

*Chilled water systems are the lifelines of cooling for large buildings and campuses. Within these complex networks lie many opportunities for improving energy efficiency, comfort, and maintainability. In large HVAC systems, water transports heat from the air handlers to the chillers (the chilled water loop), and then through another piping system (the condenser water loop) from the chillers to the cooling towers. These water systems include pumps, piping, valves, and heat exchangers, which are better optimized as a group than individually.*

This chapter examines efficiency opportunities for water-side cooling systems and components. The first half of this chapter (**8.1**) deals with system considerations, and the second half (**8.2**) deals with key components such as pipes, pumps, and cooling towers. The chiller itself is discussed in **CHAPTER 9**, while air systems are covered in **CHAPTER 4** and **CHAPTER 5**.

Chilled water systems are typically found in large commercial and industrial buildings. **Figure 8-1** shows that the larger a building is, the more likely it is cooled with a central chiller.<sup>1</sup> **Figure 8-2** shows that on a square-foot basis, offices and education facilities account for the majority of space cooled by central chillers.

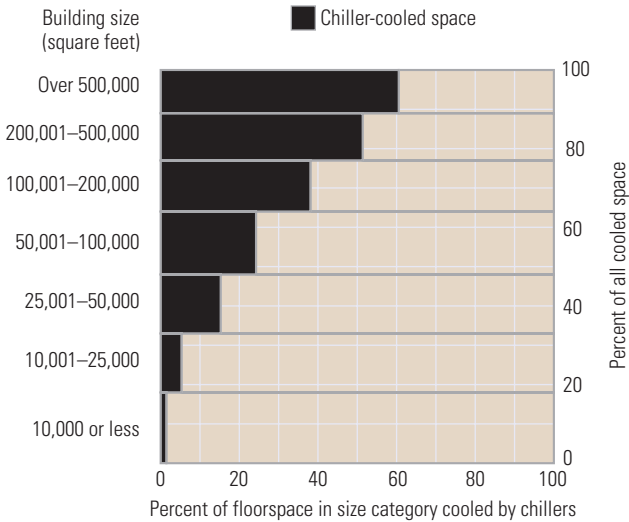
### HIGHLIGHTS

- While designing an optimal chilled water system isn't easy, powerful computer tools can help with analysis and simulation.
- Adjustable-speed pump drives provide deep energy savings, but aren't appropriate everywhere.
- Primary/secondary chilled water pumping systems maintain constant flow in the chiller loop while delivering variable-flow savings in the distribution loop.
- Improved understanding of heat transfer in cooling coils is leading to designs that provide adequate dehumidification at part load and minimize both air-side and water-side distribution energy.
- The economic impacts of pipe sizing and valve selection are often overlooked in piping design. Bigger pipes and low-loss valves reduce operating costs significantly.
- Induced-draft cooling towers are more efficient than forced-draft towers, but require more space.
- Adjustable-speed fan drives can cut cooling tower energy consumption dramatically, but speed-control savings is a two-edged sword. Chiller efficiency depends on hard-working towers, so adjustable-speed drives aren't always called for.
- Keeping heat transfer surfaces in the chiller and cooling tower clean is essential for maintaining efficiency.

**8.1 CHILLED WATER SYSTEM OPPORTUNITIES**

**Figure 8-1**  
**Penetration of chillers by building size in the United States**

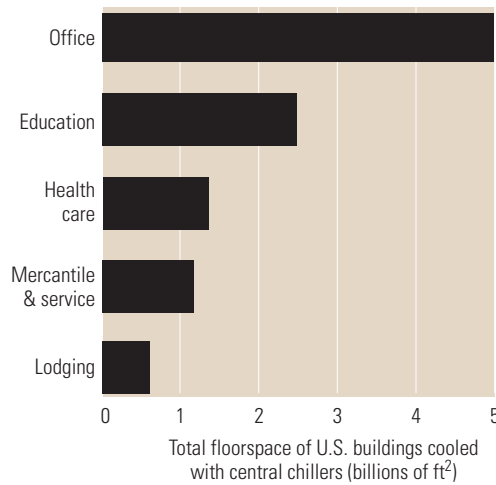
Over one-quarter of U.S. commercial floorspace is cooled with chillers. Larger buildings are more likely to have chillers.



Source: DOE/EIA [1]

**Figure 8-2**  
**Chilled water cooling systems by principal building use (U.S. 1992)**

Offices and schools account for the largest shares of cooled floorspace in the U.S.



Source: DOE/EIA [1]

A chilled-water air-conditioning system can be conceptualized as illustrated in Figure 8-3. The analysis in this chapter is concerned primarily with the second and fourth loops.

Pumped water systems are a classic example of how a whole-system approach and attention to detail can yield dramatic savings. The pumping costs of large chilled water systems typically run in the tens of thousands of dollars per year, much of which can be saved by capacity control or intelligent retrofits to the plumbing system. This section looks at some of those savings opportunities. But since every system is different, it is difficult to generalize recommendations for optimal system design; this job usually requires an engineering review by a qualified firm.

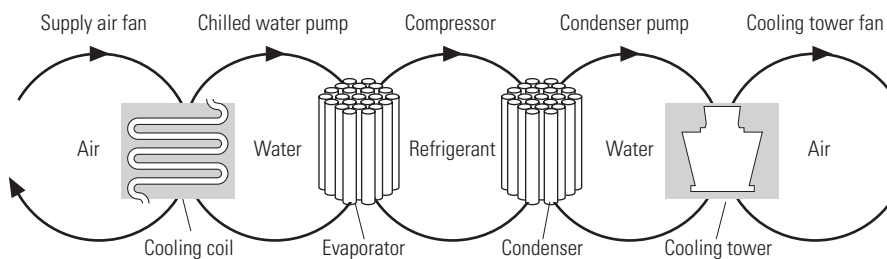
Whenever a chilled water system is installed or modified, it is an ideal time to optimize the composition and operation of the plant. For example, when a central chiller is modified or replaced to remove CFC refrigerants, the project engineer should consider options to improve the overall performance of the chilled water system at the same time. Other times to consider system-wide improvements include building additions, extension of the chilled water system to new buildings, or when making modifications to correct insufficient flow to some buildings on the chilled water loop.

Figure 8-3

**Conceptual view of a chilled-water air-conditioning system**

In this figure, thermal energy moves from left to right as it is extracted from the space and expelled into the outdoors through five loops of heat transfer:

- **Indoor air loop.** In the leftmost loop, indoor air is driven by the supply air fan through a cooling coil, where it transfers its heat to chilled water. The cool air then cools the building space.
- **Chilled water loop.** Driven by the chilled water pump, water returns from the cooling coil to the chiller's evaporator to be re-cooled.
- **Refrigerant loop.** Using a phase-change refrigerant, the chiller's compressor pumps heat from the chilled water to the condenser water.
- **Condenser water loop.** Water absorbs heat from the chiller's condenser, and the condenser water pump sends it to the cooling tower.
- **Cooling tower loop.** The cooling tower's fan drives air across an open flow of the hot condenser water, transferring the heat to the outdoors.

**8.1.1 System design**

While it's tempting to improve the efficiency of chilled water systems by tackling the efficiency of each component, this approach does not necessarily lead to the most efficient system. The pieces of a chilled water system interact in complex ways that make general prescriptions difficult. For example, the efficiency of the chiller can be improved by increasing chilled water flow. Unfortunately, this requires greater pumping power that may exceed the saved chiller power, resulting in a net loss of system efficiency. For a discussion of this complex topic, see E SOURCE *Tech Update TU-95-13*, "Proper Application of Adjustable-Speed Drives for HVAC Cooling Tower Fans" (November 1995).

In addition to the operating cost implications of different design options, many decisions

must consider trade-offs between operating cost and initial capital cost. For example, bigger heat exchangers make chillers more efficient, but with a significant marginal cost. But, will the value of energy savings from an oversized condenser exceed the additional cost?

The answer depends on numerous factors, including energy and demand prices, load shapes, local climate, building construction, operating schedules, distribution system characteristics, chiller type, and cooling tower design. Keeping track of all these variables and interactions is a daunting task, especially since some change hour by hour. Traditionally, engineers have avoided the challenge of system optimization by relying on simple rules of thumb. However, for those who wish to optimize their systems, it is possible to manage this avalanche of information by using computer-based tools.

*Building energy performance simulation* is the use of computer software to carry out the numerous and complex equations that when combined describe how buildings use energy. The most sophisticated of these programs are capable of calculating building energy consumption hour by hour for an entire year. The best-known hourly simulation software package is DOE-2 (developed by the Simulation Research Group at Lawrence Berkeley National Laboratory), which can accept—and produce—a torrent of data. Using DOE-2 is difficult and there are few practitioners who can apply it effectively. These capabilities come at a cost, however. Hourly simulation is expensive and relatively few practitioners can apply it effectively. However, for those who seek to optimize the lifecycle costs of chilled water plants, computer-based simulations are an important tool. There are several versions of DOE-2 with Windows front-ends (Figure 8-4), which greatly facilitate data input.

Modified hourly simulation tools, such as Trane’s System Analyzer™ (Figure 8-5) or Synergic Resources Corporation’s Market Manager™, perform calculations using a few days a month: hot, cold, typical weekday, and

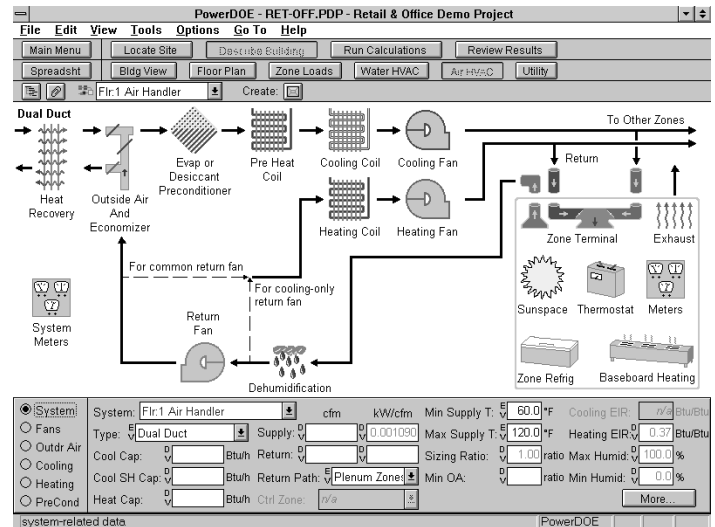
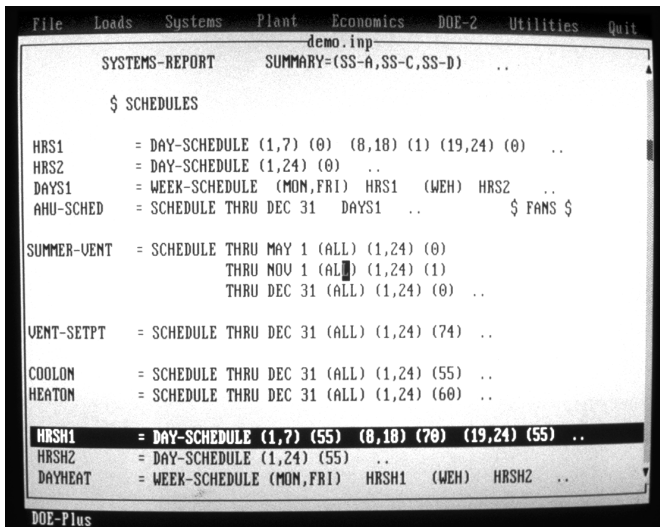
typical weekend. User-friendly interfaces make such programs much easier to use than the current version of DOE-2, but yield less accurate and detailed information. One drawback of a modified hourly or bin method is that the model cannot be trued-up to actual utility data, since the entire sequence of hours is not calculated. Additionally, peak demand impacts are treated in less detail than in a true hourly simulation. Bill impacts can be estimated by assuming the number of each type of days per month.

Efforts are underway to make hourly simulation more accessible. Several vendors now offer graphical user interfaces for DOE-2, which make the tedious process of entering data more user-friendly.<sup>2</sup> Also, a new version of DOE-2, PowerDOE™ (which operates within the Microsoft Windows graphical user interface) recently was developed by the U.S. Department of Energy and the Electric Power Research Institute. PowerDOE will allow users to select commands from a standard Windows menu bar, use online help, and generate graphic displays of both building geometry and simulation results.

Figure 8-4 The DOE-2 building simulation computer program

**The DOE-2 building simulation computer program**

DOE-2 is a powerful computer tool. Several versions with Windows interfaces make entering data and using the program much easier than previous versions.



Source: Jeff Hirsch