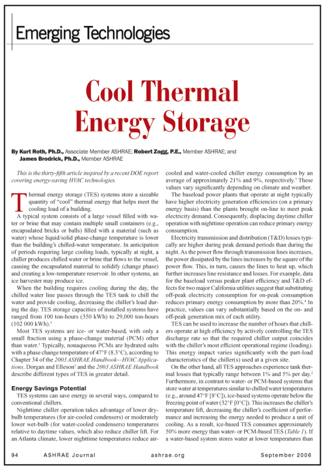
Standard 90 Energy Savings

The editor's commentary in the August issue of ASHRAE Journal heralds the estimated 40% savings in energy consumption in the first edition of Standard 90. It also touts an average increase in stringency since then of approximately 1.2% per year. The cumulative result would be $1 - 0.60 \times 0.988^{(2006-1975)}$, or approximately 59%.

The same issue includes the presidential address, which notes the *Advanced Energy Design Guide* goal to offer guidance for 30%, 50%, and 70% further efficiency improvements. ASHRAE's Standing Standards Project Committee (SSPC) 90.1, *Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings,* is now charged with additional improvement by at least 30% by the 2010 edition, or at least 71% lower energy consumption than before Standard 90-1975. My understanding is that the goal of proposed Standard 189, *Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings,* will be 30% greater stringency than 90.1, or at least an 80% improvement compared to pre-Standard 90-1975.


Emerging Technologies

Cool Thermal Energy Storage

By Kurt Roth, Ph.D., Associate Member ASHRAE; Robert Zogg, P.E., Member ASHRAE; and James Brodrick, Ph.D., Member ASHRAE

This is the thirty-fifth article inspired by a recent DOE report covering energy-saving HVAC technologies.

Thermal energy storage (TES) systems store a sizeable quantity of "cool" thermal energy that helps meet the cooling load of a building.

A typical system consists of a large vessel filled with water or brine that may contain multiple small containers (e.g., encapsulated bricks or balls) filled with a material (such as water) whose liquid/solid phase-change temperature is lower than the building's chilled-water temperature. In anticipation of periods requiring large cooling loads, typically at night, a chiller produces chilled water or brine that flows to the vessel, causing the encapsulated material to solidify (change phase) and creating a low-temperature reservoir. In other systems, an ice harvester may produce ice.

When the building requires cooling during the day, the chilled water line passes through the TES tank to chill the water and provide cooling, decreasing the chiller's load during the day. TES storage capacities of installed systems have ranged from 100 ton-hours (350 kWh) to 29,000 ton-hours (102 000 kWh).[1]

Most TES systems are ice- or water-based, with only a small fraction using a phase-change material (PCM) other than water.[1] Typically, nonaqueous PCMs are hydrated salts with a phase change temperature of 47°F (8.3°C), according to Chapter 34 of the *2003 ASHRAE Handbook—HVAC Applications*. Dorgan and Elleson[2] and the *2003 ASHRAE Handbook* describe different types of TES in greater detail.

Energy Savings Potential

TES systems can save energy in several ways, compared to conventional chillers.

Nighttime chiller operation takes advantage of lower dry-bulb temperatures (for air-cooled condensers) or moderately lower wet-bulb (for water-cooled condensers) temperatures relative to daytime values, which also reduce chiller lift. For an Atlanta climate, lower nighttime temperatures reduce air-cooled and water-cooled chiller energy consumption by an average of approximately 21% and 9%, respectively.[3] These values vary significantly depending on climate and weather.

The baseload power plants that operate at night typically have higher electricity generation efficiencies (on a primary energy basis) than the plants brought on-line to meet peak electricity demand. Consequently, displacing daytime chiller operation with nighttime operation can reduce primary energy consumption.

Electricity transmission and distribution (T&D) losses typically are higher during peak demand periods than during the night. As the power flow through transmission lines increases, the power dissipated by the lines increases by the square of the power flow. This, in turn, causes the lines to heat up, which further increases line resistance and losses. For example, data for the baseload versus peaker plant efficiency and T&D effects for two major California utilities suggest that substituting off-peak electricity consumption for on-peak consumption reduces primary energy consumption by more than 20%.[4] In practice, values can vary substantially based on the on- and off-peak generation mix of each utility.

TES can be used to increase the number of hours that chillers operate at high efficiency by actively controlling the TES discharge rate so that the required chiller output coincides with the chiller's most efficient operational regime (loading). This energy impact varies significantly with the part-load characteristics of the chiller(s) used at a given site.

On the other hand, all TES approaches experience tank thermal losses that typically range between 1% and 5% per day.[2] Furthermore, in contrast to water- or PCM-based systems that store water at temperatures similar to chilled water temperatures (e.g., around 47°F [8°C]), ice-based systems operate below the freezing point of water (32°F [0°C]). This increases the chiller's temperature lift, decreasing the chiller's coefficient of performance and increasing the energy needed to produce a unit of cooling. As a result, ice-based TES consumes approximately 50% more energy than water- or PCM-based TES (*Table 1*). If a water-based system stores water at lower temperatures than

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These numbers bother me. We were still responding to the 1973–1974 oil shock in the mid-1970s, so some conservation measures already had been implemented before completion of Standard 90-1975. Plug loads have increased radically in commercial buildings. Slide rules, manual typewriters, and carbon paper used less electricity than calculators, computers, copiers, and other office machinery. Lighting intensity has decreased for some building types, but increased for others. Overall energy use for lighting is lower, primarily due to broader application of fluorescent and halogen lighting as well as improvements in fixtures and lamp efficiencies. Building envelopes and mechanical systems are better. Typical chillers today, as an example, use 40% to 50% less power than their counterparts back then, though distribution and cooling tower burdens have not dropped as much. Performance gains have been less dramatic for other cooling equipment and typically only in the single-digit range for most heating systems for the same period. We are more conscious today of opaque fractions, ventilation and infiltration levels, vapor retarders, daylighting, orientation, and similar considerations. Still, 59% overall savings? 71%? I doubt it.

The U.S. Department of Energy Commercial Buildings Energy Consumption Survey (CBECS) data show that energy use per unit area (per ft^2 or per m^2) increased from the 1960s through the 1980s and then dropped in recent years by 12% overall. The same data show a net increase of 16% per worker for the same period. Moreover, these data exclude malls, which typically and increasingly include the most energy-intensive retailing areas. While building efficiency has improved, internal heat gains have increased and construction has shifted to climatic regions with increased cooling requirements. It is not clear how much of the performance improvements are attributable to competitive technology advances, how much to standards including 90.1, or how much each drives the other.

Does anyone have supporting data to demonstrate that:

- New commercial and institutional buildings today, even LEED®-certified buildings (for which the systems' efficiency component is small) actually achieve 59% or 71% savings over those of the early 1970s?
- The stringency requirements in 90.1 (or in the IECC) actually result in significant, measured energy savings over the life of buildings compared to the average of nonconforming buildings?
- Showcase buildings, for example those achieving LEED certification or those winning ASHRAE Technology Awards, actually yield 30% or higher savings by measurement than comparable 90.1-compliant buildings?

I am not suggesting that there is no need or margin for efficiency improvement. I think there is both clear need and opportunity. I am simply asking if anyone has objectively examined—with real data for a broad range of buildings and climates—the claims and progress thus far.

James M. Calm, P.E., Fellow ASHRAE,
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Editor's note: Calm is vice chair of SSPC 90.1.

Re: Cool Thermal Energy Storage

I have just a few comments to add to the excellent article by Kurt Roth, Ph.D., Robert Zogg, P.E., and James Brodrick, Ph.D., entitled "Cool Thermal Energy Storage" in the September 2006 issue.

- The column notes the technologies of water TES, ice TES, and PCM TES. An additional significant TES technology, first used commercially in 1994 and growing rapidly in applications since 2000, is low-temperature fluid (LTF) TES. LTF TES is quite similar to conventional stratified chilled water TES but uses an aqueous fluid stored at a lower supply temperature and a larger supply-to-return Delta *T* for more compact storage volumes (thus addressing one of the authors' noted barriers to greater market penetration for water TES).
- The range of installed TES capacities is listed as 100 to 29,000 ton-hour (350 to 102,000 kWh). In fact there have been many