

## **PREFACE**

### **INTRODUCTION**

The purpose of a heating, ventilating, and air conditioning (HVAC) system is to establish an indoor environment within which building inhabitants can live, work, and play. The indoor environment impacts the quality of life, productivity, and well being of building inhabitants. As people spend an increasing amount of time inside buildings, HVAC systems and their associated control systems are becoming more important. As a result, the complexity and cost of HVAC systems for commercial and institutional buildings is increasing. HVAC systems represent an increasingly larger percentage of the construction dollar. In addition, these systems represent a significant ongoing operation and maintenance cost for the owner over the life of the building.

The HVAC contractor is the firm that is responsible for the installation of the complete HVAC system for the owner in accordance with the scope of work defined by the contract documents. The HVAC contractor is typically responsible for planning the installation, procuring the necessary materials and equipment, determining the means and methods of installation, performing the installation, and starting up and commissioning the HVAC system. The HVAC contractor may self perform all of the HVAC work or may subcontract portions of the work such as piping, insulation, testing, adjusting, and balancing (TAB), or system controls. For a design-build project, the HVAC contractor would also be responsible for the HVAC system design.

The increasing complexity of HVAC systems and their importance in modern buildings makes it imperative that the HVAC contracting firm's office and field personnel understand not just the part of the system they normally work on but the entire system, how the various subsystems and components work, and the interrelationship between the different subsystems and components.

### **MANUAL PURPOSE**

The purpose of *HVAC Systems: Understanding The Basics* is to provide an overview of HVAC systems, the equipment and components that comprise them, and how they work. This manual is not intended to address HVAC design and does not address building heating or cooling load calculations, equipment sizing, or system layout. Instead, this manual is intended for use by the HVAC contracting firm's field and office personnel that need an overall understanding of HVAC systems for bidding and negotiating projects, planning and scheduling work, fabrication and installation of HVAC system equipment and components, and system commissioning and project closeout. This manual may also be helpful to general contractor and construction management firm personnel who want to know more about HVAC systems and equipment as well as other specialty contracting firms such as electrical contracting firms that need to interface with HVAC contractor.



## **MANUAL OVERVIEW**

This manual is divided into ten chapters and four appendices. Chapter I provides an introduction to HVAC systems and this manual. This chapter starts out with a discussion of what an HVAC system is and discusses why buildings need HVAC systems. In addition, this chapter provides a brief history of HVAC and discusses its increasing importance in 21<sup>st</sup> Century buildings. Chapter I concludes with an overview of the manual.

The properties of moist air that are key to understanding space conditioning processes and HVAC systems are introduced in Chapter II. This chapter starts by defining temperature and humidity and how these basic properties of moist air are measured. Psychrometry is defined and the psychrometric chart is used to introduce important properties of moist air including dry-bulb temperature, wet-bulb temperature, dew-point temperature, percent relative humidity, humidity ratio, and air specific volume and density as well as how these key space conditioning variables interact. Heat transfer, heat transfer mechanisms, and heat transfer units are introduced next because a basic understanding of heat transfer concepts is key to understanding HVAC equipment and systems. Moist air energy content is then covered which includes sensible heat, latent heat, and enthalpy. All of this sets the stage for understanding space conditioning processes, HVAC equipment, and HVAC systems covered throughout the remainder of this manual.

Chapter III builds on Chapter II by introducing the basics of HVAC systems. The purpose of an HVAC system is covered first and lays the foundation for the remainder of the chapter. The concept of an HVAC zone is then defined along with airflow. Thermal comfort is then discussed along with the importance of indoor air quality (IAQ) and HVAC energy use. The four basic elements of any HVAC system are presented followed by a discussion of space conditioning methods and HVAC system categories.

Unitary HVAC systems are covered in Chapter IV because unitary systems are self-contained units with all the HVAC system elements discussed in Chapter III. Unitary HVAC systems include a wide variety of different types of air-conditioning units that include their own integral refrigeration cycle and range from residential window air conditioning units to rooftop units used for commercial and light industrial applications. Most people are familiar with unitary HVAC systems and the fact that they are fully self-contained makes it easier to see the interrelationship between the elements and serves as a good introduction to central and distributed HVAC systems. This chapter covers the various types of unitary HVAC systems and their operation. A detailed overview of the mechanical refrigeration cycle is also provided that will be used again in Chapter VI where central cooling equipment is covered. This chapter finishes with a discussion of unitary heat pumps.

Central heating equipment is covered in Chapter V and includes both furnaces and boilers. Furnaces are discussed first because most people are familiar with furnaces due to their use in residential and light commercial buildings. A discussion of boilers, boiler types, and associated equipment including boiler circulating pumps and deaerators follows furnaces.



Chapter VI covers central cooling equipment that includes chillers and cooling towers. This chapter starts with a detailed discussion of chiller operation including the chiller refrigeration cycle. Types of chillers and chiller components commonly used to supply chilled water in commercial and institutional buildings are covered next. Lastly, cooling tower operation, types, and construction are discussed.

Hydronic distribution systems where water is used as the heat transfer medium in central HVAC systems are discussed in Chapter VII. Both hot and chilled water distribution systems are covered along with a detailed discussion of common hydronic piping arrangements. Convection terminal units that condition the space are also covered in detail in this chapter.

Air distribution for HVAC systems is covered in Chapter VIII. Chapter VIII starts by discussing the purpose and operation of an air-distribution system that sets the stage for the remainder of this chapter. Sections that discuss each of the components that comprise an air distribution system follow these introductory sections. A section on fans covers fan operation and briefly discusses the various types of fans found in commercial and institutional buildings and their construction and characteristics. Sections that cover metal ductwork, duct dampers, air terminal units, air outlets and inlets, and air cleaning devices follow this. Chapter VIII ends with a discussion of testing, adjusting, and balancing (TAB) air distribution systems.

Chapter IX addresses central HVAC systems that are prevalent in large commercial and institutional buildings. A central HVAC system is one where the heating source, cooling source, or both are centrally located and serve a significant part of the building. Following a general discussion of central HVAC system layout and operation, the five primary central HVAC subsystems are presented and discussed. Variable-air-volume (VAV) central HVAC systems are the focus of this chapter because they are the most common system used today. Constant volume central HVAC systems are also covered because constant volume HVAC systems are used where a constant supply of conditioned air is required in certain occupancies.

HVAC system control is covered in Chapter X. HVAC systems seldom operate at their design point and both the external and internal thermal loads are constantly changing. The purpose of HVAC system control is to ensure that the HVAC system can effectively and efficiently adapt to changing outdoor conditions as well as changing internal occupancy and activities. Chapter X starts with a discussion of the purpose of the control system followed by description of HVAC control system operation and definitions of control system elements. Control loops and example control systems are then presented. Types of HVAC control systems are then discussed followed by a discussion of building automation and control. This chapter finishes with a discussion of open-architecture HVAC system control.

Four appendices follow Chapter X. Appendix A provides a glossary of HVAC terms and abbreviations used throughout this manual. HVAC references and resources published by SMACNA that can be used for further information and study are provided in Appendix B. Division 23 of the 2004 Construction Specifications Institute (CSI) *MasterFormat*<sup>TM</sup> is provided in Appendix C for reference. Finally, Appendix D shows photos of various equipment and components.

