

2013 ASHRAE® HANDBOOK

FUNDAMENTALS

Inch-Pound Edition

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THE PROFESSION AND ITS ALLIED INDUSTRIES**

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Volunteer members of ASHRAE Technical Committees and others compiled the information in this handbook, and it is generally reviewed and updated every four years. Comments, criticisms, and suggestions regarding the subject matter are invited. Any errors or omissions in the data should be brought to the attention of the Editor. Additions and corrections to Handbook volumes in print will be published in the Handbook published the year following their verification and, as soon as verified, on the ASHRAE Internet Web site.

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CONTRIBUTORS

In addition to the Technical Committees, the following individuals contributed significantly to this volume. The appropriate chapter numbers follow each contributor's name.

James T. Schaefer, Jr. (1, 2)
Heat Transfer Research, Inc.

Yongfang Zhong (1, 2)
Penn State Erie

Timothy Wagner (2)
United Technologies Research Center

Uwe Rockenfeller (2)
Rocky Research

Reinhard Radermacher (2)
University of Maryland

Rick Couvillion (3, 4, 5, 6)
University of Arkansas

Michael M. Ohadi (4, 5, 6)
University of Maryland

Kyosung Choo (4, 5)
University of Maryland

Mirza M. Shah (5)

Gary Cloe (7)
Belimo Aircontrols

Chad Moore (7)
Engineering Resource Group, Inc.

Dave Kahn (7)
RMH Group

Jerry Lilly (8)
JGL Acoustics

Rich Peppin (8)
Engineers for Change, Inc.

Kenneth Roy (8)
Armstrong World Industries

Steve Wise (8)
Wise Associates

Hui Zhang (9)
University of California–Berkeley

Dennis Loveday (9)
Loughborough University

Eric Adams (9)
Carrier Corporation

Pawel Wargoeki (10)
DTU Civil Engineering

Zuraimi Sultan (10)
National Research Council Canada

Hal Levin (10)
Building Ecology Research

Jan Sundell (10)
Tsinghua University

Carolyn (Gemma) Kerr (11)

Chang-Seo Lee (11)
Concordia University

Charlene W. Bayer (11)
Hygieia Sciences LLC

Ashish Mathus (11)
UVDI, Inc.

Robert Morris (14)

Chris A. Gueymard (14)
Solar Consulting Services

Didier Thevenard (14)
Numerical Logics, Inc.

Mike Collins (15)
University of Waterloo

John Hogan (15)
Seattle Department of Planning and
Development

John Wright (15)
University of Waterloo

David P. Yuill (16, 36)
Building Solutions, Inc.

W. Stuart Dols (16)
National Institute of Standards and
Technology

Charles S. Barnaby (17, 19)
Wrightsoft

Steve Bruning (18)
Newcomb & Boyd

James F. Pegues (18)
Carrier Corporation

Christopher K. Wilkins (18)
Hallam-ICS

Ron Judkoff (19)
National Renewable Energy Laboratory

Peter Armstrong (19)
MIT/Masdar Institute of Science and
Technology

Joel Neymark (19)
J. Neymark & Associates

James Aswegan (20)
Titus

Kenneth Loudermilk (20)
Trox USA

Kevin Gebke (20)
DuctSox Corporation

Andrey Livchak (20)
Halton

Craig P. Wray (21)
Lawrence Berkeley National Laboratory

Herman Behls (21)

Albert A. Black, III (22)
Coad Engineering Enterprises

Darrell Peil (23)
Aeroflex USA

Jim Young (23)
ITW Insulation Systems

Gordon Hart (23)
Artek Engineering, LLC

Ted Stathopoulos (24)
Concordia University

Martin Stangl (24)
RWDI

Bert Blocken (24)
Eindhoven University of Technology

Leighton Cochran (24)
Leighton Cochran Consulting

Hartwig M. Künzel (25)
Fraunhofer-Institut für Bauphysik

Hugo Hens (25, 26)
University of Leuven

Jan Kosny (25)
Fraunhofer Center for Sustainable Energy
Systems

Alex McGowan (26, 27)
Levelton Consultants Ltd.

Anton TenWolde (26)

William B. Rose (26, 27)
University of Illinois at Urbana–
Champaign

Van D. Baxter (29)
Oak Ridge National Laboratory

Cynthia Gage (29)
U.S. Environmental Protection Agency

David S. Godwin (29)
U.S. Environmental Protection Agency

Donald Bivens (29)

Sean Cunningham (29)
Mexichem Fluor, Inc.

Glenn C. Hourahan (29)
Air Conditioning Contractors
of America

William F. Walter (29)
Carrier Corporation

James M. Calm (29)

Mark McLinden (30)
National Institute of Standards and
Technology

Kevin Connor (31)
Dow Chemical Company

Steve Brickley (32)
Munters Corporation

Donald M. Brundage (34, 35)
Southern Company Services

David L. Grumman (35)
Grumman/Butkus Associates

Neil P. Leslie (35)
Gas Technology Institute

Stephen Idem (36)
Tennessee Technological University

B. Terry Beck (36)
Kansas State University

Charles C. Wright (36)
TSI, Inc.

Birol I. Kilkis (37)
Baskent University

Bruce Billedeaux (37, 38)
Maverick Technologies

ASHRAE HANDBOOK COMMITTEE

Cindy Callaway, Chair

2013 Fundamentals Volume Subcommittee: **Hassan M. Bagheri**, Chair

James D. Aswegan

Jill A. Connell

Peter Simmonds

Jeff J. Traylor

David P. Yuill

ASHRAE HANDBOOK STAFF

W. Stephen Comstock, Publisher
Director of Publications and Education

Mark S. Owen, Editor

Heather E. Kennedy, Managing Editor

Nancy F. Thysell, Typographer/Page Designer

David Soltis, Group Manager, and **Jayne E. Jackson**, Publications Traffic Administrator
Publishing Services

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ASHRAE Research

ASHRAE is the world's foremost technical society in the fields of heating, ventilation, air conditioning, and refrigeration. Its members worldwide are individuals who share ideas, identify needs, support research, and write the industry's standards for testing and practice. The result is that engineers are better able to keep indoor environments safe and productive while protecting and preserving the outdoors for generations to come.

One of the ways that ASHRAE supports its members' and industry's need for information is through ASHRAE Research. Thousands of individuals and companies support ASHRAE Research annually, enabling

ASHRAE to report new data about material properties and building physics and to promote the application of innovative technologies.

Chapters in the ASHRAE Handbook are updated through the experience of members of ASHRAE Technical Committees and through results of ASHRAE Research reported at ASHRAE conferences and published in ASHRAE special publications and in *ASHRAE Transactions*.

For information about ASHRAE Research or to become a member, contact ASHRAE, 1791 Tullie Circle, Atlanta, GA 30329; telephone: 404-636-8400; www.ashrae.org.

Preface

The 2013 *ASHRAE Handbook—Fundamentals* covers basic principles and data used in the HVAC&R industry. The ASHRAE Technical Committees that prepare these chapters provide new information, clarify existing content, delete obsolete materials, and reorganize chapters to make the Handbook more understandable and easier to use. An accompanying CD-ROM contains all the volume's chapters in both I-P and SI units.

Some of this volume's revisions are described as follows:

- Chapter 2, Thermodynamics and Refrigeration Cycles, has new content on exergy, adsorption technology, and on the impact of fluid properties on cycle performance.
- Chapter 5, Two-Phase Flow, has new information on heat transfer in tube bundles; predictive techniques for saturated and subcooled boiling in tube bundles; subcooled boiling heat transfer; boiling, heat transfer, condensation, and pressure drop in mini- and microchannels; boiling/evaporation with enhanced surfaces; and much more.
- Chapter 9, Thermal Comfort, has new content on personal environmental control (PEC) systems; the effect of occupant and air motion on clothing insulation; and multisegment thermal physiology models.
- Chapter 10, Indoor Environmental Health, has new content on microbiology; health effects of fine particulate matter and noise; pathogens with potential for airborne transmission; semivolatile organic compounds (SVOCs); ozone; and dampness.
- Chapter 11, Air Contaminants, has updates for new ASHRAE research, plus added text and graphics on ultrafine particles, SVOCs, and health effects of various air contaminants.
- Chapter 14, Climatic Design Information, includes a complete replacement of the data tables for 6443 locations worldwide—an increase of 879 locations from the 2009 edition of the chapter. Each location's information now also includes monthly precipitation.
- Chapter 16, Ventilation and Infiltration, has added content from ASHRAE *Standard* 62.1-2010 on how to address multiple-zone recirculating systems.
- Chapter 18, Nonresidential Cooling and Heating Load Calculations, includes new plug load data, an elevation correction example, an equation summary, and an entirely new master example section based on the renovated ASHRAE headquarters building.
- Chapter 19, Energy Estimating and Modeling Methods, has new content on the comprehensive room transfer function (CRTF) method; ground heat transfer; a variable-speed vapor compression heat pump model; and validation, verification, and calibration.
- Chapter 21, Duct Design, includes new content on testing for HVAC system air leakage, a revised equation for resistance of flexible duct, and a revised table for duct roughness.

- Chapter 23, Insulation for Mechanical Systems, has new content on condensation control, piping supports, thermal conductivity of below-ambient pipe insulation systems, and includes a new design example.
- Chapter 25, Heat, Air, and Moisture Control in Building Assemblies—Fundamentals, has new material from ASHRAE research on environmental weather loads (RP-1325) and thermal bridging details (RP-1365), plus modified airflow descriptions and new content on phase change materials.
- Chapter 26, Heat, Air, and Moisture Control in Building Assemblies—Material Properties, was extensively reorganized and updated with new content on insulation thermal conductivity data; insulation types; capillary-active insulation materials (CAIMs); and thermal resistance and air and water vapor permeability.
- Chapter 27, Heat, Air, and Moisture Control in Building Assemblies—Examples, introduced explicit definitions with a new example for thermal bridging, and revised introductions to moisture transport analysis examples.
- Chapter 29, Refrigerants, has added data on HFO-1234yf and HFO-1234ze(E) and expanded content on environmental properties and compatibility with construction materials.
- Chapter 30, Thermophysical Properties of Refrigerants, has added tables and diagrams for HFO-1234yf and HFO-1234ze(E).
- Chapter 36, Measurement and Instruments, has added results from recent ASHRAE research (RP-1245) on the effects of duct fittings on measuring airflow in ducts, as well as a new example calculation.

This volume is published, as a bound print volume and in electronic format on CD-ROM and online, in two editions: one using inch-pound (I-P) units of measurement, the other using the International System of Units (SI).

Corrections to the 2010, 2011, and 2012 Handbook volumes can be found on the ASHRAE web site at <http://www.ashrae.org> and in the Additions and Corrections section of this volume. Corrections for this volume will be listed in subsequent volumes and on the ASHRAE web site.

Reader comments are enthusiastically invited. To suggest improvements for a chapter, **please comment using the form on the ASHRAE web site** or, using the cutout page(s) at the end of this volume's index, write to Handbook Editor, ASHRAE, 1791 Tullie Circle, Atlanta, GA 30329, or fax 678-539-2187, or e-mail mowen@ashrae.org.

Mark S. Owen
Editor