Contents

Section 1
Refrigeration System Fundamentals

Chapter 1
Fundamentals of Refrigeration  2
1.1 Systems of Measurement 4
1.2 Matter and Energy 4
1.3 Force, Work, and Power 5
1.4 Heat 6
1.5 Volume 14
1.6 Pressure 15
1.7 Gas Laws 21
1.8 Saturated Vapor 22
1.9 Mass and Weight 22
1.10 Density 22
1.11 Basic Processes That Provide Cooling Effect 23
1.12 Measuring Refrigeration Effect 24

Chapter 2
Basic Refrigeration Systems  28
2.1 Compression Refrigeration Cycle 30
2.2 High Side and Low Side 31
2.3 Compression 32
2.4 Condensing 34
2.5 Metering Device 36
2.6 Evaporating 36

Section 2
Service Basics

Chapter 3
Tools and Supplies  42
3.1 Hand Tools 44
3.2 Instruments 58
3.3 Standard Supplies 61
3.4 Employer-Provided Tools and Equipment 64

Chapter 4
Working with Tubing and Piping  68
4.1 Types of Refrigerant Tubing and Pipe 70
4.2 Non-Refrigerant Tubing and Pipe 71
4.3 Cutting Tubing 73
4.4 Bending Tubing 76
4.5 Connecting Tubing 77
4.6 Connecting Pipe 91

Chapter 5
Service Calls  96
5.1 Troubleshooting and Servicing 98
5.2 Customer Service 101

Section 3
Refrigerants

Chapter 6
Introduction to Refrigerants  108
6.1 Refrigerants and the Ozone Layer 110
6.2 Classifying Refrigerants 111
6.3 Identifying Refrigerants 113
6.4 Refrigerant Properties 115
6.5 Refrigerant Applications 121
6.6 Inorganic Refrigerants 124
6.7 Refrigeration Lubricants 126

Chapter 7
Equipment and Instruments for Refrigerant Handling and Service  132
7.1 Refrigerant Cylinders 134
7.2 Pressure Gauges 136
7.3 Service Valves 140
7.4 Gauge Manifolds 147
7.5 Leak Detection Devices 151
7.6 Vacuum Pumps 154
7.7 Recovery, Recycling, and Reclaiming Equipment 156

Chapter 8
Working with Refrigerants  164
8.1 Checking Refrigerant Charge 166
8.2 Redistributing Refrigerant 167
8.3 Locating and Repairing Refrigerant Leaks 176
8.4 Evacuating a System 181
8.5 Charging a System 186
Section 4  
Basic Electricity, Magnetism, and Electronics  

Chapter 9  
Basic Electricity  198  
9.1 Fundamental Principles of Electricity  200  
9.2 Types of Electricity  204  
9.3 Electrical Materials  205  
9.4 Circuit Fundamentals  206  
9.5 Magnetism  211  
9.6 Electrical Generators  212  
9.7 Transformer Basics  214  

Chapter 10  
Electrical Power  218  
10.1 Electrical Power  220  
10.2 Power Circuits  222  
10.3 Electrical Problems  229  

Chapter 11  
Basic Electronics  234  
11.1 Semiconductor Basics  236  
11.2 Control Circuits and Electronic Devices  238  
11.3 Circuit Boards and Microprocessors  242  
11.4 Switches  242  
11.5 Relays  243  

Chapter 12  
Electric Motors  250  
12.1 The Elementary Electric Motor  252  
12.2 AC Induction Motors  255  
12.3 Electronically Commutated Motors  263  
12.4 Standard Motor Data  264  
12.5 Motor Applications in HVACR Systems  266  

Chapter 13  
Electrical Control Systems  272  
13.1 Circuit Diagrams  274  
13.2 Control System Fundamentals  275  
13.3 Motor Controls  284  
13.4 Motor Protection Devices  297  

Chapter 14  
Servicing Electric Motors and Controls  304  
14.1 Electrical Test Equipment  306  
14.2 Troubleshooting Electric Motors  313  
14.3 Servicing Hermetic Compressor Motors  318  
14.4 Servicing Fan Motors  321  
14.5 Servicing External Motors  322  
14.6 Servicing Motor Control Systems  328  

11.6 Solenoids  243  
11.7 Thermocouples  244  

Section 5  
Motors and Electric Control Systems  

Chapter 12  
Electric Motors  250  
12.1 The Elementary Electric Motor  252  
12.2 AC Induction Motors  255  
12.3 Electronically Commutated Motors  263  
12.4 Standard Motor Data  264  
12.5 Motor Applications in HVACR Systems  266  

Chapter 13  
Electrical Control Systems  272  
13.1 Circuit Diagrams  274  
13.2 Control System Fundamentals  275  
13.3 Motor Controls  284  
13.4 Motor Protection Devices  297  

Chapter 14  
Servicing Electric Motors and Controls  304  
14.1 Electrical Test Equipment  306  
14.2 Troubleshooting Electric Motors  313  
14.3 Servicing Hermetic Compressor Motors  318  
14.4 Servicing Fan Motors  321  
14.5 Servicing External Motors  322  
14.6 Servicing Motor Control Systems  328
Section 6
Compressors, Valves, and Metering Devices

Chapter 15
Compressors 336
15.1 Compressor Drive Configurations 338
15.2 Types of Compressors 341
15.3 General Compressor Components and Systems 358

Chapter 16
Valves and Metering Devices 366
16.1 Metering Device Basics 368
16.2 Capillary Tubes 368
16.3 Fixed-Orifice Metering Devices 371
16.4 Thermostatic Expansion Valves (TXVs) 373
16.5 Automatic Expansion Valves (AXVs) 389
16.6 Electronic Expansion Valves (EEVs) 392
16.7 Float-Operated Refrigerant Controls 397
16.8 Other Refrigerant Control Valves 400

Section 7
Domestic Refrigerators and Freezers

Chapter 17
Overview of Domestic Refrigerators and Freezers 410
17.1 Domestic Refrigeration 412
17.2 Refrigerators and Freezers 413
17.3 Innovative Technologies 419

Chapter 18
Systems and Components of Domestic Refrigerators and Freezers 422
18.1 Basic Components of Refrigerators and Freezers 424
18.2 Specialized Systems 432

Chapter 19
Installation and Troubleshooting of Domestic Refrigerators and Freezers 450
19.1 Checking for Proper Installation 452
19.2 Diagnosing Symptoms 454
19.3 Checking External Circuits 462
19.4 Diagnosing Internal Troubles 465

Chapter 20
Service and Repair of Domestic Refrigerators and Freezers 480
20.1 External Service Operations 482
20.2 Internal Service Operations 483
20.3 Storing or Discarding a Refrigerator-Freezer 494

Section 8
Indoor Air Fundamentals

Chapter 21
Air Movement and Measurement 498
21.1 Climate 500
21.2 Atmosphere and Air 500
21.3 Comfort Conditions 514
21.4 Air Movement 517
21.5 Factors Affecting Indoor Air Conditions 525

Chapter 22
Air Quality 530
22.1 Indoor Air Quality Standards and Guidelines 532
22.2 Air Pollutants 532
22.3 Indoor Air Quality 535
22.4 Air Cleaning 542
22.5 Indoor Air Quality Systems 551

Chapter 23
Air Distribution 556
23.1 Air Properties and Behavior 558
23.2 Air Circulation 559
23.3 Basic Ventilation Requirements 560
23.4 Air Ducts 563
23.5 Duct Sizing 573
23.6 Fans 579
23.7 Air Curtains 581

Chapter 24
Ventilation System Service 586
24.1 Airflow Measurement 588
24.2 Special Duct Problems and Duct Maintenance 591
24.3 Fan Service 597
24.4 Filter Service 598
Section 9
Air-Conditioning Systems

Chapter 25
Ductless Air-Conditioning Systems 602
25.1 Principles of Cooling and Humidity Control 604
25.2 Remote Comfort Cooling Systems 605
25.3 Self-Contained Air-Conditioning Units 608

Chapter 26
Central Air-Conditioning Systems 620
26.1 Central Air Conditioning 622
26.2 Split Systems 624
26.3 Rooftop and Outdoor Units 627
26.4 Chilled Water Systems (Chillers) 630
26.5 Water-Cooled Condensers 642
26.6 Comfort Cooling Controls 646

Chapter 27
Absorption and Evaporative Cooling Systems 652
27.1 Absorption Refrigeration Systems 654
27.2 Absorption Cooling Systems 656
27.3 Evaporative Cooling 667

Chapter 28
Humidity Control 674
28.1 Humidity Levels and Comfort 676
28.2 Types of Humidifiers 678
28.3 Dehumidifying Equipment 683

Chapter 29
Thermostats 688
29.1 Thermostats for Heating and Air-Conditioning 690
29.2 Thermostat Operation 690
29.3 Types of Thermostats 695

Chapter 30
Heating and Cooling Loads 710
30.1 Heat Transfer 712
30.2 Heat Loads 712
30.3 Heat Leakage 713
30.4 Other Factors Affecting Heat Loads 728
30.5 Determining Total Heat Load 735

Chapter 31
Air Conditioning Installation, Troubleshooting, and Service 742
31.1 Central Air Conditioning System Service 744
31.2 Ductless Air Conditioning Unit Service 753
31.3 Absorption System Service 760
31.4 Servicing and Installing Humidifiers 764

Section 10
Heating Systems

Chapter 32
Forced-Air Heating Fundamentals 768
32.1 Basic Components 770
32.2 Furnace Types and Construction 773
32.3 Forced-Air Duct Arrangements 775
32.4 Makeup Air Units 775
32.5 Blower Controls 776
32.6 Unit Heaters 778

Chapter 33
Hydronic Heating Fundamentals 782
33.1 Hydronic System Components 784
33.2 Hydronic System Designs 794
33.3 Hydronic System Controls 805
33.4 Hydronic System Installation 808

Carrier Corporation, Subsidiary of United Technologies Corp.
Modern Refrigeration and Air Conditioning

Chapter 34
Heat Pumps 824
34.1 Heat Pump Basics 826
34.2 Types of Heat Pumps 827
34.3 Heat Pump Efficiency 830
34.4 Heat Pump System Components 832
34.5 Heat Pump Controls 844
34.6 Heat Pumps and Solar Heating Systems 847

Chapter 35
Gas-Fired Heating Systems 852
35.1 Combustion 855
35.2 Gas Valves 859
35.3 Gas Burners 860
35.4 Ignition Systems 862
35.5 Gas Furnace Controls 865
35.6 Gas Furnace Efficiency 869
35.7 Gas Furnace Venting Categories 871
35.8 Gas-Fired Radiant Heat 872

Chapter 36
Oil-Fired Heating Systems 876
36.1 Basic Oil Furnace Operation 878
36.2 Fuel Oil 878
36.3 Combustion Efficiency 880
36.4 Fuel Line Components 884
36.5 Oil Burners 888
36.6 Primary Control Units 895
36.7 Oil Furnace Exhaust 902

Chapter 37
Electric Heating Systems 906
37.1 Principles of Electric Resistance Heating 908
37.2 Electric Heating Elements 909
37.3 Electric Heating Systems 910
37.4 Electric Furnace and Duct Heater Controls 917
37.5 Electric Baseboard Heating Unit Controls 921
37.6 Electric Heat Construction Practices 922

Chapter 38
Heating System Installation and Service 926
38.1 Heat Pump System Service 928
38.2 Gas-Fired Heating System Service 932

Section 11
Energy Management and Conservation

Chapter 39
Solar Power and Thermal Storage 956
39.1 The Nature of Solar Energy 958
39.2 Solar Collectors 959
39.3 Solar Heating Systems 962
39.4 Applications for Solar Heating Systems 963
39.5 Supplementary Heat 965
39.6 Solar Energy Cooling Systems 966
39.7 Converting Solar Energy to Electricity 967
39.8 Thermal Energy Storage 970

Chapter 40
Energy Management 978
40.1 Energy Consumption 980
40.2 Building Control Systems 980
40.3 Controllers for Building Control Systems 982
40.4 Building Control Protocols 984
40.5 Control System Diagnostics and Repair 987

Chapter 41
Energy Conservation 990
41.1 Building Efficiency 992
41.2 HVAC Equipment Efficiency 998
41.3 HVAC Alternatives for Energy Conservation 1000
41.4 The Role of the HVACRT Technician 1002