

Audel™

HVAC Fundamentals
Volume I
Heating Systems,
Furnaces, and Boilers

All New 4th Edition

James E. Brumbaugh



Wiley Publishing, Inc.

Audel™

HVAC Fundamentals
Volume I
Heating Systems,
Furnaces, and Boilers

All New 4th Edition

James E. Brumbaugh



Wiley Publishing, Inc.

Vice President and Executive Group Publisher: Richard Swadley

Vice President and Executive Publisher: Robert Ipsen

Vice President and Publisher: Joseph B. Wikert

Executive Editorial Director: Mary Bednarek

Editorial Manager: Kathryn A. Malm

Executive Editor: Carol A. Long

Acquisitions Editors: Katie Feltman

Katie Mohr

Senior Production Manager: Fred Bernardi

Development Editor: Kenyon Brown

Production Editor: Vincent Kunkemueller

Text Design & Composition: TechBooks

Copyright © 2004 by Wiley Publishing, Inc., Indianapolis, Indiana. All rights reserved.

Published simultaneously in Canada

No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, scanning, or otherwise, except as permitted under Section 107 or 108 of the 1976 United States Copyright Act, without either the prior written permission of the Publisher, or authorization through payment of the appropriate per-copy fee to the Copyright Clearance Center, Inc., 222 Rosewood Drive, Danvers, MA 01923, (978) 750-8400, fax (978) 646-8600. Requests to the Publisher for permission should be addressed to the Legal Department, Wiley Publishing, Inc., 10475 Crosspoint Blvd., Indianapolis, IN 46256, (317) 572-3447, fax (317) 572-4447, E-mail: permcoordinator@wiley.com.

The publisher and the author make no representations or warranties with respect to the accuracy or completeness of the contents of this work and specifically disclaim all warranties, including without limitation warranties of fitness for a particular purpose. No warranty may be created or extended by sales or promotional materials. The advice and strategies contained herein may not be suitable for every situation. This work is sold with the understanding that the publisher is not engaged in rendering legal, accounting, or other professional services. If professional assistance is required, the services of a competent professional person should be sought. Neither the publisher nor the author shall be liable for damages arising herefrom. The fact that an organization or Website is referred to in this work as a citation and/or a potential source of further information does not mean that the author or the publisher endorses the information the organization or Website may provide or recommendations it may make. Further, readers should be aware that Internet Websites listed in this work may have changed or disappeared between when this work was written and when it is read.

For general information on our other products and services please contact our Customer Care Department within the United States at (800) 762-2974, outside the United States at (317) 572-3993 or fax (317) 572-4002.

Trademarks: Wiley, the Wiley Publishing logo, Audel are trademarks or registered trademarks of John Wiley & Sons, Inc. and/or its affiliates. All other trademarks are the property of their respective owners. Wiley Publishing, Inc., is not associated with any product or vendor mentioned in this book.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

Library of Congress Cataloging-in-Publication Data:

ISBN: 0-764-54206-0

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

For Laura, my friend, my daughter.

Contents

Introduction		xix
About the Author		xxi
Chapter 1	Introduction	1
	Heating and Ventilating Systems	2
	Air Conditioning	4
	Selecting a Suitable Heating, Ventilating, or Air Conditioning System	4
	Career Opportunities	5
	Professional Organizations	7
Chapter 2	Heating Fundamentals	9
	British Thermal Unit	9
	Relationship Between Heat and Work	9
	Heat Transfer	11
	Specific, Sensible, and Latent Heat	15
	Heat-Conveying Mediums	16
	Air	16
	Steam	18
	Water	22
	Electricity	25
Chapter 3	Insulating and Ventilating Structures	27
	Insulating Structures	27
	Principles of Heat Transmission	28
	Heat Transfer Values	29
	Thermal Conductivity	29
	Thermal Conductance	46
	Thermal Resistance	47
	Overall Coefficient of Heat Transmission	48

Condensation	48
Vapor Retarders	49
Air Barriers and Air/Vapor Retarders	51
Insulating Materials	52
Rigid Insulation Board	52
Reflective Insulation	54
Blanket or Batt Insulation	55
Loose-Fill Insulation	56
Blown-In Insulation	57
Foam Insulation	58
Building Construction and Location	58
Recommended Insulation Practices	59
Frame Walls	60
Masonry	60
Metal	63
Sandwich Construction	63
Basement Walls	63
Crawl Space Exterior Walls	63
Walls Between Separately Heated Dwelling Units	64
Wood or Metal Joist Frame Floors	64
Concrete Floors	66
Slab-on-Grade Floors	66
Floors of Sandwich Construction	66
Frame Ceilings and Roofs	67
Concrete Ceilings	68
Sandwich Ceilings	68
Windows and Doors	69
Insulating Attics, Attic Crawl Spaces, and Flat Roofs	69
Ventilating Structures	72
Chapter 4	
Sizing Residential Heating and Air Conditioning Systems	73
Rule-of-Thumb Methods	74
Sizing Systems Using Coefficients of Heat Transmission	75

Outside Design Temperature	77
Inside Design Temperature	77
Design Temperature Difference	80
Determining Coefficients of Heat Transmission	80
Calculating Net Area	80
Heat Transmission Loss Formula	81
Computing Total Heat Loss	82
Loss in Doors and Windows	84
Loss in Basements	84
Loss in Slab Construction	86
Infiltration Heat Loss	87
Ventilation Heat Loss	92
The Average Value Method	93
Heat Loss Tabulation Forms	95
Estimating Fuel Requirements and Heating Costs	100
The Heat Loss Formula	100
The Corrected Heat Loss Formula	102
The Degree-Day Formula	102
The NEMA Formula	106
Manual J and Related Materials Used for Sizing Heating/Cooling Systems	106
Other Heating Costs	107
Determining Utility Rates	108
Chapter 5 Heating Fuels	111
Natural Gas	112
Manufactured Gas	113
Liquefied Petroleum Gas	113
Fuel Oils	114
Coal	117
Coke	119
Briquettes	119
Coal Oil	119
Wood as Fuel	120
Ash, Slag, and Clinker Formation	122

	Soot	123
	Comparing Heating Fuel Costs	123
Chapter 6	Warm-Air Heating Systems	125
	Classifying Warm-Air Heating Systems	125
	Gravity Warm-Air Heating Systems	128
	Planning a Gravity Warm-Air Heating System	129
	Forced-Warm-Air Heating Systems	130
	Planning a Forced-Warm-Air Heating System	131
	Perimeter-Loop Warm-Air Heating Systems	132
	Ceiling Panel Systems	134
	Crawl Space Plenum Systems	134
	Zoning a Forced-Warm-Air Heating System	136
	Balancing a Warm-Air Heating System	136
	Warm-Air Furnaces	137
	Control Components	138
	Ducts and Duct Sizing	139
	Cooling with a Warm-Air Heating System	140
	Air Cleaning	141
	Humidifiers and Dehumidifiers	142
	Advantages of a Warm-Air Heating System	144
	Disadvantages of a Warm-Air Heating System	146
	Troubleshooting a Warm-Air Heating System	146
Chapter 7	Hydronic Heating Systems	149
	Classifying Hot-Water Heating Systems	149
	One-Pipe System	150
	Series-Loop System	152

	Two-Pipe, Direct-Return System	153
	Two-Pipe, Reverse-Return System	154
	Combination Pipe Systems	155
	Zoning a Two-Pipe System	155
	Radiant Panel Heating	155
	Other Applications	156
	Gravity Hot-Water Heating Systems	157
	Forced-Hot-Water Heating Systems	163
	Hot-Water Boilers	164
	Hydronic Furnaces	165
	Combination Water Heaters	168
	Control Components	169
	Pipe and Pipe Sizing	170
	Expansion Tanks	171
	Circulating Pumps (Circulators)	173
	Drainage	175
	Heat-Emitting Units	175
	Air Conditioning	176
	Moisture Control	179
	Electrically Heated Systems	179
	Advantages of Hydronic Heating Systems	182
	Disadvantages of Hydronic Heating Systems	182
	Troubleshooting Hydronic Heating Systems	183
Chapter 8	Steam Heating Systems	185
	Classifying Steam Heating Systems	185
	Gravity Steam Heating Systems	186
	One-Pipe, Reverse-Flow System	189
	Upfeed One-Pipe System	190
	Upfeed One-Pipe Relief System	192
	Downfeed One-Pipe System	196
	One-Pipe Circuit System	198
	One-Pipe, Divided-Circuit Nonrelief System	200

	One-Pipe Circuit System with Loop	200
	Two-Pipe Steam Heating Systems	201
	Two-Pipe, Divided-Circuit System	201
	Vapor Steam Heating Systems	202
	Open (Atmospheric) Vapor Systems	204
	Closed Vapor Systems	209
	Vacuum Steam Heating Systems	210
	Natural Vacuum Systems	214
	Mechanical Vacuum System	219
	Combined Atmospheric Pressure and Vacuum Systems	221
	Exhaust-Steam Heating	223
	Proprietary Systems	228
	High-Pressure Steam Heating Systems	242
	Steam Boilers	244
	Control Components	246
	Hartford Return Connection	247
	Pipes and Piping Details	248
	Steam Traps	248
	Pumps	249
	Heat-Emitting Units	249
	Air Supply and Venting	249
	Unit Heaters	250
	Air Conditioning	250
	Troubleshooting Steam Heating Systems	251
Chapter 9	Electric Heating Systems	253
	Central Hot-Water Systems	253
	Central Forced-Warm-Air Heating Systems	256
	Radiant Heating Systems	258
	Baseboard Heating Systems	259
	Electric Unit Ventilators	261
	Electric Unit Heaters	262
	Electric Space Heaters	263
	Heat Pumps	263

	Electric Heating and Cooling Controls	264
	Insulation for Electrically Heated and Cooled Structures	265
	Further Information	269
	Advantages of Electric Heating and Cooling	269
	Disadvantages of Electric Heating and Cooling	270
	Troubleshooting Electric Heating Systems	270
Chapter 10	Furnace Fundamentals	273
	Classifying Furnaces	273
	Upflow Highboy Furnace	275
	Upflow Lowboy Furnace	276
	Downflow Furnace	276
	Horizontal Furnace	278
	Gravity Warm-Air Furnaces	279
	Selecting a Furnace for a New House	279
	Selecting a Furnace for an Older House	282
	Furnace Components and Controls	282
	Pipeless Floor and Wall Furnaces	285
	Duct Furnaces	286
	Geothermal Furnaces	286
	Furnace Installation	288
	Furnace Maintenance	288
	Troubleshooting Furnaces	289
Chapter 11	Gas Furnaces	291
	Types of Gas Furnaces	291
	Standing-Pilot Gas Furnaces	294
	Mid-Efficiency Gas Furnaces	295
	High-Efficiency Gas Furnaces	297

Gas Furnace Components	299
Furnace Controls	300
Heat Exchanger	305
Gas Burners	308
Gas Pilot Assembly	311
Blower and Motor	313
Air Filter	313
Some Installation Recommendations	316
Locations and Clearances	317
Wiring	318
Duct Connections	320
Ventilation and Combustion Air	321
Venting	323
Flue Pipe	326
Chimney	330
Chimney Troubleshooting	331
Draft Hood	331
Pilot Burner Adjustment	337
Gas Input Adjustment	337
High-Altitude Adjustment	340
Changing Burner Orifices	340
Manifold Pressure Adjustment	342
Combustion Air Adjustment	343
Gas Supply Piping	346
Sizing Gas Piping	348
Installing Gas Piping	349
Typical Startup Instructions for a Standing-Pilot Gas Furnace	350
Typical Startup Instructions for an Electronic Ignition Furnace	352
Blowers and Motors	353
Air Delivery and Blower Adjustment	354
Direct-Drive Blower Adjustment	355
Belt-Drive Blower Adjustment	355
Air Filters	356
Air Conditioning	357

Installation Checklist	360
Gas Furnace Inspections, Service, and Maintenance Tips	361
Troubleshooting a Gas Furnace	363
Troubleshooting Charts	368
Chapter 12 Oil Furnaces	375
Conventional Oil Furnace	375
Mid-Efficiency and High-Efficiency Oil Furnaces	378
Mid-Efficiency (Noncondensing) Oil Furnace	379
High-Efficiency (Condensing) Oil Furnace	379
Basic Components of an Oil Furnace	382
Furnace Controls	382
Heat Exchanger	386
Oil Burner Assembly	388
Fuel Pump and Fuel Pump Motor	389
Blower and Motor	390
Combustion Air Blowers	392
Cleanout and Observation Ports	392
Vent Opening	392
Air Filter	392
Installing an Oil Furnace	393
Some Installation Recommendations	393
Location and Clearance	393
Wiring	394
Duct Connections	395
Ventilation and Combustion Air	395
Combustion Draft	397
Venting	397
Chimneys and Chimney Troubleshooting	399
Installation Checklist	400

Fuel Supply Tank and Fuel Line	401
Fuel Tank Location	402
Filler Pipe	404
Tank Vent Pipe	405
Oil Filter	405
Blowers and Motors	405
Waste Oil Furnaces	405
Air Conditioning	406
Starting the Burner	407
Oil Furnace Spillage	408
Oil Furnace Inspection, Service, and Maintenance Tips	408
Oil Furnace Adjustments	410
Troubleshooting Oil Furnaces	411
Troubleshooting Charts	414
Chapter 13	
Coal Furnaces, Wood Furnaces, and Multi-Fuel Furnaces	419
Coal Furnaces	419
Sizing Requirements	419
Location and Clearance	420
Installation Recommendations	421
Duct Connections	421
Electrical Wiring	423
Ventilation and Combustion Air	424
Venting	430
Flue Pipe	430
Chimneys and Chimney Troubleshooting	430
Furnace Components	432
Automatic Controls	432
Furnace Grate	433
Coal Stoker	434
Hand-Firing Methods	434
Blower and Motor Assembly	435
Blower Adjustment	435
Air Filter	435
System Accessory Devices	435

Wood Furnaces	436
Wood Add-On Furnaces	437
Multi-Fuel Furnaces	438
Installation, Operating, and Maintenance Instructions for Coal, Wood, and Multi-Fuel Furnaces	441
Assembly and Installation	
Recommendations	441
Maintenance Instructions	442
Multi-Fuel Furnace Operation	447
Troubleshooting Coal, Wood, and Multi-Fuel Furnaces	448
Chapter 14	Electric Furnaces
	453
Electrical Power Supply	453
Planning Suggestions	454
Location and Clearance	455
Installation Recommendations	456
Duct Connections	456
Basic Components	457
Automatic Controls	458
Heating Elements	462
Timing Sequences	463
Safety Controls	464
Temperature Limit Controls	464
Secondary High-Limit Control	464
Furnace Fuses	464
Circuit Breakers	464
Transformer	468
Thermal Overload Protector	470
Electrical Wiring	470
Blowers and Motors	471
Air Delivery and Blower	
Adjustment	471
Air Filter	471
Air Conditioning	471

Maintenance and Operating Instructions	475
Furnace Air Filters, Electronic Air Cleaners, and Humidifiers	475
Heating Elements and Heating Control Wiring	475
Blowers/Fans	476
Ducts	476
Thermostats	476
Furnaces without Air Conditioners	477
Troubleshooting an Electric Furnace	477
Chapter 15	
Steam and Hot-Water Space Heating Boilers	481
Boiler Rating Method	485
Boiler Heating Surface	486
Boiler Efficiency	486
Types of Boilers	487
Gas-Fired Boilers	492
Oil-Fired Boilers	493
Coal-Fired Boilers	493
Electric Boilers	497
High-Efficiency Boilers	502
Steam Boiler Valves, Controls, and Accessories	502
Steam Boiler Low-Water Cutoffs	505
Installing a Low-Water Cutoff	508
Fusible Plugs	515
Pressure Relief Valves	515
Pressure Controllers	517
Vacuum Relief Valve	519
Steam Boiler Aquastat	521
Blowdown Valve	521
Try Cocks	522
Steam Boiler Injectors	523

Water Gauges	524
Water Columns	526
Steam Gauges	526
Steam Gauge Pigtails	528
Hartford Return Connection	529
Hot-Water Boiler Valves, Controls, and Accessories	529
Hot-Water Boiler Low-Water Cutoffs	532
Hot-Water Boiler Pressure Relief Valves	534
High-Pressure Limit Switch	535
Hot-Water Boiler Aquastats	535
Pressure-Reducing Valves	538
Combination Valves	541
Balancing Valve	548
Backflow Preventer	548
Altitude Gauges	549
Circulator (Pump)	550
Air Separator	550
Purging Air from the System	553
Expansion Tanks	553
Air Supply and Venting	553
Induced-Draft Fans	558
Controlling Excessive Draft (Gas-Fired Boilers)	559
Tankless Water Heaters	560
Leaking Coils	561
Blowing Down a Boiler	561
Boiler Operation, Service, and Maintenance	562
Steam Boilers	563
Hot-Water (Hydronic) Boilers	564
Boiler Water	564
Cleaning Boilers	565
Troubleshooting Boilers	565
Boiler Repairs	568
Installing Boilers	568

Chapter 16	Boiler and Furnace Conversion	569
	Preparation for Conversion	570
	Basic Combustion Chamber Requirements	572
	Combustion Chambers for Conversion Gas Burners	572
	Combustion Chambers for Conversion Oil Burners	574
	Construction Materials	576
	Building a Combustion Chamber	578
	Ventilation Requirements	580
	Flue Pipe and Chimney	582
	Baffling	584
	Gas Piping and Piping Connections	584
	Gas Input Setting	587
	Installing a Conversion Gas Burner	589
	Starting a Conversion Gas Burner (with Pilot Light)	590
	Starting a Conversion Gas Burner (Pilotless)	593
	Servicing a Conversion Gas Burner	594
	Oil Tanks and Oil Piping	597
	Installing a Conversion Oil Burner	598
	Starting a Conversion Oil Burner	600
	Servicing a Conversion Oil Burner	601
	Troubleshooting Oil and Gas Conversion Burners	602
Appendix A	Professional and Trade Associations	603
Appendix B	Manufacturers	615
Appendix C	HVAC/R Education, Training, Certification, and Licensing	627
Appendix D	Data Tables	631
Appendix E	Conversion Tables	669
Index		679

Introduction

The purpose of this series is to provide the layman with an introduction to the fundamentals of installing, servicing, troubleshooting, and repairing the various types of equipment used in residential and light-commercial heating, ventilating, and air conditioning (HVAC) systems. Consequently, it was written not only for the HVAC technician and others with the required experience and skills to do this type of work but also for the homeowner interested in maintaining an efficient and trouble-free HVAC system. A special effort was made to remain consistent with the terminology, definitions, and practices of the various professional and trade associations involved in the heating, ventilating, and air conditioning fields.

Volume 1 begins with a description of the principles of thermal dynamics and ventilation, and proceeds from there to a general description of the various heating systems used in residences and light-commercial structures. Volume 2 contains descriptions of the working principles of various types of equipment and other components used in these systems. Following a similar format, Volume 3 includes detailed instructions for installing, servicing, and repairing these different types of equipment and components.

The author wishes to acknowledge the cooperation of the many organizations and manufacturers for their assistance in supplying valuable data in the preparation of this series. Every effort was made to give appropriate credit and courtesy lines for materials and illustrations used in each volume.

Special thanks is due to Greg Gyorda and Paul Blanchard (Watts Industries, Inc.), Christi Drum (Lennox Industries, Inc.), Dave Cheswald and Keith Nelson (Yukon/Eagle), Bob Rathke (ITT Bell & Gossett), John Spuller (ITT Hoffman Specialty), Matt Kleszezynski (Hydrotherm), and Stephanie DePugh (Thermo Pride).

Last, but certainly not least, I would like to thank Katie Feltman, Kathryn Malm, Carol Long, Ken Brown, and Vincent Kunkemueller, my editors at John Wiley & Sons, whose constant support and encouragement made this project possible.

James E. Brumbaugh

About the Author

James E. Brumbaugh is a technical writer with many years of experience working in the HVAC and building construction industries. He is the author of the *Welders Guide*, *The Complete Roofing Guide*, and *The Complete Siding Guide*.

Chapter I

Introduction

This series is an introduction to the basic principles of heating, ventilating, and air conditioning (HVAC). Each represents a systematic attempt to control the various aspects of the environment within an enclosure, whether it is a room, a group of rooms, or a building.

Among those aspects of the immediate environment that people first sought to control were heat and ventilation. Attempts at controlling heat date from prehistoric times and probably first developed in colder climates, where it was necessary to produce temperatures sufficient for both comfort and health. Over the years the technology of heating advanced from simple attempts to keep the body warm to very sophisticated systems of maintaining stabilized environments in order to reduce heat loss from the body or the structural surfaces of the room.

Ventilation also dates back to very early periods in history. Certainly the use of slaves to wave large fans or fanlike devices over the heads of rulers was a crude early attempt to solve a ventilating problem. Situating a room or a building so that it took advantage of prevailing breezes and winds was a more sophisticated attempt. Nevertheless, it was not until the nineteenth century that any really significant advances were made in ventilating. During that period, particularly in the early stages of the Industrial Revolution, ventilating acquired increased importance. Work efficiency and the health of the workers necessitated the creation of ventilation systems to remove contaminants from the air. Eventually, the interrelationship of heating and ventilating became such that it is now regarded as a single subject.

Air conditioning is a comparatively recent development and encompasses all aspects of environmental control. In addition to the control of temperature, both humidity (i.e., the moisture content of the air) and air cleanliness are also regulated by air conditioning. The earliest attempts at air conditioning involved the placing of wet cloths over air passages (window openings, entrances, etc.) to cool the air. Developments in air conditioning technology did not progress much further than this until the nineteenth century. From about 1840 on, several systems were devised for both cooling and humidifying rooms. These were first developed by textile manufacturers in order to reduce

the static electricity in the air. Later, adaptations were made by other industries.

Developments in air conditioning technology increased rapidly in the first four decades of the nineteenth century, but widespread use of air conditioning in buildings is a phenomenon of the post-World War II period (i.e., 1945 to the present). Today, air conditioning is found not only in commercial and industrial buildings but in residential dwellings as well. Unlike early forms of air conditioning, which were designed to cool the air or add moisture to it, modern air conditioning systems can control temperature, air moisture content, air cleanliness, and air movement. That is, modern systems *condition* the air rather than simply cool it.

Heating and Ventilating Systems

Many different methods have been devised for heating buildings. Each has its own characteristics, and most methods have at least one objectionable aspect (e.g., high cost of fuel, expensive equipment, or inefficient heating characteristics). Most of these heating methods can be classified according to one of the following four criteria:

1. The heat-conveying medium
2. The fuel used
3. The nature of the heat
4. The efficiency and desirability of the method

The term *heat-conveying medium* means the substance or combination of substances that carries the heat from its point of origin to the area being heated. There are basically four mediums for conveying heat. These four mediums are:

1. Air
2. Water
3. Steam
4. Electricity

Different types of wood, coal, oil, and gas have been used as fuels for producing heat. You may consider electricity as both a fuel and a heat-conveying medium. Each heating fuel has its own characteristics; the advantage of one type over another depends upon such variables as availability, efficiency of the heating equipment (which, in turn, is dependent upon design, maintenance, and other

factors), and cost. A detailed analysis of the use and effectiveness of the various heating fuels is found in Chapter 5 (“Heating Fuels”).

Heating methods can also be classified with respect to the nature of the heat applied. For example, the heat may be of the exhaust steam variety or it may consist of exhaust gases from internal combustion engines. The nature of the heat applied is inherent to the heat system and can be determined by reading the various chapters that deal with each type of heating system (Chapters 6 through 9) or with heat-producing equipment (e.g., Chapter 11, “Gas Furnaces”).

The various heating methods differ considerably in efficiency and desirability. This is due to a number of different but often interrelated factors, such as energy cost, conveying medium employed, and type of heating unit. The integration of these interrelated components into a single operating unit is referred to as a *heating system*.

Because of the different conditions met within practice, there is a great variety in heating systems, but most of them fall into one of the following broad classifications:

1. Warm-air heating system (Chapter 6)
2. Hydronic heating systems (Chapter 7)
3. Steam heating systems (Chapter 8)
4. Electric heating systems (Chapter 9)

You will note that these classifications of heating systems are based on the heat-conveying method used. This is a convenient method of classification because it includes the vast majority of heating systems used today.

As mentioned, ventilating is so closely related to heating in its various applications that the two are very frequently approached as a single subject. In this series, specific aspects of ventilating are considered in Chapter 6 (“Ventilation Principles”) and Chapter 7 (“Ventilation and Exhaust Fans”) of Volume 3.

The type and design of ventilating system employed depends on a number of different factors, including:

1. Building use or ventilating purpose
2. Size of building
3. Geographical location
4. Heating system used

A residence will have a different ventilating system from a building used for commercial or industrial purposes. Moreover, the

requirements of a ventilating system used to provide fresh air result in fundamental design differences from a ventilating system that must remove noxious gases or other dangerous contaminants from the enclosure.

The size of a building is a factor that also must be considered. For example, a large building presents certain ventilating problems if the internal areas are far from the points where outside air would initially gain access. Giving special attention to the overall design of the ventilating system can usually solve these problems.

Buildings located in the tropics or semitropics present different ventilating problems from those found in temperature zones. The differences are so great that they often result in different architectural forms. At least this was the case *before* the advent of widespread use of air conditioning. The typical southern house of the nineteenth century was constructed with high ceilings (heat tends to rise); large porches that sheltered sections of the house from the hot, direct rays of the sun; and large window areas to admit the maximum amount of air. They were also usually situated so that halls, major doors, and sleeping areas faced the direction of the prevailing winds. Today, with air conditioning so widely used, these considerations are not as important—at least not until the power fails or the equipment breaks down.

Air Conditioning

Although the major emphasis in this series has been placed on the various aspects of heating and ventilating, some attention has also been given to air conditioning. The reason for this, of course, is the increasing use of year-round air conditioning systems that provide heating, ventilating, and cooling. These systems *condition* the air by controlling its temperature (warming or cooling it), cleanliness, moisture content, and movement. This is the true meaning of the term *air conditioning*. Unfortunately, it has become almost synonymous with the idea of cooling, which is becoming less and less representative of the true function of an air conditioning system. Air conditioning, particularly the year-round air conditioning systems, is examined in detail in Chapters 8, 9, and 10 of Volume 3.

Selecting a Suitable Heating, Ventilating, or Air Conditioning System

There are a number of different types of heating, ventilating, and air conditioning equipment and systems available for installation in the home. The problem is choosing the most efficient one in terms

of the installation and operating costs. These factors, in turn, are directly related to one's particular heating and cooling requirements. The system must be the correct size for the home. Any reputable building contractor or heating and air conditioning firm should be able to advise you in this matter.

If you are having a heating and ventilating or air conditioning system installed in an older house, be sure to check the construction. Weather stripping is the easiest place to start. All doors and windows should be weather-stripped to prevent heat loss. Adequate weather stripping can cut heating costs by as much as 15 to 20 percent. If the windows provide suitable protection (they should be double- or triple-glazed) from the winter cold, check the caulking around the edge of the glass. If it is cracking or crumbling, replace it with fresh caulking. You may even want to go to the expense of insulating the ceilings and outside walls. This is where a great deal of heat loss and air leakage occurs.

You have several advantages when you are building your own house. For example, you may be able to determine the location of your house on the lot. This should enable you to establish the direction in which the main rooms and largest windows face. If you position your house so that these rooms and windows face south, you will gain maximum sunlight and heat from the sun during the cold winter months. This will reduce the heat requirement and heating costs. The quality of construction depends on how much you wish to spend and the reliability of the contractor. It is advisable to purchase the best insulation you can afford. Your reduced heating costs will eventually pay for the added cost of the insulation. If you suspect that your building contractor cannot be trusted, you can reduce opportunities for cheating and careless work by making frequent and unexpected visits to the construction site.

Career Opportunities

Many career opportunities are available in heating, ventilating, and air conditioning fields, and they extend over several levels of education and training. Accordingly, the career opportunities open to an individual seeking employment in these fields can be divided roughly into four categories, each dependent upon a different type or degree of education and/or training. This relationship is shown in Table 1-1.

Among workers in these fields, engineers receive the highest pay, but they also undergo the longest periods of education and training. Engineers are usually employed by laboratories, universities, and colleges or, frequently, by the manufacturers of materials and

Table 1-1 Relationships between Career Category and Type of Work or Education and/or Training Required

Career Category	Type of Work	Education/Training
Engineer	Design and development	4 years or more of college
Technician	Practical application	Technical training school and/or college
Skilled worker	Installation, maintenance, and repair	Apprentice program or on-the-job training (OJT)
Apprentice or OJT worker	Training for skilled-worker position	High school degree or equivalency

equipment used in heating, ventilating, air conditioning, and related industries. Their primary responsibility is designing, developing, and testing the equipment and materials used in these fields. In some cases, particularly when large buildings or district heating to several buildings is employed, they also supervise the installation of the entire system. Moreover, industry codes and standards are usually the results of research conducted by engineers.

Technicians obtain their skills through technical training schools, some college, or both. Many assist engineers in the practical application of what the latter have designed. Technicians are particularly necessary during the developmental stages. Other technicians are found in the field working for contractors in the larger companies. Their pay often approximates that of engineers, depending on the size of the company for which they work.

Skilled workers are involved in the installation, maintenance, and repair of heating, ventilating, and air conditioning equipment. Apprentices and OJT (on-the-job training) workers are in training for the skilled positions and are generally expected to complete at least a 2- to 5-year training program. Local firms that install or repair equipment in residential, commercial, and industrial buildings employ most skilled workers and trainees. Some also work on the assembly lines of factories that manufacture such equipment. Their pay varies, depending on the area, their seniority, and the nature of the work. Most employers require that both skilled workers and trainees have at least a high school diploma or its equivalent (e.g., the GED). The requirement for a high school diploma may be waived if the individual has already acquired the necessary skills on a previous job. The pay for skilled workers and trainees is lower than that earned by engineers