

**2004  
ASHRAE HANDBOOK**

**HVAC Systems  
and Equipment**

**I-P Edition**

**Supported by ASHRAE Research**

**2004 ASHRAE® HANDBOOK**

**Heating, Ventilating,  
and  
Air-Conditioning  
SYSTEMS AND EQUIPMENT**

**Inch-Pound Edition**

**American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.**

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# ASHRAE Research: Improving the Quality of Life

The American Society of Heating, Refrigerating and Air-Conditioning Engineers is the world's foremost technical society in the fields of heating, ventilation, air conditioning, and refrigeration. Its members worldwide are individuals who share ideas, identify needs, support research, and write the industry's standards for testing and practice. The result is that engineers are better able to keep indoor environments safe and productive while protecting and preserving the outdoors for generations to come.

One of the ways that ASHRAE supports its members' and industry's need for information is through ASHRAE Research. Thousands of individuals and companies support ASHRAE Research

annually, enabling ASHRAE to report new data about material properties and building physics and to promote the application of innovative technologies.

Chapters in the ASHRAE Handbook are updated through the experience of members of ASHRAE technical committees and through results of ASHRAE Research reported at ASHRAE meetings and published in ASHRAE special publications and in *ASHRAE Transactions*.

For information about ASHRAE Research or to become a member, contact ASHRAE, 1791 Tullie Circle, Atlanta, GA 30329; telephone: 404-636-8400; [www.ashrae.org](http://www.ashrae.org).

## Preface

The 2004 *ASHRAE Handbook—HVAC Systems and Equipment* discusses various common systems and the equipment (components or assemblies) that comprise them, and describes features and differences. This information helps system designers and operators in selecting and using equipment. A new chapter (47), Mechanical Dehumidifiers and Heat Pipes, has been added. ASHRAE Technical Committees have updated chapters for current technology, clarified existing information, deleted obsolete material, and reorganized some chapters. Some of the revisions are as follows:

- Chapter 1, HVAC System Analysis and Selection, has expanded lists and discussion of system selection criteria.
- Chapter 2, Building Air Distribution, has added information on mixing plenums and static air mixers.
- Chapter 3, In-Room Terminal Systems, contains more information on both humidity control and fan-coils.
- Chapter 4, Central Cooling and Heating, has been rewritten to include more information on central systems' advantages and disadvantages; controls; and considerations for plant location, including noise and vibration.
- Chapter 5, Decentralized Cooling and Heating, has been updated throughout, with additional discussion on advantages and disadvantages of various systems.
- Chapter 6, Panel Heating and Cooling, extensively revised, now has panel performance rating equations and information on hybrid (load-sharing) systems using panels.
- Chapter 7, Cogeneration Systems and Engine and Turbine Drives, now contains content previously published in the 2000 volume's Chapter 47, Engine-Driven Heating and Cooling Equipment, plus new information on electrical system interface, fuel cells, and microturbines.
- Chapter 8, Applied Heat Pump and Heat Recovery Systems, has added the results of two ASHRAE research projects that (1) provided guidelines for evaluating the environmental benefits of using heat recovery heat pumps, and (2) evaluated computer models for water loop heat pumps and heat recovery chillers.
- Chapter 9, Design of Small Forced-Air Heating and Cooling Systems, has expanded discussions on commercial systems and on air distribution design considerations, especially duct location, leakage, and insulation.
- Chapter 16, Duct Construction, has been updated for research on sealing of duct/terminal connections, and has new sections on antimicrobial and fabric ducts.
- Chapter 17, Room Air Distribution Equipment, has been updated throughout and included new sections on supply nozzles and variable-geometry diffusers.
- Chapter 18, Fans, contains new sections on calculating the temperature rise across fans and on fan vibration concerns.

- Chapter 21, Air Cooling and Dehumidifying Coils, has expanded coil construction descriptions and new maintenance recommendations.
- Chapter 22, Desiccant Dehumidification and Pressure-Drying Equipment, updated for new technology, also has new material on ventilation air applications, plus a description of an interactive desiccant wheel performance estimator available on the TC 8.12 homepage via the ASHRAE Web site.
- Chapter 23, Air-Heating Coils, has updated sections on steam coils and coil maintenance.
- Chapter 35, Condensers, has added a comparison of water-cooled versus air-cooled condensers and information on biological control, brazed condensers, pony motors, and purging non-condensables.
- Chapter 36, Cooling Towers, has more information on closed-circuit towers, capacity control (including variable-frequency drives), critical speeds, biological control, wet/dry towers, plume, and cold-weather operation.
- Chapter 37, Liquid Coolers, has expanded descriptions of cooler types, including a new table listing feed devices, capacity ranges, and commonly used refrigerants for each.
- Chapter 44, Air-to-Air Energy Recovery, extensively revised, has added examples, figures, and calculation procedures, plus new material on air leakage, performance ratings, fan power requirements, pressure drop, and membrane plate heat exchangers.
- Chapter 46, Room Air Conditioners and Packaged Terminal Air Conditioners, no longer has dehumidifier information (see new Chapter 47) but has added tables on energy efficiency standards for room air conditioners.
- Chapter 47, Mechanical Dehumidifiers and Heat Pipes, a new chapter, includes basic construction and operating practices on this equipment for high-dew-point applications, plus discussion of heat pipes and their use with mechanical dehumidifiers.

This Handbook volume is published, both as a bound print volume and in electronic format on a CD-ROM, in two editions: one using inch-pound (I-P) units of measurement, the other using the International System of Units (SI).

Corrections to the 2001, 2002, and 2003 Handbook volumes are posted on the ASHRAE Web site at <http://www.ashrae.org>. Corrections for this volume will be reported in the 2005 *ASHRAE Handbook—Fundamentals* and on the ASHRAE Web site.

To make suggestions for improving a chapter or for information on how you can help revise a chapter, please comment using the form on the ASHRAE Web site; or e-mail [mowen@ashrae.org](mailto:mowen@ashrae.org); or write to Handbook Editor, ASHRAE, 1791 Tullie Circle, Atlanta, GA 30329; or fax 404-321-5478.

Mark S. Owen  
ASHRAE Handbook Editor

## CHAPTER 1

# HVAC SYSTEM ANALYSIS AND SELECTION

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**A**N HVAC system maintains desired environmental conditions in a space. In almost every application, many options are available to the design engineer to satisfy this basic goal. In the selection and combination of these options, the design engineer must consider all criteria defined here to achieve the functional requirements associated with the goal.

HVAC systems are categorized by the method used to control heating, ventilating, and air conditioning in the conditioned area. This chapter addresses procedures for selecting the appropriate system for a given application. It also describes and defines the design concepts and characteristics of basic HVAC systems. Chapters 2 through 5 describe specific systems and their attributes, based on their heating and cooling medium and commonly used variations.

This chapter applies to HVAC conversion, upgrades, retrofits, building renovations and expansion, and new construction. This analysis and selection process helps determine the optimum system(s) for any building. Regardless of facility type, analysis examines objective, subjective, short-term, and long-term goals.

### SELECTING A SYSTEM

The design engineer is responsible for considering various systems and recommending one or two that will meet the goal and perform as desired. It is imperative that the design engineer and owner collaborate to identify and prioritize criteria associated with the design goal. Occupant comfort, process heating, and cooling or ventilation criteria may be considered, including the following:

- Temperature
- Humidity
- Air motion
- Air purity or quality
- Air changes per hour
- Air and/or water velocity requirements
- Local climate
- Mean radiant temperature (MRT)
- Space pressure requirements
- Capacity requirements, from a load calculation analysis
- Redundancy
- Spatial requirements
- First cost
- Operating cost, including energy and power costs
- Maintenance cost
- Reliability
- Flexibility
- Life cycle analysis
- Sustainability of design
- Acoustics and vibration
- Mold and mildew prevention

Because these factors are interrelated, the owner and design engineer must consider how these criteria affect each other. The relative importance of factors such as these varies with different owners and often changes from one project to another for the same owner. For example, typical owner concerns include first cost compared to operating cost, extent and frequency of maintenance and whether that maintenance requires entering the occupied space, expected frequency of system failure, effect of a failure, and time required to correct the failure. Each concern has a different priority, depending on the owner's goals.

### Additional Goals

In addition to the primary goal of providing the desired environment, the design engineer must be aware of and account for other goals the owner may require. These goals may include the following:

- Supporting a process, such as operation of computer equipment
- Promoting a germ-free environment
- Increasing sales
- Increasing net rental income
- Increasing property salability

The owner can only make appropriate value judgments if the design engineer provides complete information on the advantages and disadvantages of each option. Just as the owner does not usually know the relative advantages and disadvantages of different systems, the design engineer rarely knows all the owner's financial and functional goals. Hence, the owner must be involved in system selection.

### System Constraints

Once the goal criteria and additional goal options are listed, many constraints must be determined and documented. These constraints may include the following:

- Performance limitations (e.g., temperature, humidity, space pressure)
- Available capacity
- Available space
- Available utility source
- Building architecture
- Construction budget
- Construction schedule
- Equipment availability (i.e., delivery lead-times)

Few projects allow detailed quantitative evaluation of all alternatives. Common sense, historical data, and subjective experience can be used to narrow choices to one or two potential systems.

Heating and air-conditioning loads often contribute to constraints, narrowing the choice to systems that will fit in available space and be compatible with building architecture. Chapters 28 and 29 of the 2001 *ASHRAE Handbook—Fundamentals* describe methods to determine the size and characteristics of heating and air-conditioning loads. By establishing the capacity requirement, equipment size can be determined, and the choice may be narrowed to those systems that work well on projects within a size range.

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In general, HVAC systems have the following Equipments / elements: Equipment to generate heating or cooling: The equipment is selected with a capacity to offset the peak load of the space or spaces to be served. A means of distributing heat, cooling, and/or filtered ventilation air where needed: air, water, or steam. Devices that deliver the heat, cooling, and/or fresh air into the building: registers and diffusers, hydronic radiators or convectors, and fan coil units. The electrical engineers will be interested in having a good background about the first point and some about the third one whi