2005 Fundamentals (SI Edition)

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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.

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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 2005 ASHRAE Handbook—Fundamentals covers basic principles and data used in the HVAC&R industry. Research sponsored by ASHRAE and others continues to generate new information to support the HVAC&R technology that has improved the quality of life worldwide. 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.

This edition includes a new chapter (26), Insulation for Mechanical Systems, and an accompanying CD-ROM containing not only all the chapters in both I-P and SI units, but also the vastly expanded and revised climatic design data described in Chapter 28.

Some of the major revisions and additions are as follows:

- Chapter 2, Fluid Flow, has new examples on calculating pressure loss, flow, and pipe sizes, and new text on port-shape friction factors in laminar flow.
- Chapter 3, Heat Transfer, contains updated convection correlations; more information on enhanced heat transfer; radiation, heat exchangers, conduction shape factors, and transient conduction; a new section on plate heat exchangers; and several new examples.
- Chapter 4, Two-Phase Flow, has new information on boiling and pressure drop in plate heat exchangers, revised equations for boiling heat transfer and forced-convection evaporation in tubes, and a rewritten section on pressure drop correlations.
- Chapter 7, Sound and Vibration, contains expanded and clarified discussions on key concepts and methods throughout, and updates for research and standards.
- Chapter 12, Air Contaminants, contains a rewritten section on bioaerosols, added text on mold, and updated tables.
- Chapter 14, Measurement and Instruments, has a new section on optical pyrometry, added text on infrared radiation thermometers, thermal anemometers, and air infiltration measurement with tracer gases, as well as clarified guidance on measuring flow in ducts.
- Chapter 20, Thermophysical Properties of Refrigerants, has newly reconciled reference states for tables and diagrams, plus diagrams for R-143a, R-245fa, R-410A, and R-507A.
- Chapter 25, Thermal and Water Vapor Transmission Data, contains a new table relating water vapor transmission and relative humidity for selected materials.
- Chapter 26, Insulation for Mechanical Systems, a new chapter, discusses thermal and acoustical insulation for mechanical systems in residential, commercial, and industrial facilities, including design, materials, systems, and installation for pipes, tanks, equipment, and ducts.
- Chapter 27, Ventilation and Infiltration, updated to reflect ASHRAE Standards 62.1 and 62.2, has new sections on the shelter-in-place strategy and safe havens from outdoor air quality hazards.
- Chapter 28, Climatic Design Information, extensively revised, has expanded table data for each of the 4422 stations listed (USA/Canada/world; on the CD-ROM accompanying this book), more than three times as many stations as in the 2001 edition.
- Chapter 29, Residential Cooling and Heating Load Calculations, completely rewritten, presents the Residential Load Factor (RLF) method, a simplified technique suitable for manual calculations, derived from the Heat Balance (HB) method. A detailed example is provided.
- Chapter 30, Nonresidential Cooling and Heating Load Calculations, rewritten, has a new, extensively detailed example demonstrating the Radiant Time Series (RTS) method for a realistic office building, including floor plans and details.
- Chapter 32, Energy Estimating and Modeling Methods, includes new information on boilers, data-driven models, combustion chambers, heat exchangers, and system controls, and a new section on model validation and testing.
- Chapter 33, Space Air Diffusion, has a rewritten, expanded section on displacement ventilation.
- Chapter 34, Indoor Environmental Modeling, rewritten, retitled, and significantly expanded, now covers multizone network airflow and contaminant transport modeling as well as HVAC computational fluid dynamics.
- Chapter 35, Duct Design, includes new guidance on flexible duct losses, balancing dampers, and louvers.
- Chapter 36, Pipe Sizing, has new text and tables on losses for ells, reducers, expansions, and tees, and the interactions between fittings.

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 2002, 2003, and 2004 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.

To make suggestions for improving a chapter or for information on how you can help revise a chapter, please comment using the form on the ASHRAE Web site; or e-mail mowen@ashrae.org; or write to Handbook Editor, ASHRAE, 1791 Tullie Circle, Atlanta, GA 30329; or fax 404-321-5478.

Mark S. Owen
Editor

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Additions and Corrections

2002 Refrigeration

p. 2.2, Figs. 1 and 2. In the captions, replace “ton of refrigeration” with “kilowatt of refrigeration.”

p. 2.4, Example 1, Solution. The correct calculations are as follows:

Actual temperature drop = (50 × 0.02) = 0.46 K

Estimated friction loss = 0.46/(50 × 0.749) = 17.2 kPa

Loss for the riser = 6 × 11.3 = 67.8 kPa

Total pressure losses = 67.8 + 17.2 = 85.0 kPa

Saturation pressure at 40°C condensing (see R-22 properties in Chapter 20, 2001 ASHRAE Handbook—Fundamentals) = 1534.1 kPa

Initial pressure at beginning of liquid line = 1534.1 kPa

Total liquid line losses = 85.0 kPa

Net pressure at expansion device = 1449.1 kPa

The saturation temperature at 1449.1 kPa is 37.7°C.

Required subcooling to overcome the liquid losses = (40.0 – 37.7) or 2.3 K

p. 2.10, 2nd col. In the first sentence under Refrigerant Line Capacity Tables, replace “tons of refrigeration” with “kilowatts of refrigeration.”

p. 2.16, Example 2. In the Solution, the reference to Table 10 should be to Table 16.

p. 8.5, Table 3. The specific heats above and below freezing for bacon should both be 2.70 kJ/(kg·K); for whole cured lean ham they should be 3.47 and 2.22 kJ/(kg·K), respectively.

p. 8.8, Eq. (18). The equation should read as follows:

\[ H = (t - t_f) \left( 1.55 + 1.26x_s \frac{x_w - x_s}{L_v} \right) \]

p. 8.9, 2nd col., 3rd equation. Delete the 3 directly to the right of the equals sign.

p. 10.9, Table 2. Delete the entry for “Maple syrup.”

p. 12.1, 1st col., 5th line from bottom. Change “15 mph” to “25 km/h.”

p. 12.1, 2nd col. In the first full paragraph, change “These values decrease” to “These values increase.”

p. 12.2, Example 1. The solution should be as follows:

Specific heat of beef before freezing is listed in Table 3, Chapter 8 as 3.52 kJ/(kg·K); after freezing, 2.12 kJ/(kg·K).

To cool from 18 to 4°C in a chilled room:

100 × 3.52(18 – 4) = 4928 kJ

To cool from 4°C to freezing point in freezer:

100 × 3.52(4 – (–2)) = 2112 kJ

To freeze:

100 × 233 = 23 300 kJ

To cool from freezing to storage temperature:

100 × 2.12[(–2) – (–18)] = 3392 kJ

Total:

4928 + 2112 + 23 300 + 3392 = 33 732 kJ

p. 12.7, Infiltration Load values. Delete “°C” from the definitions for \( h_p \), \( h_c \), and \( \rho_p \); for \( \rho_p \), the entire definition should read only “density incoming air, kg/m³.”

p. 16.10, 2nd col. The next to the last sentence under Fresh Pork Holding should read, “Care must be taken to maintain the ratio of kilograms of CO₂ to kilograms of meat for the retention period.”

p. 7.14, Fig. 17. The viscosity data are for 38°C, in mm²/s.

p. 22.7, Airflow Requirements. The units for \( c_p \) should be J/(kg·K), and the symbol for mass flow rate of air should be \( m \).

p. 25.2, 16th line. Change “metre” to “cubic metre.”

p. 30.2, Controls. Change “several hundred feet” to “hundreds of yards.”

p. 31.3, 2nd col., 4th line. The text in parentheses should read “(i.e., a total area of 3.0 m² and a capacity of 0.33 m³).”

p. 34.3, Example 2 values. Change the unit for Ceiling radiating area from “mm²” to “m².”

p. 38.21, Fig. 30. Along the x axis, change “10³” to “10⁵.”

p. 1.30, Index. Add the following entry after Load coefficients:

Louvers, F30.45
sizing, F34.17-18

2003 HVAC Applications

p. 1.4, Evaporative Cooling. The reference to Chapter 50 should be to Chapter 51.

p. 8.2, Indoor Air Quality, 4th line. Delete “by a minimum of 1.5 K.”

p. 9.2, Power Consumption and Availability. Change “to maintain gas mileage” to “for minimum vehicle fuel use.”

p. 13.6, Reverse the order of Figures 6 and 7.

p. 13.10, Example 1. The unit for total floor area should be m².

p. 16.9, Semiconductor Cleanrooms, 1st paragraph. Insert “(0.0283 m³)” after “cubic foot.”


p. 16.13, Temperature and Humidity, 3rd paragraph. If full-coverage smocks are not used, temperature set points can be higher, not lower.

Ch. 17. This chapter has been reassigned to TC 9.9, which recommends using ASHRAE’s Thermal Guidelines for Data Processing Environments (2004) as a primary source of information for data processing environment design.
A.2

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2004 HVAC Systems and Equipment

p. 2.5, Fig. 8. The caption for Figure 9 should read “Chemical Dehumidification.”

p. 6.7, Table 1. The complete table is supplied here.
Additions and Corrections

p. 7.22, 1st col., 13th line from bottom. Change “horsepower” to “power.”

p. 7.23, Turbocharger Heat Recovery. Delete “(280 kJ/kWh).”

p. 8.5, Fig. 5. The top two figures, for air/air and water/air refrigerant changeover, were cut off. The two figures are provided here.

Table 1  Thermal Resistance of Ceiling Panels
(2004 HVAC Systems and Equipment, Ch. 6, p. 7)

<table>
<thead>
<tr>
<th>Type of Panel</th>
<th>( \frac{x_p}{k_p} ) (m(^2)-K)/W</th>
<th>( \frac{x_s}{k_p} ) (m(^2)-K)/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEEL PIPE</td>
<td>0.32</td>
<td></td>
</tr>
<tr>
<td>COPPER TUBE SECURED TO ALUMINUM SHEET</td>
<td>0.38</td>
<td></td>
</tr>
<tr>
<td>COPPER TUBE SECURED TO ALUMINUM EXTRUSION</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>METAL OR GYPSUM LATH TUBES OR PIPES</td>
<td>( \frac{x_p - D_p/2}{k_p} ) ( \approx 0 )</td>
<td>( \frac{x_p - D_p/2}{k_p} ) ( \leq 0.12 )</td>
</tr>
</tbody>
</table>

Fig. 5  Heat Pump Types (first two rows)
(2004 HVAC Systems and Equipment, Ch. 8, p. 5)

Fig. 16  Direct- and Reverse-Return Two-Pipe Systems
(2004 HVAC Systems and Equipment, Ch. 12, p. 9)

p. 12.9, Fig. 16. The figure for reverse-return two-pipe systems was incorrect; the corrected version is provided here.

p. 24.2, 1st two lines. Change “15 to 35 cfm” to “7 to 16 L/s,” and “15 cfm” to “7 L/s.”

p. 25.4, Eq. (5). There should be an equals symbol after \( D_{pc} \).

p. 25.21, Tables 8 and 9. Delete “g·” from the units for \( K_{gfa} \).

p. 31.3, 2nd equation. The unit for \( q_c \) should be W.

p. 34.31, Symbols. Delete the definition for \( g_c \).

p. 35.19, Purging, 2nd paragraph. Change “Chapters 35 and 38 of this volume” to “Chapter 38 of this volume.”

p. 36.4, Fig. 9. Change “350 to 500 ft” to “100 to 150 m.”

p. 36.14, Fig. 25. The corrected figure is supplied on p. A.4.

p. 44.10, Fig. 5. Replace with the corrected figure, supplied on p. A.4.
p. 44.19, Ex. 4, Step 7. The reference to Figure 17 should be to Figure 19.

p. 44.25, Bibliography. The correct entry for the ASHRAE (1974) source is as follows:

Index. The following are the correct page numbers for these entries:

Compressors, heat pump systems, S8.6
Control, heat recovery systems, S8.18
Defrosting, air-source heat pump coils, S8.7, 8; S45.9
Heat balance (HB), studies, S8.19
Heat pumps (all subentries with S1 should be S8)
Heat recovery (all subentries with S1 should be S8)

Industrial applications, heat pumps, S8.8
Net positive suction, S39.9
Refrigerant control devices, R45
heat pumps, system, S8.7
Solar energy, heat pump systems, S8.4