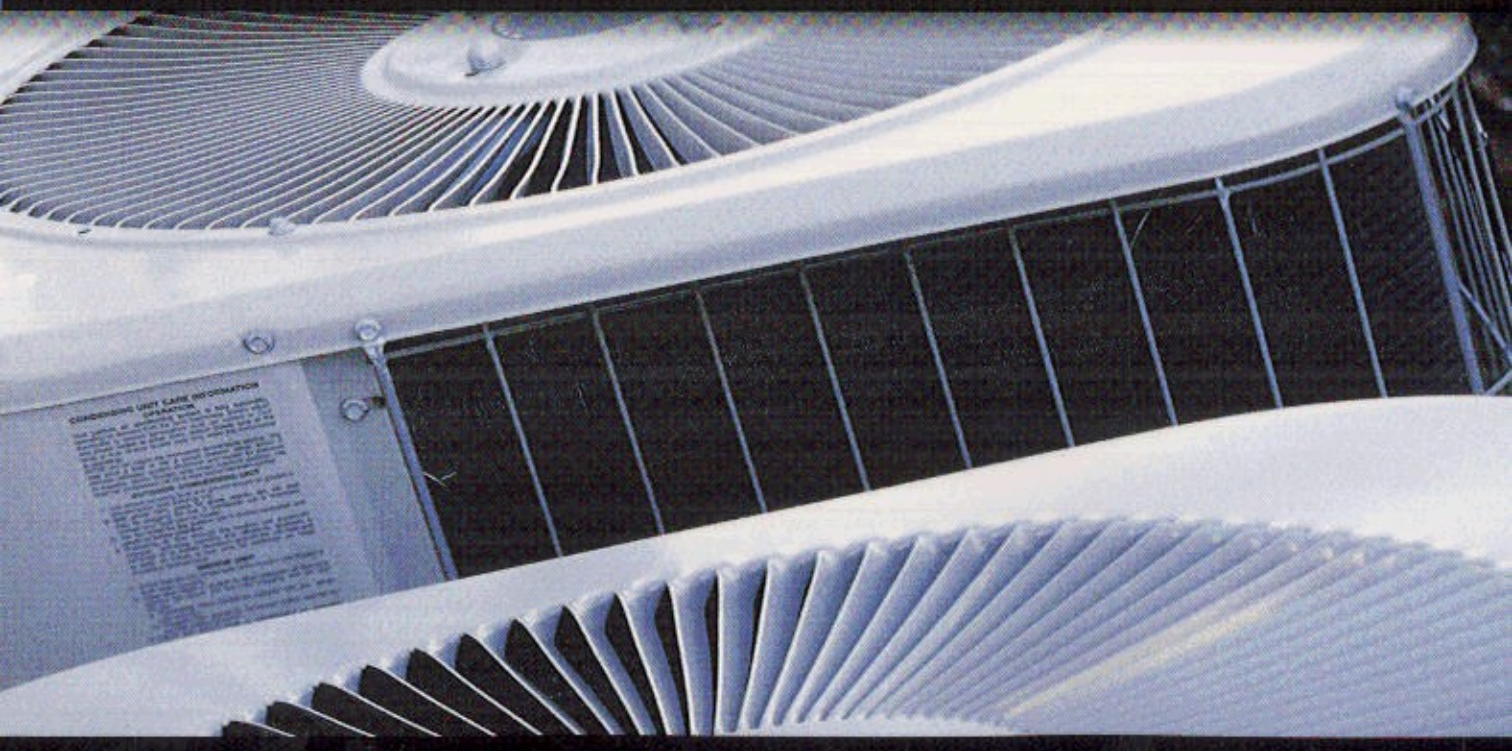
Over 800 Illustrations

AIR CONDITIONING and REFRIGERATION



REX MILLER • MARK R. MILLER

Contents

Preface xv
Acknowledgments xvii

1 Air-Conditioning and Refrigeration Tools and Instruments

Performance Objectives 2
Tools and Equipment 2
Pliers and Clippers 2
Fuse Puller 2
Screwdrivers 2
Wrenches 3
Soldering Equipment 3
Drilling Equipment 4
Knives and Other Insulation-Stripping Tools 5
Meters and Test Prods 6
Tool Kits 7
Gages and Instruments 9
Pressure Gages 9
Gage Selection 10
Line Pressure 11
Effects of Temperature on Gage Performance 12
Care of Gages 12
Gage Recalibration 12
Thermometers 13
Pocket Thermometer 13
Bimetallic Thermometers 15
Thermocouple Thermometers 16
Resistance Thermometers 16
Superheat Thermometer 17
Superheat Measurement Instruments 17
Halide Leak Detectors 21
Setting Up 21
Lighting 22
Leak Testing the Setup 22
Adjusting the Flame 22
Detecting Leaks 22
Maintenance 22
Electrical Instruments 23
Ammeter 23
Voltmeter 25
Ohmmeter 26
Multimeter 26
Wattmeter 27
Other instruments 28
Air–Filter Efficiency Gages 28
Air-Measurement Instruments 28
Humidity-Measurement Instruments 29
Vibration and Sound Meters 29
Service Tools 30
Special Tools 31
Vacuum Pumps 32
Vacuum Pump Maintenance 34
Vacuum Pump Oil Problems 34
Operating Instructions 34
Evacuating a System 35
Charging Cylinder 35
Charging Oil 36
Changing Oil 37
Mobile Charging Stations 37
Tubing 37
Soft Copper Tubing 37
Hard-Drawn Copper Tubing 38
Cutting Copper Tubing 39
Flaring Copper Tubing 40
Constricting Tubing 41
Swaging Copper Tubing 41
Forming Refrigerant Tubing 42
Fitting Copper Tubing by Compression 43
Soldering 43
Soft Soldering 44
Silver Soldering or Brazing 46
Testing for leaks 47
Cleaning and Degreasing Solvents 47
Review Questions 47

2 Development of Refrigeration

Performance Objectives 50
Historical Development 50

Structure of Matter 50
Elements 51
Atom 51
Properties of Matter 51
Pressure 52
Pressure Indicating Devices 52
Pressure of Liquids and Gases 53
Atmospheric Pressure 53
Gage Pressure 53
Absolute Pressure 53
Compression Ratio 54
Temperature and Heat 54
Specific Heat 55
Heat Content 55
Sensible Heat 55
Latent Heat 55
Other Sources of Heat 56
Refrigeration Systems 56
Refrigeration from Vaporization (Open System) 56
Basic Refrigeration Cycle 56
Capacity 57
Refrigerants 57
Refrigerant Replacements and the Atmosphere 58
Review Questions 59

3 Voltage, Current, and Resistance

Performance Objectives 62
Ohm's Law 62
Series Circuits 62
Parallel Circuits 64
Current in a Parallel Circuit 64
Resistance in a Parallel Circuit 65
AC and DC Power 65
Phase 66
Power in DC Circuits 66
Power Rating of Equipment 67
Capacitors 67
How a Capacitor Works 68
Capacity of a Capacitor 69
Dielectric Failure 69
Basic Units of Capacitance 69
Working with Capacitive Values 69
Capacitor Types 70
Capacitor Tolerances 73
The AC Circuit and the Capacitor 73
Uses of Capacitors 75
Inductance 75
Four Methods of Changing Inductance 75
Self-Inductance 75
Mutual Inductance 76
Inductive Reactance 77
Uses of Inductive Reactances 77
Transformers 77
Transformer Construction 77
Turns Ratio 78
Transformer Applications 78
Semiconductors 78
Diodes 78
Transistors 79
Silicon-controlled Rectifier (SCR) 80
Bridge circuits 80
Wheatstone Bridges 80
Variable Resistor 81
Sensors 81
Temperature Elements 82
Humidity Elements 82
Controllers 83
Single-Element Controllers 84
Dual-Element Controllers 86
Actuators 86
Electro-Hydraulic Actuators 86
Thermal Actuators 87
Auxiliary Devices 88
Electronic Compressor Motor Protection 88
Operation 88
Troubleshooting the Control 89
Restoring Service 91
Review Questions 91

4 Solenoids and Valves

Performance Objectives 94
Industrial Solenoids 94
Tubular Solenoids 94
Frame Solenoids 94
Applications 97
Solenoids as Electromagnets 97
Solenoid Coils 97
Servicing Coils 97
Solenoid Valves in Circuits 98
Refrigeration Valve 99
Review Questions 100

5 Electric Motors: Selection, Operational Characteristics, and Problems

Performance Objectives 102
Construction of an Induction Motor 102
Single-Phase Motors 103
Shaded-Pole Motor 103
Split-Phase Motor 103
Capacitor-Start Motor 104
Sizes of Motors 104
Cooling and Mounting Motors 105
Direction of Rotation 106
Synchronous Motor 107
Theory of Operation 107
Synchronous Motor Advantages 108
Properties of the Synchronous Motor 108

Electric Motors 109
Starting the Motor 109
Repulsion-Induction Motor 110
Capacitor-Start Motor 111
Permanent Split-Capacitor Motor 112
Shaded-Pole Motor 112
Split-Phase Motor 114
Polyphase-Motor Starters 115
Reduced-Voltage Starting Methods 116
Primary-Resistor Starting 116
Autotransformer Starting 119
Part-winding Starting 120
Wye-delta or Star-delta Starters 121
Multispeed Starters 123
Consequent-Pole Motor Controller 124
Full-Voltage Controllers 127
Starting Sequence 129
Protection Against Low Voltage 129
Time-Delay Protection 129
Electric Motors: Their Uses, Operation, and Characteristics 132
Motor Rotation 133
Variable-Speed Drives 133
Troubleshooting Electric Motors with a Volt-Ammeter 133
Split-Core AC Volt-Ammeter 134
Testing for Grounds 135
Testing for Opens 135
Checking for Shorts 136
Testing Squirrel-Cage Rotors 136
Testing the Centrifugal Switch in a Split-Phase Motor 136
Test for Short Circuit Between Run and StartWindings 136
Test for Capacitors 136
Using the Megohmmeter for Troubleshooting 138
Insulation-Resistance Testing 138
Measuring Insulation Resistance 139
Power Tools and Small Appliances 139
Hermetic Compressor Systems 140
Circuit Breakers and Switches 140
Coils and Relays 140
AC Motor Control 140
Motor Controller 141
AC Squirrel-Cage Motor 141
Enclosures 142
Code 142
Protection of the Motor 142
Contactors, Starters, and Relays 142
Motor-Overload Protector 142
Motor-Winding Relays 143
Solenoid Valves 143
Refrigeration Valve 144
Application 144
Operation 144
Installation 145
Temperature Controls 145
Bimetallic Thermostats 146
Thermostat Construction and Wiring 147
Defrost Controls 147
Defrost Timer Operation 147
Hot-Gas Defrosting 148
Motor Burnout Cleanup 148
Procedure for Small Tonnage Systems 148
Procedure for Large Tonnage Systems 150
Reading a Schematic 150
Review Questions 152

6 Refrigerants: New and Old

Performance Objectives 156
Classification of Refrigerants 156
Common Refrigerants 156
Freon Refrigerants 158
Molecular Weights 158
Flammability 158
Toxicity 158
Skin Effects 158
Oral Toxicity 158
Central Nervous System (CNS) Effects 159
Cardiac Sensitization 161
Thermal Decomposition 162
Applications of Freon Refrigerants 162
Reaction of Freon to Various Materials Found in Refrigeration Systems 165
Metals 165
Plastics 165
Refrigerant Properties 166
Pressure 166
Temperature 166
Volume 166
Density 167
Enthalpy 167
Flammability 168
Capability of Mixing with Oil 168
Moisture and Refrigerants 168
Odor 168
Toxicity 169
Tendency to Leak 169
Detecting Leaks 169
Sulfur Dioxide 169
Carbon Dioxide 169
Ammonia 170
Methyl Chloride 170
Ban on Production and Imports of Ozone-Depleting Refrigerants 170
Phase-out Schedule for HCFCs, Including R-22 170
Availability of R-22 171
Cost of R-22 171
Alternatives to R-22 171
Servicing Existing Units 171
Installing New Units 171

Servicing Your System 172
Purchasing New Systems 172
Air Conditioning and Working with Halon 172
General Information 172
Leak Repair 173
Trigger Rates 173
When Additional Time Is Necessary 173
Relief from Retrofit/Retirement 173
System Mothballing 174
EPA-Certified Refrigerant Reclaimers 174
Newer Refrigerants 174
Freon Refrigerants 174
Classifications 174
Properties of Freons 175
Physical Properties 175
Refrigerant Characteristics 176
Critical Temperature 176
Latent Heat of Evaporation 177
Specific Heat 177
Power Consumption 177
Volume of Liquid Circulated 178
Handling Refrigerants 178
Storing and Handling Refrigerant Cylinders 178
Lubricants 178
R-134a Refrigerant 179
R-134a Applications 180
R-12 Systems—General Considerations 180
R-12 Medium/High Temperature Refrigeration (>0°F evap) 180
R-12 Low Temperature Refrigeration (<20°F evap) 180
R-401B 180
R-402A 180
R-402B 181
Reclaiming Refrigerant 181
Description 181
Compressor 182
Oil Separator 182
Condenser 183
Filter Drier 183
Accumulator/Oil Trap 183
Operation of the Unit 183
Recovery Plus/Recovery Operations 184
Storage Cylinder Cooling 185
Recycle Operation 185
Recharge Operation 187
Service Operation 187
Test Operation 187
Control Circuits 187
Troubleshooting 189
Troubleshooting Approach 189
Review Questions 189

7 Refrigeration Compressors

Performance Objectives 192
Condensers 192
Air-Cooled Condensers 194
Water-Cooled Condensers 194
Hermetic Compressors 194
Compressor Types 194
Newer Models Designations and Coding 202
Hermetic Compressor Motor Types 205
Resistance Start-Induction Run 205
Capacitor Start-induction Run 206
Capacitor Start and Run 206
Permanent Split Capacitor 206
Compressor Motor Relays 207
Current-type Relay 207
Potential-type Relay 207
Compressor Terminals 207
Built-up Terminals 208
Glass Quick-Connect Terminals 209
Motor Mounts 209
Crankcase Heaters 209
Electrical Systems for Compressor Motors 212
Normal-Starting Torque Motors (RSIR) with a Current-Type Relay 212
High-Starting Torque Motors (CSIR) with a Current-Type Relay 215
High-Starting Torque Motors (CSIR) with a Two-Terminal External Overload and a Remote-Mounted Potential Relay 219
High-Starting Torque Motors (CSR) with Three-Terminal Overloads and Remote-Mounted Relays 222
PSC Motor with a Two-Terminal External Overload and Run Capacitor 223
PSC Motor with an Internal Overload (Line Breaker) 224
CSR or PSC Motor with the Start Components and an Internal Overload or Line Breaker 225
Compressors with Internal Thermostat, Run Capacitor, and Supplementary Overload 226
CSR or PSC Motor with Start Components, Internal Thermostat, and Supplementary External Overload 227
Compressor Connections and Tubes 230
Process Tubes 230
Other Manufacturers of Compressors 230
Rotary Compressors 230
Stationary Blade Rotary Compressors 230
Rotating Blade Rotary Compressors 233
Screw Compressors 233
Single Screw 235
Twin Screw 238
Making the Rotors 238
Scroll Compressors 238
Scroll-Compression Process 238
Operation 239
Scroll Compressor Models 239
Review Questions 239

8 Condensers, Chillers, and Cooling Towers

Performance Objectives 242
Condensers 242
Air-Cooled Condensers 242
Water-Cooled Condensers 243
Chillers 246
Refrigeration Cycle 246
Motor-Cooling Cycle 247
Dehydrator Cycle 247
Lubrication Cycle 249
Controls 249
Solid-State Capacity Control 250
Cooling Towers 250
Cooling Systems Terms 251
Design of Cooling Towers 251
Evaporative Condensers 252
New Developments 253
Temperature Conversion 253
Types of Towers 254
Crossflow Towers 254
Fluid Cooler 254
Review Questions 257

9 Working with Water-Cooling Problems

Performance Objectives 260
Pure Water 260
Fouling, Scaling, and Corrosion 260
Prevention of Scaling 261
Scale Identification 262
Field Testing 262
Corrosion 263
Control of Algae, Slime, and Fungi 264
Bacteria 264
The Problem of Scale 265
Evaporative Systems 265
Scale Formation 265
How to Clean Cooling Towers and Evaporative Condensers 266
Determining the Amount of Water in the Sump 266
Determining the Amount of Water in the Tank 266
Total Water Volume 266
Chilled Water Systems 268
How to Clean Shell (Tube or Coil) Condensers 269
Safety 270
Solvents and Detergents 270
Review Questions 270

10 Evaporators

Performance Objectives 274
Coiled Evaporator 274
Application of Controls for Hot-Gas Defrost of Ammonia Evaporators 275
Direct-Expansion Systems 277
Cooling Cycle 277
Direct Expansion with Top Hot-Gas Feed 279
Direct Expansion with Bottom Hot-Gas Feed 279
Flooded Liquid Systems 279
Flooded-gas Leg Shutoff (Bottom Hot-Gas Feed) 279
Flooded-Ceiling Evaporator—Liquid-Leg Shutoff (Bottom Hot-Gas Feed) 280
Flooded-Ceiling Evaporator—Liquid-Leg Shutoff (Top Hot-Gas Feed) 280
Flooded-Ceiling Blower (Top Hot-Gas Feed) 282
Flooded-Ceiling Blower (Hot-Gas Feed through Surge Drum) 283
Flooded Floor-Type Blower (Gas and Liquid-Leg Shutoff) 283
Flooded Floor-Type Blower (Gas Leg Shutoff) 283
Liquid-Recirculating Systems 284
Flooded Recirculator (Bottom Hot-Gas Feed) 285
Flooded Recirculator (Top-Gas Feed) 285
Low-Temperature Ceiling Blower 285
Year–Round Automatic Constant Liquid-Pressure Control System 286
Dual-Pressure Regulator 287
Valves and Controls for Hot-Gas Defrost of Ammonia-Type Evaporators 288
Back-Pressure Regulator Applications of Controls 290
Refrigerant-Powered Compensating-Type Pilot Valve 291
Air-Compensating Back-Pressure Regulator 291
Electric-Compensating Back-Pressure Regulator 292
Valve Troubleshooting 292
Noise in Hot-Gas Lines 297
Review Questions 298

11 Refrigerant: Flow Control

Performance Objectives 300
Metering Devices 300
Hand-Expansion Valve 300
Automatic-Expansion Valve 300
Thermostatic-Expansion Valve 300
Capillary Tubing 301
Float Valve 301
Fittings and Hardware 301
Copper Tubing 301

Line 302
Solder 302
Suction Line P-Traps 302
Compressor Valves 303
Line Valves 304
Driers, Line Strainers, and Filters 305
Driers 305
Line Strainers and Filters 306
Liquid Indicators 307
Construction 308
Installation 309
Bypass Installations 309
Excess Oil and the Indicator 309
Alcohol 309
Leak Detectors 309
Liquid Water 309
Hermetic-Motor Burnouts 309
Hardware and Fittings 309
Thermostatic-Expansion Valve (TEV) 309
Valve Location 312
Bulb Location 312
External Equalizer 314
Field Service 314
Crankcase Pressure-Regulating Valves 315
Operation of the Valve 315
Valve Location 315
Strainer 316
Brazing Procedures 316
Test and Operating Pressures 316
Adjusting the Pressure 316
Service 317
Evaporator Pressure-Regulating Valves 317
Operation 317
Type of System 317
Valve Location 318
Test and Operating Pressures 318
Service 319
Head-Pressure Control Valves 319
Operation 319
ORO-Valve Operation 320
ORD Valve Operation 320
Installation 321
Brazing Procedures 321
Test and Operating Pressures 321
Service 321
Nonadjustable ORO/ORD System Operation 322
Discharge Bypass Valves 323
Operation 323
Application 323
Externally Equalized Bypass Valves 324
Bypass to Evaporator Inlet without Distributor 324
Installation 324
Special Considerations 325
Testing and Operating Pressures 325
Hot Gas 326
Malfunctions 326
Level Control Valves 326
Capillary Tubes 326
Float Valve 327
Level-Master Control 329
Installation 330
Electrical Connections 330
Hand Valves 330
Oil Return 330
Oil and Ammonia Systems 330
Oil and Halocarbon Systems 331
Conclusions 334
Other Types of Valves 334
Service Valves on Sealed Units 334
Water Valves 334
Check Valves 334
Receiver Valves 335
Accumulators 335
Purpose 335
Rating Data 336
Minimum Evaporator Temperature and Minimum Temperature of Suction Gas at the Accumulator 336
Installation of the Accumulator 336
Review Questions 336

12 Servicing and Safety

Performance Objectives 340
Safety 340
Handling Cylinders 340
Pressurizing 340
Working with Refrigerants 341
Lifting 341
Electrical Safety 341
Servicing the Refrigerator Section 341
Sealed Compressor and Motor 342
Condenser 342
Filter Drier 342
Capillary Tube 342
Heat Exchanger 343
Freezer-Compartment and Provision-Compartment Assembly 343
Compressor Replacement 343
Troubleshooting Compressors 343
Troubleshooting Refrigerator Components 343
Compressor Will Not Run 343
Compressor Runs, but There Is No Refrigeration 345
Compressor Short Cycles 345
Compressor Runs Too Much or 100 Percent 345
Noise 346
To Replace the Compressor 346

Compressor Motor Burnout 347
Cleaning System After Burnout 347
Replacing the Filter Drier 347
Replacing the Condenser 349
Replacing the Heat Exchanger 349
Repairing the Perimeter Tube (Fiberglass Insulated) 349
Top-Freezer and Side-by-Side Models 349
Foam-Insulated 12 and 14 ft^3, Top-Freezer Models 351
Foam-Insulated 19 ft^3 Side-by-Side Models 353
Replacing the Evaporator-Heat Exchanger Assembly 354
Top-Freezer, No-Frost Models 354
Side-by-Side Models 354
Adding Refrigerant 354
Low-Side Leak or Slight Undercharge 355
High-Side Leak or Slight Undercharge 355
Overcharge of Refrigerant 355
Testing for Refrigerant Leaks 355
Service Diagnosis 356
On the Initial Contact 356
Before Starting a Test Procedure 356
Thermostat Cut-Out and Cut-In Temperatures 357
Freezer- and Provision-Compartment Air Temperatures 357
Line Voltage 358
Wattage 358
Compressor Efficiency 358
Refrigerant Shortage 358
Restrictions 359
Defrost-Timer Termination 359
Computing Percent Run Time 359
Start and Run Capacitors 359
Capacitor Ratings 359
Start Capacitor and Bleeder Resistors 360
Run Capacitors 360
Permanent Split-Capacitor (PSC) Compressor Motors 360
Field Testing Hermetic Compressors 361
Warranty Test Procedure 363
Method of Testing 363
Resistance Checks 364
Testing Electrical Components 364
Installing an Air-Cooled Condensing Unit 365
General Information 365
Checking Product Received 365
Corrosive Environment 365
Locating Unit 366
Unit Mounting 366
Refrigerant Connections 368
Replacement Units 368
Evaporator Coil 368
Interconnecting Tubing 368
Suction and Liquid Lines 368
Maximum Length of Interconnecting Tubing 368
Condensing Unit Installed Below Evaporator 368
Condensing Unit Installed Above Evaporator 369
Tubing Installation 370
Tubing Connections 370
Leak Testing 370
Flow-Check Piston 371
Evacuation Procedure 372
Checking Refrigerant Charge 373
Charging by Superheat 373
Charging by Liquid Pressure 373
Charging by Weight 373
Final Leak Testing 374
Service 374
Operation 374
Single-Pole Compressor Contactor (CC) 374
Compressor Crankcase Heat (CCH) 374
Hard Start Components (SC and SR) 374
Time Delay Control (TDC) 374
Low Ambient Control (LAC) 374
High- and Low-Pressure Controls (HPC or LPC) 374
Electrical Wiring 375
Power Wiring 375
Control Wiring 375
Start-up and Performance 376
Troubleshooting 376
Review Questions 377

13 Freezers

Performance Objectives 380
Types of Freezers 380
Installing a Freezer 381
Freezer Components 382
Wrapped Condenser 382
Cold-Ban Trim 382
Shelf Fronts 383
Vacuum Release 383
Lock Assembly 383
Hinges 383
Lid 384
Thermostats 384
Drain System 386
Wrapper Condenser 386
Evaporator Coil 387
Replacing the Compressor 387
Repairing the Condenser 387
Installing the Drier Coil 387
Complete Recharge of Refrigerant 389
Overcharge of Refrigerant 389
Restricted Capillary Tube 389

Testing for Refrigerant Leaks 389
Troubleshooting Freezers 390
Portable Freezers 390
Review Questions 394

14 Temperature, Psychrometrics, and Air Control

Performance Objectives 398
Temperature 398
Degrees Fahrenheit 398
Degrees Celsius 398
Absolute Temperature 398
Converting Temperatures 399
Psychrometrics 399
Pressures 399
Gage Pressure 399
Atmospheric Pressure 399
Pressure Measuring Devices 399
Hygrometer 401
Properties of Air 401
People and Moisture 404
Psychrometric Chart 404
Air Movement 404
Convection, Conduction, and Radiation 404
Comfort Conditions 406
Velocity 406
Terminology 408
Designing a Perimeter System 410
Locating and Sizing Returns 411
Airflow Distribution 411
Selection of Diffusers and Grilles 412
Air-Volume Requirement 413
Throw Requirement 413
Pressure Requirement 413
Sound Requirement 414
Casing Radiated Noise 414
Locating Terminal Boxes 414
Controlling Casing Noise 415
Vortex Shedding 415
Return Grilles 415
Performance 415
Return Grille Sound Requirement 416
Types of Registers and Grilles 416
Fire and Smoke Dampers 416
Smoke Dampers for High-Rise Buildings 416
Ceiling Supply Grilles and Registers 416
Ceiling Diffusers 417
Antismudge Rings 418
Air-Channel Diffusers 418
Luminaire Diffusers 418
Room Air Motion 419
Linear Grilles 419
Fans and Mechanical Ventilation 419
Air Volume 419
Fans and Blowers 419
Air Volume 421
Horsepower Requirements 421
Fan Driving Methods 421
Selecting a Fan 422
Applications of Fans 422
Operation of Fans 423
Installation of Attic Fans 423
Routine Fan Operation 424
Ventilation Methods 425
Review Questions 425

15 Comfort Air Conditioning

Performance Objectives 428
Window Units 428
Mounting 428
Electrical Plugs 429
Maintenance 430
Low-Voltage Operation 430
Troubleshooting 431
Evaporator Maintenance 431
Automatic Defrosting 431
Evaporators for Add-on Residential Use 433
Troubleshooting 435
Remote Systems 435
Single-Package Rooftop Units 437
Smoke Detectors 437
Firestats 437
Return-Air Systems 438
Acoustical Treatment 438
Volume Dampers 439
Refrigerant Piping 439
Troubleshooting 439
Refrigerant Pipe Sizes 441
Liquid-Line Sizing 441
Suction-Line Sizing 442
Troubleshooting 444
Mobile Homes 444
Troubleshooting 445
Wall-Mounted Ductless Air Conditioners 445
Fan Control Mode 446
Restart Function 447
Rotary Compressor 447
Review Questions 447

16 Commercial Air-Conditioning Systems

Performance Objectives 450
Expansion-Valve Air-Conditioning System 450
Compressor 450
Condenser 450
Expansion-Valve Kit 450
Troubleshooting 450

Packaged Cooling Units 451
Rooftop Heating and Cooling Units 452
Electrical 453
Sequence of Operation 454
Compressor Safety Devices 455
Maintenance 455
Troubleshooting 456
Direct Multizone System 456
Troubleshooting 458
Evaporative Cooling System 458
Absorption-Type Air-Conditioning Systems 459
Chilled Water Air Conditioning 459
Refrigerant Cycle 460
Control System 463
Chillers 463
Reciprocating Chillers 464
Components Used with Chillers 464
Console-Type Air-Conditioning Systems 466
Installation 466
Service 467
Troubleshooting 467
Review Questions 467

17 Various Types of Air Conditioners and Heat Pumps

Performance Objectives 470
Gas Air Conditioning 470
Absorption Cooling Cycle 470
Ammonia Refrigerant in a Gas-Fired System 471
Gas-Fired Chillers 471
Chiller-Heater 472
Changeover Sequence for Chilled Water Operation 472
Changeover Sequence for Hot Water Operation 472
Self-Leveling Feature 472
Absorption Refrigeration Machine 472
Absorption Operation Cycle 472
Solar Air Conditioners 476
History of Solar Cooling 476
Systems of Solar Cooling 477
Lithium-Bromide Water Absorption Cycle 477
Solar Cooling Research Centers 477
Heat Pumps 480
Operation 482
Defrost 482
Outdoor Thermostat 482
Special Requirements of Heat Pump Systems 483
Sizing Equipment 484
Defrost Cycle 484
Balance Point 484
Using the Heat Pump 484
Review Questions 486

18 Estimating Load and Insulating Pipes

Performance Objectives 488
Refrigeration and Air-Conditioning Load 488
Running Time 488
Calculating Cooling Load 488
Wall Gain Load 489
Air Change Load 489
Product Load 489
Miscellaneous Loads 489
Calculating Heat Leakage 489
Calculating Product Cooling Load 490
Capacity of the Machines Used in the System 490
Air Doors 491
Insulation 492
Sheet Insulation 492
Tubing Insulation 492
Pipe Insulation 494
Refrigeration Piping 494
Pressure-Drop Considerations 495
Liquid Refrigerant Lines 495
Interconnection of Suction Lines 496
Discharge Lines 496
Water Valves 496
Multiple-Unit Installation 497
Piping Insulation 498
Cork Insulation 498
Rock-Cork Insulation 498
Wool-Felt Insulation 499
Hair-Felt Insulation 499
Review Questions 500

19 Installing and Controlling Electrical Power for Air-Conditioning Units

Performance Objectives 502
Choosing Wire Size 502
Limiting Voltage Loss 502
Minimum Wire Size 502
Wire Selection 502
Wire Size and Low Voltage 502
Voltage Drop Calculations 503
The Effects of Voltage Variations on AC Motors 503
Selecting Proper Wire Size 505
Unacceptable Motor Voltages 505

Calculating Starting Current Values and Inrush Voltage Drops 507
Single-Phase Current 507
Three-Phase Circuits 507
Inrush Voltage Drop 507
Code Limitations on Amperes per Conductor 508
Heat Generated within Conductors 508
Circuit Protection 509
Standard Rule 509
Fuses 509
One-Time Single-Element Fuses 509
Time-Delay Two-element Fuses 509
Types of Fuses 509
Thermostats 510
Thermostat as a Control Switch 510
Service 511
Start Kits 512
Single-Phase Line Monitors 513
Time Delays 513
Head Pressure Control 513
Pressure Controls 516
Line-Voltage Head Pressure Controls 516
Three-Phase Line-Voltage Monitor 516
Current Sensing 519
Review Questions 522

20 Air-Conditioning and Refrigeration Careers

Performance Objectives 524
Industries that Employ Air-Conditioning and Refrigeration Mechanics 524
Job Qualifications 525
The Future 526
Pay and Benefits 527
Teaching as a Career 528
Sources of Additional Information 528
Review Questions 529

Appendices

A. Some New Refrigerants 531
B. Electrical and Electronic Symbols Used in Schematics 539
C. Programming Thermostats 549
D. Tools of the Trade (Plus Frequently Asked Questions with Answers) 569

Glossary 581
Index 591