Chapter 1

Introduction to HVAC

Contents of Chapter 1

Instructions

Read the material of Chapter 1. Re-read the parts of the chapter that are emphasized in the summary and memorize important definitions.

Objectives of Chapter 1

Chapter 1 introduces the history, uses and main processes of heating, ventilating and air conditioning. There are no calculations to be done. The ideas will be addressed in detail in later chapters. After studying the chapter, you should be able to:

Define heating, ventilating, and air conditioning.
Describe the purposes of heating, ventilating, and air conditioning.
Name and describe seven major air-conditioning processes.
Identify five main aspects of a space that influence an occupant's comfort.

1.1 Introduction

Heating, Ventilating, and Air Conditioning (HVAC) is a huge field. HVAC systems include a range from the simplest hand-stoked stove, used for comfort heating, to the extremely reliable total air-conditioning systems found in submarines and space shuttles. Cooling equipment varies from the small domestic unit to refrigeration machines that are 10,000 times the size, which are used in industrial processes.

Depending on the complexity of the requirements, the HVAC designer must consider many more issues than simply keeping temperatures comfortable. This chapter will introduce you to the fundamental concepts that are used by designers to make decisions about system design, operation, and maintenance.

1.2 Brief History of HVAC

For millennia, people have used fire for heating. Initially, the air required to keep the fire going ensured adequate ventilation for the occupants. However, as central furnaces with piped steam or hot water became available for heating, the need for separate ventilation became apparent. By the late 1880s, rules of thumb for ventilation design were developed and used in many countries.

In 1851 Dr. John Gorrie was granted U.S. patent 8080 for a refrigeration machine. By the 1880s, refrigeration became available for industrial purposes. Initially, the two main uses were freezing meat for transport and making ice. However, in the early 1900s there was a new initiative to keep buildings cool for comfort. Cooling the New York Stock Exchange, in 1902, was one of the first comfort cooling systems. Comfort cooling was called "air conditioning."

Our title, "HVAC," thus captures the development of our industry. The term "air conditioning" has gradually changed, from meaning just cooling to the total control of:

- Temperature
- Moisture in the air (humidity)
- Supply of outside air for ventilation
- Filtration of airborne particles
- Air movement in the occupied space.

Throughout the rest of this text we will use the term "air conditioning" to include all of these issues and continue to use "HVAC" where only some of the elements of full air conditioning are being controlled.

To study the historical record of HVAC is to take a fascinating trip through the tremendous technical and scientific record of society. There are the pioneers such as Robert Boyle, Sadi Carnot, John Dalton, James Watt, Benjamin Franklin, John Gorrie, Lord Kelvin, Ferdinand Carré, Willis Carrier, and Thomas Midgley, along with many others, who have brought us to our current state. Air-conditioning technology has developed since 1900 through the joint accomplishments of science and engineering. Advances in thermodynamics, fluid mechanics, electricity, electronics, construction, materials, medicine, controls, and social behavior are the building blocks to better engineered products of air conditioning.

Historical accounts are not required as part of this course but, for the enjoyment and perspective it provides, it is worth reading an article such as *Milestones in Air Conditioning*, by Walter A. Grant[1] or the book about Willis Carrier, *The Father of Air Conditioning*.[2] The textbook *Principles of Heating, Ventilating, and Air Conditioning*,[3] starts with a concise and comprehensive history of the HVAC industry.

HVAC evolved based on:

- Technological discoveries, such as refrigeration, that were quickly adopted for food storage.
- Economic pressures, such as the reduction in ventilation rates after the 1973 energy crisis.
- Computerization and networking, used for sophisticated control of large complex systems serving numerous buildings.
- Medical discoveries, such as the effects of second hand smoke on people, which influenced ventilation methods.

1.3 Scope of Modern HVAC

Modern air conditioning is critical to almost every facet of advancing human activity. Although there have been great advances in HVAC, there are several areas where active research and debate continue.

Indoor air quality is one that directly affects us. In many countries of the world there is a rapid rise in asthmatics and increasing dissatisfaction with indoor air quality in buildings and planes. The causes and effects are extremely complex. A significant scientific and engineering field has developed to investigate and address these issues.

Greenhouse gas emissions and the destruction of the earth's protective *ozone layer* are concerns that are stimulating research. New legislation and guidelines are evolving that encourage: recycling; the use of new forms of energy; less energy usage; and low polluting materials, particularly refrigerants. All these issues have a significant impact on building design, including HVAC systems and the design codes.

Energy conservation is an ongoing challenge to find novel ways to reduce consumption in new and existing buildings without compromising comfort and indoor air quality. Energy conservation requires significant cooperation between disciplines.

For example, electric lighting produces heat. When a system is in a cooling mode, this heat is an additional cooling load. Conversely, when the system is in a heating mode, the lighting heat reduces the load on the building heating system. This interaction between lighting and HVAC is the reason that ASHRAE and the Illuminating Engineering Society of North America (IESNA) joined forces to write the building energy conservation standard, *ASHRAE Standard 90.1-2004, Energy Standard for Buildings Except Low-Rise Residential Buildings*.[4]

1.4 Introduction to Air-Conditioning Processes

As mentioned earlier, the term "air conditioning," when properly used, now means the total control of temperature, moisture in the air (humidity), supply of outside air for ventilation, filtration of airborne particles, and air movement in the occupied space. There are seven main processes required to achieve full air conditioning and they are listed and explained below:

The processes are:

1. *Heating*—the process of adding thermal energy (heat) to the conditioned space for the purposes of raising or maintaining the temperature of the space.

2. *Cooling*—the process of removing thermal energy (heat) from the conditioned space for the purposes of lowering or maintaining the temperature of the space.
3. *Humidifying*—the process of adding water vapor (moisture) to the air in the conditioned space for the purposes of raising or maintaining the moisture content of the air.
4. *Dehumidifying*—the process of removing water vapor (moisture) from the air in the conditioned space for the purposes of lowering or maintaining the moisture content of the air.
5. *Cleaning*—the process of removing particulates (dust, etc.) and biological contaminants (insects, pollen, etc.) from the air delivered to the conditioned space for the purposes of improving or maintaining the air quality.
6. *Ventilating*—the process of exchanging air between the outdoors and the conditioned space for the purposes of diluting the gaseous contaminants in the air and improving or maintaining air quality, composition, and freshness. Ventilation can be achieved either through *natural ventilation* or *mechanical ventilation*. Natural ventilation is driven by natural draft, like when you open a window. Mechanical ventilation can be achieved by using fans to draw air in from outside or by fans that exhaust air from the space to outside.
7. *Air Movement*—the process of circulating and mixing air through conditioned spaces in the building for the purposes of achieving the proper ventilation and facilitating the thermal energy transfer.

The requirements and importance of the seven processes varies. In a climate that stays warm all year, heating may not be required at all. Conversely, in a cold climate the periods of heat in the summer may be so infrequent as to make cooling unnecessary. In a dry desert climate, dehumidification may be redundant, and in a hot, humid climate dehumidification may be the most important design aspect of the air-conditioning system.

Defining Air conditioning

The actual use of the words "air conditioning" varies considerably, so it is always advisable to check what is really meant. Consider, for example, "window air conditioners." The vast majority provide cooling, some dehumidification, some filtering, and some ventilation when the outside temperature is well above freezing. They have no ability to heat or to humidify the conditioned space and do not cool if it is cold outside.

In colder climates, heating is often provided by a separate, perimeter heating system that is located within the outside walls. The other functions: cooling, humidification, dehumidification, cleaning, ventilating, and air movement are all provided by a separate air system, often referred to as the "air-conditioning system." **It is important to remember that both the heating and the air system together form the "air-conditioning" system for the space.**

1.5 Objective: What is your system to achieve?

Before starting to design a system, it is critical that you know what your system is to achieve.

Often, the objective is to provide a comfortable environment for the human occupants, but there are many other possible objectives: creating a suitable environment for farm animals; regulating a hospital operating room; maintaining cold temperatures for frozen food storage; or maintaining temperature and humidity to preserve wood and fiber works of art. Whatever the situation, it is important that the objective criteria for system success are clearly identified at the start of the project, because different requirements need different design considerations.

Let us very briefly consider some specific design situations and the types of performance requirements for HVAC systems.

Example 1: *Farm animals.* The design issues are economics, the health and well-being of both animals and workers, plus any regulations. Farm animal spaces are always ventilated. Depending on the climate, cooling and/or heating may be provided, controlled by a simple thermostat. The ventilation rate may be varied to:

- Maintain indoor air quality (removal of body and excrement fumes).
- Maintain inside design temperature (bring in cool air and exhaust hot air).
- Remove moisture (bring in drier air and exhaust moist air).
- Change the air movement over the animals (higher air speed provides cooling).

A complex control of ventilation to meet the four design requirements may well be very cost effective. However, humidification and cleaning are not required.

Example 2: *Hospital operating room.* This is a critical environment, often served by a dedicated air-conditioning system. The design objectives include:

- Heating, to avoid the patient from becoming too cold.
- Cooling, to prevent the members of the operating team from becoming too hot.
- Control adjustment by the operating team for temperatures between 18 °C (Centigrade) and 27 °C.
- Humidifying, to avoid low humidity and the possibility of static electricity sparks.
- Dehumidifying, to minimize any possibility of mold and to minimize operating team discomfort.
- Cleaning the incoming air with very high efficiency filters, to remove any airborne organisms that could infect the patient.
- Ventilating, to remove airborne contaminants and to keep the theatre fresh.
- Providing steady air movement from ceiling supply air outlets down over the patient for exhaust near the floor, to minimize contamination of the operating site.

This situation requires a very comprehensive air-conditioning system.

Example 3: *Frozen food storage.* The ideal temperature for long storage varies: i.e., ice cream requires temperatures below −25 °C and meat requires temperatures below −20 °C. The design challenge is to ensure that the temperature is accurately maintained and that the temperature is as even as possible throughout the storage facility. Here, accurate cooling and good air movement are the prime issues. Although cooling and air movement are required, we refer to this system as a "freezer," not as an air-conditioning system, because heating, ventilation, humidification, and dehumidification are not controlled.

Example 4: *Preserving wood and fiber works of art*. The objectives in this environment are to minimize any possibility of mold, by keeping the humidity low, and to minimize drying out, by keeping the humidity up. In addition, it is important to minimize the expansion and contraction of specimens that can occur as the moisture content changes. As a result the design challenge is to maintain a very steady humidity, reasonably steady temperature, and to minimize required ventilation, from a system that runs continuously. For this situation, the humidity control is the primary issue and temperature control is secondary. Typically, this situation will require all seven of the air-conditioning features and we will describe the space as fully "air-conditioned."

Now let us go on to consider the more complex subject of human comfort in a space.

1.6 Environment For Human Comfort

"Provide a comfortable environment for the occupants" sounds like a simple objective, until you start to consider the variety of factors that influence the comfort of an individual. *Figure 1-1* is a simplified diagram of the three main groups of factors that affect comfort.

- Attributes of the space – on the left
- Characteristics of the individual – on the right
- Clothing and activity of the individual – high center

1.6.1 Attributes of the Space Influencing Comfort

As you can see, six attributes of the space influence comfort: thermal, air quality, acoustical, lighting, physical, and psychosocial. Of these, only the thermal conditions and air quality can be directly controlled by the HVAC system. The acoustical (noise) environment may be influenced to some extent. The lighting and architectural aspects are another field, but these can influence how the HVAC is perceived. The psychosocial environment (how people interact sociably or unsociably!) in the space is largely dependent on the occupants, rather than the design of the space.

We will briefly consider these six aspects of the space and their influence on comfort.

1. *Thermal conditions* include more than simply the air temperature. If the air speed is very high, the space will be considered drafty. If there is no air movement, occupants may consider the space "stuffy." The air velocity in a mechanically conditioned space is largely controlled by the design of the system.

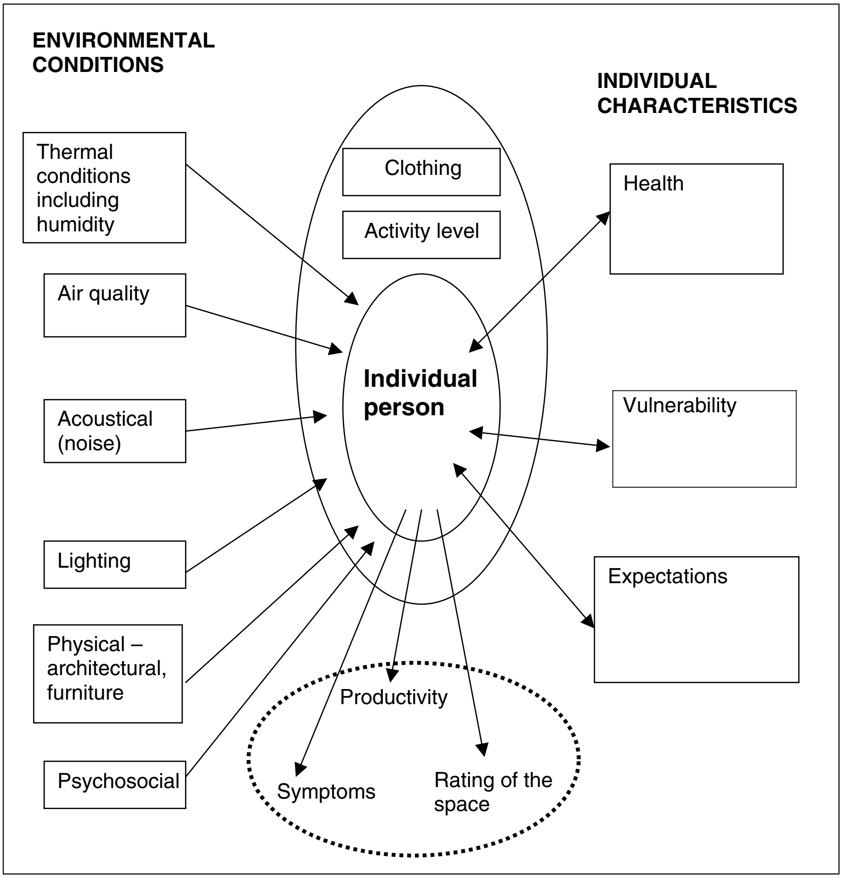

Figure 1-1 Personal Environment Model (adapted with permission from *The construct of comfort: a framework for research*, by W.S. Cain[5])

On the other hand, suppose the occupants are seated by a large unshaded window. If the air temperature stays constant, they will feel very warm when the sun is shining on them and cooler when clouds hide the sun. This is a situation where the architectural design of the space affects the thermal comfort of the occupant, independently of the temperature of the space.

2. The *air quality* in a space is affected by pollution from the occupants and other contents of the space. This pollution is, to a greater or lesser extent, reduced by the amount of outside air brought into the space to dilute the pollutants. Typically, densely occupied spaces, like movie theatres, and heavy polluting activities, such as cooking, require a much higher amount of outside air than an office building or a residence.
3. The *acoustical* environment may be affected by outside traffic noise, other occupants, equipment, and the HVAC system. Design requirements are dictated by the space. A designer may have to be very careful to design a virtually silent system for a recording studio. On the other hand, the design for a noisy foundry may not require any acoustical design consideration.
4. The *lighting* influences the HVAC design, since all lights give off heat. The lighting also influences the occupants' perception of comfort. If the lights are much too bright, the occupants may feel uncomfortable.

5. The *physical* aspects of the space that have an influence on the occupants include both the architectural design aspects of the space and the interior design. Issues like chair comfort, the height of computer keyboards, or reflections off computer screens have no relation to the HVAC design, however they may affect how occupants perceive the overall comfort of the space.
6. The *psychosocial* situation, the interaction between people in the space, is not a design issue but can create strong feelings about the comfort of the space.

1.6.2 Characteristics of the Individual that Influence Comfort

Now let us consider the characteristics of the occupants of the space. All people bring with them health, vulnerabilities, and expectations.

Their *health* may be excellent and they may not even notice the draft from the air conditioning. On the other hand, if the occupants are patients in a doctor's waiting room, they could perceive a cold draft as very uncomfortable and distressing.

The occupants can also vary in *vulnerability*. For example, cool floors will likely not affect an active adult who is wearing shoes. The same floor may be uncomfortably cold for the baby who is crawling around on it.

Lastly the occupants bring their *expectations*. When we enter a prestigious hotel, we expect it to be comfortable. When we enter an air-conditioned building in summer, we expect it to be cool. The expectations may be based on previous experience in the space or based on the visual perception of the space. For example, when you enter the changing room in the gym, you expect it to be smelly, and your expectations make you more tolerant of the reality.

1.6.3 Clothing and Activity as a function of Individual Comfort

The third group of factors influencing comfort is the amount of clothing and the activity level of the individual. If we are wearing light clothing, the space needs to be warmer for comfort than if we are heavily clothed. Similarly, when we are involved in strenuous activity, we generate considerable body heat and are comfortable with a lower space temperature.

In the summer, in many business offices, managers wear suits with shirts and jackets while staff members may have bare arms, and light clothing. The same space may be thermally comfortable to one group and uncomfortable to the other.

There is much more to comfort than most people realize. These various aspects of comfort will be covered in more detail in later chapters.

The Next Step

Chapter 2 introduces the concept of an air-conditioning system. We will then consider characteristics of systems and how various parameters influence system choice.

Summary

This has been an introduction to heating, ventilating, and air conditioning and some of the terminology and main processes that are involved in air conditioning.

1.2 Brief History of HVAC

The field of HVAC started in the mid-1800s. The term "air conditioning" has gradually changed from meaning just cooling to the total control of temperature, moisture in the air (humidity), supply of outside air for ventilation, filtration of airborne particles, and air movement in the occupied space.

1.3 Scope of Modern HVAC

Some of the areas of research, regulation, and responsibility include indoor air quality, greenhouse gas emissions, and energy conservation.

1.4 Introduction to Air-Conditioning Processes

There are seven main processes required to achieve full air conditioning: heating, cooling, humidifying, dehumidifying, cleaning, ventilating, air movement. The requirements and importance of the seven processes vary with the climate.

1.5 System Objectives

Before starting to design a system, it is critical that you know what your system is supposed to achieve. The objective will determine the type of system to select, and the performance goals for it.

1.6 Environment For Human Comfort

The requirements for human comfort are affected by: the physical space; the characteristics of the individual, including health, vulnerability, and expectations; and the clothing and activities of the individual.

Six attributes of the physical space that influence comfort are thermal, air quality, acoustical, lighting, physical, and the psychosocial environment. Of these, only the thermal conditions and air quality can be directly controlled by the HVAC system. The acoustical (noise) environment may be influenced to some extent. The lighting and architectural aspects can influence how the HVAC is perceived. The psychosocial environment in the space is largely dependent on the occupants rather than the design of the space.

Bibliography

1. Grant, W. 1969. "Milestones in Air Conditioning." *ASHRAE Journal* 11(9): 45–51.
2. Ingels, M. 1991. *The Father of Air Conditioning*. Louisville, KY: Fetter Printing Co.

3. Sauer, Harry J., Jr., Ronald H. Howell, and William J. Coad. 2001. *Principles of Heating, Ventilating, and Air Conditioning*. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
4. ASHRAE. 2004. *ASHRAE Standard 90.1-2004, Energy Standard for Buildings Except Low-Rise Residential Buildings*. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
5. Cain, W.S. 2002. The construct of comfort: a framework for research. *Proceedings: Indoor Air 2002*, Volume II, pp. 12–20.