

Declaration of Catherine Vassilkova

1. I, Catherine Vassilkova, am an employee of BEADOX LLC ("BEA").
2. I am over the age of 21 and have personal knowledge of the facts contained herein unless otherwise indicated.
3. I have worked in the field of information research and document retrieval for law firms since 2005.
4. I have been with BEA since I established the company in 2019.
5. BEA, based in Silver Spring, MD, conducts research at the District of Columbia federal and local courts, archives, government agencies, and libraries around the world. BEA's services include interlibrary loans, specialized research, article location and delivery, and other document retrieval. One of my responsibilities is to scan textbooks for requesters.
6. BEA specializes in the research and delivery of materials from the Library of Congress.
7. On September 26, 2025, I was asked by the requester Morrison and Foerster LLP to obtain a scan from the following book: HVAC : handbook of heating, ventilation and air conditioning for design and implementation (1st ed. 2007).
8. On September 30, 2025, I obtained HVAC : handbook of heating, ventilation and air conditioning for design and implementation (1st ed. 2007) from the Library of Congress, and scanned the requested excerpts including book cover, title page, copyright page date-stamped (February 28 2009), table of contents pages, and chapter sections 13-1, 13-2 from HVAC : handbook of heating, ventilation and air conditioning for design and implementation (1st ed. 2007). Those excerpts are included as Exhibit 1019.
9. I confirm that the copyright page of the scanned book has a stamped date of receipt of February 28 2009.
10. I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and that these statements were made with knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code.
11. Executed on the 1st of October, 2025, in Silver Spring, MD 20910.

Signed:

C. Vassilkova

uded
2
FUL CD's

More detailed and comprehensive than other HVAC handbooks
More data, More tables, More graphs.
Plus 2 useful software packages!



This Handbook provides comprehensive technical information in a modular form to heating, ventilating, and air conditioning (HVAC) designers and practitioners, namely plant and design engineers, architects, technicians, contractors, and building managers. It is also a very useful reference for students mastering the intricacies of the HVAC rudiments. Each chapter and topic is self-contained to the extent possible and emphasis is placed on graphical and tabular presentations of data that are useful for easy understanding of fundamentals and for solving problems of design, installation, and operation. It provides in-depth coverage of both HVAC fundamental concepts and design processes, and is suitable for single or multiple-topic continuing education studies and training.

This Handbook includes two very useful software packages. The first is Bell and Gossett's **ESP-PLUS** software that provides calculations for the selection of equipment such as hydraulic pumps, heat exchangers, and hydronic and steam system components. This program also helps select commercially available equipment and components. The second is **Trane's Load 700** heating and cooling load calculation software that allows the designer to use detailed geometric, weather, and exposure parameters to accurately estimate load during the heating and cooling cycles.

Ali Vedavarz received his Ph.D. in mechanical engineering from Polytechnic University in Brooklyn, NY and is a licensed Professional Engineer in the State of NY. He is a member of ASME and ASHRAE and has published technical papers in ASME journals. He is currently Deputy Director of Engineering (for Design) in the Office of Capital Projects at the New York City Housing Authority and also Industry Professor at Polytechnic University.

Sunil Kumar received a doctoral degree in mechanical engineering from the University of California at Berkeley. He is presently Professor of Mechanical Engineering and the Dean of Graduate School and Associate Provost at Polytechnic University. Dr. Kumar has authored over 100 journal and conference papers in the area of thermal-fluid sciences.

Muhammed Iqbal Hussain received a master's degree in mechanical engineering from Polytechnic University. He is a licensed Professional Engineer in the State of NY and is presently working as a mechanical design engineer in the Department of Citywide Administrative Services in New York City. He is also a contributor to and editor of *Machinery's Handbook*.

INDUSTRIAL PRESS INC.
989 Avenue of the Americas, New York, NY 10018
Tel: 212-889-6330 Toll-Free: 1-888-528-7852
Fax: 212-545-8327
www.industrialpress.com info@industrialpress.com



Vedavarz
Kumar
Hussain

HVAC

Heating, Ventilation and Air Conditioning
for Design and Implementation

FT MEADE
MRC

TH 7011
.V46
2006
Copy 1



HVAC

The Handbook of
Heating, Ventilation and Air Conditioning
for Design and Implementation



Vedavarz • Kumar • Hussain

THIS HANDBOOK PROVIDES COMPREHENSIVE
TECHNICAL INFORMATION TO HEATING,
VENTILATING, AND AIR CONDITIONING
ENGINEERS, DESIGNERS AND PRACTITIONERS

HVAC:

Handbook of Heating, Ventilation and Air Conditioning for Design and Implementation

BY

ALI VEDAVARZ, PH.D., PE

*Deputy Director of Engineering, New York City Capital Projects,
New York City Housing Authority and
Industry Professor, Polytechnic University, Brooklyn, NY*

SUNIL KUMAR, PH.D.

*Professor of Mechanical Engineering and Dean of Graduate School
Polytechnic University, Brooklyn, NY*

MUHAMMED IQBAL HUSSAIN, PE

*Mechanical Engineer, Department of Citywide Administrative Services
New York City, NY*

2007

INDUSTRIAL PRESS INC.

NEW YORK

COPYRIGHT © 2007 by Industrial Press Inc., New York, NY.

Library of Congress Cataloging-in-Publication Data

Vedavarz, Ali.

HVAC: handbook of heating ventilation and air conditioning / Ali Vedavarz, Sunil Kumar, Muhammed Hussain.

p. cm.

ISBN 0-8311-3163-2

ISBN13 978-0-8311-3163-0

I. Heating--Handbooks, manuals, etc. 2. Ventilation--Handbooks, manuals, etc. 3. Air conditioning--Handbooks, manuals, etc. 4. Buildings--Environmental engineering--Handbooks, manuals, etc. I. Kumar, Sunil. II. Hussain, Muhammed Iqbal. III. Title.

TH7011.V46 2006

697--dc22

2006041837

Cover Photo: Image published with kind permission of CVRD and Bluhm Engineering.

INDUSTRIAL PRESS, INC.

989 Avenue of the Americas
New York, New York 10018 -5410

1st Edition

First Printing

10 9 8 7 6 5 4 3 2 1

Printed and bound in the United States of America

All rights reserved. This book or parts thereof may not be reproduced, stored in a retrieval system, or transmitted in any form without permission of the publishers.

TABLE OF CONTENTS

1.	FUNDAMENTALS	5.	LOAD ESTIMATING FUNDAMENTALS
1-1	Fundamentals of Thermodynamics	(Continued)	
1-3	Conservation of Mass	5-17	Relative Thermal Resistances of Building Materials
1-3	First Law of Thermodynamics	5-18	Surface Conductances and Resistances
1-4	Second Law, Reversibility, and Possible Processes	5-18	Emittance Values of Various Surfaces
1-4	Thermodynamic Cycles	5-19	Thermal Resistances of Plane Airspaces
1-6	Fundamentals of Fluid Flow	5-21	Thermal Properties of Building and Insulating Materials
1-6	Flow in Pipes and Ducts	5-27	Coefficients of Heat Transmission of Various Fenestrations
1-11	Noise from Fluid Flow	5-28	Transmission Coefficients for Wood and Steel Doors
1-11	Fundamentals of Heat Transfer	5-29	Outdoor Air Load Components
1-14	Overall Heat Transfer		
1-15	Fins and Extended Surfaces	6.	HEATING LOAD CALCULATIONS
1-18	Some Details of Heat Exchange	6-1	Introduction
1-19	Augmentation of Heat Transfer	6-1	Calculating Design Heating Loads
		6-2	Heat loss Through Walls, Roofs, and Glass Area
		6-2	Heat Loss from Walls below Grade
		6-3	Below-Grade Wall U-Factors
		6-3	Heat Loss from Basement Floor Below Grade
		6-4	Heat Loss Coefficients
		6-4	Heat Loss from Floor Slab On Grade
		6-6	Ventilation and Infiltration Heat Loss
2.	PSYCHROMETRY		
2-1	Psychrometrics	7.	COOLING LOAD CALCULATIONS
2-1	Ideal Gas Approximation	7-1	Transfer Function Method (TFM)
2-1	Equation of State	7-1	Heat Source in Conditioned Space
2-2	Humidity Ratio	7-2	Heat Gain from Occupants
2-2	Relative Humidity	7-3	Heat Gain from Cooking Appliances
2-2	Degree of Saturation	7-6	Heat Gain from Medical Equipments
2-2	Wet Bulb Temperature	7-6	Heat Gain from Computer
2-3	Partial Pressure of Water Vapor	7-6	Heat Gain from Office Equipments
2-4	Dew Point Temperature	7-6	CLTD/SCL/CLF Calculation Procedure
2-4	Saturation	7-7	Cooling Load by CLTD/SCL/CLF Method
2-4	Enthalpy	7-8	Roof Numbers
2-5	Wet Bulb Temperature	7-9	CLTD for Roofs
2-6	Properties of Moist Air	7-11	CLTD for Walls
2-7	Psychrometric Chart Presentation	7-27	Code Number for Wall and Roof
2-12	Thermodynamic Properties of Water at Saturation	7-28	Wall Types
2-18	Thermodynamic Properties of Moist Air	7-31	CLTD for Glass
		7-31	Zone Types for CLF Tables
		7-31	Zone Types for SCL and CLF Tables
		7-35	Residential Cooling Load Procedure
		7-36	SCL for Glass
		7-44	CLF for People and Unhooded Equipments
		7-46	CLF for Hooded Equipments
		7-47	Window GLF for Residences
		7-49	CLTD for Residences
		7-50	SC for Windows
		7-50	SLF for Windows
		7-50	Air Exchange Rates
3.	AIR CONDITIONING PROCESSES		
3-1	Introduction	8.	DUCT DESIGN
3-1	Heating and Cooling Process	8-1	Introduction
3-2	Cooling with Dehumidification	8-1	Pressure Head and Energy Equation
3-3	Heating with Humidification	8-2	Friction Loss Analysis
3-3	Adiabatic Mixing of Two Air Streams	8-7	Dynamic Losses
3-5	Evaporative Cooling	8-7	Ductwork Sectional Losses
3-5	Heating and Air Conditioning System Cycles	8-8	Fan System Interface
		8-8	Pressure Changes System
		8-9	Duct System Design
		8-9	Design Considerations
		8-12	Duct Design Methods
		8-13	Duct Design Procedures
		8-13	Automated Duct Design
		8-14	Duct Fitting Friction Loss Example
		8-14	Equal Friction Method Example
		8-15	Resistance in Low Pressure Duct System Example
		8-15	Static Regain Method Example
		8-17	Fitting Loss Coefficients
4.	INDOOR AIR QUALITY AND VENTILATION		
4-1	Indoor Air Quality		
4-1	Ventilation Procedure		
4-5	Concentration of Air Pollutants		
4-6	Indoor Air Quality Procedure		
4-8	Filters		
4-10	Hepa Filters		
4-10	Carbon Media Filters		
4-10	Fiber and Foam Filters		
4-10	Ozone		
4-10	Ultraviolet Light		
5.	LOAD ESTIMATING FUNDAMENTALS		
5-1	Conduction		
5-1	Thermal Conductivities of Materials		
5-2	Convection		
5-4	Thermal Radiation		
5-4	Emissivities of Some Materials		
5-6	Overall Heat Transfer Coefficient		
5-8	Parallel Arrangement		
5-11	Coefficient of Transmission		

9.	PIPE SIZING	10.	HYDRONIC HEATING AND COOLING SYSTEM
		(Continued)	
9-1	Pressure Drop Equations	10-8	Characteristics of Centrifugal Pumps
9-1	Valve and Fitting Losses	10-8	Operating Characteristics
9-3	Water Piping	10-9	Pump Laws
9-3	Flow Rate Limitations	10-9	Change of Performance
9-3	Noise Generation	10-10	Centrifugal Pump Selection
9-3	Erosion	10-10	Total Dynamic Head
9-3	Allowances for Aging	10-11	Net Positive Suction Head (NPSH)
9-4	Water Hammer	10-11	Pumping System
9-4	Hydronic System Piping	10-16	Parallel Pumping
9-6	Valve and Fitting Pressure Drop	10-17	Series Pumping
9-28	Service Water Piping	10-18	Design Procedures
9-29	Plastic Pipe	10-18	Preliminary Equipment Layout
9-29	Cold Water Pipe Sizing	10-19	Final Pipe Sizing and Pressure Drop Determination
9-31	Steam Flow in Pipes	10-19	Final Pressure Drop
9-31	Steam Flow Formulas	10-19	Final Pump Selection
9-32	Vertical Pipes	10-19	Freeze Prevention
9-32	Steam Piping		
9-59	Gas Piping For Buildings	11.	ENERGY CALCULATION
9-59	Residential Piping		
9-61	Commercial-Industrial Piping	11-1	Degree Day
9-72	Compressed Air Systems	11-1	65°F as the Base
9-72	Compressed Air	11-2	Application of Degree Days
9-78	Viscosity of Liquids	11-4	Predicting Fuel Consumption
9-80	Piping	11-5	Predicting Future Needs
9-80	Types of Materials	11-7	Empirical Constants
9-91	Plastics Pipe	11-7	Load Factor and Operating Hours
9-91	Joining Techniques	11-7	Limitations
9-93	Standards for Specification and Identification	11-8	Degree-Days Abroad
9-93	Design Parameters	11-9	Degree Days for Various US Locations
9-96	Installation		
9-97	Codes and Regulations	12.	COMBUSTION
9-97	Pipe Fittings		
9-97	Taper Pipe Thread	12-1	Combustion Basics
9-132	Laying Lengths of Pipe with Screwed Fittings	12-3	Efficiency Calculations
9-134	Allowable Spaces for Pipes	12-7	Saving Fuel with Combustion Controls
9-134	Expansion of Pipe	12-11	Combustion Considerations
9-136	Corrosion Resistance	12-11	Pressure and Flow Basic Principles
9-136	Pipe Support Spacing	12-12	Atomizing Media Considerations
9-139	Gate, Globe, and Check Valves	12-12	Combustion Air Considerations
9-139	Operation	12-13	Flue Gas Considerations
9-141	Maintenance Methods	12-14	Gas Fuel Firing Considerations
9-142	Formulas for Sizing Control Valves	12-14	Fuel Oil Firing Considerations
9-142	To Determine Valve Size	12-15	Operational Rules of Thumb
9-142	To Determine Valve Capacity	12-16	Common Application
9-142	For Vapors Other Than Steam	12-20	Combustion Control Strategies
9-143	Identification of Piping Systems	12-20	Control System Errors
9-143	Dangerous Materials	12-21	Parallel Positioning Systems
9-143	Fire Protection Materials and Equipment	12-22	Fully Metered Control
9-144	Safe Materials	12-23	Feedwater Control Systems
9-144	Protective Materials	12-24	Draft Control
9-144	Method of Identification	12-26	Oxygen Trim
9-144	Heat Losses in Piping	12-27	Combustion Air Flow Control Techniques
9-144	Heat Losses from Bare Pipe	12-28	Flue Gas Recirculation (FGR)
9-145	Heat Losses from Steam Piping	12-33	Fuel Oil Handling System Design
9-157	Heat Loss from Insulated Pipe	12-33	Determination of Required Flow Rate
9-158	Cold Surface Temperature	12-34	Stand by Generator Loop Systems
		12-34	Multiple Pumps
10.	HYDRONIC HEATING AND COOLING SYSTEM	12-34	Burner Loop Systems
10-1	Basic System	12-36	Maximum Inlet Suction
10-4	Temperature Classifications	12-37	Pump Discharge Pressure
10-4	Closed Hydronic System Components Design	12-37	Piping System Design
10-4	Convectors or Terminal Units	12-37	Pump Set Control System Strategies
10-4	Boiler		
10-4	Air Eliminations Methods		
10-6	Pressure Increase Due to Change in Temperature		
10-6	Expansion Tank		
10-7	Expansion Tank Sizing		

13.	AIR CONDITIONING SYSTEMS	13.	AIR CONDITIONING SYSTEMS
		(Continued)	
13-1	Air Conditioning Systems	13-91	Hot Water System Control
13-1	Single Package Units	13-94	Mixing Box Control
13-5	Single Package Installations	13-95	Rotary Air-to-Air Heat Exchanger Control
13-7	Installation of Split Systems	13-95	Automatic Control for Dual Duct System
13-8	Zoning Unitary Installations	13-97	Winterizing Chilled Water System
13-10	Selection Procedure	13-97	Water Circulation to Prevent Freeze-Up
13-14	Evaporative Air Conditioning	13-99	Mechanical Draft Cooling Towers
13-14	Permissible Air Motion	13-102	Atmospheric Cooling Towers
13-17	Variable Volume AC System	13-104	Quantity of Cooling Water Required
13-18	Initial Costs	13-105	Roof is a Location for AC Equipment
13-20	Cooling Considerations	13-105	Advantages of Roof
13-21	Overlapping	13-106	Disadvantages of Roof
13-22	Heat Recovery	13-107	Servicing Cooling Plant
13-22	Heating Cooling Systems	13-107	Servicing Cooling Plant for Summer Use
13-23	Air Systems	13-107	Water System
13-26	Controls	13-107	Air Handling System
13-27	Air Water Systems	13-107	Compressor Oil
13-30	Sources of Internal Heat	13-107	Condenser
13-31	Heat from Service Refrigeration	13-108	Refrigeration Unit
13-31	Exhaust Air Heat Recovery Systems	13-108	Check Oil
13-36	Heat Pumps	13-108	Compressor
13-36	Reverse-Cycle Principle	13-108	Air Conditioning Equipment Maintenance
13-36	Coefficient of Performance	13-108	Air Handling Equipment
13-37	Heating Season Performance Factor	13-108	Air Distribution Equipment
13-37	Types of Heat Pumps	13-108	Water-Using Equipment
13-38	Air-to-Air Heat Pumps	13-108	Cooling Equipment
13-39	Water-to-Water Heat Pumps	13-110	Air Conditioning Maintenance Schedule
13-40	Water-to-Air Heat Pumps	13-111	Unit Air Conditioners
13-40	Air-to-Water Heat Pumps	13-111	Central Systems
13-41	Ground Source Heat Pumps	13-111	Condensing Water Circuit
13-41	Special Heat Sources	13-112	Cooling Water System
13-42	Operating and Installation Factors	13-112	Filters and Ducts
13-42	Outdoor Temperature Effects	13-112	Air Conditioning Maintenance Procedure
13-43	Thermostats	13-112	Refrigerant Circuit and Controls
13-43	Heat Anticipators	13-113	Condensing Water Circuit
13-44	Equipment Arrangement	13-113	Cooling Water System
13-44	Electrohydraulic Heat Recovery	13-113	Filters and Ducts
13-45	Cooling Cycle	13-114	Rotating Apparatus
13-47	System Design	13-114	Unit Air Conditioners
13-47	Supplementary Heat	13-114	Checklist for Air Conditioning Surveys
13-47	Optimized Data for Heat Pump		
13-48	Development of Equations	14.	AIR HANDLING AND VENTILATION
13-48	Development of Tables		
13-49	Selecting Air Handling Units	14-1	Terminology, Abbreviations, and Definitions
13-54	Well Water Air Conditioning	14-3	Fan Laws
13-54	Heat Pump/Solar Energy Application	14-11	Fan Performance Curves
13-54	System Description and Operation	14-16	Class Limits for Fans
13-60	High Velocity Dual Duct Systems	14-21	Fan Selection
13-60	Advantages and Disadvantages	14-26	Fan Inlet Connections
13-60	Dual Duct Cycles	14-27	Fan Discharge Conditions
13-65	Duct Sizing Technique	14-31	Useful Fan Formulas
13-65	Large vs. Small Ducts	14-32	Nomographs for Fan Horsepower
13-66	Design Velocity	14-32	Monographs for Fan Horsepower and Actual Capacity
13-66	Maximum Velocity	14-34	Fan Selection Questionnaire
13-67	Sizing High Pressure Ducts	14-37	Air Flow in Ducts
13-68	Return Air Ducts	14-40	Pitot Traverse
13-68	Low Pressure Ductwork	14-40	Friction Losses
13-69	Basic Arrangement	14-40	Correction for Roughness
13-69	Zoning	14-40	Rectangular Duct
13-70	Ceiling Plenum	14-52	Air Balancing and Air Turning Hardware
13-73	Modular Type Office Buildings	14-56	Air Distribution
13-76	Constant Volume Mixing Units	14-56	Fire Dampers and Fire Protection
13-77	Apparatus Floor Area	14-56	Duct System Design
13-80	Construction Details	14-59	High Velocity System Design
13-81	Automatic Control Applications	14-68	Step by Step Design
13-81	Rooftop Multizone Units	14-68	Main Duct
13-84	Multizone Unit Control	14-70	Branch Trunk Ducts
13-88	Damper Control	14-71	Single Branch Lines
13-88	Economizer Control Cycle	14-72	Duct Design by Computer
13-88	Unit Ventilator Control	14-73	Fibrous Glass Duct Construction

14. AIR HANDLING AND VENTILATION

(Continued)

14-75	Determining Required Air Volume
14-75	Estimating Weight of Metal
14-77	Apparatus Casing Construction
14-77	Condensate Drains for Air Conditioning Units
14-78	Air Filters and Dust Collectors
14-78	Air Filters
14-79	Dust Collectors
14-82	Dry Centrifugal Collectors
14-82	Wet Collectors
14-82	Fabric Collectors
14-83	Electrostatic Precipitators
14-83	Breeching Design and Construction
14-83	Expansion
14-84	Aerodynamics
14-85	Access
14-85	Round Breeching Construction
14-85	Rectangular Breeching Construction
14-90	Chimney Draft and Velocities
14-92	Forced Draft and Draft Control
14-94	Sizing of Large Chimneys
14-95	Chimney Design and Construction
14-96	Balancing Small Air Conditioning Systems
14-97	Balancing Medium and Large Systems
14-98	Balancing Duct Distribution
14-98	Balancing Systems Using Booster Fans
14-99	Air Balancing by Balancing and Testing Engineers

15. STEAM HEATING SYSTEM DESIGN

15-1	Large Systems
15-1	Equivalent Direct Radiation
15-1	Piping Connections to Boilers
15-3	Direct Return Connection
15-3	Common Return Header
15-3	Two Boilers with Common Return Header and Hartford Connection
15-4	Two Boilers with Separate Direct Return Connections from Below
15-4	Separate Direct Return Connections
15-4	Connections to Steam Using Equipment
15-26	Piping Application
15-30	Industrial and Commercial Steam Requirements
15-39	Flash Steam Calculations
15-40	Sizing of Vertical Flash Tanks
15-40	To Size Flash Tank
15-41	To Size Float Trap
15-41	Airbinding
15-46	Estimating Friction in Hot Water Piping
15-49	Hot Water Heating Systems
15-49	Service Water Heating
15-49	Operating Water Temperature
15-49	Air Removal from System
15-49	Water Flow Velocity
15-49	Prevention of Freezing
15-49	Water Circulation below Mains
15-49	Limitation of Pressure
15-50	System Adaptability
15-50	Use of Waste Steam Heat
15-50	Heat from District Steam System
15-50	Summer Cooling
15-50	Types of Water Heating Systems
15-52	Design Recommendations for Hot Water Systems
15-52	Water Velocity
15-52	Pump Location
15-52	Air Venting
15-53	Balancing Circuits
15-53	Filling Pressure
15-53	Preventing Backflow
15-53	Connecting Returns to Boiler
15-53	Locating the Circulating Pump

15. STEAM HEATING SYSTEM DESIGN

(Continued)

15-53	Sizing the Expansion Tank
15-54	Compressed Air to Reduce Tank Size
15-54	Piping Details
15-55	Design of Piping Systems
15-58	Design of Two Pipe Reversed Return System
15-58	Final Check of Pipe Sizes
15-58	Design of Two Pipe Direct Return System
15-59	Piping for One-Pipe Diversion System
15-59	Sizing Piping for Main
15-59	Sizing Piping for Branches
15-59	Pipe Size Check
15-60	Piping for One-pipe Series System
15-60	Combination of Piping Systems
15-60	Sizing Hot Water Expansion Tanks
15-60	Conditions Affecting Design
15-61	Sizing Hot Water Expansion Tanks
15-61	High Temperature Water Systems
15-63	High Temperature Drop
15-63	Heat Storage
15-63	Limitation of Corrosion
15-63	Pressurization of HTW System
15-63	Steam Pressurization
15-64	Gas Pressurization
15-64	Air Pressurization
15-64	Nitrogen Pressurization
15-65	Expansion Tanks
15-65	Expansion Conditions
15-65	Determining Expansion Tank Size
15-65	Location of Steam Pressurizing Tank
15-66	Nitrogen Pressurizing Tanks
15-66	Application of HTW for Process Steam
15-66	Circulating Pumps
15-67	Pumps for HTW Systems
15-67	Manufacturer's Information
15-67	Pump Specifications
15-68	Net Positive Suction Head
15-68	Effect of Cavitation Within Pump
15-68	Pump Construction for HTW Systems
15-68	Circulating Pump Seals
15-69	Boiler Recirculating Pump
15-69	Boilers for HTW Systems
15-69	Boiler Emergency Protection
15-69	Pipe, Valves, and Fittings for HTW Systems
15-69	Valve Installation
15-70	Welded Joints
15-70	Venting of Piping
15-70	Effect of Load Variation on Operation
15-71	Pipe Sizing for HTW Systems
15-73	Ratings of Steel Boilers
15-73	Ratings
15-74	Ratings for Steel Boilers
15-76	Stack Dimensions
15-81	Heating and Cooling Media
15-81	Brine
15-81	Glycerine
15-81	Glycol
15-81	Other Media
15-82	Warm Air Heating
15-82	Early Types
15-83	Current Types
15-85	Furnace Performance
15-85	Testing and Rating of Furnaces
15-86	Acceptable Limits
15-87	Selection of Furnace
15-87	Rule for Selection
15-87	Blower Characteristics
15-88	Blower Sizes
15-88	Duct System Characteristics
15-88	Trends
15-89	Warm Air Registers
15-90	Return Air Intakes

15. STEAM HEATING SYSTEM DESIGN

(Continued)

15-91	Arrangement of Furnace and Ducts
15-94	Basic Thermostatic Controls
15-94	Continuous Air Circulation
15-95	Continuous Blower Operation
15-95	Intermittent Blower Operation
15-109	Steam Supplied Unit Heater
15-109	Gas Fired Radiant Heaters
15-112	Sizing of Steam Traps
15-117	Unit Heaters
15-124	Checklist for Heating System Servicing

16. NOISE AND VIBRATION CONTROL

16-1	Noise and Vibration
16-1	Definitions and Terminology
16-2	Noise Criteria
16-2	Speech Interference Criteria
16-2	Sound Levels of Sources
16-7	Ratings and Standards
16-7	Airborne Sound Transmission
16-7	Vibration Isolation
16-9	Isolation Mount Selection
16-13	Airborne Noise Through Ducts
16-13	Regenerated Noise
16-13	Other Mechanical Noise Sources
16-14	Calculation of Sound Levels from HVAC Systems
16-14	Description of Decibels
16-14	Addition of Decibels
16-15	The Sabin
16-17	Determination of Sound Pressure Level
16-20	Noise in Ducted Systems
16-23	Fan Noise Generation
16-23	Estimating Fan Noise
16-24	Distribution of Sound Power at Branch Takeoffs
16-24	Attenuation of Untreated Duct
16-24	Duct Lining Attenuation
16-25	Sound Attenuation of Plenums
16-26	Duct Lining and Elbows
16-27	Open End Reflection Loss
16-27	Air Flow Noise
16-31	Flow Noise Generation of Silencers
16-31	Sound Transmission Through Duct Walls
16-32	Calculation of Sound Levels in Ducted Systems
16-36	Control of Cooling Tower Noise
16-36	Fan Noise
16-37	Water Noise
16-37	Drive Components
16-37	External Noise Sources
16-38	Configuration Factors
16-39	Location
16-39	Reducing Sound Generated
16-39	Half-Speed Operation
16-39	Oversizing of the Tower
16-39	Changing Leaving Conditions
16-40	Sound Absorbers
16-40	Obtaining Desired Sound Levels
16-40	Acoustical Problems in High Velocity Air Distribution
16-40	System Noise
16-42	Air Handling Apparatus Rooms
16-42	Selection of Fan Isolation Bases
16-42	Apparatus Casings
16-42	Dampers and Air Valves
16-43	Flexible Connectors
16-43	Air Distributing Systems
16-43	Duct Velocities
16-43	Choice of Duct Design Method
16-43	Ductwork Adjacent to Apparatus Room
16-44	Duct Connections to Apparatus Casings
16-44	Type Duct Construction
16-44	Fittings for High Velocity Ductwork

16. NOISE AND VIBRATION CONTROL

(Continued)

16-45	Take-off Fittings
16-45	Dual Duct Area Ratio
16-46	Dampers as a Noise Generating Source
16-46	Sound Barrier for High Velocity Ductwork
16-46	Sound Traps
16-46	Cross Over of Horizontal Dual Duct Mains
16-47	Testing of High Pressure Ductwork
16-47	Terminal Devices
16-48	Radiation Protection at Wall Openings for Duct or Pipe
16-49	Medical Installations

17. MOTORS AND STARTERS

17-1	NEMA Motor Classifications
17-1	Locked Rotor Torque
17-2	Classification of Single-Phase, Induction Motors by Design Letter
17-2	Torque, Speed, and Horsepower Ratings for Single-Phase Induction Motors
17-3	Classification by Environmental Protection and Method of Cooling
17-3	Standard Voltages and Frequencies for Motors
17-6	The National Electrical Code
17-6	Grounding
17-8	Motor and Load Dynamics, and Motor Heating
17-8	Torque Speed Relationships
17-9	Torque, Inertia, and Acceleration Time
17-10	Dynamics of the Motor and the Load
17-11	Motor Heating and Motor Life
17-12	Rotor Heating During Starting
17-12	Single Phase Motors
17-12	Types of Motors
17-15	Repulsion-Induction
17-15	Large Single-Phase Motors
17-16	Application
17-17	Loading
17-18	Motor Protection
17-18	Motor Selection
17-18	Analysis of Application
17-19	Polyphase Motors
17-19	Enclosure
17-20	Bearings
17-20	Quietness
17-20	Polyphase, Squirrel Cage Induction Motors
17-21	Speed Control
17-21	Two-Speed Polyphase, Squirrel Cage Induction Motors
17-21	Two Speed Motors Come in Two Types
17-23	Wound-Rotor Polyphase Induction Motors
17-24	Variable Speed
17-24	Synchronous Motors
17-25	Hermetic Type Motor Compressors
17-25	Hermetic Compressors to 5 hp
17-29	Starters
17-29	Motor Controllers
17-29	Overcurrent Protection
17-30	Overload Protection
17-31	Starters for Large AC Motors
17-33	Winding and Reduced-voltage Starting
17-33	Electric Utility Limitations
17-33	Minimizing Mechanical Shocks
17-33	Application
17-36	Types of Starters
17-36	Open Circuit Transition
17-37	Advantages and Disadvantages
17-39	Useful Formulas
17-39	Electric Motor Maintenance

18. DESIGN PROCEDURE, ABBREVIATIONS, SYMBOLS	
18-1	Design Procedure
18-1	Contract and Mechanical Drawings
18-1	HVAC Drawings
18-1	Floor Plans
18-5	Valve Symbols
18-6	Piping Symbols
18-7	Pipe Fittings Symbols
18-8	Abbreviations for Scientific and Engineering Terms
18-9	Lists of Abbreviations and Symbols
19. CLIMATIC DESIGN INFORMATION	
19-1	Climatic Design Conditions
19-1	Applicability and Characteristics of the Design Conditions
19-27	Dry Bulb and Wet Bulb Temperature for US Locations
20. UNITS AND CONVERSIONS	
20-1	U.S. Customary Unit System
20-1	Linear Measures
20-1	Surveyor's Measure
20-1	Nautical Measure
20-1	Square Measure
20-1	Cubic Measure
20-1	Shipping Measure
20-2	Dry Measure
20-2	Liquid Measure
20-2	Old Liquid Measure
20-2	Apothecaries' Fluid Measure
20-2	Avoirdupois or Commercial Weight
20-2	Troy Weight, Used for Weighing Gold and Silver
20-2	Apothecaries' Weight
20-2	Measures of Pressure
20-3	Miscellaneous
20. UNITS AND CONVERSIONS	
(Continued)	
20-4	U.S. System And Metric System Conversion
20-4	Length and Area
20-4	Mass and Density
20-5	Volume and Flow
20-6	Force, Energy, Work, Torque and Power Conversion
20-7	Velocity and Acceleration
20-8	Metric Systems Of Measurement
20-8	Measures of Length
20-8	Square Measure
20-8	Surveyors Square Measure
20-8	Cubic Measure
20-8	Dry and Liquid Measure
20-8	Measures of Weight
20-10	Binary Multiples
20-10	Terminology of Sheet Metal
21. INDEX	

This Handbook provides comprehensive technical information in a modular form to heating, ventilating, and air conditioning (HVAC) designers and practitioners, namely engineers, architects, contractors, and plant engineers. It is also a handy reference for students mastering the intricacies of the HVAC rudiments. Each chapter is self-contained to the extent possible and emphasis is placed on graphical and tabular presentations of data that are useful for easy understanding of fundamentals and solving problems of design, installation, and operation.

This Handbook draws upon the material presented in the *Handbook of Air Conditioning, Heating, and Ventilating, Third Edition*, Industrial Press, which forms the basis of the presentation. New topics and chapters have been introduced and previous information updated or rewritten. Examples using software solution tools have been added alongside traditional solutions using formulae from the handbook. The organization, however, remains, in the literal sense, a handbook.

We gratefully acknowledge the contributors and editors of the aforementioned *Handbook of Air Conditioning, Heating, and Ventilating*, whose knowledge is embedded throughout the present book. We did not have the opportunity to meet any of them, but their written legacy has left an indelible imprint on the present work.

An important source of information is the ASHRAE (American Society of Heating, Refrigerating, and Air-Conditioning Engineers) repertoire of publications. ASHRAE serves as the authoritative, and occasionally the sole, source of up-to-date HVAC related data and analysis. We acknowledge their permission to use material from various publications, especially the latest ASHRAE Handbook series.

ASHRAE Publications
1791 Tullie Circle, NE
Atlanta, GA 30329
Web Site: www.ashrae.org

We also acknowledge three corporations for supplying us with material for inclusion in the Handbook. We profusely thank Mr. Michael White of Bell & Gossett (an ITT Division), Mr. Kent Silveria and Mr. Thomas Gorman of Trane Corporation, and Mr. Steven Boediartho of Preferred Utilities, for facilitating the acquisition of these materials.

The Bell & Gossett corporation has graciously provided the ESP-PLUS software package to accompany the Handbook. This software, a \$100 value, permits users to select components based on design or operating conditions.

Bell & Gossett (ITT Fluid Handling)
8200 N. Austin Ave
Morton Grove, IL 60053
Web Site: www.bellgossett.com

The Trane corporation has generously allowed us to include their Trace Load 700 load calculation limited capability demonstration version software with the Handbook.

Trane C.D.S. Department
3600 Pammel Creek Road
La Crosse, WI 54601
Web Site: www.trane.com

AIR CONDITIONING SYSTEMS

AIR CONDITIONING SYSTEMS

A unitary air conditioner is an apparatus consisting of one or more factory made assemblies that normally include an evaporator, a blower, a compressor, and a condenser, designed to be used together. The unit often performs heating as well as cooling functions.

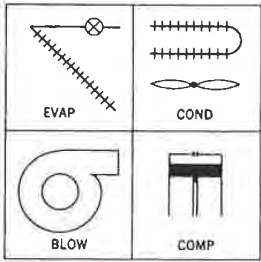


Fig 13-1. Self contained air conditioner

Air Conditioning Systems

Single Package Units.—The single package, or so-called *self-contained* air conditioner, is shown symbolically in Fig. 13-1. All four basic components of the refrigeration cycle are placed in a single *package* or housing. Vertical single-package equipment is usually designed for inside-the-building application. Units often are equipped with line voltage controls, including integral thermostat, all factory prewired. Return air filter and grille are standard with supply air duct flanges usually located at the top of the unit. Most AC units have water-cooled condensers, which can be used with either city water or cooling tower water. Fig. 13-2 is a typical unit of this type. When it is necessary to install a unit without ductwork, a plenum and grille may be fitted to the unit for free air delivery.

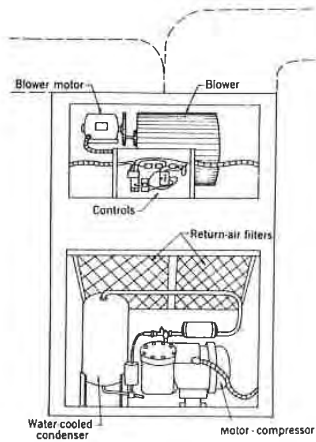


Fig 13-2. Vertical self contained air conditioned unit

Vertical units are available for installation in the space (the traditional *store cooler*) or with more utilitarian cabinets (sometimes designated *commercial*) for remote location; especially where space and noise factors assume extra importance. Commercial units are available in capacities to 50 tons and higher.

Horizontal single package units (Fig. 13-3) are designed for both indoor and outdoor installation, with the majority of units incorporating air cooled or evaporative-cooled condensers. The most common design has supply and return air connections located in the same face with horizontal air flow. Since horizontal units are designed for remote location, they are usually equipped with low voltage thermostat control. Filters are not usually supplied with the unit.

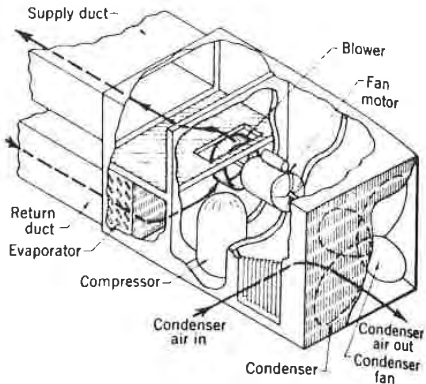


Fig 13-3. Horizontal self contained air conditioned unit

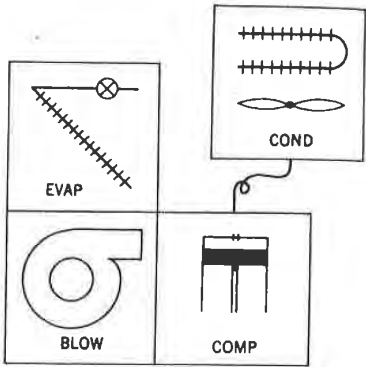


Fig 13-4. Vertical self contained air conditioned unit

Horizontal units are manufactured in capacities from 2 to 20 tons with many modifications for use in residential and light commercial applications. Their outstanding virtue is flexibility, as they can be installed, with ducted air for condensing; outdoors with ducted conditioned air supply and return; and through the wall. Indoors, they can be

floor, wall, or ceiling-mounted, and placed in the attic, basement, or in the conditioned space.

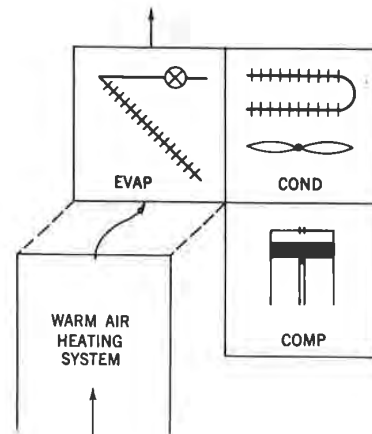


Fig 13-5. Warm air heating system

Units with Remote Condensers: Unitary air conditioners with remote condenser, piped and charged in the field, are basically the same as store coolers but with remote air cooled condensing substituted for integral water cooled condenser.

Refrigeration Chassis: Units in this category are designed to be used with a warm air heating system whose blower supplies the air for the units cooling coil (see Fig. 13-5).

In one version, the compressor-condenser is connected to the evaporator only by several feet of precharged refrigerant line for not too remote location, (see Figs. 13-6 and 13-7). These units are somewhat of a cross between single-package and split systems. Refrigeration chassis are available, also, with (truly) remote air-cooled condensers.

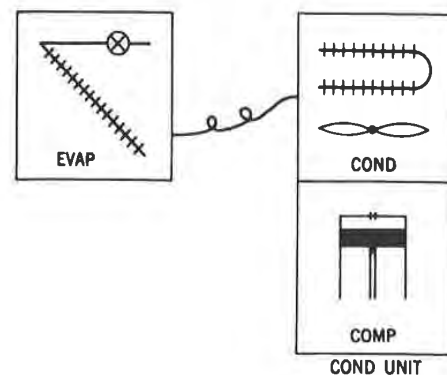


Fig 13-6. Split condenser and evaporator unit

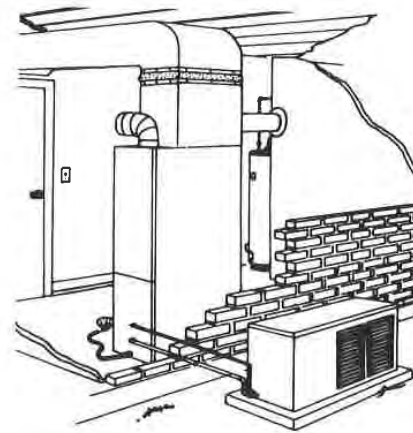


Fig 13-7. Warm air heating system

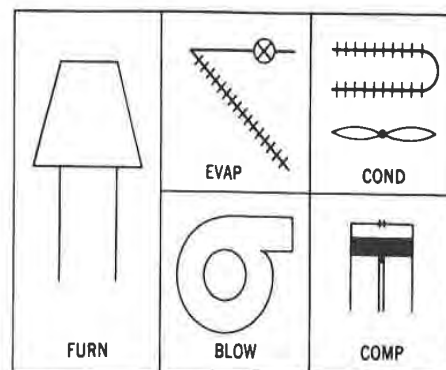


Fig 13-8. Single package year round unit

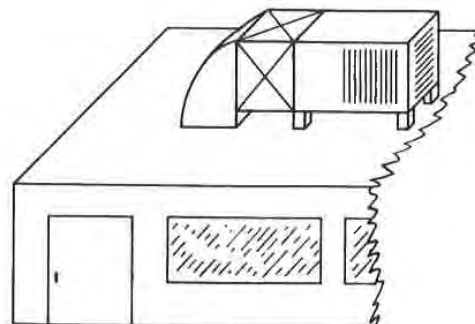


Fig 13-9. Roof mounted A-C unit

Single-Package Year-Round Units: Operated by a factory-wired, interconnected control system through a single heating-cooling thermostat, these units contain a fuel-fired heat exchanger and a factory-sealed and charged

refrigeration cycle, (see Fig. 13-8). There are water cooled models designed for installation indoors, but by far the majority are designed for roof mounting with air condensing (see Fig. 13-9). Units are available with natural gas engine compressor drive.

Year-Round Remote Units: These units are the single-package and single package with remote condenser units with heating units attached (see Fig. 13-10).

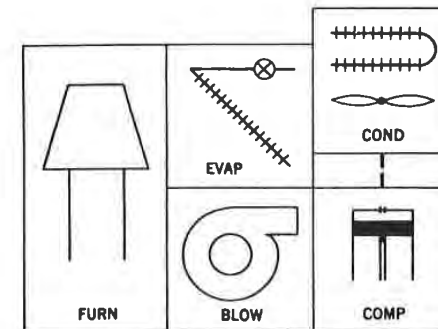


Fig 13-10. Year round air conditioner with remote air cooled conjurers

The round air unit, year-round air conditioner with remote condensing unit (Fig. 13-11) makes the real jump to the *split system*. In the case of both units, interconnecting refrigerant piping is usually field-supplied.

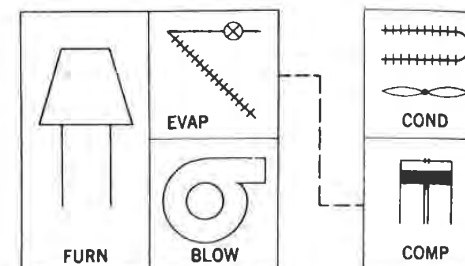


Fig 13-11. Split system year round air conditioner

Remote Condensing Units: A split system air conditioner is a unitary conditioner whose components are assembled in more than one factory made enclosure. The cooling coil is remote from the condensing unit. Because of its similarity to the single package air conditioner units whose condensers only are remote, and refrigeration chassis with or without remote condenser, have already been discussed in conjunction with single-package air conditioners, although they are not truly single package.

Split system components include electric and engine-driven condensing units, remote gas-fired water chillers, cooling coils (evaporators without blowers), and cooling coils with blowers. There is more split-system equipment available than any other type.

Condensing units contain compressor, condenser, and electrical controls. Air cooled and evaporative-cooled

condenser models also contain a fan and fan motor. Units are normally designed for outdoor installation, but some models are designed for indoor or through the wall installations (Figs. 13-12 and 13-13).

Evaporator coils (Fig. 13-14) come in a multitude of sizes and designs. Coils for use with warm air heating systems are available for upflow, downflow, and horizontal air patterns, that is, in bonnet units, under the furnace units, and duct units, respectively.



Fig 13-12. Remote condensing unit application

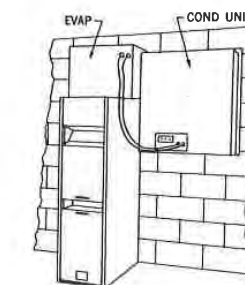


Fig 13-13. Split system, flush wall condensing unit

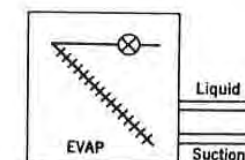


Fig 13-14. Evaporator coils in conjunction with warm air furnace

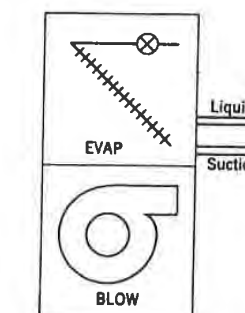


Fig 13-15. Coil with blower units