

HVAC SYSTEMS APPLICATIONS



**SHEET METAL AND AIR CONDITIONING CONTRACTORS'
NATIONAL ASSOCIATION, INC.**

www.smacna.org

This is a preview of "SMACNA 1099-2010". [Click here to purchase the full version from the ANSI store.](#)

HVAC SYSTEMS APPLICATIONS

SECOND EDITION – MARCH, 2010



**SHEET METAL AND AIR CONDITIONING CONTRACTORS'
NATIONAL ASSOCIATION, INC.**

4201 Lafayette Center Drive
Chantilly, VA 20151-1209
www.smacna.org

HVAC SYSTEMS APPLICATIONS

COPYRIGHT © SMACNA 2010
All Rights Reserved
by

**SHEET METAL AND AIR CONDITIONING CONTRACTORS'
NATIONAL ASSOCIATION, INC.**

4201 Lafayette Center Drive
Chantilly, VA 20151-1209

Printed in the U.S.A.

FIRST EDITION – JANUARY 1987
SECOND EDITION – MARCH 2010

Except as allowed in the Notice to Users and in certain licensing contracts, no part of this book may be reproduced, stored in a retrievable system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of the publisher.

FOREWORD

It is the policy of the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) to continually re-visit and update the technical manuals that have become the backbone of the industry.

With this policy in mind, a Task Force was organized and tasked with the purpose of reviewing and bringing up to date the HVAC Systems Applications. This manual is often referred to as one-of-three manuals that constitute SMACNA's approach to HVAC systems. The other two manuals making up this group are the "*HVAC Systems – Duct Design*" manual and the "*HVAC Systems – Testing, Adjusting and Balancing*" manual. It is recommended that this manual be used in conjunction with the latest ASHRAE (American Society of Heating, Refrigeration and Air-Conditioning Engineers) "*HVAC Applications*" handbook.

Accordingly, the Task Force found areas that were in need of updating, primarily due to the advancement of technology, since the manual was last revised. This included hardware as well as software improvements. In addition, the science and methodology of Heating, Ventilating and Air Conditioning has changed, with an increased emphasis on energy efficiency and sustainability.

As you review this 2nd edition, you will notice that some chapters have been re-named, others have been deleted, and the order of the remaining chapters presented has been adjusted. However the emphasis is still on Air and Hydronic systems. You will also notice new topics of discussion, *i.e.*:

- Displacement Ventilation
- Variable Flow Refrigerant systems
- Fan Wall Systems
- HVAC Systems as they pertain to Sustainable Buildings
- Updated review of modern Variable Frequency Drives
- Revised/Updated Figures
- Expanded chapters for Smoke Control, Cleanrooms and Laboratory HVAC systems

It is the hope of the Task Force that this revised manual will be of value to those contractors who participate in the Design Build arena, as well as those that are involved with retro-fitting existing building systems. For those working in the retro-fit market, references to systems that may be obsolete by today's standards have been retained to offer an insight into these systems.

Finally, the Glossary has also been updated to reflect these changes.

SHEET METAL AND AIR CONDITIONING CONTRACTORS'
NATIONAL ASSOCIATION, INC.



HVAC SYSTEMS APPLICATIONS TASK FORCE

Douglas Ahlberg, *Chairman*
Arctic Sheet Metal, Inc.
Portland, OR

Christopher A. Fulton
Bright Sheet Metal Co., Inc.
Indianapolis, IN

James E. Hall
Systems Management & Balancing, Inc.
Des Moines, IA

James Matthews
Precision Test & Balance
Colorado Springs, CO

Peyton Collie, *Staff*
SMACNA
Chantilly, VA

Eli P. Howard, *Staff*
SMACNA
Chantilly, VA

NOTICE TO USERS OF THIS PUBLICATION

1. DISCLAIMER OF WARRANTIES

- a) The Sheet Metal and Air Conditioning Contractors' National Association ("SMACNA") provides its product for informational purposes.
- b) The product contains "Data" which is believed by SMACNA to be accurate and correct but the data, including all information, ideas and expressions therein, is provided strictly "AS IS," with all faults. SMACNA makes no warranty either express or implied regarding the Data and SMACNA EXPRESSLY DISCLAIMS ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR PARTICULAR PURPOSE.
- c) By using the data contained in the product user accepts the Data "AS IS" and assumes all risk of loss, harm or injury that may result from its use. User acknowledges that the Data is complex, subject to faults and requires verification by competent professionals, and that modification of parts of the Data by user may impact the results or other parts of the Data.
- d) IN NO EVENT SHALL SMACNA BE LIABLE TO USER, OR ANY OTHER PERSON, FOR ANY INDIRECT, SPECIAL OR CONSEQUENTIAL DAMAGES ARISING, DIRECTLY OR INDIRECTLY, OUT OF OR RELATED TO USER'S USE OF SMACNA'S PRODUCT OR MODIFICATION OF DATA THEREIN. This limitation of liability applies even if SMACNA has been advised of the possibility of such damages. IN NO EVENT SHALL SMACNA'S LIABILITY EXCEED THE AMOUNT PAID BY USER FOR ACCESS TO SMACNA'S PRODUCT OR \$1,000.00, WHICHEVER IS GREATER, REGARDLESS OF LEGAL THEORY.
- e) User by its use of SMACNA's product acknowledges and accepts the foregoing limitation of liability and disclaimer of warranty and agrees to indemnify and hold harmless SMACNA from and against all injuries, claims, loss or damage arising, directly or indirectly, out of user's access to or use of SMACNA's product or the Data contained therein.

2. ACCEPTANCE

This document or publication is prepared for voluntary acceptance and use within the limitations of application defined herein, and otherwise as those adopting it or applying it deem appropriate. It is not a safety standard. Its application for a specific project is contingent on a designer or other authority defining a specific use. SMACNA has no power or authority to police or enforce compliance with the contents of this document or publication and it has no role in any representations by other parties that specific components are, in fact, in compliance with it.

3. AMENDMENTS

The Association may, from time to time, issue formal interpretations or interim amendments, which can be of significance between successive editions.

4. PROPRIETARY PRODUCTS

SMACNA encourages technological development in the interest of improving the industry for the public benefit. SMACNA does not, however, endorse individual manufacturers or products.

5. FORMAL INTERPRETATION

a) A formal interpretation of the literal text herein or the intent of the technical committee or task force associated with the document or publication is obtainable only on the basis of written petition, addressed to the Technical Resources Department and sent to the Association's national office in Chantilly, Virginia. In the event that the petitioner has a substantive disagreement with the interpretation, an appeal may be filed with the Technical Resources Committee, which has technical oversight responsibility. The request must pertain to a specifically identified portion of the document that does not involve published text which provides the requested information. In considering such requests, the Association will not review or judge products or components as being in compliance with the document or publication. Oral and written interpretations otherwise obtained from anyone affiliated with the Association are unofficial. This procedure does not prevent any committee or task force chairman, member of the committee or task force, or staff liaison from expressing an opinion on a provision within the document, provided that such person clearly states that the opinion is personal and does not represent an official act of the Association in any way, and it should not be relied on as such. The Board of Directors of SMACNA shall have final authority for interpretation of this standard with such rules or procedures as they may adopt for processing same.

b) SMACNA disclaims any liability for any personal injury, property damage, or other damage of any nature whatsoever, whether special, indirect, consequential or compensatory, direct or indirectly resulting from the publication, use of, or reliance upon this document. SMACNA makes no guaranty or warranty as to the accuracy or completeness of any information published herein.

6. APPLICATION

a) Any standards contained in this publication were developed using reliable engineering principles and research plus consultation with, and information obtained from, manufacturers, users, testing laboratories, and others having specialized experience. They are subject to revision as further experience and investigation may show is necessary or desirable. Construction and products which com-



ply with these Standards will not necessarily be acceptable if, when examined and tested, they are found to have other features which impair the result contemplated by these requirements. The Sheet Metal and Air Conditioning Contractors' National Association and other contributors assume no responsibility and accept no liability for the application of the principles or techniques contained in this publication. Authorities considering adoption of any standards contained herein should review all federal, state, local, and contract regulations applicable to specific installations.

b) In issuing and making this document available, SMACNA is not undertaking to render professional or other services for or on behalf of any person or entity. SMACNA is not undertaking to perform any duty owed to any person or entity to someone else. Any person or organization using this document should rely on his, her or its own judgement or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstance.

7. REPRINT PERMISSION

Non-exclusive, royalty-free permission is granted to government and private sector specifying authorities to reproduce *only* any construction details found herein in their specifications and contract drawings prepared for receipt of bids on new construction and renovation work within the United States and its territories, provided that the material copied is unaltered in substance and that the reproducer assumes all liability for the specific application, including errors in reproduction.

8. THE SMACNA LOGO

The SMACNA logo is registered as a membership identification mark. The Association prescribes acceptable use of the logo and expressly forbids the use of it to represent anything other than possession of membership. Possession of membership and use of the logo in no way constitutes or reflects SMACNA approval of any product, method, or component. Furthermore, compliance of any such item with standards published or recognized by SMACNA is not indicated by presence of the logo.

TABLE OF CONTENTS

This is a preview of "SMACNA 1099-2010". [Click here to purchase the full version from the ANSI store.](#)

TABLE OF CONTENTS

FOREWORD	iii
HVAC SYSTEMS APPLICATIONS TASK FORCE	iv
NOTICE TO USERS OF THIS PUBLICATION	v
TABLE OF CONTENTS	vii
CHAPTER 1 INTRODUCTION	Page
1.1 INTRODUCTION	1.1
1.2 HVAC SYSTEM PURPOSE	1.1
1.3 HUMAN THERMAL COMFORT	1.1
1.4 BASIC HVAC SYSTEM COMPONENTS	1.2
1.5 HVAC SYSTEM OPERATIONAL EFFICIENCY	1.6
1.6 GREEN BUILDING RATING SYSTEMS	1.9
1.7 HVAC SYSTEM SELECTION PARAMETERS	1.10
1.8 SPACE CONDITIONS	1.10
1.9 HVAC EQUIPMENT AND SPACE	1.10
CHAPTER 2 HVAC SYSTEM APPLICATION FUNDAMENTALS	
2.1 INTRODUCTION	2.1
2.2 AIR CHEMISTRY	2.1
2.3 MOIST AIR PHYSICAL PROPERTIES	2.1
2.4 MOIST AIR ENERGY CONTENT	2.2
2.5 ZONE DEFINED	2.5
2.6 AIRFLOW DEFINED	2.7
2.7 SPACE CONDITIONING METHODS	2.7
2.8 HVAC SYSTEMS CATEGORIZED BY PRIMARY HEAT TRANSFER MEDIA	2.8
CHAPTER 3 VARIABLE-AIR-VOLUME HVAC SYSTEMS	
3.1 INTRODUCTION	3.1
3.2 VAV SYSTEM DESCRIPTION	3.1
3.3 VAV VERSUS CONSTANT-AIR-VOLUME HVAC SYSTEMS	3.1
3.4 VAV SYSTEM OPERATION	3.2
3.5 VAV TERMINAL UNITS	3.4
3.6 BASIC VAV TERMINAL UNITS	3.8
3.7 FAN-POWERED VAV TERMINAL UNITS	3.11
3.8 VAV TERMINAL UNITS WITH REHEAT	3.18
3.9 BYPASS VAV TERMINAL UNITS	3.18
3.10 VAV TERMINAL UNIT	3.21
3.11 HVAC SYSTEMS INCORPORATING VAV	3.22
CHAPTER 4 MULTIZONE HVAC SYSTEMS	
4.1 INTRODUCTION	4.1
4.2 MULTIZONE HVAC SYSTEM DESCRIPTION	4.1
4.3 USE OF A MULTIZONE HVAC SYSTEM	4.1
CHAPTER 5 TERMINAL REHEAT HVAC SYSTEMS	
5.1 INTRODUCTION	5.1
5.2 SYSTEM DESCRIPTION	5.1



5.3	SYSTEM FEATURES	5.1
5.4	SYSTEM LAYOUT	5.1
5.5	SYSTEM OPERATION	5.2
5.6	VAV HVAC SYSTEM WITH TERMINAL REHEAT	5.3
CHAPTER 6	DUAL-DUCT HVAC SYSTEMS	Page
6.1	INTRODUCTION	6.1
6.2	DUAL-DUCT HVAC SYSTEM DESCRIPTION	6.1
6.3	DUAL-DUCT HVAC SYSTEM APPLICATION	6.1
6.4	DUAL-DUCT HVAC SYSTEM OPERATION	6.5
6.5	DUAL-DUCT HVAC SYSTEM FEATURES	6.5
6.6	CENTRAL DUAL-DUCT HVAC SYSTEM EQUIPMENT	6.8
6.7	DUAL-DUCT HVAC SYSTEM AIR TERMINAL UNITS	6.9
6.8	SYSTEM OPERATION	6.12
6.9	IMPROVING EXISTING DUAL-DUCT HVAC SYSTEM PERFORMANCE	6.12
CHAPTER 7	INDUCTION REHEAT HVAC SYSTEMS	
7.1	INTRODUCTION	7.1
7.2	SYSTEM DESCRIPTION	7.1
7.3	INDUCTION TERMINAL UNITS	7.1
7.4	SYSTEM OPERATION	7.4
7.5	SYSTEM ADVANTAGES AND DISADVANTAGES	7.5
CHAPTER 8	UNITARY HVAC SYSTEMS	
8.1	INTRODUCTION	8.1
8.2	UNITARY HVAC SYSTEM CHARACTERISTICS	8.1
8.3	UNITARY HVAC SYSTEM	8.1
8.4	UNITARY HVAC SYSTEM ADVANTAGES AND DISADVANTAGES	8.4
8.5	CONVENTIONAL UNITARY HVAC SYSTEM TYPES	8.5
8.6	SINGLE-PACKAGED UNITS	8.5
8.7	SPLIT SYSTEMS	8.8
8.8	PACKAGED TERMINAL AIR CONDITIONERS	8.9
8.9	UNITARY HEAT PUMPS	8.13
8.10	COMBINATION UNITARY AND CENTRAL HVAC SYSTEMS	8.15
CHAPTER 9	CENTRAL COOLING PLANT	
9.1	INTRODUCTION	9.1
9.2	CENTRAL COOLING PLANT OPERATION AND COMPONENTS	9.1
9.3	CHILLER PURPOSE	9.1
9.4	CHILLER REFRIGERATION CYCLE	9.1
9.5	REFRIGERANT	9.5
9.6	MOTOR-COMPRESSOR UNITS	9.6
9.7	MECHANICAL COMPRESSOR OPERATION AND CHARACTERISTICS	9.6
9.8	ABSORPTION CHILLERS	9.8
9.9	CENTRAL COOLING PLANTS WITH MULTIPLE CHILLERS	9.10
9.10	COOLING TOWERS	9.11
9.11	CONDENSER WATER SYSTEMS	9.15
9.12	EVAPORATIVE COOLING SYSTEMS	9.20
CHAPTER 10	CENTRAL HEATING PLANT	
10.1	INTRODUCTION	10.1
10.2	FURNACES	10.1
10.3	BOILERS	10.1
10.4	HOT WATER VERSUS STEAM	10.2

10.5	BOILER PLANT OPERATION	10.2
10.6	BOILER CONSTRUCTION	10.3
10.7	BOILER FUELS	10.4
10.8	ELECTRIC BOILERS	10.4
10.9	BOILER RATING	10.4
10.10	BOILER CONTROLS	10.5
10.11	BOILER FEEDWATER AND CIRCULATING PUMPS	10.6
10.12	DEAERATORS	10.6
10.13	INCREASING CONVENTIONAL BOILER PLANT EFFICIENCY	10.6
10.14	CONDENSING BOILERS	10.7
10.15	HEAT EXCHANGERS	10.8
CHAPTER 11 ENGINEERED HEAT PUMP SYSTEMS		Page
11.1	INTRODUCTION	11.1
11.2	HEAT PUMP SYSTEMS	11.1
11.3	HEAT PUMP SYSTEM CHARACTERISTICS	11.1
11.4	BASIC HEAT PUMP SYSTEM ARRANGEMENTS	11.4
11.5	HEAT PUMP SYSTEM TYPES	11.6
11.6	WATER-TO-AIR HEAT PUMP SYSTEMS	11.7
11.7	WATER-TO-AIR HEAT PUMP SYSTEM DESIGN CONSIDERATIONS	11.11
CHAPTER 12 AIR DISTRIBUTION SYSTEMS		
12.1	INTRODUCTION	12.1
12.2	AIR DISTRIBUTION SYSTEM PURPOSE	12.1
12.3	AIR DISTRIBUTION SYSTEM COMPONENTS	12.1
12.4	SMACNA AIR DISTRIBUTION SYSTEM STANDARDS	12.1
12.5	AIR DUCTS AND PLENUMS	12.2
12.6	AIR TERMINAL UNITS	12.4
12.7	AIR OUTLETS AND INLETS	12.4
12.8	PROVISIONS FOR TESTING, ADJUSTING, AND BALANCING	12.5
CHAPTER 13 FANS AND AIR-HANDLING UNITS		
13.1	INTRODUCTION	13.1
13.2	FANS	13.1
13.3	AIR DISTRIBUTION SYSTEM OPERATION	13.12
13.4	AIR DISTRIBUTION SYSTEM OPERATING POINT	13.12
13.5	AIR DISTRIBUTION SYSTEM DYNAMICS	13.16
13.6	SYSTEM OPERATING POINT AND FAN SPEED	13.16
13.7	SUPPLY FAN AIRFLOW CONTROL	13.20
13.8	AIR HANDLING UNITS	13.23
CHAPTER 14 AIR FILTRATION AND CLEANING		
14.1	INTRODUCTION	14.1
14.2	AIR FILTRATION AND CLEANING	14.1
14.3	RATING AIR FILTERS AND CLEANERS	14.1
14.4	AIR POLLUTANT CAPTURE METHODS	14.2
14.5	CATEGORIES OF AIR FILTERS AND CLEANERS	14.3
14.6	PANEL FILTERS	14.5
14.7	RENEWABLE MEDIA FILTERS	14.7
14.8	ELECTRONIC AIR CLEANERS	14.8
14.9	AIR CLEANER AND FILTER LOCATION	14.9
14.10	FILTER INSTALLATION	14.10
14.11	ODOR REMOVAL	14.11



CHAPTER 15	HYDRONIC DISTRIBUTION SYSTEMS	Page
15.1	INTRODUCTION	15.1
15.2	HOT WATER DISTRIBUTION SYSTEM OPERATION	15.1
15.3	CHILLED WATER DISTRIBUTION SYSTEM OPERATION	15.1
15.4	HYDRONIC DISTRIBUTION SYSTEM ADVANTAGES AND DISADVANTAGES	15.4
15.5	HYDRONIC PIPING SYSTEM CLASSIFICATION	15.5
15.6	HYDRONIC DISTRIBUTION SYSTEM OPERATING TEMPERATURE CLASSIFICATIONS	15.5
15.7	HYDRONIC DISTRIBUTION SYSTEM FLOW	15.5
15.8	HYDRONIC DISTRIBUTION SYSTEM ARRANGEMENTS	15.6
15.9	MULTI-LOOP HYDRONIC DISTRIBUTION SYSTEMS	15.15
15.10	CONTROLLING HYDRONIC DISTRIBUTION SYSTEM FLOW	15.15
15.11	HYDRONIC DISTRIBUTION SYSTEM COMPONENTS	15.19
15.12	HYDRONIC SYSTEM HEAT TRANSFER MODE	15.24
15.13	CONVECTION TERMINAL UNITS	15.24
15.14	THERMAL FLUIDS	15.29
15.15	SIZING CENTRAL EQUIPMENT FOR ALL-WATER SYSTEMS	15.30
15.16	HYDRONIC DISTRIBUTION SYSTEM DESIGN	15.31
CHAPTER 16	HVAC HYDRONIC PUMPS	
16.1	INTRODUCTION	16.1
16.2	PUMPS	16.1
16.3	CENTRIFUGAL PUMP OPERATION	16.3
16.4	HYDRONIC SYSTEM OPERATION	16.6
16.5	EXPANSION OR COMPRESSION TANK	16.8
CHAPTER 17	MOTORS AND VARIABLE FREQUENCY DRIVES	
17.1	INTRODUCTION	17.1
17.2	ELECTRIC MOTOR TYPES	17.1
17.3	INDUCTION MOTOR SIZE CLASSIFICATION	17.2
17.4	INDUCTION MOTOR PURPOSE CLASSIFICATION	17.2
17.5	INDUCTION MOTOR	17.4
17.6	INDUCTION MOTOR SPEED-TORQUE RELATIONSHIP	17.5
17.7	INDUCTION MOTOR CHARACTERISTICS	17.7
17.8	MOTOR STARTING	17.14
17.9	VARIABLE FREQUENCY DRIVES	17.16
CHAPTER 18	HVAC SYSTEM CONTROL	
18.1	INTRODUCTION	18.1
18.2	CONTROL SYSTEM BASICS	18.1
18.3	CONTROL LOOPS	18.5
18.4	THERMOSTAT: SIMPLE CONTROL SYSTEM	18.6
18.5	TYPES OF CONTROL SYSTEMS	18.6
18.6	SENSING ELEMENTS	18.14
18.7	CONTROL SIGNAL TRANSMISSION	18.15
18.8	BUILDING AUTOMATION AND CONTROL SYSTEMS	18.17
18.9	REMOTE HVAC SYSTEM MONITORING AND CONTROL	18.17
18.10	OPEN-ARCHITECTURE CONTROL SYSTEMS	18.17
18.11	CONTROL SYSTEM APPLICATIONS	18.18
18.12	CONTROL SYSTEM LAYOUT AND OPERATIONAL CONSIDERATIONS	18.39
CHAPTER 19	SMOKE CONTROL SYSTEMS	
19.1	INTRODUCTION	19.1

19.2	SMOKE CONTROL SYSTEMS	19.1
19.3	SMOKE MOVEMENT	19.1
19.4	SMOKE MANAGEMENT	19.4
19.5	SMOKE CONTROL	19.4
19.6	SIMPLE STAIRWELL PRESSURIZATION	19.7
19.7	COMPLEX STAIRWELL PRESSURIZATION	19.9
19.8	ZONED SMOKE CONTROL	19.11
CHAPTER 20 CLEANROOM HVAC SYSTEMS		Page
20.1	INTRODUCTION	20.1
20.2	CLASSES OF CLEANROOMS	20.1
20.3	CLEANROOM HVAC SYSTEMS	20.3
20.4	CLEANROOM AIRFLOW PARAMETERS	20.5
20.5	DESIGN AND PERFORMANCE CONSIDERATIONS FOR CLEANROOMS	20.10
20.6	CONTROL SYSTEMS	20.10
20.7	HVAC DUCTWORK	20.12
20.8	TYPICAL CLEANROOM SYSTEMS	20.13
20.9	CLEANROOM TESTING	20.16
CHAPTER 21 LABORATORY HVAC SYSTEMS		
21.1	INTRODUCTION	21.1
21.2	LABORATORY ENVIRONMENTAL REQUIREMENTS	21.1
21.3	SUPPLY AIR SYSTEMS	21.1
21.4	EXHAUST AIR SYSTEMS	21.3
21.5	LABORATORY FUME HOODS	21.6
21.6	BIOLOGICAL SAFETY CABINETS	21.11
21.7	BIOMEDICAL LABORATORIES AND ANIMAL RESEARCH FACILITIES	21.14
APPENDIX A DISPLACEMENT VENTILATION		
A.1	DISPLACEMENT VENTILATION OVERVIEW	A.1
A.2	DV SYSTEM OPERATION	A.1
A.3	DV SYSTEM THERMAL PLUME	A.1
A.4	DV SYSTEM ENERGY CONSIDERATIONS	A.2
A.5	CEILING HEIGHT	A.2
A.6	HEATING WITH DV SYSTEMS	A.2
A.7	DV SYSTEMS AND UNDERFLOOR AIR DISTRIBUTION SYSTEMS	A.2
A.8	CONCLUSION	A.3
APPENDIX B DEDICATED OUTSIDE AIR SYSTEMS		
B.1	DEDICATED OUTSIDE AIR SYSTEMS OVERVIEW	B.1
B.2	DOAS ADVANTAGES	B.1
B.3	DOAS DISADVANTAGES	B.2
B.4	FRACTIONAL AND INTEGRATED DOAS SYSTEMS	B.2
APPENDIX C SUSTAINABLE BUILDING HVAC SYSTEMS		
C.1	SUSTAINABLE BUILDINGS	C.1
C.2	WHAT IS A SUSTAINABLE BUILDING?	C.1
C.3	SUSTAINABLE BUILDING RATING SYSTEMS	C.1
C.4	LEED™ GREEN BUILDING CERTIFICATION	C.2
C.5	LEED™ CERTIFICATION	C.2
C.6	EXAMPLE LEED™ HVAC REQUIREMENTS	C.3
C.7	SUSTAINABLE BUILDING INFORMATION FOR THE HVAC CONTRACTOR	C.3



APPENDIX D THERMAL ENERGY STORAGE	Page
D.1 FULL OR PARTIAL STORAGE	D.1
GLOSSARY	



TABLES		Page
10-1	Boiler Rating by Facility Type	10.4
11-1	Basic Heat Pump System Arrangements	11.4
14-1	Mechanical Air Filter MERV Rating Information	14.4
15-1	Physical and Heat Transfer Characteristics	15.30
17-1	System and Motor Voltages	17.9
17-2	Voltage Tolerance Ranges	17.9
17-3	Voltage Impact on Induction Motor's Operation	17.10
17-4	Induction Motor Speeds for Specified Poles	17.11
20-1	FS 209(D) Cleanroom Classifications	20.1
20-2	History of FS 209: Airborne Particulate Cleanliness Classes in Clean Rooms and Clean Zones	20.2
20-3	FS 209(E) Cleanroom Classifications	20.2
20-4	ISO 14644 Family of Standards	20.3
20-5	ISO Cleanroom and Other Associated Controlled Environments Classifications ...	20.4
20-6	Air Pressure Relationship	20.10
20-7	Cleanroom Temperature and Humidity	20.10
21-1	Typical Characteristics of Biological Safety Cabinets	21.12



FIGURES		Page
1-1	Comfort Zone	1.3
1-2	Basic HVAC System Components	1.5
1-3	Typical Central HVAC System	1.7
1-4	Commercial Building Energy Use	1.8
1-5	HVAC System Selection Parameters	1.9
2-1	Typical HVAC Psychrometric Chart	2.3
2-2	Psychrometric Chart Example	2.4
2-3	Commercial Office Building Floor Plan	2.6
2-4	All-Air HVAC System	2.9
2-5	Air-Hydronic HVAC System	2.11
2-6	All-Hydronic HVAC System	2.12
3-1	Basic Single-Zone Cooling Only VAV System	3.3
3-2	Basic Multi-Zone Cooling-Only VAV System	3.5
3-3	VAV Air Terminal Unit Serving Multiple Air Outlets	3.6
3-4	Basic VAV Single-Duct Terminal Unit – Functional Diagram	3.7
3-5	Basic VAV Single-Duct Terminal Unit – Cutaway View	3.7
3-6	VAV Terminal Unit Types, Configurations, and Features	3.8
3-7	Single-Duct VAV Terminal Unit Control Strategy	3.9
3-8	Basic VAV Dual-Duct Terminal Unit – Functional Diagram	3.10
3-9	Basic VAV Dual-Duct Terminal Unit – Cutaway View	3.10
3-10	Dual-Duct VAV Terminal Unit Schematic Diagram	3.12
3-11	Dual-Duct VAV Terminal Unit – Non-Blending Control Strategy	3.13
3-12	Dual-Duct VAV Terminal Unit – Maximum Heating Blending Control Strategy	3.13
3-13	Dual-Duct VAV Terminal Unit – Unequal Flow Blending Control Strategy	3.14
3-14	Dual-Duct VAV Terminal Unit – Constant Volume Blending Control Strategy	3.14
3-15	Fan-Powered VAV Terminal Unit Schematic Diagram	3.15
3-16	Parallel Flow Fan-Powered VAV Terminal Unit – Functional Diagram	3.17
3-17	Parallel Flow Fan-Powered VAV Terminal Unit – Cutaway View	3.17
3-18	Series Flow Fan-Powered VAV Terminal Unit – Functional Diagram	3.19
3-19	Series Flow Fan-Powered VAV Terminal Unit – Cutaway View	3.19
3-20	VAV Terminal Unit with Reheat – Functional Diagram	3.20
3-21	Bypass (Dump) VAV Terminal Unit – Functional Diagram	3.20
3-22	VAV Terminal Unit Inlet Multipoint Pressure Sensor	3.23
3-23	Multipoint Pressure Sensor	3.23
4-1	Multizone HVAC System	4.2
5-1	Typical Terminal Reheat HVAC System Functional Diagram	5.2
5-2	Constant Volume Terminal Reheat Unit	5.3
6-1	Dual-Duct Single-Fan HVAC System	6.2
6-2	Dual-Duct Single-Fan HVAC System Schematic Diagram	6.3
6-3	Dual-Duct Dual-Fan HVAC System Schematic Diagram	6.4
6-4	Dual-Duct Low Velocity System	6.6
6-5	Dual-Duct High Velocity System	6.7
6-6	Mixing and Volume Control Method Using Self-Actuated Spring-Loaded Volume Regulator for Constant Volume System	6.10
6-7	Mixing and Volume Control Method Using Flow Regulator for Constant Volume System	6.11
7-1	Induction Reheat System	7.2
7-2	Induction Terminal Unit Functional Diagram	7.3
7-3	Two-Pipe Induction Terminal Unit Bypass Control	7.4
8-1	Mechanical Refrigeration Cycle	8.2
8-2	Rooftop Unitary HVAC System	8.7
8-3	Split-System Unitary HVAC System	8.10
8-4	Through-The-Wall PTAC with Separate Heating and Cooling Chassis	8.12
8-5	Through-The-Wall PTAC with Combined Chassis	8.12
9-1	Central Cooling Plant Schematic Diagram	9.2
9-2	Vapor-Compression Refrigeration Cycle	9.3
9-3	Direct-Contact Evaporative Cooling Tower	9.13
9-4	Indirect-Contact Evaporative Cooling Tower	9.14
9-5	Forced-Draft Cooling Tower with Counterflow	9.16
9-6	Induced-Draft Cooling Tower with Counterflow	9.16

FIGURES		Page
9-7	Forced-Draft Cooling Tower with Crossflow	9.17
9-8	Induced-Draft Cooling Tower with Crossflow	9.17
9-9	Double-Entry Induced-Draft Cooling Tower with Crossflow	9.18
11-1	Basic Heat Pump System Arrangements	11.5
11-2	Air-Source Heat Pump System Schematic Diagram	11.8
11-3	Water-Source Heat Pump System Schematic Diagram	11.9
11-4	Closed Loop Water-To-Air Heat Pump System Schematic Diagram	11.10
13-1	Axial-Flow Fan: Propeller Type	13.2
13-2	Axial-Flow Fan: Tube-Axial Type	13.3
13-3	Axial-Flow Fan: Vane-Axial Type	13.3
13-4	Centrifugal Fan: Backward Inclined (Airfoil) Blade	13.5
13-5	Centrifugal Fan: Radial (Straight) Blade	13.5
13-6	Centrifugal Fan: Forward Curved Blade	13.6
13-7(a)	Summary of Fan Categories, Types, and Characteristics	13.7
13-7(b)	Summary of Fan Categories, Types, and Characteristics	13.8
13-8	Fan Curve for Typical Centrifugal Fan: Backward Inclined Blade	13.9
13-9	Family of Fan Curves	13.11
13-10	Fan Law Example Illustrated with Fan Curves	13.13
13-11	System Curve	13.14
13-12	System Curve Change Due To Increased Resistance To Flow	13.15
13-13	System Operating Point	13.17
13-14	Fan Airflow Modulation "Riding The Fan Curve"	13.18
13-15	Varying Fan Operating Points with Fan Speed	13.19
13-16	Supply Fan Airflow Control Methods	13.21
13-17	Fan Power Input Versus Rated Airflow	13.22
13-18	Air Handling Unit Schematic Diagram	13.25
15-1	Simple Hot Water Distribution System	15.2
15-2	Simple Chilled Water Distribution System	15.3
15-3	One-Pipe Hydronic Distribution System	15.7
15-4	Two-Pipe Hydronic Distribution System (Direct Return)	15.8
15-5	Two-Pipe Hydronic Distribution System (Reverse Return)	15.10
15-6	Three-Pipe Hydronic Distribution System	15.11
15-7	Four-Pipe Hydronic Distribution System (Single Coil Convection Terminal Units)	15.12
15-8	Four-Pipe Hydronic Distribution System (Dual Coil Convection Terminal Units) ..	15.14
15-9	Multi-Loop Hydronic Distribution System	15.16
15-10	Constant Volume Hydronic Distribution System (Diverting Valve)	15.17
15-11	Diverting Valve	15.18
15-12	Constant Volume Hydronic Distribution System (Mixing Valve)	15.20
15-13	Mixing Valve	15.21
15-14	Single-Seated Two-Way Valve	15.22
15-15	Double-Seated Two-Way Valve	15.22
15-16	Passive Chilled Beam	15.28
15-17	Active Chilled Beam	15.28
16-1	Typical Centrifugal Pump Performance Curves	16.2
16-2	Typical Centrifugal Pump Performance Curves Supplied By Pump Manufacturers	16.5
16-3	Pump and System Curves	16.7
16-4	Correct Pump Connection To Expansion Tank	16.9
16-5	Incorrect Pump Connection To Expansion Tank	16.9
17-1	Typical Integral Horsepower Squirrel Cage Induction Motor	17.3
17-2	Typical Squirrel Cage Induction Motor Rotor	17.3
17-3	Induction Motor Speed-Torque Curve	17.6
17-4	NEMA Design Letter Toque-Speed Curves	17.13
17-5	Typical Full-Voltage Motor Starter	17.15
17-6	HVAC System VFD Use	17.17
17-7	VFD Drive System Functional Diagram	17.18
17-8	Fan and Pump Operation as a Function of Speed	17.20
18-1	Generic HVAC Control System Block Diagram	18.2
18-2	VAV Terminal Unit Control Block Diagram	18.3



FIGURES		Page
18-3	Control Loop	18.6
18-4	Example HVAC Closed Loop Control System	18.7
18-5	Typical Pneumatic Control System	18.9
18-6	Typical Pneumatic Control Valves	18.10
18-7	Automatic Multiblade Dampers	18.11
18-8	Typical Bleed Type Thermometer and Operator	18.13
18-9	Thermostat Flapper-Nozzle-Bimetal Assembly	18.14
18-10	Static Pressure Control of Outdoor Air	18.20
18-11	Basic Economy Cycle for Control of Outdoor Air	18.20
18-12	Enthalpy Control of Outdoor Air	18.21
18-13	Outdoor Air Control of Preheat Coil	18.22
18-14	Preheat Secondary Pump and Three-Way Valve	18.22
18-15	Preheat Secondary Pump and Two-Way Valve	18.23
18-16	Heating Coil and Two-Way Valve	18.23
18-17	Electric Coil with Solid-State Controller	18.25
18-18	Cooling and Dehumidification: Practical Low Limit	18.25
18-19	Cooling and Dehumidification with Reheat	18.26
18-20	Evaporative Cooling Process	18.27
18-21	Evaporative Cooling with an Air Washer	18.27
18-22	Pan humidifier Control	18.28
18-23	Mixed Loads with Demand Reset	18.29
18-24	Coil Control Using a Three-Way Valve	18.30
18-25	Pump and System Curves with Valve Control	18.31
18-26	Two-Way Valve with Pump Bypass	18.32
18-27	Two-Pipe Central Plant System	18.33
18-28	Control of a Hot Water Boiler	18.34
18-29	Hydronic System Load and Zone Control	18.36
18-30	Stem-To-Hot Water Heat Exchange Control	18.36
18-31	Duct Heater Control	18.37
18-32	Dead Band Control System	18.40
19-1	Smoke Control System Design Factors	19.2
19-2	Air Movement Due to Normal and Reverse Stack Effect	19.3
19-3	Smoke Control System Using Pressure Differential Across a Smoke Barrier To Prevent Smoke Migration From The Low- to the High-Pressure Side	19.5
19-4	Smoke Backflow Against Low Air Velocity Through an Open Doorway	19.5
19-5	No Smoke Backflow with High Air Velocity Through an Open Doorway	19.6
19-6	Top Injection Stairwell Pressurization	19.8
19-7	Multiple Injection with Ground Level Fan	19.8
19-8	Multiple Injection with Roof Mounted Fan	19.9
19-9	Stairwell Pressurization with Air Supply at Each Floor	19.10
19-10	Stairwell Pressurization with Bypass Around Supply Fan	19.11
19-11	Typical Smoke Control Zone Arrangements	19.13
20-1	Conventional Flow Cleanroom	20.6
20-2	Cross Flow Laminar Flow Cleanroom	20.6
20-3	Down Flow Laminar Flow Cleanroom	20.7
20-4	Laminar Flow Workstations	20.8
20-5	Typical Secondary Air Location: Cross Flow Laminar Flow Cleanroom	20.8
20-6	Conventional Cleanroom with Bypass Fan	20.9
20-7	Conventional Cleanroom with Packaged Fan/HEPA Units	20.9
20-8	Cleanroom Mechanical Design Considerations	20.11
20-9	Typical ISO Class 4 Cleanroom	20.14
20-10	Typical ISO Class 5 Cleanroom	20.15
20-11	Typical ISO Class 7 Cleanroom	20.17
21-1	Typical Process Fume Hood	21.8
21-2	Typical Bypass Fume Hood with Vertical Sash and Bypass Air Inlet	21.9
21-3	Typical Auxiliary Fume Hood	21.10
21-4	Typical Class I Biological Safety Cabinet	21.12
21-5	Typical Class II Type A Biological Safety Cabinet	21.13
21-6	Typical Class II Type B Biological Safety Cabinet	21.14
21-7	NIH Design Requirements Manual Contents	21.16

CHAPTER 1

INTRODUCTION

This is a preview of "SMACNA 1099-2010". [Click here to purchase the full version from the ANSI store.](#)

1.1 INTRODUCTION

This chapter provides an introduction to heating, ventilating, and air conditioning (HVAC) applications. This chapter starts with stating the purpose of HVAC systems followed by a discussion of human thermal comfort and the industry standards that are used to establish the operating parameters for HVAC systems. Basic HVAC system components are then identified and discussed and a typical central HVAC system is presented. The importance of HVAC operating efficiency is addressed along with discussion of energy codes and standards. Energy codes and standards, green building rating systems and their relationship to HVAC system applications are also covered. This chapter closes by addressing various issues that should be considered when selecting, designing, and installing HVAC systems.

1.2 HVAC SYSTEM PURPOSE

The purpose of an HVAC system is to provide a suitable thermal environment in a defined space that meets the needs of the occupants and the activity that takes place in the space. Most HVAC systems are installed to establish an indoor environment within which building occupants can live, work, and play. The indoor environment impacts the quality of life, productivity, and well being of building occupants. As people spend an increasing amount of time inside buildings HVAC systems and their associated control systems are becoming more important. To address this growing need this manual focuses on HVAC equipment that creates human comfort indoors. Energy use in buildings is becoming increasingly important and impacting the type of the HVAC distribution system design, the HVAC equipment specified, and how the HVAC operates. HVAC systems are also required to provide suitable environmental conditions in addition to providing human comfort. In addition, energy use in buildings is becoming increasingly important and impacting the type of the HVAC distribution system design, the HVAC equipment specified, and how the HVAC operates. HVAC systems are also required to provide suitable environmental conditions for purposes other than human comfort.

1.3 HUMAN THERMAL COMFORT

1.3.1 Variables That Determine Human Thermal Comfort

Human thermal comfort is determined by the following four variables:

- Temperature
- Humidity
- Air Movement
- Air Quality

The objective of an HVAC system installed for human comfort is to control these four variables within an acceptable range for the occupants in the zone served by the HVAC system. The zone can be an entire building, an enclosed space within a building such as a room, or an area within a building. The HVAC system must be capable of controlling these four variables considering the activity taking place in the zone as well as changes in the outside environment, changes in the occupancy of the zone, and changes in the activity taking place in the zone. All of these changes take place continuously throughout the day and the HVAC system must be able to adjust and adapt to the dynamic nature of building thermal loads.

1.3.2 Establishing Parameters For Human Thermal Comfort

There are a number of industry standards and recommended practices that provide recommendations and guidance in establishing the parameters for achieving human thermal comfort for a given occupancy that take into account the activity being performed in the zone served by the HVAC system. Two important industry standards that establish the general parameters for human thermal comfort are published by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE) and are as follows:

- ASHRAE Standard 55-2004: *Thermal Environmental Conditions for Human Occupancy*
- ASHRAE Standard 62.1-2004: *Ventilation for Acceptable Indoor Air Quality*

Both of these standards are referenced in building codes, project technical specifications, and green building rating systems and their requirements may be mandatory on a building project. The following sections will discuss each of these industry standards.

1.3.2.1 ASHRAE Standard 55

ASHRAE Standard 55 specifies the combinations of indoor space environment and personal factors that will produce thermal environmental conditions acceptable to 80 percent of the occupants in a space. The environmental factors addressed are temperature,

