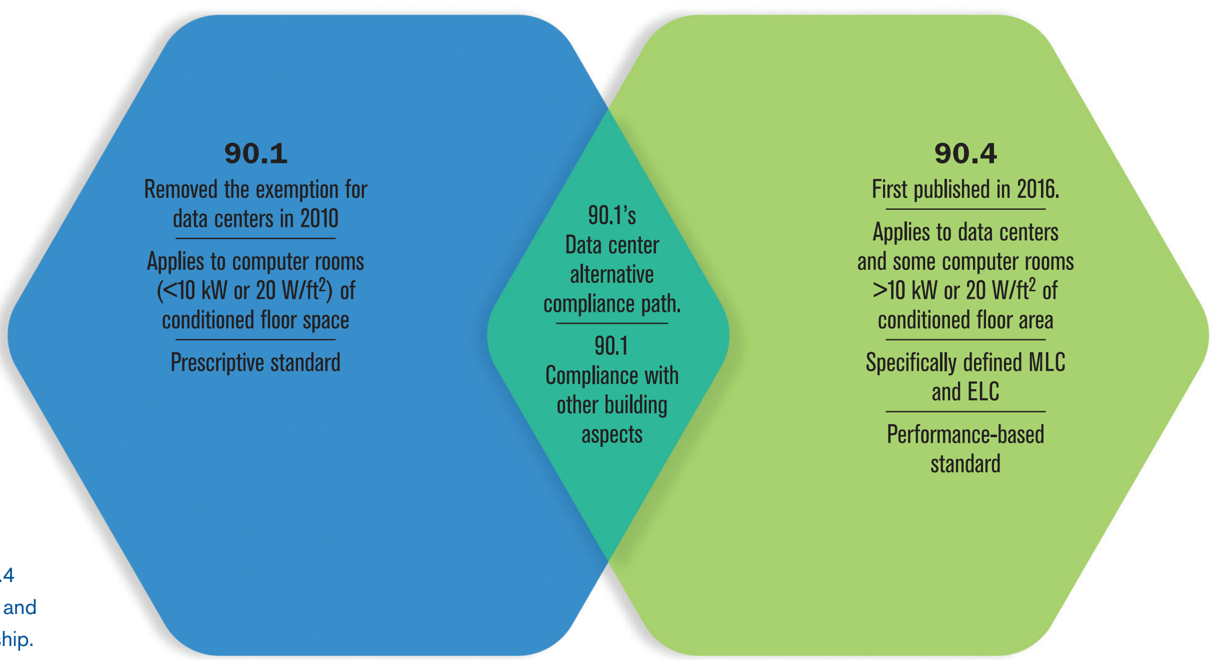

FIGURE 1. Standards 90.1 and 90.4 demarcation and interrelationship.

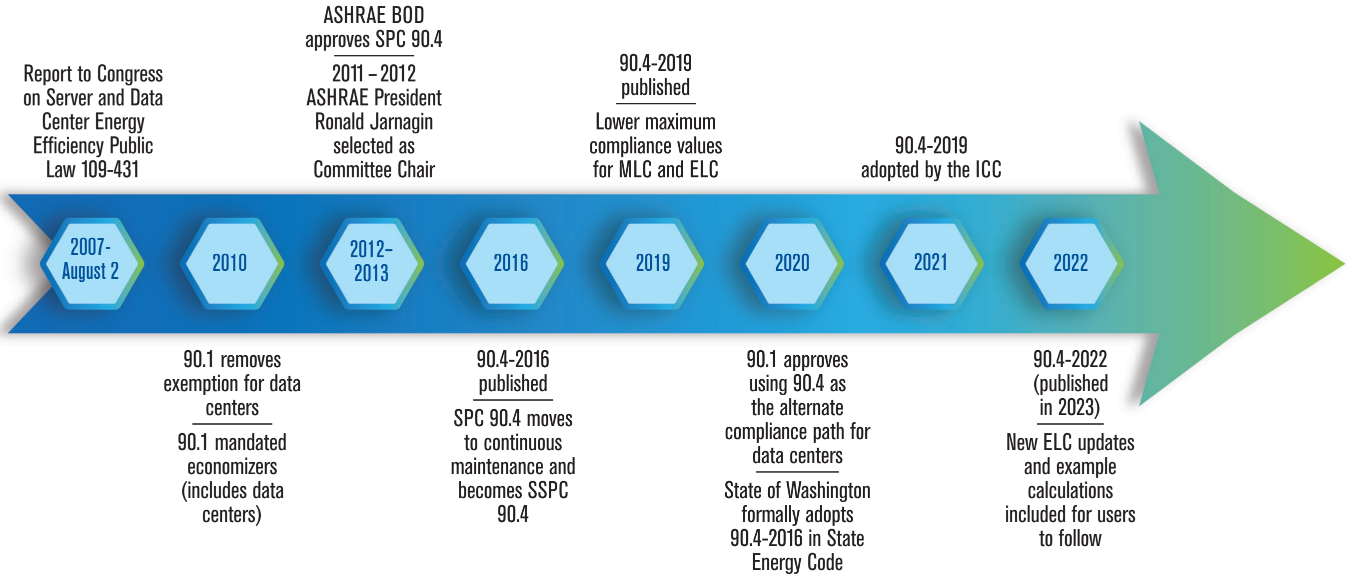

FIGURE 2. Standard 90.4 development timeline.

these considerations also be required.

The Scope section of Standard 90.4 clarifies the application. It states, "this standard applies to

a. new data centers, or portions thereof, and their systems;

b. new additions to data centers, or portions thereof, and their systems; and

c. modifications to systems and equipment in existing data centers or portions thereof."

The Scope also says, "The provisions of this standard do not apply to

a. telephone exchanges,

b. essential facilities, and

c. information technology equipment (ITE)."

Understanding the exceptions is crucial. Telephone exchanges are not governed, but if telephone exchanges become data centers (as many do) and parts of them are no longer classified as Common Carriers, then Standard 90.4 does apply. Likewise, "essential facilities" must meet specific requirements. Most data centers are classified as "mission critical," but that does *not* automatically make them "essential facilities." The clarifications are included in the standard. Lastly, the standard does not attempt to impose efficiency requirements on the actual data processing equipment (computers, processors, servers, switches, routers, etc.), more properly known as information technology equipment (ITE). It applies only to the environment and related infrastructure in which the ITE is operated. Design engineers need to quantify the maximum ITE load (and day-one minimum ITE load), but there are no ITE energy efficiency requirements for the actual electronic equipment.

Standard 90.4 does not just apply to new greenfield projects. It also applies to data center expansions and modifications to infrastructure. Data centers are often pre-planned with significant expansions engineered into the original designs. Further, as data centers and respective technologies continue to evolve, existing sites can require upgrades and modifications. It follows, therefore, that facility expansions as well as system and equipment modifications are the norm and should adhere to the latest efficiency requirements.

After Title, Purpose and Scope, the most important part of the standard is Definitions, as listed in Section 3, and two of the most important definitions are those for "data centers" and "computer rooms." The delineation between these two classifications resulted from collaboration between the SSPC 90.1 committee and SPC 90.4 committee. It was agreed that a computer room is defined as "a room or portions of a building serving an ITE (information technology equipment) load less than or equal to 10 kW or 20 W/ft^2 (215 W/m^2) of conditioned floor area." A data center, on the other hand, is defined as "a room or building, or portions thereof, including computer rooms being served by the data center systems, serving a total ITE load greater than 10 kW and 20 W/ft^2 (215 W/m^2) of conditioned floor area. Why is this distinction so important? Because computer rooms remain under the purview of Standard 90.1, but data centers are covered by Standard 90.4. In short, it is the ITE power load and density that serve as the demarcation between the applicability of these two independent, but interrelated standards.

What made it necessary to develop a separate energy efficiency standard for data centers when all other energy aspects of commercial buildings are well covered by Standard 90.1? There are four major reasons:

1. Standard 90.1 is primarily a prescriptive standard and mandates economizers as a major part of its mechanical system energy saving strategy. Nothing is wrong with economizers. Economizers are not only allowed, but are also encouraged in the 90.4 standard. However, if used in the same manner as in conventional office buildings, economizers can have serious reliability consequences for mission critical data centers. Further, the data center industry has developed methods of cooling efficiently that are not practical for commercial buildings. This enables data centers to be constructed in existing buildings where the addition of an economizer under Standard 90.1 requirements would be impractical or cost-prohibitive, precluding an important business need. Standard 90.4 is first and foremost a performance standard, enabling any available solution or solutions to be used by the design engineer that meets the prescribed efficiency requirements.

2. Modern data centers consume enormous quantities of energy over relatively small footprints compared with typical office buildings, and they do it continuously (24/7). Where 2.5 W/ft^2 (27 W/m^2) is reasonable for a typical office building during occupied hours, 250 W/ft^2 (2700 W/m^2) for data center server rooms is not unusual. Conventional cooling solutions are simply not applicable and, if used, will almost certainly fail to meet the efficiency requirements of Standard 90.4 as well as likely undercooling the critical computing hardware.

3. Data center ITE loads can be cooled with 80°F (27°C) inlet air, exhaust 110°F (43.3°C) or higher air, and are 100% sensible (no latent cooling required). The environment can also vary from a low of 8% relative humidity (RH) to as high as 70% RH depending on facility grounding and gaseous contamination conditions. These design parameters are radically different than typical "comfort cooling." The combination of heat levels, temperature differentials, humidity and year-round operation does not even enable viable simulations using standard energy modeling tools. This drives different engineering challenges and provides interesting opportunities for the development of cooling solutions with or without conventional economizers.

And because of the high, and continually increasing, heat loads, the data center industry is using more and more liquid cooling approaches of various types. The wide range of requirements and available solutions make it critical that Standard 90.4 be a performance-based standard.

4. Last, but possibly most important over the long haul, is that data center designs must quickly evolve as the ITE technology changes. This inevitably creates facility and infrastructure challenges to meet new and more demanding requirements. Future changes can be anticipated to at least some extent—and planned for in greenfield projects. But existing facilities must also undergo constant ITE "refreshes" to support computing demands that weren't even in existence when the facility was originally designed. A good historical example was the introduction of "blade servers" in 2001, in which boxes of very expensive hardware waited unused for months because they couldn't be either powered or cooled in existing facilities. Newer cooling solutions are the use of indirect adiabatic and other compressor-less cooling solutions, and the aforementioned trend toward deploying direct liquid-cooled ITE in lieu of traditional air-cooled servers.

Saving energy by improving efficiency is always a good thing, but there is also an associated cost savings. Those not familiar with the computing industry might not appreciate the financial gains possible with these investments. Smaller "enterprise" data centers, owned and operated by individual businesses, can easily run from 1 MW to 10 MW capacities. At the industry's hyperscale end, facilities are often designed to grow modularly, with demand in as much as 50 MW increments.

These "hyperscale" campuses are being built around the world and can reach over 1 gigawatt capacities. In other words, this relatively small aspect of real estate is consuming a disproportionate amount of energy, so even very small improvements in efficiency have the same disproportional benefits in both total energy conserved and reduced operating costs. A 1% efficiency increase in a 10 MW data center, for example, could mean 240 kWh per day savings or more than $7 million annually at only $.08 per kWh. For a hyperscaler, the difference could be $700 million per year. Likewise, inefficient sites of any size waste a disproportional amount of energy and can be uneconomical.

A Time Line of Standard 90.4

When the U.S. Department of Energy (DOE) commissioned Lawrence Livermore National Laboratory to undertake a study of data center energy consumption in the United States, the resulting publication in December 2007 caused many to take notice. It concluded that data centers were already consuming 1.5% of the total U.S. energy production, that data center power consumption had doubled in the previous five years, would double again in the next five years, and would require the equivalent of 10 new utility electric power plants to handle. In short, the rate of growth was unsustainable. The industry took notice, and ASHRAE SSPC 90.1 certainly took notice. The clause exempting data centers from Standard 90.1 requirements was simply removed in the 2010 revision.

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When ASHRAE published Standard 90.1-2010, two significant factors created concerns in the data center industry. First was simply that the removal of the data center exemption required data center designs to undergo efficiency scrutiny as part of the permitting process. Second was the mandate that data centers, like all other buildings, had to use free-cooling economizers. The data center industry stakeholders were not pleased and let their concerns be known publicly, including formal comments submitted during the public review process that is required for all proposed revisions to ANSI standards. The data center industry stakeholders also expressed their concerns through correspondence with relevant ASHRAE committees including SSPC 90.1 and Technical Committee 9.9, Mission Critical Facilities, Data Centers, Technology Spaces and Electronic Equipment, as well as through correspondence with ASHRAE leadership.

Some of the concerns regarded risks of ITE outages and possible ITE damage due to failed economizer operation, particularly during switchovers, resulting in loss of cooling, condensation or other catastrophic scenarios. These were not theoretical. There had been enough documented real-life cases to validate the comments and objections. More broadly was the general concern that new regulatory red-tape, particularly in the form of a "prescriptive" standard, would inhibit and impair the power and cooling innovation required to support ever more sophisticated ITE needs.

Moreover, the data center industry was fully focused on energy conservation. ASHRAE TC 9.9 had already published *Thermal Guidelines for Data Processing Environments* as a radical step in this direction. The Uptime Institute had long before established the hot aisle/cold aisle concept and was pushing aisle containment. The Green Grid had published the power usage effectiveness (PUE) metric to track operational efficiency. Computing devices had also became more energy efficient and were continuing to improve. In short, industry action without mandates from Standard 90.1 had already kept the DOE's dire predictions from becoming reality. Though still increasing, data center power consumption remained well below the 2007 DOE study prediction.

Further, as the power densities of new generations of ITE continued to increase, the ratio between the capital cost to purchase ITE vs. the operating costs to power it were continually changing. When the costs of powering the ITE for three years (the average ITE life span due to technology "refreshes") cost more than the ITE itself, CFOs everywhere took notice of increasing electricity costs, and the industry responded with more research, innovation and unique solutions. In short, a prescriptive mandate was regarded as both an unnecessary imposition and a worrisome constraint. However, that did not mean that energy efficiency in the data center industry could simply be ignored. There were still far too many data centers, both existing and under design and construction, using equipment and design approaches that were simply not suitable for efficient operation in the unique data center environment.

An important part of ASHRAE's mission is to promote energy conservation and, as already stated, data centers were basically an unregulated niche responsible for an increasingly disproportionate consumption of electric power. But forcing data centers to comply with Standard 90.1 was seen as something of a "round peg in a square hole" situation. So if not in 90.1, something still had to be done to ensure data center energy efficiency. ASHRAE responded by asking TC 9.9 to spearhead the creation of a new Standards Committee tasked with developing a data center efficiency standard. The ASHRAE Board of Directors approved creation of Standard Project Committee 90.4 (SPC 90.4) in late 2012 with the goal to aggressively expedite development of a new standard for data centers. Committee membership was approved and the first meeting was held in January 2013 chaired by a past ASHRAE president, Ronald Jarnagin, Fellow/Life Member ASHRAE, who had also been a past chair of SSPC 90.1. The original SPC 90.4 committee membership included longtime representatives from both SSPC 90.1 and TC 9.9 as well as other industry stakeholders including the Edison Electric Institute, National Renewable Energy Lab, various engineering firms, general contractors and equipment suppliers. After four drafts and public reviews, the ASHRAE Board of Directors approved the standard for publication at the June 2016 Annual Conference.

ASHRAE is an American National Standards Institute (ANSI) certified Standard Development Organization, which means its standard development process is compliant with ANSI requirements. Like other ASHRAE standards such as 90.1, Standard 90.4 is written in "enforceable" language suitable for adoption by jurisdictions as federal, state and/or local building codes and regulations.

As previously noted, Standard 90.4 is incorporated into Standard 90.1 and is also being adopted independently by some states and jurisdictions. Unfortunately, it could not be adopted in May 2019 by the International Code Council (ICC) due primarily to administrative issues. But there were also ICC concerns regarding ambiguities on how AHJs demarcate where Standard 90.1 and Standard 90.4 apply in mixed-use buildings. These concerns were addressed through more collaboration between SSPC 90.1 and SSPC 90.4, wherein Standard 90.1-2019 included Standard 90.4 as an alternate compliance path where applicable. This also ensured that Standard 90.4 would be adopted by normative reference wherever Standard 90.1-2019 or later versions are adopted as code. Standard 90.4-2019 and approved addenda were adopted by the ICC in 2021.

Another important decision made in the development of Standard 90.4 was to create new metrics suitable for the design industry. The Green Grid had already created the power usage effectiveness or "PUE" metric, and there were many who thought this should be used in the new energy efficiency standard since it was being widely adopted and used. However, PUE is an operational metric, relying on actual hour-by-hour and day-to-day measurements to compute. The committee recognized that attempting to compute a realistic PUE in the design stage would involve many thousands of computations and would further assume that facilities would actually operate exactly as the designers had assumed. Considering that the actual complement of ITE is never fully known during design, and that it changes even as the facility is being constructed, attempting to predictively calculate a PUE was considered unrealistic, onerous for the designer, unconfirmable by the AHJ, and misleading to the owner since the calculated number would likely never actually be realized in practice.

The result was development of two design metrics: the mechanical load component or MLC, and the electrical loss component or ELC. These can be readily calculated from available design information, compared with simple tables in the standard and realistically verified by the AHJ. Moreover, when facility upgrades involve only the mechanical or the electrical, the components can be separated so that the standard does not force unjustifiable investment to meet the total tandard requirements.

Summary

Standard 90.4 meets the needs of the data center industry primarily because it is a performance-based standard, intended to be used by designers and constructed for realistic verification by AHJs. It also encourages innovation by focusing on overall system performance and allowing offsets between mechanical and electrical system efficiencies to achieve overall site infrastructure efficiency goals. And in keeping with overall energy conservation goals, it enables credits for both on-site and off-site renewable energy sources, as well as process heat recovery designs for on-site or export to adjacent sites. In short, it ensures energy efficiency achievement while also being specifically geared to the highly unusual and very demanding data center industry. ■