

2024 ASHRAE® HANDBOOK

**Heating, Ventilating,
and
Air-Conditioning
SYSTEMS AND EQUIPMENT**

Inch-Pound Edition

© 2024 ASHRAE. All rights reserved.

**DEDICATED TO THE ADVANCEMENT OF
THE PROFESSION AND ITS ALLIED INDUSTRIES**

No part of this publication may be reproduced without permission in writing from ASHRAE, except by a reviewer who may quote brief passages or reproduce illustrations in a review with appropriate credit; nor may any part of this book be reproduced, stored in a retrieval system, or transmitted in any way or by any means—electronic, photocopying, recording, or other—without permission in writing from ASHRAE. Requests for permission should be submitted at www.ashrae.org/permissions.

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 website.

DISCLAIMER

ASHRAE has compiled this publication with care, but ASHRAE has not investigated, and ASHRAE expressly disclaims any duty to investigate, any product, service, process, procedure, design, or the like that may be described herein. The appearance of any technical data or editorial material in this publication does not constitute endorsement, warranty, or guaranty by ASHRAE of any product, service, process, procedure, design, or the like. ASHRAE does not warrant that the information in this publication is free of errors. The entire risk of the use of any information in this publication is assumed by the user.

ISBN 978-1-955516-83-9

ISSN 1078-6074

The paper for this book is both acid- and elemental-chlorine-free and was manufactured with pulp obtained from sources using sustainable forestry practices.

ASHRAE TECHNICAL COMMITTEES, TASK GROUPS, AND TECHNICAL RESOURCE GROUPS

SECTION 1.0—FUNDAMENTALS AND GENERAL

- 1.1 Thermodynamics and Psychrometrics
- 1.2 Instruments and Measurements
- 1.3 Heat Transfer and Fluid Flow
- 1.4 Control Theory and Application
- 1.5 Emerging Computing Applications
- 1.6 Terminology
- 1.7 Business, Management & General Legal Education
- 1.8 Mechanical Systems Insulation
- 1.9 Electrical Systems
- 1.10 Combined Heat and Power Systems
- 1.11 Electric Motors and Motor Control
- 1.12 Moisture Management in Buildings
- 1.13 Optimization

SECTION 2.0—ENVIRONMENTAL QUALITY

- 2.1 Physiology and Human Environment
- 2.2 Plant and Animal Environment
- 2.3 Gaseous Air Contaminants and Gas Contaminant Removal Equipment
- 2.4 Particulate Air Contaminants and Particulate Contaminant Removal Equipment
- 2.5 Global Climate Change
- 2.6 Sound and Vibration
- 2.7 Seismic, Wind, and Flood Resistant Design
- 2.8 Building Environmental Impacts and Sustainability
- 2.9 Ultraviolet Air and Surface Treatment
- 2.10 Resilience and Security
- TG2 Reactive Air and Surface Disinfection

SECTION 3.0—MATERIALS AND PROCESSES

- 3.1 Refrigerants and Secondary Coolants
- 3.2 Refrigerant System Chemistry
- 3.4 Lubrication
- 3.6 Water Treatment
- 3.8 Refrigerant Containment

SECTION 4.0—LOAD CALCULATIONS AND ENERGY REQUIREMENTS

- 4.1 Load Calculation Data and Procedures
- 4.2 Climatic Information
- 4.3 Ventilation Requirements and Infiltration
- 4.4 Building Materials and Building Envelope Performance
- 4.5 Fenestration
- 4.7 Energy Calculations
- 4.10 Indoor Environmental Modeling
- TRG4 Indoor Air Quality Procedure Development

SECTION 5.0—VENTILATION AND AIR DISTRIBUTION

- 5.1 Fans
- 5.2 Duct Design
- 5.3 Room Air Distribution
- 5.4 Industrial Process Air Cleaning (Air Pollution Control)
- 5.5 Air-to-Air Energy Recovery
- 5.6 Control of Fire and Smoke
- 5.7 Evaporative Cooling
- 5.9 Enclosed Vehicular Facilities
- 5.10 Kitchen Ventilation
- 5.11 Humidifying Equipment

SECTION 6.0—HEATING EQUIPMENT, HEATING AND COOLING SYSTEMS AND APPLICATIONS

- 6.1 Hydronic and Steam Equipment and Systems
- 6.2 District Energy
- 6.3 Central Forced Air Heating and Cooling Systems
- 6.5 Radiant Heating and Cooling
- 6.6 Service Water Heating Systems
- 6.7 Solar and Other Renewable Energies

- 6.8 Geothermal Heat Pump and Energy Recovery Applications
- 6.9 Thermal Storage
- 6.10 Fuels and Combustion

SECTION 7.0—BUILDING PERFORMANCE

- 7.1 Integrated Building Design
- 7.2 HVAC&R Construction & Design Build Technologies
- 7.3 Operation, Maintenance, and Cost Management
- 7.4 Exergy Analysis for Sustainable Buildings (EXER)
- 7.5 Smart Building Systems
- 7.6 Building Energy Performance
- 7.7 Testing and Balancing
- 7.9 Building Commissioning

SECTION 8.0—AIR-CONDITIONING AND REFRIGERATION SYSTEM COMPONENTS

- 8.1 Positive Displacement Compressors
- 8.2 Centrifugal Machines
- 8.3 Absorption and Heat Operated Machines
- 8.4 Air-to-Refrigerant Heat Transfer Equipment
- 8.5 Liquid-to-Refrigerant Heat Exchangers
- 8.6 Cooling Towers and Evaporative Condensers
- 8.7 Variable Refrigerant Flow (VRF)
- 8.8 Refrigerant System Controls and Accessories
- 8.9 Residential Refrigerators and Food Freezers
- 8.10 Mechanical and Desiccant Dehumidification Equipment, Heat Pipes and Components
- 8.11 Unitary and Room Air Conditioners and Heat Pumps

SECTION 9.0—BUILDING APPLICATIONS

- 9.1 Large Building Air-Conditioning Systems
- 9.2 Industrial Air Conditioning and Ventilation
- 9.3 Transportation Air Conditioning
- 9.6 Healthcare Facilities
- 9.7 Educational Facilities
- 9.8 Specialized Building Air-Conditioning Applications
- 9.9 Mission Critical Facilities, Data Centers, Technology Spaces and Electronic Equipment
- 9.10 Laboratory Systems
- 9.11 Clean Spaces
- 9.12 Tall Buildings
- TRG9 Cold Climate Design

SECTION 10.0—REFRIGERATION SYSTEMS

- 10.1 Custom Engineered Refrigeration Systems
- 10.2 Refrigeration Applications
- 10.6 Transport Refrigeration
- 10.7 Commercial Food and Beverage Refrigeration Equipment

SECTION MTG—MULTIDISCIPLINARY TASK GROUPS

- MTG.ACR Air Change Rate
 - MTG.BIM Building Information Modeling
 - MTG.CEA Controlled Environment Agriculture
 - MTG.CYB Cybersecurity for HVAC Systems and Related Infrastructure
 - MTG.EBO Effective Building Operations
 - MTG.HCDG Hot Climate Design Guide
 - MTG.IAST Impact of ASHRAE Standards and Technology on Energy Savings/Performance
 - MTG.LowGWP Lower Global Warming Potential Alternative Refrigerants
 - MTG.OBB Occupant Behavior in Buildings
 - MTG.RAC Refrigeration and Air-Conditioning Plant Assessment Guide
 - MTG.RES Resilience
 - MTG.VIC Ventilation for Infection Control
-