

**2009**  
**ASHRAE HANDBOOK**

**FUNDAMENTALS**

**I-P Edition**

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# **2009 ASHRAE® HANDBOOK**

## **FUNDAMENTALS**

**Inch-Pound Edition**

**American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.**

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# ASHRAE Research: Improving the Quality of Life

The American Society of Heating, Refrigerating and Air-Conditioning Engineers 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 meetings 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](http://www.ashrae.org).

## Preface

The 2009 *ASHRAE Handbook—Fundamentals* covers basic principles and data used in the HVAC&R industry. The ASHRAE Technical Committees that prepare these chapters strive not only to provide new information, but also to clarify existing information, 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.

This edition includes a new chapter (35), Sustainability, which defines this concept for HVAC&R and describes the principles, design considerations, and detailed evaluations needed in designing sustainable HVAC&R systems.

Also new for this volume, chapter order and groupings have been revised for more logical flow and use. Some of the other revisions and additions to the volume are as follows:

- Chapter 1, Psychrometrics, has new information on the composition of dry air, and revised table data for thermodynamic properties of water and moist air.
- Chapter 6, Mass Transfer, has added examples on evaluating diffusion coefficients, and on heat transfer and moisture removal rates.
- Chapter 7, Fundamentals of Control, includes new content on dampers, adaptive control, direct digital control (DDC) system architecture and specifications, and wireless control.
- Chapter 9, Thermal Comfort, has a new section on thermal comfort and task performance, based on multiple new studies done in laboratory and office environments.
- Chapter 10, Indoor Environmental Health, was reorganized to describe hazard sources, health effects, exposure standards, and exposure controls. New and updated topics include mold, *Legionella*, indoor air chemistry, thermal impacts, and water quality standards.
- Chapter 14, Climatic Design Information, has new climate data for 5564 stations (an increase of 1142 new stations compared to 2005 *Fundamentals*) on the CD-ROM accompanying this book. A subset of data for selected stations is also included in the printed chapter for convenient access.
- Chapter 15, Fenestration, has been revised to include new examples of solar heat gain coefficient (SHGC) calculations, and new research results on shading calculations and U-factors for various specialized door types.
- Chapter 16, Ventilation and Infiltration, has new, detailed examples, updates from ASHRAE *Standards* 62.1 and 62.2, discussion of relevant LEED® aspects, and new information on airtightness and ventilation rates for commercial buildings.
- Chapter 18, Nonresidential Cooling and Heating Load Calculations, has been updated to reflect new ASHRAE research results on climate data and on heat gains from office equipment, lighting, and commercial cooking appliances.

- Chapter 20, Space Air Diffusion, has been completely rewritten to harmonize with related chapters in other volumes, with major sections on fully mixed, partially mixed, stratified, and task/ambient systems and the principles behind their design and operation.
- Chapter 21, Duct Design, has new data for round and rectangular fittings in agreement with the ASHRAE Duct Fitting Database, as well as new content on duct leakage requirements, spiral duct roughness, and flexible duct pressure loss correction.
- Chapter 23, Insulation for Mechanical Systems, has added tables from ASHRAE *Standard* 90.1-2007, and a new section on writing specifications.
- Chapter 24, Airflow Around Buildings, has added a detailed discussion on computational evaluation of airflow, plus new references including updated versions of design standards and manuals of practice.
- Chapters 25, 26, and 27 carry new titles, reorganized as chapters on Heat, Air, and Moisture Control Fundamentals, Material Properties, and Examples, respectively, with updated content throughout.
- Chapter 29, Refrigerants, has new content on stratospheric ozone depletion, global climate change, and global environmental characteristics of refrigerants.
- Chapter 30, Thermophysical Properties of Refrigerants, has updated data for R-125, R-245fa, R-170, R-290, R-600, and R-600a.
- Chapter 36, Measurement and Instruments, has revised content on measurement of air velocity, infiltration, airtightness, and outdoor air ventilation, plus new information on particle image velocimetry (PIV) and data acquisition and recording.

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

Corrections to the 2006, 2007, and 2008 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](mailto:mowen@ashrae.org).

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