

HVAC SYSTEMS DUCT DESIGN



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

www.smacna.org

This is a preview of "SMACNA 1958-2006". [Click here to purchase the full version from the ANSI store.](#)

HVAC SYSTEMS DUCT DESIGN

FOURTH EDITION – DECEMBER 2006



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

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

HVAC SYSTEMS DUCT DESIGN

COPYRIGHT © SMACNA 2006
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 – JULY 1977
SECOND EDITION – JULY 1981
THIRD EDITION – JUNE 1990
FOURTH EDITION – DECEMBER 2006

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

In keeping with its policy of disseminating information and providing standards of design and construction, the Sheet Metal and Air Conditioning Contractors' National Association, Inc. (SMACNA), offers this comprehensive fundamental *HVAC Systems-Duct Design* manual as part of our continuing effort to upgrade the quality of work produced by the heating, ventilating and air conditioning (HVAC) industry. This manual presents the basic methods and procedures required to design HVAC air distribution systems. It does not deal with the calculation of air conditioning loads or room air ventilation quantities.

This manual is part one of a three set HVAC Systems Library. The second manual is the SMACNA *HVAC Systems-Applications* manual that contains information and data needed by designers and installers of more specialized air and hydronic HVAC systems. The third manual is the *HVAC Systems-Testing, Adjusting and Balancing* manual, a recently updated publication on air and hydronic system testing and balancing.

The HVAC duct system designer is faced with many considerations after the load calculations are completed and the type of distribution system is determined. This manual provides not only the basic engineering guidelines for the sizing of HVAC ductwork systems, but also related information in the areas of:

- a. Materials
- b. Methods of Construction
- c. Economics of Duct Systems
- d. Duct System Layout
- e. Pressure Losses
- f. Fan Selection
- g. Duct Leakage
- h. Acoustic Considerations
- i. Duct Heat Transfer
- j. Testing, Adjusting and Balancing

With emphasis on energy conservation, the designer must balance duct size with the space allocated and duct system pressure loss. Duct pressure loss increases fan power and associated operating costs. Materials, equipment, and construction methods must be carefully chosen to achieve the most advantageous balance between both initial and life cycle costing considerations. This manual is designed to offer both the HVAC system designer and installer detailed information on duct design, materials and construction methods. Both U. S. and metric units have been provided in examples, calculations, and tables.

The SMACNA *HVAC Systems-Duct Design* manual is intended to be used in conjunction with the American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE) *Fundamentals* Handbook. The basic fluid flow equations are not included here, but may be found in the ASHRAE handbook. Practical applications of these equations are included through use of reference tables and examples. Some sections of this manual have been reprinted with permission from various ASHRAE publications. Another important source of HVAC systems information is the Air Movement and Control Association International, Inc. (AMCA). SMACNA and the entire HVAC industry owe these two organizations a debt of gratitude for continued investments testing and development of HVAC standards.

Although most HVAC systems are constructed to pressure classifications between minus 3 inches water gage (wg) to 10 inches wg, (-750 to 2,500 Pascals (Pa), the design methods, tables, charts, and equations provided in this text may be used to design other duct systems operating at higher pressures and temperatures. Air density correction factors for both higher altitudes and temperatures are included.

SMACNA recognizes that this manual will be expanded and updated as new material becomes available. We will continue to provide the HVAC industry with the latest construction methods and engineering data from recognized sources including SMACNA research programs and the services of local SMACNA Chapters and SMACNA Contractors.

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

SMACNA DUCT DESIGN COMMITTEE

Ken Groeschel Jr, PE
Butters-Fetting Co., Inc.
1669 South 1st Street
Milwaukee, WI 53204

Michael F. Mamayek
Illingworth Corporation
Milwaukee, Wisconsin

Roy Ricci
McCusker – Gill, Inc.
Hingham, Massachusetts

Dwight D. Silvia
D. D. S. Industries Inc.
Somerset, Massachusetts

Eli Howard, III, *Staff*
SMACNA, Inc.
Chantilly, Virginia

Peyton Collie, *Staff Liaison*
SMACNA, Inc.
Chantilly, Virginia

TECHNICAL CONSULTANT

Jeffrey R. Yago, P.E., CEM
J. R. YAGO & ASSOCIATES
Gum Spring, Virginia

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 comply 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 1958-2006". [Click here to purchase the full version from the ANSI store.](#)

TABLE OF CONTENTS

FOREWORD iii

SMACNA DUCT DESIGN COMMITTEE iv

NOTICE TO USERS v

TABLE OF CONTENTS vii

CHAPTER 1 INTRODUCTION	Page
1.1 SCOPE	1.1
1.2 HOW TO USE THIS MANUAL	1.1
1.3 PURPOSE	1.1
1.4 HISTORY OF AIR DUCT SYSTEMS	1.1
1.5 GENERAL REQUIREMENTS	1.2
1.6 HVAC SYSTEMS LIBRARY	1.2
1.7 CODES AND ORDINANCES	1.3
1.8 HVAC DUCT SYSTEM TYPES	1.5
1.9 SMOKE CONTROL SYSTEMS	1.6
1.10 INDOOR AIR QUALITY	1.7
1.11 VENTILATION RATES	1.8
 CHAPTER 2 ECONOMICS OF DUCT SYSTEMS	
2.1 SCOPE	2.1
2.2 RESPONSIBILITIES	2.1
2.3 INITIAL SYSTEM COSTS	2.2
2.4 ANNUAL OWNING COSTS	2.3
2.5 ANNUAL OPERATING COSTS	2.3
2.6 OPERATION COSTS	2.3
2.7 CONTROLLING COSTS	2.5
2.8 DUCT ASPECT RATIOS	2.5
2.9 PRESSURE CLASSIFICATION AND LEAKAGE	2.5
2.10 COST OF FITTINGS	2.7
 CHAPTER 3 ROOM AIR DISTRIBUTION	
3.1 SCOPE	3.1
3.2 COMFORT	3.1
3.3 AIR DISTRIBUTION FUNDAMENTALS	3.13
3.4 OUTLET LOCATION	3.15
3.5 OUTLET CRITERIA	3.20
3.6 GRILLE AND REGISTER APPLICATIONS	3.20
3.7 SLOT DIFFUSER APPLICATIONS	3.20
3.8 CEILING DIFFUSER APPLICATIONS	3.21
3.9 OUTLETS IN VARIABLE AIR VOLUME (VAV) SYSTEMS	3.23
3.10 INLET CRITERIA	3.23
3.11 EXHAUST OUTLETS	3.25
3.12 SPECIAL SITUATIONS	3.25
3.13 AIR DISTRIBUTION SUMMARY	3.25
3.14 ROOM TERMINAL DEVICES	3.26
3.15 SUPPLY AIR GRILLE AND REGISTER TYPES	3.28
3.16 SUPPLY AIR CEILING DIFFUSER TYPES	3.28
3.17 VAV AND THERMAL BOXES	3.29



3.18	TERMINAL BOX VARIATIONS	3.30
3.19	BASIC VAV SYSTEM DESIGN	3.31
3.20	VAV COMPONENTS AND CONTROLS	3.32
3.21	VAV SYSTEM ADVANTAGES	3.33
3.22	VAV SYSTEM DESIGN PRECAUTIONS	3.33
3.23	VAV TERMINAL DEVICES	3.35

CHAPTER 4 GENERAL APPROACH TO DUCT DESIGN Page

4.1	SCOPE	4.1
4.2	DESIGN METHODS – OVERVIEW	4.3
4.3	SELDOM USED METHODS	4.4
4.4	DUCT HEAT GAIN OR LOSS	4.5
4.5	SOUND AND VIBRATION	4.5
4.6	PRESSURE CLASSIFICATION	4.5
4.7	DUCT LEAKAGE	4.6
4.8	FAN SIZING	4.6
4.9	TESTING, ADJUSTING AND BALANCING (TAB)	4.6
4.10	FINAL DESIGN DOCUMENTS	4.6

CHAPTER 5 DUCT DESIGN FUNDAMENTALS

5.1	SCOPE	5.1
5.2	FLUID PROPERTIES	5.1
5.3	FLUID STATICS	5.2
5.4	FLUID DYNAMICS	5.3
5.5	FLUID FLOW PATTERNS	5.6
5.6	DUCT SYSTEM PRESSURES	5.9
5.7	FRICTION LOSSES	5.10
5.8	DYNAMIC LOSSES	5.12
5.9	BASIC DUCT SIZING	5.14
5.10	DUCT CONFIGURATIONS	5.16
5.11	DUCT FITTINGS	5.18
5.12	SYSTEM PRESSURE CHANGES	5.22
5.13	STRAIGHT DUCT LOSSES	5.25
5.14	DYNAMIC LOSSES	5.25
5.15	SPLITTER VANES	5.27
5.16	TURNING VANES	5.27
5.17	PRESSURE LOSSES IN DIVIDED-FLOW FITTINGS	5.30
5.18	LOSSES DUE TO AREA CHANGES	5.31
5.19	OTHER LOSS COEFFICIENTS	5.31
5.20	OBSTRUCTION AVOIDANCE	5.32
5.21	DUCT AIR LEAKAGE	5.34
5.22	DUCT HEAT GAIN/LOSS	5.38
5.23	SMACNA DUCT RESEARCH	5.40
5.24	FAN PRESSURES	5.41
5.25	FAN DEFINITIONS	5.42
5.26	FAN LAWS	5.44
5.27	FAN TESTING	5.46
5.28	FAN CLASSIFICATIONS	5.46
5.29	FAN TYPES	5.46
5.30	FAN CURVES	5.49
5.31	DUCT SYSTEM AIRFLOW	5.52
5.32	SYSTEM CURVES	5.52
5.33	AIR DENSITY EFFECTS	5.56
5.34	ESTIMATING SYSTEM RESISTANCE	5.58
5.35	SAFETY FACTORS	5.59
5.36	THE FAN OUTLET	5.59



5.37	THE FAN INLET	5.63
5.38	ASHRAE METHODS	5.64
5.39	FUNDAMENTALS HANDBOOK	5.66
5.40	DEFICIENT FAN PERFORMANCE	5.67
5.41	SYSTEM EFFECT FACTORS	5.67
5.42	BUILDING PRESSURES	5.70
5.43	BUILDING AIRFLOW CONTROL	5.73
CHAPTER 6	FAN-DUCT CONNECTION PRESSURE LOSSES	Page
6.1	SCOPE	6.1
6.2	FAN OUTLET CONDITIONS	6.1
6.3	FAN INLET CONDITIONS	6.7
6.4	EFFECTS OF FACTORY SUPPLIED ACCESSORIES	6.13
6.5	CALCULATING SYSTEM EFFECT	6.16
CHAPTER 7	DUCT SIZING PROCEDURES	
7.1	SCOPE	7.1
7.2	DESIGN OBJECTIVES	7.1
7.3	DUCT SYSTEM SIZING PROCEDURES	7.1
7.4	FITTING PRESSURE LOSS TABLES	7.2
7.5	SUPPLY AIR DUCT SYSTEM-SIZING EXAMPLE 1 (I-P)	7.4
7.6	RETURN AIR (EXHAUST AIR) DUCT SYSTEM-SIZING EXAMPLE 2	7.18
7.7	SUPPLY AIR DUCT SYSTEM SIZING EXAMPLE 3 (I-P)	7.21
7.8	EXTENDED PLENUM DUCT SIZING	7.26
7.9	DESIGN FUNDAMENTALS (SI)	7.32
7.10	SUPPLY AIR DUCT SYSTEM - SIZING EXAMPLE 1 (SI)	7.32
7.11	RETURN AIR (EXHAUST AIR) DUCT SYSTEM-SIZING EXAMPLE 2 (SI)	7.40
7.12	SUPPLY AIR DUCT SYSTEM SIZING EXAMPLE 3 (SI)	7.47
7.13	EXTENDED PLENUM DUCT SIZING	7.52
CHAPTER 8	PRESSURE LOSS OF SYSTEMS COMPONENTS	
8.1	SCOPE	8.1
8.2	USE OF TABLES AND CHARTS	8.1
8.3	DAMPER CHARTS	8.8
8.4	DUCT SYSTEM APPARATUS CHARTS	8.9
8.5	ROOM AIR TERMINAL DEVICES	8.15
8.6	LOUVER DESIGN DATA	8.17
CHAPTER 9	PROVISIONS FOR TESTING, ADJUSTING, AND BALANCING	
9.1	SCOPE	9.1
9.2	TAB DESIGN CONSIDERATIONS	9.1
9.3	AIR MEASUREMENT DEVICES	9.5
9.4	BALANCING WITH ORIFICES	9.5
9.5	PROVISIONS FOR TAB IN SYSTEM DESIGN	9.5
9.6	LABORATORY TESTING	9.6
9.7	FIELD TESTING AND BALANCING	9.7
9.8	TEST INSTRUMENTATION	9.10



CHAPTER 10	DESIGNING FOR SOUND AND VIBRATION	Page
10.1	SCOPE	10.1
10.2	BUILDING NOISE	10.1
10.3	HVAC NOISE	10.2
10.4	COMMON SOUND SOURCES	10.6
10.5	SOUND DATA STANDARDS	10.7
10.6	DUCT NOISE	10.7
10.7	DUCT SILENCERS	10.8
10.8	ACOUSTIC LAGGING	10.10
10.9	DUCT SOUND BREAKOUT	10.10
CHAPTER 11	DUCT SYSTEM CONSTRUCTION	
11.1	SCOPE	11.1
11.2	DUCT SYSTEM SPECIFICATION CHECK LIST	11.1
11.3	DUCT CONSTRUCTION MATERIALS	11.1
11.4	ASTM STANDARDS	11.5
CHAPTER 12	SPECIAL DUCT SYSTEMS	
12.1	SCOPE	12.1
12.2	KITCHEN AND MOISTURE – LADEN SYSTEMS	12.1
12.3	SYSTEMS HANDLING SPECIAL GASES	12.1
12.4	INDUSTRIAL DUCT	12.1
APPENDIX A	DUCT DESIGN TABLES AND CHARTS	
	FITTING LOSS COEFFICIENT TABLES	A.15
	HVAC EQUATIONS (I-P)	A.51
	HVAC EQUATIONS (SI)	A.56
	SI UNITS AND EQUIVALENTS	A.59

INDEX



TABLES	Page
2-1 Annual Life Cycle Cost Factors	2.2
2-2 Cost of Owning and Operating a Typical Commercial Building	2.3
2-3 Initial Cost Systems	2.4
2-4 Aspect Ratio Example	2.5
2-5 Relative Duct System Costs (Fabrication and Installation of Same Size Duct)	2.7
2-6 Estimated Equipment Service Lives	2.8
3-1 Metabolic Rates of Typical Tasks	3.1
3-2 Operative Temperatures for Thermal Acceptability or Sedentary or Slightly Active Persons (≤ 1.2 Mets) At 50 Percent Relative Humidity ^a	3.4
3-3 Clo Units for Individual Items of Clothing = 0.82 (S Individual Items)	3.8
3-4 Characteristic Room Lengths for Diffusers	3.10
3-5 Air Diffusion Performance Index (ADPI)	3.12
3-6 Guide for Selection of Supply Outlets	3.17
3-7 Supply Air Outlet Types	3.22
3-8 Supply Air Outlet Performance	3.24
3-9 Recommended Return Air Inlet Face Velocities	3.26
3-10 Return and Exhaust Air Inlet Types	3.26
3-11 Accessory Devices	3.27
4-1 HVAC Duct Pressure Velocity Classification	4.5
5-1 Unsealed Longitudinal Seam Leakage for Metal Ducts	5.33
5-2 Applicable Leakage Classes ^a	5.36
5-3 Leakage as a Percentage of System Airflow	5.36
5-4 K Values for Outlet Ducts	5.65
5-5 K Values for Single Width, Single Inlet Fans (SWSI)	5.66
6-1 System Effect Curves for Outlet Ducts	6.4
6-2 System Effect Factor Curves for Outlet Elbows	6.6
6-3 System Effect Curves for Inlet Obstructions	6.16
6-4	6.17
7-1 Duct Sizing, Supply Air System – Example 1	7.6
7-1(a) Duct Sizing, Supply Air System – Example 1 (Continued)	7.7
7-2 Duct Sizing, Exhaust Air System – Example 2 (I-P)	7.15
7-3 Duct Sizing, Exhaust Air System – Example 3 (I-P)	7.16
7-3(a) Duct Sizing, Exhaust Air System – Example 3 (I-P) (Continued)	7.17
7-4 Semi-extended Plenum Comparison	7.28
7-5 Semi-extended Plenum Installation Cost Comparison	7.28
7-6 Duct Sizing, Supply Air System – Example 1	7.30
7-6(a) Duct Sizing, Supply Air System – Example 1 (Continued)	7.31
7-7 Duct Sizing, Exhaust Air System – Example 2 (SI)	7.44
7-8 Duct Sizing, Supply Air System – Example 3	7.45
7-8(a) Duct Sizing, Supply Air System – Example 3 (Continued)	7.46
7-9 Semi-extended Plenum Comparison	7.53
7-10 Semi-extended Plenum Installation Cost Comparison	7.53
8-1 Filter Pressure Loss Data	8.1
8-2 Louver Free Area Chart 2 in. Blades At 45 Degree Angle	8.4
8-3 Louver Free Area Chart 4 in. Blades At 45 Degree Angle	8.5
8-4 Louver Free Area Chart 6 in. Blades At 45 Degree Angle	8.6
8-5 Air Outlets & Diffusers – Total Pressure Loss Average	8.15
8-6 Supply Registers – Total Pressure Loss Average	8.15
8-7 Return Registers – Total Pressure Loss Average	8.15
8-8 Typical Design Velocities	8.16
9-1 Airflow Measuring Instruments	9.11
10-1 Sound Sources, Transmission Paths, and Recommended Noise Reduction Methods	10.5
11-1 Sheet Metal Properties	11.4



FIGURES	Page
1-1 U.S.A. Building Codes and Ordinances	1.4
2-1 Relative Costs of Duct Segments Installed	2.6
2-2 Relative Installed Cost Versus Aspect Ratio	2.6
2-3 Relative Operating Cost Versus Aspect Ratio	2.7
3-1 Clothing Insulation Necessary for Various Levels of Comfort at a Given Temperature During Light, Mainly Sedentary Activities	3.3
3-2 Comfort Zone	3.6
3-3 Range of Average Air Movements Permitted in The Summer and Extended Summer Zones	3.7
3-4 Optimum Operative Temperatures for Active People in Low Air Movement Environments	3.9
3-5 Percentage of Occupants Objecting to Drafts in Air-conditioned Rooms (I-P)	3.11
3-6 Percentage of Occupants Objecting to Drafts in Air-conditioned Rooms (SI)	3.11
3-7 Surface (Coanda) Effect	3.13
3-8 Outlet Velocity and Air Direction Diagrams for Stack Heads With Expanding Outlets	3.16
3-9 Air Motion Characteristics of Group A Outlets	3.17
3-10 Air Motion Characteristics of Group B Outlets	3.18
3-11 Air Motion Characteristics of Group C Outlets	3.19
3-12 Air Motion Characteristics of Group D Outlets	3.19
3-13 Air Motion Characteristics of Group E Outlets	3.20
4-1 Duct Pressure Class Designation (I-P)	4.7
4-1M Duct Pressure Class Designation (SI)	4.8
4-2 Symbols for Ventilation and Air Conditioning (I-P)	4.9
4-2M Symbols for Ventilation and Air Conditioning (SI)	4.10
5-1 Capillary Action	5.2
5-2 Velocity Profile	5.3
5-3 Relation Between Friction Factor and Reynolds Number	5.4
5-4 Velocity Profiles of Flow in Ducts	5.7
5-5 Separation in Flow in a Diffuser	5.7
5-6 Changing Velocity Profiles At a Mitered Elbow	5.8
5-7 Effect of Duct Length On Damper Action	5.8
5-8 Part Duct Friction Loss Chart (I-P)	5.15
5-9 Part Duct Friction Loss Chart (SI)	5.16
5-10 Pressure Changes During Flow-in Ducts	5.24
5-11 Return Air Duct Example	5.24
5-12 To Calculate Splitter Vane Spacing for a Smooth Radius Rectangular Elbow	5.27
5-13 Turning Vanes Research	5.28
5-14 Turbulence Caused By Improper Mounting and Use of Turning Vanes	5.29
5-15 Proper Installation of Turning Vanes	5.30
5-16 AMCA Damper Tests	5.32
5-17 Duct Obstructions	5.32
5-18 Example 5-5 Fan/System Curve	5.34
5-19 Duct Leakage Classifications	5.35
5-20 Rectangular Elbow 90 Degree Throat, 90 Degree Heel	5.40
5-21 Different Configuration Elbow Research	5.41
5-22 End Tap Research	5.42
5-23 Fan Total Pressure (TP)	5.43
5-24 Fan Static Pressure (SP)	5.43
5-25 Fan Velocity Pressure (V_p)	5.43
5-26 Tip Speed	5.44
5-27 Centrifugal Fan Components	5.45
5-28 Axial Fan Components	5.46
5-29 Method of Obtaining Fan Performance Curves	5.47
5-30 Characteristic Curves for FC Fans	5.47
5-31 Characteristic Curves for BI Fans	5.48

5-32	Characteristic Curves for Airfoil Fans	5.48
5-33	Tubular Centrifugal Fan	5.48
5-34	Characteristic Curves for Tubular Centrifugal Fans	5.49
5-35	Characteristic Curves for Propeller Fans	5.49
5-36	Characteristic Curves for Vaneaxial Fans	5.49
5-37	Application of the Fan Laws	5.50
5-38	Centrifugal Fan Performance Table (I-P)	5.51
5-39	Centrifugal Fan Performance Table (Metric Units)	5.51
5-40	System Resistance Curve	5.52
5-41	Fan Curve Plots	5.53
5-42	Normalized Duct System Curves	5.54
5-43	Operating Point	5.54
5-44	Variations from Design – Air Shortage	5.54
5-45	Effect of 10 Percent Increase in Fan Speed	5.55
5-46	Interactions of System Curves and Fan Curve	5.56
5-47	Effect of Density Change (Constant Volume)	5.56
5-48	Effect of Density Change (Constant Static Pressure)	5.57
5-49	Effect of Density Change (Constant Mass Flow)	5.58
5-50	Duct System Curve Not At Design Point	5.59
5-51	AMCA Fan Test – Pitot Tube	5.60
5-52	Establishment of a Uniform Velocity Profile	5.61
5-53	Effects of System Effect	5.62
5-54	System Effect Curves for Inlet Duct Elbows – Axial Fans	5.63
5-55	Sample ASHRAE Fan System Effect “Loss Coefficients”	5.68
5-56	Changes from System Effect	5.69
5-57	Sensitivity of System Volume to Locations of Building Openings, Intakes, and Exhausts	5.70
5-58	Building Surface Flow Patterns	5.71
5-59	Pressure Difference Due to Stack Effect	5.72
5-60	Air Movements Due to Normal and Reverse Stack Effect	5.73
6-1	System Effect Curves	6.2
6-2	Controlled Diffusion and Establishment of a Uniform Velocity Profile in a Straight Length of Outlet Duct	6.3
6-3	Outlet Duct Elbows	6.5
6-4	Parallel Versus Opposed Dampers	6.7
6-5	Typical HVAC Unit Connections	6.8
6-6	Typical Inlet Connections for Centrifugal and Axial Fans	6.8
6-7	Non-uniform Flow into a Fan Inlet Induced by a 90 Degree Round Section Elbow – No Turning Vanes	6.9
6-8	Non-uniform Flow Induced into Fan Inlet by a Rectangular Inlet Duct	6.9
6-9	System Effects for Various Mitered Elbows Without Vanes	6.10
6-10	System Effects for Square Duct Elbows	6.11
6-11	Example of a Forced Inlet Vortex (Spin-Swirl)	6.12
6-12	Inlet Duct Connections Causing Inlet Spin	6.12
6-13	Corrections for Inlet Spin	6.13
6-14	AMCA Standard 210 Flow Straightener	6.13
6-15	System Effect Curves for Fans Located in Plenums and Cabinet Enclosures and for Various Wall to Inlet Dimensions	6.14
6-16	Enclosure Inlet Not Symmetrical With Fan Inlet, Prerotational Vortex Induced	6.14
6-17	Flow Condition of 6-16 Improved With a Splitter Sheet	6.14
6-18	Centrifugal Fan Inlet Box	6.15
6-19	Free Inlet Area Plane – Fan With Inlet Collar	6.16
6-20	Free Inlet Area Plane – Fan Without Inlet Collar	6.16
6-21	Typical Normalized Inlet Valve Control Pressure – Volume Curve	6.17
6-22	Common Terminology for Centrifugal Fan Appurtenances	6.18
7-1	Duct Systems for Duct Sizing Examples 1 and 2	7.5
7-2	Supply Air Duct System for Sizing Example 3	7.23
7-3	System “A” – Sized by Equal Friction Method	7.27
7-4	System “B” – Modified by Semi-extended Plenum Concept	7.28



7-5	Duct Sizing Work Sheet (I-P)	7.29
7-6M	Duct Systems for Duct Sizing Examples 1 and 2 (SI)	7.33
7-7M	Supply Air Duct System for Sizing Example 3	7.47
7-8M	Systems "A" Sized by Equal Friction Method	7.53
7-9M	"B" Modified by Semi-Extended Plenum Concept	7.54
7-10	Duct Sizing Work Sheet (I-P)	7.55
7-10M	Duct Sizing Work Sheet (SI)	7.56
8-1	System Pressure Loss Check List	8.3
8-2	Volume Dampers (*Based upon AMCA Certified Volume Dampers)	8.8
8-3	Backdraft or Relief Dampers	8.8
8-4	2-hour Fire & Smoke Dampers (Based on AMCA Certified Fire Dampers)	8.8
8-5	Heating Coils With 1 Row	8.9
8-6	Heating Coils With 2 Rows	8.9
8-7	Heating Coils With 3 Rows	8.9
8-8	Heating Coils With 4 Rows	8.9
8-9	Cooling Coils (Wet) 4 Row	8.10
8-10	Cooling Coils (Wet) 6 Row	8.10
8-11	Cooling Coils (Wet) 8 Row	8.10
8-12	Air Monitor Device	8.10
8-13	Louvers with 45° Blade Angle (*Based on AMCA Certified Louvers)	8.11
8-14	3 Rectangular Sound Traps – 3 Foot (1M)	8.11
8-15	Rectangular Sound Traps – 5 Foot (1.5M)	8.11
8-16	Rectangular Sound Traps – 7 Foot (2M)	8.11
8-17	Rectangular Sound Traps – 10 Foot (3M)	8.12
8-18	Round Sound Traps	8.12
8-19	Eliminators Three Bend	8.12
8-20	Air Washer	8.12
8-21	Screens	8.13
8-22	Air-to-Air Plate Exchangers (Modular)	8.13
8-23	Air-to-Air Single Tube Exchangers	8.13
8-24	Rotary Wheel Exchanger	8.13
8-25	Multiple Tower Energy Exchangers	8.14
8-26	Dry Air Evaporative Cooler	8.14
8-27	Recommended Criteria for Louver Sizing	8.17
9-1	Design Considerations for Diffuser Layouts and Balancing Damper Locations	9.2
9-2	Duct Design Considerations for Suggested Balancing Damper Locations	9.3
9-3	Design Considerations to Minimize Airflow Turbulence and Stratification from Terminal Boxes	9.4
9-4	Fan Rating Test	9.6
9-5	Typical Velocity Profiles Encountered in Velocity Pressure Measurement Planes ...	9.9
10-1	Source, Path, and Receiver	10.1
10-2	Mechanical Equipment Room Adjacent to Office Area	10.2
10-3	Illustration of Well- Balanced Hvac Sound Spectrum for Occupied Spaces	10.3
10-4	Frequency Ranges of the Most Likely Sources of Acoustical Complaints	10.4
10-5	Frequency At Which Different Types of Mechanical Equipment Generally Control Sound Spectra	10.4
10-6	Dissipative Passive Duct Silencers	10.9
10-7	Active Duct Silencer	10.9
10-8	External Duct Lagging on Rectangular Ducts	10.10
10-9	Breakout and Break-In of Sound in Ducts	10.11

CHAPTER 1

INTRODUCTION

This is a preview of "SMACNA 1958-2006". [Click here to purchase the full version from the ANSI store.](#)

1.1 SCOPE

This manual provides the duct system designer with the technical information required to design a complete air distribution system. This text has been extensively revised and updated, and now includes key portions of the previously separate Duct Design Home Course Study material.

1.2 HOW TO USE THIS MANUAL

This manual is divided into chapters that address each step of duct system design, layout, and sizing.

CHAPTER 1 INTRODUCTION

Brief introduction to the history, related building codes, smoke control, and system types for duct installations in commercial facilities.

CHAPTER 2 ECONOMICS OF DUCT SYSTEMS

How duct sizing and system layout impacts the economics for a project.

CHAPTER 3 ROOM AIR DISTRIBUTION

All of the design considerations related to room air distribution and indoor air quality.

CHAPTER 4 GENERAL APPROACH TO DUCT DESIGN

Basics of duct system design, including pressure losses, duct and diffuser noise, and basic system balancing issues.

CHAPTER 5 DUCT DESIGN FUNDAMENTALS

Fundamental elements of fan curves, pressure loss calculations, duct leakage, and duct heat gains and losses.

CHAPTER 6: FAN-DUCT CONNECTION PRESSURE LOSSES

Issues related to the transition from supply and return fans to the ductwork.

CHAPTER 7 DUCT SIZING PROCEDURES

Pressure loss design information for duct components including fittings, diffusers, registers, and duct transitions.

CHAPTER 8 PRESSURE LOSS OF SYSTEM COMPONENTS

Tables and graphs to estimate pressure drop for each component in a duct system.

CHAPTER 9 PROVISIONS FOR TESTING, ADJUSTING, AND BALANCING

How a new air distribution system should be balanced. Common duct system testing and balancing procedures.

CHAPTER 10 DESIGNING FOR SOUND AND VIBRATION

Noise generation and methods to reduce system noise.

CHAPTER 11 DUCT SYSTEM CONSTRUCTION

Construction and how duct material selection can improve indoor air quality.

CHAPTER 12 SPECIAL DUCT SYSTEMS

Kitchen and dishwasher exhaust ducts, and duct systems for corrosive and noxious gases.

APPENDIX

Tables and charts of duct design information in an easy to use format.

1.3 PURPOSE

The purpose of any heating, ventilating, and air conditioning (HVAC) duct system is to provide:

- a. Thermal comfort
- b. Humidity control
- c. Ventilation air
- d. Air filtration

However, a poorly designed or constructed HVAC duct system may result in a system that is costly to operate, noisy, and does not meet occupant comfort requirements.

This manual and associated SMACNA publications will assist both the system designer and the installer to provide an HVAC system that meets all these basic requirements.

1.4 HISTORY OF AIR DUCT SYSTEMS

Over 2,000 years ago, both the Greeks and Romans used masonry and terra cotta pipe to distribute flue gases from a central heating source to indirectly heat interior rooms and baths. The use of flues and ducts eventually disappeared until the twelfth century when heating fireplaces were moved from the center of a great-room to a sidewall, and chimneys or flues were used again.

