Air-Conditioning System *DESIGN MANUAL*

THIRD EDITION

Howard J. McKew, *Editor*

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AIR-CONDITIONING SYSTEM
DESIGN MANUAL

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PREFACE

This third edition represents a major update and revision of *Air-Conditioning System Design Manual*. The request that drove this revision effort was simply to make a successful resource more current. The revision process involved a thorough editing of all text in the manual, updating references, and editing many illustrations. New material covered in this manual includes creating and implementing a designer's business plan, decentralized cooling and heating and central cooling and heating, and commissioning and testing, adjusting, and balancing. In addition, there have been significant updates and enhancements to the health, wellness, and safety, components, and special HVAC&R systems chapters.

The editor acknowledges the book review volunteers of ASHRAE Technical Committee (TC) 9.1, who provided an extra pair of eyes and their years of experience to review and comment chapter by chapter.

I want to offer a special thank you to Dr. Stephanie Taylor, MD, M. Arch, Harvard Medical School InciteHealth Fellow, of Taylor Healthcare Commissioning, Inc. for her contribution in revising the "Occupant Health, Wellness, and Safety" chapter (formerly titled, "Occupant Comfort and Health"), and to Robert N. Heinlein, Jr., CEM, R.N. Heinlein Consulting LLC, Consultant for his contribution in revising the chapter addressing HVAC&R controls based on his years of technical experience in the building automation industry. Both have brought to these major chapter revisions their years of experience and knowledge.

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Chapter 1

INTRODUCTION

1.1 PURPOSE OF THIS MANUAL

This manual was prepared to assist entry-level engineers in the design of heating, ventilating, and air-conditioning (HVAC) systems. It is also intended as a design guideline reference manual for the more experienced HVAC design engineer as well as a reference design manual for those in the construction industry, e.g., mechanical-electrical field coordinators, and for building owners' capital project personnel, e.g., owner's project engineer. It can also be used in conjunction with fundamental heating, ventilating, air-conditioning, and refrigeration (HVAC&R) resource materials as a senior- or graduate-level text for a university course in HVAC system design. This manual was intended to fill the void between theory and practice, to bridge the gap between real-world design practices and the theoretical knowledge acquired in the typical college course or textbook. Courses and texts usually concentrate on theoretical calculations and analytical procedures or the design of components. This manual focuses on applications.

The manual has been organized into 13 chapters, beginning with the business of HVAC design engineering followed by the design process. Next, this design manual addresses human health, wellness, and safety in regards to HVAC design and occupants.

The user/reader should be familiar with the general concepts of HVAC&R equipment and possess or have access to the four-volume *ASHRAE Handbook* series and appropriate ASHRAE publications, e.g., ASHRAE Guidelines and Standards, to obtain grounding in the fundamentals of HVAC&R system design. Information contained in the Handbooks and in other publications referenced herein is not generally repeated in this design manual. There is a broad range of publications referenced at the end of each chapter, which are to be used by the designer as a list of general references to compliment this manual.

The initial difficult task in any design problem is how to begin. The entry-level professional may not have experience (or have limited experience)

from past design projects to fall back on and may be at a loss as to where to start a design. To assist the reader in this task, a business plan based on sound business strategy and fundamental engineering concepts should be created as a guide for the designer to follow that takes into account the project timeline and delivery method. With an understanding of the HVAC&R system design process for the application a step-by-step sequence of design procedures is outlined as part of the design process herein. Simple rules are given, where applicable to assist the new designer in making decisions regarding equipment types and size based on the project's available budget.

Chapters 2 and 3 address the guidelines by which the HVAC designer will proceed with a business plan that accommodates the design process. These chapters will also cover the selection of the optimum HVAC system for the application, the satisfaction of occupant comfort, health, and wellness needs, the calculation of the required HVAC&R loads, and the identification of HVAC components. It also includes a discussion on the four types of HVAC systems (all-air, air-water, all-water, and special HVAC systems).

Chapter 3 goes into further detail on the difference between analysis and design. This chapter covers basic issues that are addressed during the design phases of a building project and discusses a number of factors that influence building design, such as codes and economic considerations. Health, wellness, indoor air quality, and safety and their implications for HVAC systems design, are discussed in Chapter 4. Load calculations are discussed in Chapter 5. The specifics of load calculation methodologies are not presented herein because they are thoroughly covered in numerous ASHRAE Handbook resources and are typically conducted via computer programs today.

Chapter 6 introduces the topic of decentralized HVAC systems and central cooling and heating plants. Before the design engineer can proceed with a design, the decision must be made to provide an engineered solution based on either decentralized and/or central plant servicing decentralized HVAC systems. In addition to this chapter, Chapter 1, "HVAC System Analysis and Selection," in *ASHRAE Handbook—HVAC Systems and Equipment* is one of the best places for a designer to start the design process.

Chapter 7 highlights the components of HVAC&R systems, e.g., refrigeration equipment, heating, equipment, and so on. Chapters 8 through 11 cover the design parameters of all-air, air-and-water, all-water systems, and special HVAC systems, respectively. A conscious effort was made here not to duplicate material from *ASHRAE Handbook—HVAC Systems and Equipment*, except in the interest of continuity. Its treatment of the air side of HVAC systems is equally applicable to the air side of air-water systems; thus, this information is not repeated in Chapter 9. Chapter 10 addresses all-water heating and air-conditioning systems with limited ventilation features. Chapter 11 covers a variety of special HVAC sys-

tems, including energy recovery, heat pump systems, underfloor air distribution systems, variable refrigerant, and so on.

Chapter 12 addresses controls and provides an overview of control strategy as well as building management, energy management, and HVAC security. Chapter 13, "Commissioning and Testing, Adjusting, and Balancing," covers the HVAC system requirements that must work in sync for the specific HVAC systems to achieve the design intent, demonstrate the HVAC system's performance under all conditions, and to document the as-built results of the operating conditions and basis of design.

A few words of advice: do not hesitate to make initial design assumptions. No matter how far off the specific values of a final solution they might prove to be, assumptions enable the designer to start on a project and to gradually iterate and improve a proposed design until a satisfactory solution has been obtained. Frequently, more experienced colleagues may be able to assist by giving counsel and the benefit of their experience, but do not hesitate to plunge ahead on your own. Good luck!

1.2 HOW BEST TO USE THIS MANUAL

The following suggestions are made to obtain maximum benefit from this manual:

1. Consider the general category of the building being designed and read the appropriate chapters in *ASHRAE Handbook—HVAC Applications* and *ASHRAE Handbook—HVAC Systems and Equipment* to determine likely systems to consider for application to the project.
2. Familiarize yourself with the theory and basic functions of common HVAC&R equipment. The best sources for this information are HVAC&R textbooks and the *ASHRAE Handbook* series.
3. Read the chapters in this manual that address the systems of interest.
4. Become familiar with state and local building codes, ASHRAE standards and guidelines, and applicable National Fire Protection Association (NFPA) resources
5. Remember that this manual, in general, does not repeat information contained in *ASHRAE Handbooks* and special publications. You cannot, therefore, rely on this manual as the only reference for design work. As you gain experience, make notes of important concepts and ideas (what worked and what did not work) and keep these notes in a readily accessible location. This manual is intended to point the way toward building such a design database.

While an attempt has been made in this manual to incorporate the experiences of design professionals, no static written material can replace dynamic face-to-face interaction with your colleagues. Use every opportunity to pick their brains, and let them tell you what worked and what they would do differently the

next time. Although the experience of your colleagues and peers is one of the best design references available, their experience and rules-of-thumb cannot replace sound design engineering practices learned from firsthand experience.

1.3 UNITS

The first edition of this manual was written using I-P (inch-pound) units as the primary measurement system. In this edition SI (System International) units are shown in parentheses following the I-P units. Conversions to SI units are "soft approximations" with, for example, 4 in. being converted as 100 mm (versus the more accurate conversion to 101.6 mm or use of a true SI commercial size increment for a given product). See the ASHRAE's "SI Guide for HVAC&R" (available at no cost from the ASHRAE website, www.ashrae.org) for detailed information on preferred measurement units and conversion factors for HVAC&R design work.

1.4 TERMINOLOGY

In addition to units, the designer is referred to "ASHRAE Terminology," which can also be found at www.ashrae.org/terminology. It is a free, comprehensive online glossary of more than 3700 terms and definitions related to the built environment, with a focus on HVAC&R, as well as building envelope, electrical, lighting, water and energy use, and measurement terms.

1.5 GENERAL BIBLIOGRAPHY

In addition to specific references listed in each of the chapters of this manual, the following publications are generally useful to HVAC&R system designers. They should be available in every design office. ASHRAE publications are updated on a regular basis (every four years for handbooks, often more frequently for standards and guidelines). Consult the ASHRAE website (www.ashrae.org) for information on current publication dates.

1.5.1 ASHRAE Handbooks (available as printed volumes or on CD, in I-P or SI units)

ASHRAE. 2016. *ASHRAE handbook—HVAC systems and equipment*. Atlanta: ASHRAE.

ASHRAE. 2017. *ASHRAE handbook—Fundamentals*. Atlanta: ASHRAE.

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ASHRAE. 2019. *ASHRAE handbook—HVAC applications*. Atlanta: ASHRAE.

1.5.2 ASHRAE Standards and Guidelines

ASHRAE. 2007. ASHRAE Guideline 1.1-2007, *HVAC&R Technical Requirements For The Commissioning Process*. Atlanta: ASHRAE.

ASHRAE. 2017. ANSI/ASHRAE Standard 55-2017, *Thermal Environmental Conditions for Human Occupancy*. Atlanta: ASHRAE.
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1.5.3 Other ASHRAE Publications

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1.5.4 Other Resources

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NEBB. 2015. *Procedural standards for testing, adjusting, and balancing of environmental systems*, 8th ed. Gaithersburg, MD: National Environmental Balancing Bureau.
NFPA. NFPA Publications. Quincy, MA: National Fire Protection Association.

SMACNA. 2003. *TAB procedural guide*. Chantilly, VA: Sheet Metal and Air Conditioning Contractors' National Association.
SMACNA. SMACNA publications. Chantilly, VA: Sheet Metal and Air Conditioning Contractors' National Association.
USGBC. LEED–BC+D (Leadership in Energy and Environmental Design—Building Design and Construction). Washington, DC: United States Green Building Council.
USGBC. LEED–ID+C (Leadership in Energy and Environmental Design—Interior Design and Construction). Washington, DC: United States Green Building Council.
USGBC. LEED–O+M (Leadership in Energy and Environmental Design—Building Operation and Maintenance). Washington, DC: United States Green Building Council.

Several equipment manufacturers have developed HVAC design manuals and/or equipment application notes. These are not specifically listed here, in accordance with ASHRAE's commercialism policy, but are recommended as sources of practical design and application advice. A search of manufacturers' websites (for manuals or education) will usually show what is currently available (for free or for a fee).

An extensive list of applicable codes and standards, including contact addresses for promulgating organizations, is provided in a concluding chapter in each of the ASHRAE Handbooks.