

2019 ASHRAE® HANDBOOK

Heating, Ventilating, and Air-Conditioning APPLICATIONS

Inch-Pound Edition

ASHRAE, 1791 Tullie Circle, N.E., Atlanta, GA 30329
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**DEDICATED TO THE ADVANCEMENT OF
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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ISBN 978-1-947192-12-6

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.

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ASHRAE Research: Improving the Quality of Life

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, *ASHRAE Transactions*, and ASHRAE's journal of archival research, *Science and Technology for the Built Environment*.

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 2019 *ASHRAE Handbook—HVAC Applications* comprises 65 chapters covering a broad range of facilities and topics, written to help engineers design and use equipment and systems described in other Handbook volumes. Main sections cover comfort, industrial, energy-related, general applications, and building operations and management. ASHRAE Technical Committees in each subject area have reviewed all chapters and revised them as needed for current technology and design practice.

Full and associate ASHRAE members can download Handbook PDFs in I-P or SI units by going to technologyportal.ashrae.org. Nonmembers can purchase these PDFs at the same location, or purchase individual chapter PDFs from ashrae.org/bookstore.

This edition includes three new chapters:

- Chapter 6, Indoor Swimming Pools
- Chapter 59, Indoor Airflow Modeling
- Chapter 65, Occupant-Centric Sensing and Controls

Other particularly notable highlights include the following:

- Ch 8, Educational Facilities, provides updated design criteria, and a new section on central plant optimization for higher education campuses and educational facilities for students with disabilities.
- Ch. 9, Health Care Facilities, has been extensively rewritten to address current health care requirements.
- Ch. 16, Enclosed Vehicular Facilities, has new material on parking garage ventilation and updated ventilation flow rates.
- Ch. 20, Data Centers and Telecommunication Facilities, includes updates to reflect the current ASHRAE Datacom series, and text updates to reflect changes in the industry and new technologies such as PoE lighting and lithium-ion batteries.
- Ch. 34, Kitchen Ventilation, now discusses solid-fuel cooking, and life-cycle cost analysis, with updates from research and SSPC 154.
- Ch. 35, Geothermal Energy, has new content on direct exchange systems and pressure considerations for deep boreholes, calculation methods for design, and an updated example.
- Ch. 36, Solar Energy, added updated guidance on solar thermal collectors and photovoltaic applications, with new information on design and performance of photovoltaic systems and on installation and operation guidelines for photovoltaic systems, with new practical examples
- Ch. 40, Operation and Maintenance Management, has been extensively rewritten to address current best practices

- Ch. 41, Computer Applications, was extensively rewritten to more directly focus on immediate concerns of HVAC engineers
- Ch. 51, Service Water Heating, added discussion of water heater redundancy in large systems, and has updated information about new uniform energy factor (UEF) ratings, diversified electrical demand of whole-house/large tankless electric water heaters, and a new figure describing recommended tank and plumbing layout for heat pump water heater (HPWH) systems, showing series/parallel arrangement of HPWH and conventional water heaters.
- Ch. 52, Snow Melting, added guidance for recommended values by application type and for concrete strength and maximum temperature difference, as well as discussion of new research.
- Ch. 54, Fire and Smoke Control, has new sections on balanced approach and smoke feedback, plus extensively revised discussion of dampers, pressurization system design, and stairwells with open doors.
- Ch. 60, Integrated Building Design, has been completely rewritten to give more detail on IBD process.
- Ch. 64, Mold and Moisture, revised the order of risk factors for mold to better reflect their relative importance, and added information from ASHRAE research project RP-1712 to advise on components and configuration of dedicated outdoor air (DOAS) systems to help avoid mold growth in schools, universities, and military barracks during extended periods of unoccupied-mode HVAC operation.

This volume is published as a bound print volume and in electronic format as a downloadable PDF 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 2016, 2017, and 2018 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 write to Handbook Editor, ASHRAE, 1791 Tullie Circle, Atlanta, GA 30329, or fax 678-539-2187, or e-mail hkennedy@ashrae.org.

Heather E. Kennedy
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CHAPTER 13

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ENVIRONMENTAL control system (ECS) is a generic term used in the aircraft industry for the systems and equipment associated with ventilation, heating, cooling, humidity/contamination control, and pressurization in the occupied compartments, cargo compartments, and electronic equipment bays. The term ECS often encompasses other functions such as windshield defog, airfoil anti-ice, oxygen systems, and other pneumatic demands. The regulatory or design requirements of these related functions are not covered in this chapter.

1. DESIGN CONDITIONS

Design conditions for aircraft applications differ in several ways from other HVAC applications. Commercial transport aircraft often operate in a physical environment that is otherwise not survivable for humans. In flight, the ambient air may be extremely cold and dry, and can contain high levels of ozone. On the ground, the ambient air may be hot, humid, and contain many pollutants such as particulate matter, aerosols, and hydrocarbons. These conditions change quickly from ground operations to flight. A hot-day, high-humidity ground condition usually dictates the thermal capacity of the air-conditioning equipment, and flight conditions determine the supply air compressor's capacity. Maximum heating requirements can be determined by either cold-day ground or flight operations.

In addition to essential safety requirements, the ECS should provide a comfortable cabin environment for the passengers and crew. This presents a unique challenge because of the high-density seating of the passengers. Furthermore, aircraft systems must be lightweight, accessible for quick inspection and servicing, highly reliable, able to withstand aircraft vibratory and maneuver loads, and able to compensate for various possible system failures.

Ambient Temperature, Humidity, and Pressure

Figure 1 shows typical design ambient temperature profiles for hot, standard, and cold days. The ambient temperatures used for the design of a particular aircraft may be higher or lower than those shown in Figure 1, depending on the regions in which the aircraft is to be operated. The design ambient moisture content at various altitudes as recommended for commercial aircraft is shown in Figure 2. However, operation at moisture levels exceeding 200 gr/lb of dry air is possible in some regions. The variation in ambient pressure with altitude is shown in Figure 3. Refer to the psychrometric chart for higher altitudes for cabin humidity calculations. Figure 4 shows a psychrometric chart for 8000 ft altitude.

Heating/Air Conditioning Load Determination

The cooling and heating loads for a particular aircraft model are determined by a heat transfer study of the several elements that comprise the air-conditioning load. Heat transfer involves the following factors:

- Convection between the boundary layer and the outer aircraft skin

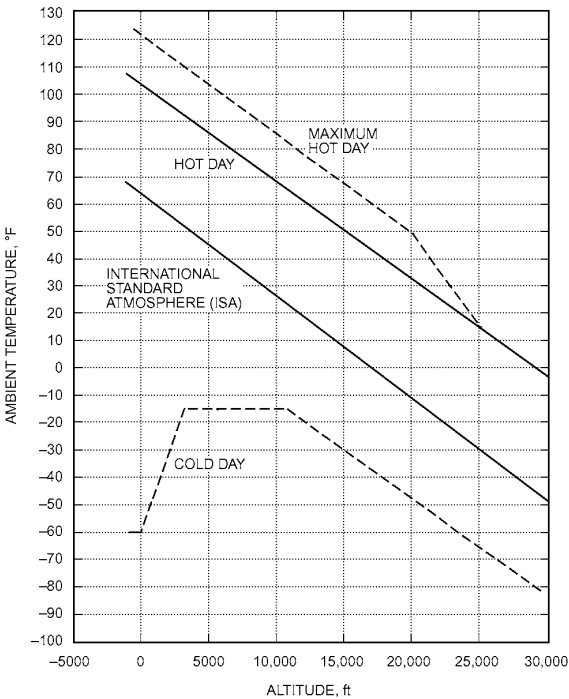


Fig. 1 Ambient Temperature Profiles

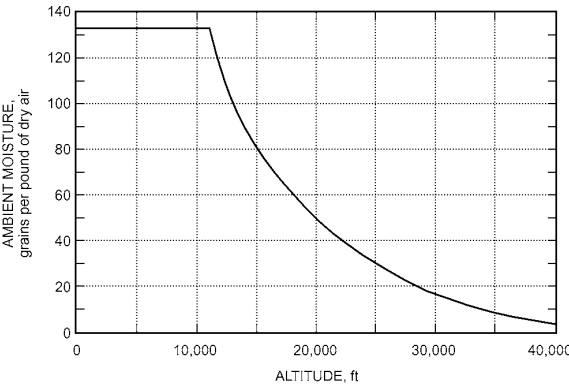


Fig. 2 Design Humidity Ratio

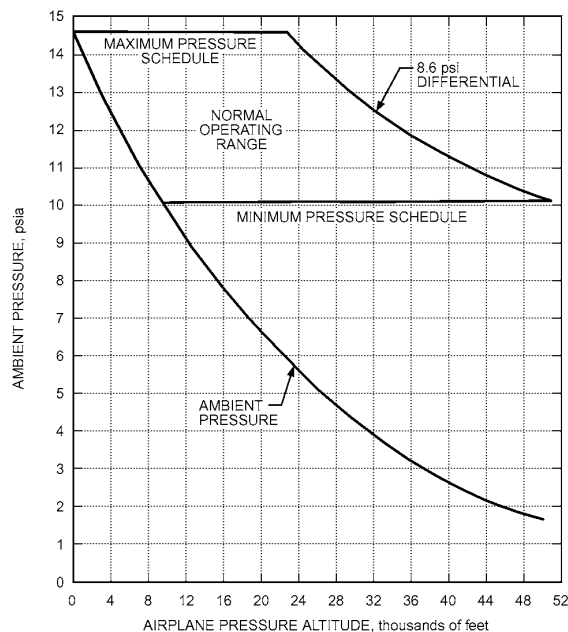


Fig. 3 Cabin Pressure Versus Altitude

- Radiation between the outer aircraft skin and the external environment
- Solar radiation through windows, on the fuselage, and reflected from the ground.
- Conduction through cabin walls and the aircraft structure
- Convection between the interior cabin surface and the cabin air
- Convection and radiation between the cabin and occupants
- Convection and radiation from internal sources of heat (e.g., electrical equipment)
- Latent heat from vapor cycle systems

Ambient Air Temperature in Flight

During flight, very cold ambient air adjacent to the outer surface of the aircraft increases in temperature through ram effects, and may be calculated from the following equations:

$$T_{AW} = T_{\infty} + r(T_T - T_{\infty})$$

$$T_T = T_{\infty} \left(1 + \frac{k-1}{2} M^2 \right)$$

or

$$T_{AW} = T_{\infty} \left(1 + r \frac{k-1}{2} M^2 \right)$$

$$r = \text{Pr}^{1/3}$$

where

Pr = Prandtl number for air (e.g., Pr = 0.73 at 432°R)

T_{∞} = ambient static temperature, °R

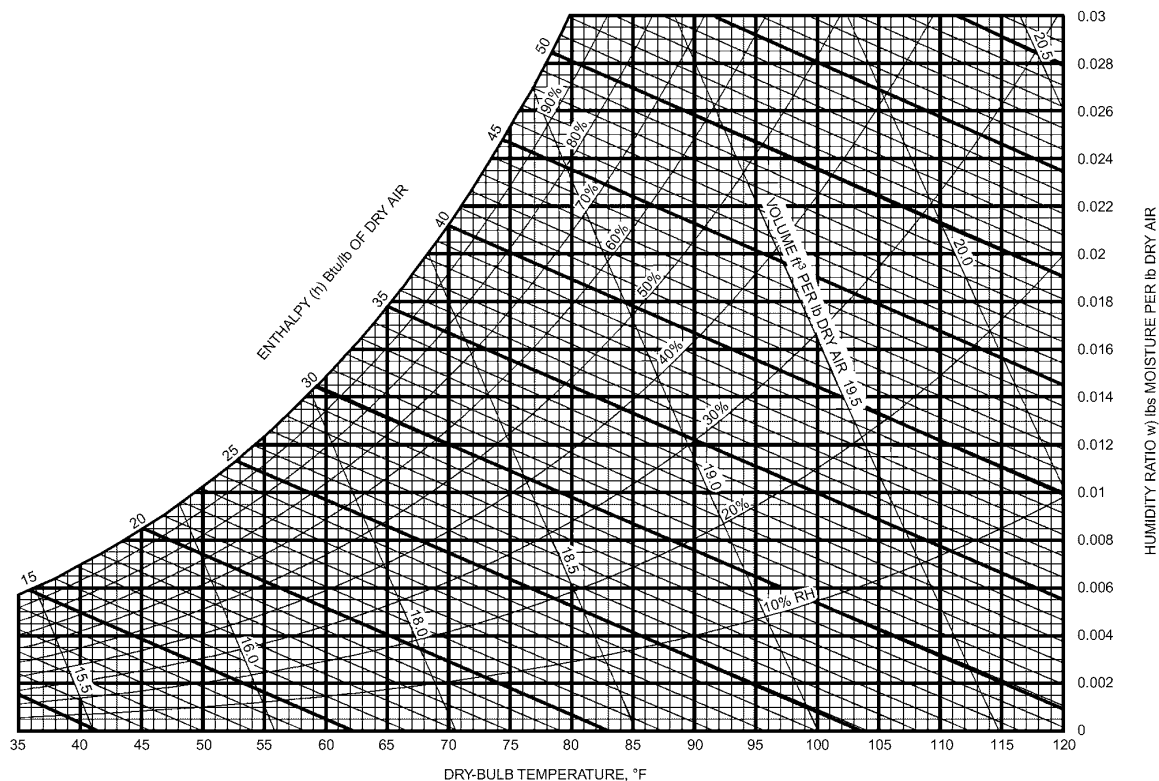


Fig. 4 Psychrometric Chart for Cabin Altitude of 8000 ft

T_T = ambient total temperature, °R
 k = ratio of specific heat; for air, $k = 1.4$
 M = airplane Mach number
 r = recovery factor for turbulent boundary layer (i.e., fraction of total temperature recovered in boundary layer as air molecules rest on the surface)
 T_{AW} = recovery temperature (or adiabatic wall temperature), °R

Example 1. The International Civil Aviation Organization (ICAO) cold day at 30,000 to 40,000 ft altitude has a static temperature of -85°F (375°R) and a Prandtl number of 0.739. If an airplane is traveling at 0.8 Mach, what would the external temperature be at the airplane's skin?

Solution: Iteration is usually required. First guess for $r \gg 0.9$:

$$\text{Pr} = 0.728 \text{ at } 0.9(423 - 375) + 375 = 418^\circ\text{R}$$

$$r = \text{Pr}^{1/3} = (0.728)^{1/3} = 0.8996$$

$$T_T = T_\infty \left(1 + \frac{k-1}{2} M^2 \right) = 375 \left(1 + \frac{1.4-1}{2} [0.8]^2 \right) = 423^\circ\text{R}$$

$$T_{AW} = T_\infty + r(T_T - T_\infty) = 375 + 0.8996(423 - 375)$$

$$= 418.2^\circ\text{R} \quad (-41.5^\circ\text{F})$$

Air Speed and Mach Number

The airplane airspeed is related to the airplane Mach number by the local speed of sound:

$$u_\infty = M \sqrt{kRT_\infty}$$

where

k = ratio of specific heats; 1.4 for air
 R = gas constant; $1716 \text{ ft}^2/\text{s}^2 \cdot ^\circ\text{R}$
 M = airplane Mach number
 u_∞ = airplane airspeed, fps

Ambient Pressure in Flight

The static pressure over most of the fuselage (the structure around the cabin) is essentially equal to the ambient pressure at the appropriate altitude.

$$P_s = P_{inf} + C_p \frac{1}{2} \rho_\infty u_\infty^2$$

where

P_s = pressure surrounding the fuselage, lb/ft²
 C_p = pressure coefficient, dimensionless; approximately zero for passenger section of fuselage
 ρ_∞ = free-stream or ambient air density, slug/ft³

External Heat Transfer Coefficient in Flight

The fact that the fuselage is essentially at free-stream static pressure implies that a flat-plate analogy can be used to determine the external heat transfer coefficient at any point on the fuselage:

$$h = \rho_w c_p u_\infty 0.185 (\log_{10} \text{Re}_x)^{-2.584} \text{Pr}^{-2/3}$$

(note: $10^7 < \text{Re}_x < 10^9$)

$$\text{Re}_x = \frac{\rho_w u_\infty x}{\mu}$$

$\rho_w, c_p, \mu, \text{Pr}$

$$\text{evaluated at } T^* = \frac{T_{AW} + T_\infty}{2} + 0.22(T_{AW} - T_\infty)$$

$$q = hA(T - T_{AW})$$

where

h = external heat transfer coefficient, Btu/s · ft² · °F
 Re_x = local Reynolds number, dimensionless
 x = distance along the fuselage from nose to point of interest, ft
 c_p = constant-pressure specific heat; for air, $0.24 \text{ Btu/lb} \cdot ^\circ\text{F}$
 ρ_w = ambient air (weight) density at film temperature T^* , lb/ft³
 μ = absolute viscosity of air at T^* ; $1.021 \times 10^{-9} (T^*)^{3/2} [734.7 / (T^* + 216)] \text{ lb}_m/\text{ft} \cdot \text{s}$
 A = outside surface area, ft²
 T = outer skin temperature, °R
 q = convective heat loss from outer skin, Btu/h
 u_∞ = airplane airspeed, ft/h

External Heat Transfer Coefficient on Ground

The dominant means of convective heat transfer depends on wind speed, fuselage temperature, and other factors. The (free convection) heat transfer coefficient for a large, horizontal cylinder in still air is entirely buoyancy-driven and is represented as follows:

$$\text{Gr} = \frac{g(\beta)(\Delta T)d^3}{\nu^2}$$

for $10^9 \leq \text{GrPr} \leq 10^{12}$:

$$h_{free} = \frac{0.13k(\text{GrPr})^{1/3}}{d}$$

where

g = gravitational acceleration, 32.2 ft/s^2
 k = thermal conductivity of air, $\text{Btu} \cdot \text{ft}/\text{h} \cdot \text{ft}^2 \cdot ^\circ\text{R}$
 ν = kinematic viscosity, ft²/s
 d = fuselage diameter, ft
 h_{free} = free-convection heat transfer coefficient, $\text{Btu}/\text{h} \cdot \text{ft}^2 \cdot ^\circ\text{R}$
 β = expansion coefficient of air = $1/T_f$, where $T_f = (T_{skin} + T_\infty)/2$, °R
 $\Delta T = T_{skin} - T_\infty$
 T_{skin} = skin temperature, °R
 T_∞ = ambient temperature, °R
 Gr = Grashof number
 Pr = Prandtl number

A relatively light breeze introduces a significant amount of heat loss from the same horizontal cylinder. The forced-convection heat transfer coefficient for a cylinder may be extrapolated from the following:

$$\text{Re} = \frac{Vd}{\nu}$$

$$\text{for } 4 \times 10^4 \leq \text{Re} \leq 4 \times 10^5$$

$$h_{forced} = \frac{0.0266k(\text{Re})^{0.805} \text{Pr}^{1/3}}{d}$$

where V is wind speed in ft/s, and ν is evaluated at $T_f = (T_{skin} + T_\infty)/2$.

Example 2. One approximation of the fuselage is a cylinder in cross-flow.

The fuselage is 12 ft in diameter and 120 ft long, in a 14 fps crosswind and a film temperature of 575°R . The surface temperature varies with the paint color and the degree of solar heating. For instance, a typical white paint could be 30°F higher than the ambient air temperature, so the heat transfer from the fuselage would be

Free convection:

$$\text{Gr} = \frac{g(\beta)(\Delta T)d^3}{\nu^2} = \frac{32.2(0.00174)(30)(12)^3}{(1.9 \times 10^{-4})^2} = 8.05 \times 10^{10}$$

for $10^9 \leq \text{GrPr} \leq 10^{12}$.

$$h_{free} = \frac{0.13k(\text{GrPr})^{1/3}}{d} = \frac{0.13(0.016)[8.05 \times 10^{10}(0.704)]^{1/3}}{12}$$

$$= 0.67 \text{ Btu/h} \cdot \text{ft}^2 \cdot ^\circ\text{F}$$

Forced convection:

$$\text{Re} = \frac{Vd}{\nu} = \frac{14(12)}{1.9 \times 10^{-4}} = 8.84 \times 10^5$$

for $4 \times 10^4 \leq \text{Re} \leq 4 \times 10^5$. Note that, although this Reynolds number is beyond the recommended range, the extrapolation has about a 10% error (underprediction) when compared to other more complicated methods.

Comparison of heat transfer coefficients shows that, in this situation, heat transfer is dominated by forced convection, so the free-convection aspect can be ignored.

External Radiation

The section of airplane fuselage that surrounds the cabin radiates primarily to the sky. At sea level, the sky temperature is about 30°F cooler than the surrounding air temperature (depending on humidity and other factors). As the airplane climbs, there is a decreasing amount of air above to radiate to, so the difference between air temperature and sky temperature increases. For example, at a cruising altitude of 30,000 to 35,000 ft, the sky temperature is about 100°F cooler than the air temperature (free-stream static). The limiting condition, of course, is outer space, where the sky temperature is the cosmic background radiation (CBR). The sky temperature in this case is only about 6°R. The heat loss to the sky by radiation is

$$q_R = A\sigma(\epsilon)(T^4 - T_{sky}^4)$$

where

q_R = radiation heat loss from outer skin, Btu/h
 A = outside surface area, ft²
 T = outer skin temperature, °R
 σ = Stephan-Boltzmann constant, 1.712×10^{-9} Btu/h · ft² · R⁴
 ϵ = emissivity of surface, paint, etc.
 T_{sky} = sky temperature, °R

Solar radiation on the ground is covered in detail elsewhere (e.g., Chapter 36); however, during cruising, the incident solar radiation should be adjusted for altitude. The column of air between the sun and the airplane varies with time of day (angle) and altitude. Standard sea-level solar flux, for a given latitude and time of day, can be adjusted for altitude using Beer's law:

$$I_{SL} = I_o e^{-na_{ms}}$$

$$I_y = I_o e^{-na_{ms}m}$$

$$C_y = I_y/I_{SL}$$

$$q_s = A\alpha(C_y)I$$

where

I = solar radiation to a surface at sea level after accounting for latitude and time of day, Btu/h · ft²
 I_o = solar constant, 429.5 Btu/h · ft²
 I_y = normal solar flux at altitude, Btu/h · ft²
 I_{SL} = normal solar flux at sea level, Btu/h · ft²
 C_y = correction factor for altitude
 n = turbidity factor: 2.0 for clear air, 4 to 5 for smog
 m = relative thickness of air mass, P_y/P_{SL} = (altitude pressure)/(sea level barometric pressure)
 a_{ms} = molecular scattering coefficient = $0.128 - 0.054 \log_{10}(m)$
 α = solar absorptivity of surface, window, paint, etc.
 A = outside surface area, ft²

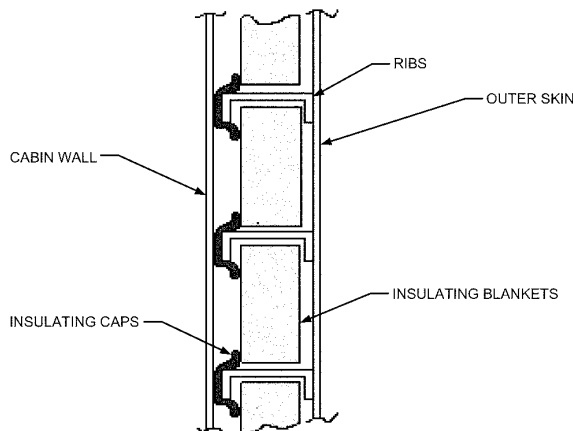


Fig. 5 Example of Aircraft Insulation Arrangement

Conduction

The conductive path from the air in the cabin to the surrounding environment is generally described as several heat transfer elements in series and in parallel with each other. The structure is typically quite conductive (e.g., aluminum), and must be insulated to avoid a direct heat path from inside to outside. The structure typically has an outer skin supported by circumferential and longitudinal ribs. The members require a structurally efficient attachment, which often is also thermally efficient, so that the entire structure is essentially at the same temperature. As a result, the effective “fin” area may be much larger than the simple outside surface area of the fuselage. Figure 5 shows an example of an aircraft insulation arrangement.

For occupant comfort, the cabin wall temperature should not be drastically different from the air temperature within the cabin, because the passengers frequently are in contact with this and other interior surfaces. The insulation accommodates this requirement as well as noise reduction, which on occasion is the dominant requirement.

Stack Pressure across Cabin Wall

The cold outer skin during flight generates buoyancy-driven flow between the cabin and the cavity formed by the cabin wall and the outer skin. Because this cavity is normally filled with insulation blankets, it may be relatively porous to airflow. The outer skin is frequently below the cabin dew point (and below freezing), so water condenses on the structure and ice may build up with time. The amount of flow in and out of the cavity depends on the leakage area of the cabin wall. Leakage commonly occurs through panel joints and gaps surrounding penetrations, as well as around doors, where additional structure and mechanisms may provide additional thermal conductivity and air passages to the outer skin. A certain amount of flow in and out of the cavity is unavoidable because of normal pressurization and depressurization of the cabin during descent and climb. The driving pressure, or stack pressure, is simply the density difference between the connected volumes:

$$\Delta P_{stack} = (\rho_{cavity1} - \rho_{cavity2})gh$$

$$= \frac{P_{cabin} \left(\frac{1}{T_{cavity1}} - \frac{1}{T_{cavity2}} \right) gy}{R}$$

where

y = cavity height, ft
 T = temperature, °R

ρ = air density, slug/ft³
 g = gravitational constant = 32.3 ft/s²
 R = gas constant, 1716 ft²/s²·°R
 ΔP = stack pressure, lb/ft²
 P_{cabin} = absolute cabin pressure, lb/ft²

Metabolic Heat from Occupants

A thorough treatment of metabolic heat from humans is covered in Chapter 9 of the 2017 *ASHRAE Handbook—Fundamentals*. Because an airplane cabin is frequently at higher altitudes, the balance between sensible and latent heat changes slightly from that given in that chapter. To correct for altitude, the following approach is recommended. First, examining the heat transfer coefficient:

For low air velocity ($V < 40$ fpm), flow is dominated by natural convection:

$$h = \frac{k}{d} C (Gr Pr)^m = \frac{k}{d} C \left(\frac{\rho^2 g \beta (\Delta T) d^3 Pr}{\mu^2} \right)^m \rightarrow h \propto \rho^{2m}$$

For a cylindrical approximation of an adult at rest, $Gr = 10^7$, so $C = 0.59$ and $m = 1/4$, which leads to

$$h_{alt} = h_{SL} \left(\frac{\rho_{alt}}{\rho_{SL}} \right)^{2(1/4)} = h_{SL} \left(\frac{P_{alt}}{P_{SL}} \right)^{0.5}$$

For higher air velocity ($40 < V < 800$ fpm), flow is dominated by forced convection:

$$h = \frac{k}{d} C (Re)^n Pr^{1/3} = \frac{k}{d} C \left(\frac{\rho V d}{\mu} \right)^n Pr^{1/3} \rightarrow h \propto \rho^n$$

For a cylindrical approximation of an adult at rest, $Re > 4000$, so $C = 0.193$ and $n = 0.618$, which leads to

$$h_{alt} = h_{SL} \left(\frac{\rho_{alt}}{\rho_{SL}} \right)^{0.618} = h_{SL} \left(\frac{P_{alt}}{P_{SL}} \right)^{0.618}$$

These two correction factors have been combined (see Equation [37] in Chapter 9 of the 2017 *ASHRAE Handbook—Fundamentals*) to produce a simpler relationship that applies to the full velocity range ($0 < V < 800$ fpm):

$$h_{alt} \approx h_{SL} \left(\frac{P_{alt}}{P_{SL}} \right)^{0.55}$$

Next, examining the evaporation or mass transfer from the occupants, the evaporative heat transfer coefficient varies inversely with the ambient pressure (see Equation [38] in Chapter 9 of the 2017 *ASHRAE Handbook—Fundamentals*):

$$h_e = (LR)(h)$$

$$h_{e,alt} = LR_{alt} h_{SL} \left(\frac{P_{alt}}{P_{SL}} \right)^{0.55} \quad \text{and} \quad h_{SL} = \frac{h_{e,SL}}{LR_{SL}}$$

$$h_{e,alt} = LR_{alt} h_{SL} \left(\frac{h_{e,SL}}{LR_{SL}} \right) \left(\frac{P_{alt}}{P_{SL}} \right)^{0.55}$$

Substitute

$$LR_{alt} = \frac{R_{air} h_{fg} (144) \left(\frac{D_v}{\alpha} \right)^{2/3}}{P_{alt} c_{p,air} R_w}$$

$$LR_{SL} = \frac{R_{air} h_{fg} (144) \left(\frac{D_v}{\alpha} \right)^{2/3}}{P_{SL} c_{p,air} R_w}$$

(a conversion of pressure by 144 is shown here because LR is customarily in units of °F/psi)

$$h_{e,alt} \approx h_{e,SL} \left(\frac{P_{SL}}{P_{alt}} \right)^{0.45}$$

where

LR = Lewis relation, °F/psi

h = heat transfer coefficient, Btu/h·ft²·°F

h_{SL} = heat transfer coefficient at sea level, Btu/h·ft²·°F

h_e = evaporative heat transfer coefficient, Btu/h·ft²·psi

$h_{e,alt}$ = evaporative heat transfer coefficient at altitude, Btu/h·ft²·psi

$h_{e,SL}$ = evaporative heat transfer coefficient at sea level, Btu/h·ft²·psi

P_{alt} = cabin pressure at altitude, lb/ft²

P_{SL} = pressure at sea level; 2116 lb/ft²

R_{air} = gas constant for air; 1716 ft²/s²·°R

h_{fg} = evaporation enthalpy at human skin temperature, 1037 Btu/lb

D_v = mass diffusivity of water vapor in air; 0.99 ft²/h

α = diffusivity; 0.8366 ft²/h

$c_{p,air}$ = specific heat of air; 0.24 Btu/lb·°F

R_w = gas constant for water vapor; approximately 2758 ft²/s²·°R

About 70% of the metabolic heat is lost through convection/radiation (245 Btu/h sensible or 98 Btu/h convection, $h_r = 0.55$, plus 147 Btu/h radiation, $h_r = 0.83$) and 30% through evaporation (105 Btu/h latent) while seated at rest at sea level (see Table 1). At 8000 ft cabin altitude, in still air, the sensible heat would drop to $(0.47/0.55)98 = 84$ Btu/h convection, the radiation would remain at 147 Btu/h, and the latent heat would rise to $(129/113)105 = 120$ Btu/h for a total of 351 Btu/h. This would indicate a slightly higher temperature for comfort, or a net effect of a slightly cooler sensation at altitude, compared to the 350 Btu/h total required.

Internal Heat Sources

When considering heat sources in the cabin, there are several parallels to commercial and residential HVAC. Many heat sources such as appliances (refrigerators, conventional ovens, microwave ovens), lighting, and entertainment (TV, stereo), may be in the cabin. In addition, the electronics and equipment associated with the

Table 1 Heat and Mass Transfer Coefficients for Human Body Versus Altitude

Altitude, ft	Pressure, lb/ft ²	Convection h , Btu/h·ft ² ·°F		Evaporation h_e , Btu/h·ft ² ·psi	
		$V < 40$	$40 < V < 800$	$V < 40$	$40 < V < 800$
0	2116	0.55	$0.061V^{0.6}$	113	$12.5V^{0.6}$
1000	2041	0.54	$0.060V^{0.6}$	115	$12.7V^{0.6}$
2000	1968	0.53	$0.059V^{0.6}$	117	$12.9V^{0.6}$
3000	1897	0.52	$0.057V^{0.6}$	119	$13.1V^{0.6}$
4000	1828	0.51	$0.056V^{0.6}$	121	$13.4V^{0.6}$
5000	1761	0.50	$0.055V^{0.6}$	123	$13.6V^{0.6}$
6000	1696	0.49	$0.054V^{0.6}$	125	$13.8V^{0.6}$
7000	1633	0.48	$0.053V^{0.6}$	127	$14.0V^{0.6}$
8000	1572	0.47	$0.052V^{0.6}$	129	$14.3V^{0.6}$

operation of a commercial aircraft put demands on the airplane's environmental control system.

Cooling Requirements. The sizing criteria for air conditioning are usually ground operation on a hot, humid day with the aircraft fully loaded and the doors closed. A second consideration is cool-down of an empty, heat-soaked aircraft before passenger loading; a cooldown time of less than 30 min is usually desired. A cabin temperature of between 75 and 80°F is typically specified for these hot-day ground design conditions. During cruise, the system should maintain a cabin temperature of 75°F with a full passenger load. The cooling load is entirely sensible in most cases when air-cycle machines are used. When a vapor-cycle recirculation system is used, latent heat is added.

Heating Requirements. Heating requirements are based on a partially loaded aircraft on a very cold day. Cabin temperature warm-up for a cold-soaked aircraft is desired to be within 30 min as well. A cabin temperature of 70°F is typically specified for cold-day ground-operating conditions. During cruise, the system should be able to maintain a cabin temperature of 75°F with a 20% passenger load, a cargo compartment temperature above 40°F, and cargo floor temperatures above 32°F to prevent freezing of cargo.

Temperature Control

Whenever a section of the cabin or flight deck has capability for independent supply temperature control, it is termed a **zone**. Commercial aircraft (over 19 passengers) can have as few as two zones (cockpit and cabin) and as many as seven. These crew and passenger zones are individually temperature-controlled to a crew-selected temperature for each zone, ranging from 65 to 85°F. Some systems have limited temperature control in the passenger zones that can be adjusted by the flight attendants. The selected zone temperature is controlled to within 2°F of the sensed temperature, and temperature uniformity in the zone should be within 5°F. Separate temperature controls can be provided for cargo compartments.

Temperature control may also be the predominant driver of ventilation requirements. The interior of the fuselage has several electronic/electrical heat sources that are required for the aircraft's operation, as well as heat loads from ambient and from occupants and their activities. These increasing heat loads are accommodated by reducing supply temperatures:

$$T_{\text{supply}} = T_{\text{cabin}} - \frac{q_{\text{sources}}}{c_p \dot{w}}$$

where

q_{sources} = all heat into cabin, Btu/h

$\dot{w}$ = air weight flow, lb/h

c_p = specific heat; 0.24 Btu/lb·°F for air

T = temperature, °F

Supply temperatures in each of the zones have practical limits, such as the freezing temperature of water (humidity), when either the heat loads are too large or the mass flow is too low.

Air Velocity

The passenger cabin is most similar to buildings with very high occupant densities, such as theaters or lecture halls. In these situations, the air-conditioning system is typically in cooling mode (i.e., the supply diffuser temperature is cooler than the room temperature). The ducting and diffuser networks are best described as cold-air systems, in which the duct velocities are higher, duct temperatures lower, and the fraction of recirculated air smaller (about 50% of the mixture) than in buildings (which use up to 95%). The cold-air diffuser is also in much closer proximity to the occupants in an aircraft cabin. The design challenge is to deliver cool air to the passengers without uncomfortable drafts.

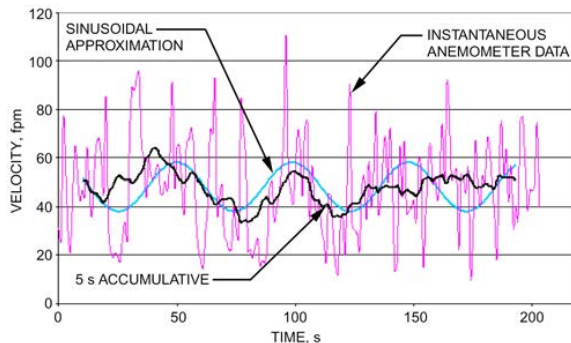


Fig. 6 Transient Air Velocity Measured in Seated Area of Aircraft Cabin

The velocity characteristics of an airplane cabin are uniquely affected by transitional flow behavior. The supply diffuser Reynolds number is typically between 3000 and 5000. Turbulence induced by the diffuser affects the perceived draftiness. Figure 6 shows the unsteady velocity variations measured in an aircraft cabin.

At any instant in time, the velocity field in the cabin will change, but an overall pattern develops for the time-averaged velocity. An example of this comes from computational fluid dynamics (CFD) modeling of a passenger cabin. Ventilation air enters the cabin near the center and blows outward in two directions. Air leaves near the floor on both sides, as shown in Figure 7.

Several comfort indices are used to evaluate air velocity, such as predicted percent dissatisfied (PPD) or predicted mean vote (PMV). Draft-sensitive areas of the body such as the ankles or neck receive special attention during air distribution system design. The velocity requirements are described in detail in Chapter 9 of the 2017 ASHRAE Handbook—Fundamentals and ASHRAE Standard 55.

Ventilation

Air drawn from the compressor section of the jet engine is called **bleed air** (also known as outside air, fresh air, outdoor air, or ambient air). When air is provided by sources other than the engine, it is not bleed air in the strict sense, because it is no longer bled from the engines. The current FAA requirement is to provide 0.55 lb/min of bleed/outdoor air per person. Because this requirement is expressed as a weight flow, the bleed air ventilation rate as a volumetric flow varies with cabin pressure and temperature. Cabin altitude is a convenient way of expressing cabin pressure by referencing the cabin pressure to a standard atmosphere. The required 0.55 lb/min is equivalent to about 7 cfm/person at sea level and 75°F. Based on ASHRAE research, ASHRAE Standard 161 established a ventilation rate for aircraft passengers at 7.5 cfm per passenger. This rate was based in part on the consideration that not all spaces in the enclosed area achieve 100% ventilation effectiveness. At other cabin pressures or altitudes, flow volumes can be found with the following equation:

$$Q_{FR} = \frac{\dot{w}}{\rho} = \frac{\dot{w}}{\left(\frac{P_c g}{RT_c}\right)} = \frac{\dot{w} R T_c}{P_c g}$$

where

$\dot{w}$ = 0.55 lb/min

R = 1716 ft²/s²·°R

g = 32.2 ft/s²

T_c = cabin temperature; 70°F = 529.67°R

P_c = cabin pressure from Table 2, lb/ft²

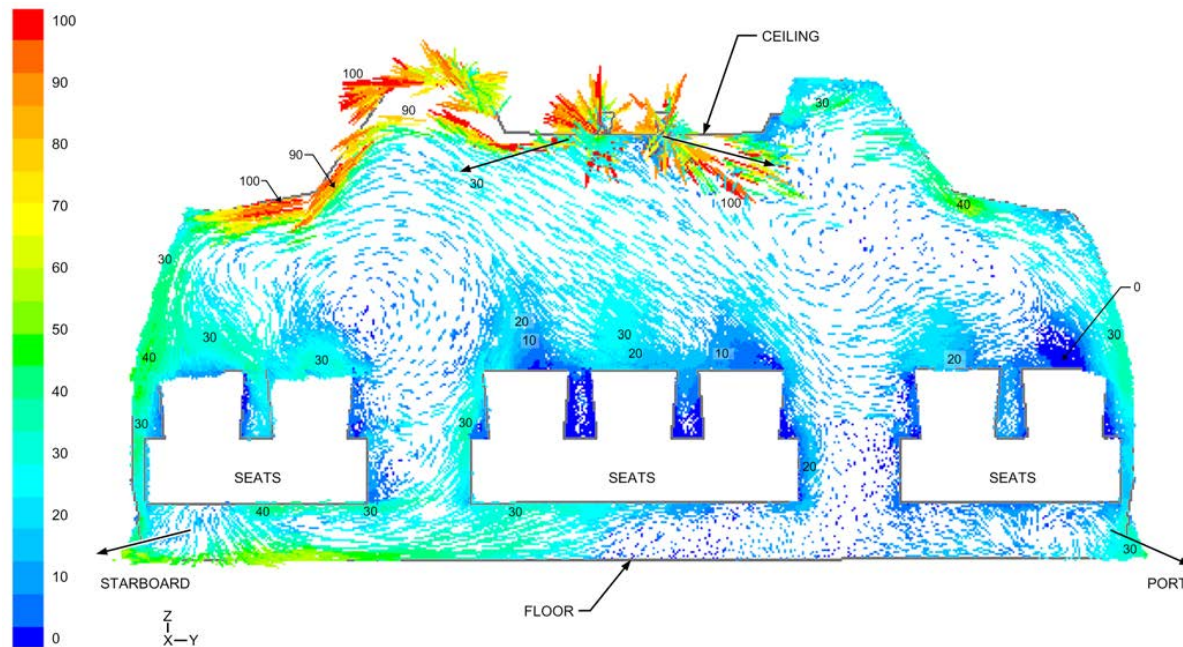


Fig. 7 Cabin Air Velocities from CFD, fpm

(Lin et al. 2005)

In many aircraft, the bleed/outdoor air flow is augmented by filtered or recirculated air. There are currently no regulatory requirements on the amount of recirculated air that enters the cabin, but it is customary to provide about 10 cfm per person of recirculated air in addition to the bleed air required by regulation, for a total of about 20 cfm per person at 8000 ft cabin altitude.

Ventilation Effectiveness. ASHRAE *Standards* 62.1-2018 and 161-2018 address ventilation effectiveness (VE), a measure of mixing within the volume relative to a perfectly mixed system (*Standard* 62.1 uses the term **zone air distribution effectiveness** E_z instead of VE). It is described with the following equations:

$$VE = \frac{c_{mixed} - c_{in}}{c_{local} - c_{in}}$$

where c = contaminant concentration, or

$$VE = \frac{Q_{local}}{Q_{cabin}}$$

where

c_{local} = local contaminant concentration by volume

c_{in} = inlet contaminant concentration

c_{mixed} = concentration if perfectly mixed

Q_{cabin} = contaminant flow to cabin or zone, cfm

Q_{local} = flow delivered to breathing zone, cfm

Contaminant concentrations in a perfectly mixed system are the same in the cabin volume as at the exit (floor grilles), and the concentration in the exit is based only on the ventilation rate and generation rate (including source and sink). Therefore, ventilation effectiveness indicates the degree of contaminant stratification with the volume. $VE > 1$ means that concentrations in the breathing zone are lower than in a perfectly mixed system; $VE < 1$ means they are higher.

There is a distinction between VE for bleed air and VE for total ventilation. For bleed air, the inlet concentration c_{in} is the

Table 2 FAA-Specified Bleed Airflow per Person

Cabin Pressure		Altitude, ft	Required Flow per Person at 75°F, cfm
psia	lb/ft ²		
14.696	2116	0	7.4
14.432	2078	500	7.5
14.173	2041	1000	7.7
13.917	2004	1500	7.8
13.664	1968	2000	8.0
13.416	1932	2500	8.1
13.171	1897	3000	8.3
12.930	1862	3500	8.4
12.692	1828	4000	8.6
12.458	1794	4500	8.7
12.228	1761	5000	8.9
12.001	1728	5500	9.1
11.777	1696	6000	9.2
11.557	1664	6500	9.4
11.340	1633	7000	9.6
11.126	1602	7500	9.8
10.916	1572	8000	10.0

concentration of gases in the supply air to the entire system (i.e., bleed air concentration). The local concentration will be larger than the inlet concentration only if the contaminant is generated within the cabin. For total ventilation, VE uses the c_{in} at the nozzle (i.e., supply mixture concentration) and includes contaminants from the recirculation system. The practical use of this VE applies to particulate levels in the cabin, because the recirculated air is equivalent to bleed air in this regard.

Contaminant concentrations in the cabin can be converted to flows delivered to the breathing zone Q_{local} using the following relationship:

$$Q_{local} = \frac{q_{gen}}{c_{local} - c_{in}}$$

Substitute

$$q_{gen} = Q_{supplied}(c_{mixed} - c_{in})$$

$$Q_{local} = Q_{supplied} \frac{c_{mixed} - c_{in}}{c_{local} - c_{in}}$$

where

$$q_{gen} = \text{CO}_2 \text{ generation rate, 0.0105 scfm/person}$$

$$c_{local} = \text{local CO}_2 \text{ concentration by volume}$$

$$c_{in} = \text{inlet CO}_2 \text{ concentration}$$

$$Q_{supplied} = \text{flow to cabin or zone, cfm}$$

$$Q_{local} = \text{flow delivered to breathing zone, cfm}$$

Some consideration can be given to distribution effectiveness (DE), where flows to higher-occupant-density sections of the cabin (e.g., coach) are used to set minimum flows to the cabin, and lower-density sections (e.g., first class) may subsequently be over-ventilated:

$$DE = \frac{Q_{zone}/n_{zone}}{Q_{cabin}/n_{cabin}}$$

where

$$Q_{zone}/n_{zone} = \text{flow per person in zone}$$

$$Q_{cabin}/n_{cabin} = \text{average flow per person for entire cabin}$$

Distribution effectiveness accounts for a system that provides a uniform flow per length of cabin yet has varying seating densities along the length. For bleed air distribution, this effectiveness is tempered somewhat by occupant diversity D (see ASHRAE *Standard* 62.1), because underventilated zones feed into the same recirculation flow. For total flow (bleed + recirculated) and for systems without recirculation, however, occupant diversity does not apply.

System ventilation efficiency (SVE) is a measure of how well mixed the recirculated air is with the bleed air before it enters the cabin. The SVE can be determined from the concentration variations in the ducts leaving the mix manifold (see Figure 11), for instance. The SVE is similar to VE in formulation:

$$SVE = \frac{c_{all\ zones} - c_{amb}}{c_{zone} - c_{amb}}$$

where

$$c_{all\ zones} = \text{average concentration of all supply ducts}$$

$$c_{zone} = \text{concentration in individual supply duct}$$

$$c_{amb} = \text{ambient reference concentration} = C_{fr} \text{ (bleed air concentration)}$$

Dilution Ventilation and TLV

Contaminants that are present in the supply air and are also generated within the cabin require increasing dilution flows to avoid reaching Threshold Limit Values (TLVs®) (ACGIH). For example, suppose carbon monoxide is present in the atmosphere at 210 ppb and that each person generates 0.168 mL CO per minute, or 5.93×10^{-6} cfm (Owens and Rossano 1969). The amount of bleed air required to stay below the EPA guideline of 9000 ppb will depend on the ambient CO levels, the human generation rate, and the CO contribution of the ventilation system:

$$Q_{req} = \frac{q_{gen}}{C_{TLV} - \Delta C_{system} - C_{fr}} = \frac{q_{gen}}{C_{TLV} - C_{supply}}$$

where

$$C_{TLV} = \text{allowable concentration}$$

$$\Delta C_{system} = \text{concentration rise from system}$$

$$C_{supply} = \text{concentration in supply (air entering cabin)}$$

$$C_{fr} = \text{concentration in bleed air}$$

$$q_{gen} = \text{CO generated per person}$$

Example 3. If the ventilation system does not contribute carbon monoxide to the supply air, then the required ventilation rate to stay below the threshold is

$$C_{TLV} = 9000 \text{ ppb} = 0.000009$$

$$q_{gen} = 5.93 \times 10^{-6} \text{ cfm}$$

$$\Delta C_{system} = 0$$

$$C_{fr} = 210 \text{ ppb} = 2.1 \times 10^{-7}$$

$$Q_{req} = \frac{q_{gen}}{C_{TLV} - \Delta C_{system} - C_{fr}} = \frac{5.93 \times 10^{-6}}{0.000009 - 0 - 2.1 \times 10^{-7}}$$

$$= 0.67 \text{ cfm/person}$$

If, however, the ventilation system produces a 1000 ppb rise in carbon monoxide, then the required ventilation is

$$C_{TLV} = 9000 \text{ ppb} = 0.000009$$

$$q_{gen} = 5.93 \times 10^{-6} \text{ cfm}$$

$$\Delta C_{system} = 1000 \text{ ppb} = 0.000001$$

$$C_{fr} = 210 \text{ ppb} = 2.1 \times 10^{-7}$$

$$Q_{req} = \frac{q_{gen}}{C_{TLV} - \Delta C_{system} - C_{fr}} = \frac{5.93 \times 10^{-6}}{0.000009 - 0.000001 - 2.1 \times 10^{-7}}$$

$$= 0.76 \text{ cfm/person}$$

It is important to note that, under certain circumstances, q_{gen} and ΔC_{system} may change sign as contaminant sources become contaminant sinks. This simplified approach shown here is more conservative, and could overpredict contaminant levels in real situations.

Air Exchange

High occupant density ventilation systems have higher air exchange rates than most buildings (i.e., offices). The typical airplane may have an air exchange rate of 10 to 20 air changes per hour (ach), whereas an office might have 1 ach. The air is not replaced in a mixed system at every air exchange. Actually, the ratio Q/V (air exchange rate) is more like the inverse of decay time constant τ . An airplane cabin can be approximated as a partially mixed volume (a volume with ventilation effectiveness) as long as the contaminant sources are uniformly distributed throughout the volume. For a well-mixed volume, contaminant in equals contaminant out plus contaminant accumulated in the volume, or

$$Qc_{in} = Qc_{out} + V \frac{dc}{dt}$$

Accounting for ventilation effectiveness, the concentration leaving the volume c_{out} is related to the concentration within the volume c and the concentration entering the volume c_{in} by the ventilation effectiveness VE:

$$VE = \frac{c_{mixed} - c_{amb}}{c_{local} - c_{amb}} = \frac{c_{out} - c_{amb}}{c_{local} - c_{amb}} \rightarrow c_{out} = c_{in} + VE(c - c_{in})$$

Substituting,

$$Qc_{in} = Q[c_{in} + VE(c - c_{in})] + V \frac{dc}{dt}$$

which leads to

$$c = c_{in} - (c_{in} - c_o)e^{-\frac{Q(VE)}{V}t}$$

Although air exchange rates are occasionally used as requirements on the ventilation system, in the case of cabin ventilation, there is no basis for setting one. Air exchange rate can be a surrogate (only for similarly sized volumes) for temperature uniformity, air quality, or smoke clearance. The flow-per-person specification is preferred, because it can be related to the predominant pollutant source more directly. Air exchange rates therefore indirectly provide valid ventilation comparisons between airplanes of similar volume and seating density. However, comparisons with buildings are misleading: occupant densities could be 30 times higher in aircraft, and bioeffluent doses (defined here as the time integral of the concentration of occupant-generated contaminants) for the same ventilation rate per person are greater in aircraft passenger cabins, depending upon occupancy times (see the section on Air Quality).

Filtration

Most airplane manufacturers have provisions for recirculated air filtration. Common practice is to install high-efficiency particulate air (HEPA) filters. The current industry standard for new build production aircraft is EU class H13 according to EN *Standard* 1822-1 and ISO *Standard* 29463-1 class 35H (i.e., 99.95% minimum removal efficiency by sodium flame test) (Eurovent 4/4, BS3928). This is equivalent to 99.97% minimum removal efficiency of approximately $0.3\ \mu\text{m}$ when tested according to Institute of Environmental Sciences and Technology *Recommended Practice* RP-CC001.5 (IEST 1997).

Filters are required to have sufficient particulate capacity to remain effective between normal maintenance intervals. The life of the filter is related to the recirculation system pressure drop, system operating pressure, and the recirculation fan curve. As the filter becomes loaded, pressure drop increases. When added to the system losses, the effect is a reduction in flow, as shown in [Figure 8](#).

It is important to change the filters at least as often as recommended by the manufacturer to maintain flow capacity.

Carbon/HEPA filters are available on the recirculation system for some aircraft models. Performance is not fully characterized. Filters must be tested and certified for each aircraft design. Currently available designs are intended to replace standard HEPA filters. The system designer must verify with the filter manufacturer the service life of the filter for the intended application. Most systems have no filtration of the engine bleed air supply as standard equipment, although some technologies (e.g., combined VOC/ozone converters

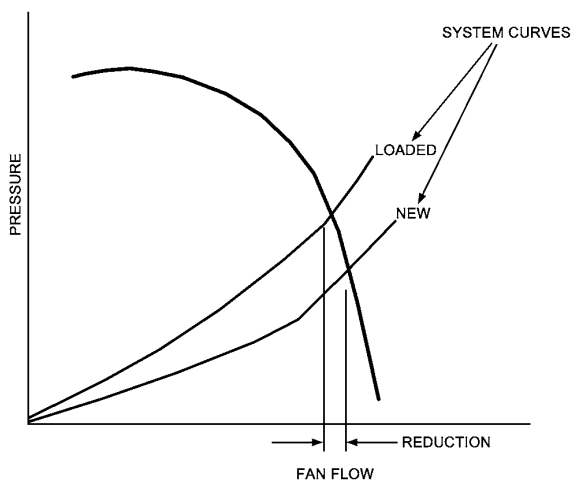


Fig. 8 Flow Reduction Caused by Filter Loading

and bleed air centrifugal cleaners) are sometimes offered as optional equipment.

Pressurization/Oxygen

Cabin pressurization achieves the required partial pressures of oxygen for the crew and passengers during high-altitude flight. At altitudes above 8000 ft, the occupied cabin must be pressurized to an equivalent altitude of 8000 ft or less to allow normal physiological functions without supplemental oxygen. The maximum pressure difference between the cabin and outside environment is limited by aircraft structural design limits. The differential pressure control provides a cabin pressure based on the flight altitude of the aircraft. A typical cabin altitude schedule is shown in [Figure 3](#). Additional provisions that are separate from normal cabin pressure controls must be provided for positive- and negative-pressure relief to protect the aircraft structure.

A DOT-sponsored study (DOT 1989) concluded that current pressurization criteria and regulations are generally adequate to protect the traveling public. The study also noted that the normal maximum rates of change of cabin pressure (approximately 500 ft/min in increasing altitude and 300 ft/min in decreasing altitude) do not pose a problem for the typical passenger.

However, pressurization of the cabin to equivalent altitudes of up to 8000 ft, as well as changes in the normal rates of pressure during climb and descent, may create discomfort for some people, such as those suffering from upper respiratory or sinus infections, obstructive pulmonary diseases, anemia, or certain cardiovascular conditions. In those cases, supplemental oxygen may be recommended. Children and infants sometimes experience discomfort or pain because of pressure changes during climb and descent. Injury to the middle ear has occurred to susceptible people, but is rare.

During a sudden cabin depressurization in flight, passengers and crew are provided with overhead masks supplying supplemental oxygen. Passengers with respiratory diseases can bring portable oxygen containers on board.

Humans at rest breathe at a rate of approximately 0.32 cfm while consuming oxygen at a rate of 0.014 cfm at 8000 ft. The percent oxygen makeup of the supply air remains at approximately 21% at cruise altitude. A person receiving 10 cfm of outside air and 10 cfm of recirculation air would therefore receive approximately 4.2 cfm of oxygen. The level drops to 4.186 cfm as it leaves the cabin. Consequently, the content of oxygen in cabin air is little affected by breathing (i.e., it drops 0.33%). Although the percentage of oxygen in cabin air remains virtually unchanged (20.93%) at all normal flight altitudes, the partial pressure of oxygen decreases with increasing altitude, which decreases the amount of oxygen held by the blood's hemoglobin. The increase in cabin altitude may cause low-grade hypoxia (reduced tissue oxygen levels) in some people. However, the National Academy of Sciences (NAS 1986, 2002) concluded that pressurization of the cabin to an equivalent altitude of 5000 to 8000 ft is physiologically safe for healthy individuals: no supplemental oxygen is needed to maintain sufficient arterial oxygen saturation.

System Description

The outdoor air supplied to the airplane cabin is usually provided by the compressor stages of the engine, and cooled by air-conditioning packs located under the wing center section. An air-conditioning pack uses the compressed ambient air as the refrigerant in air-cycle cooling.

Air is supplied and exhausted from the cabin on a continuous basis. As shown in [Figure 9](#), air enters the passenger cabin from supply nozzles that run the length of the cabin. Exhaust air leaves the cabin through return air grilles located in the sidewalls near the floor, running the length of the cabin on both sides. Exhaust air is continuously extracted from below the cabin floor by recirculation

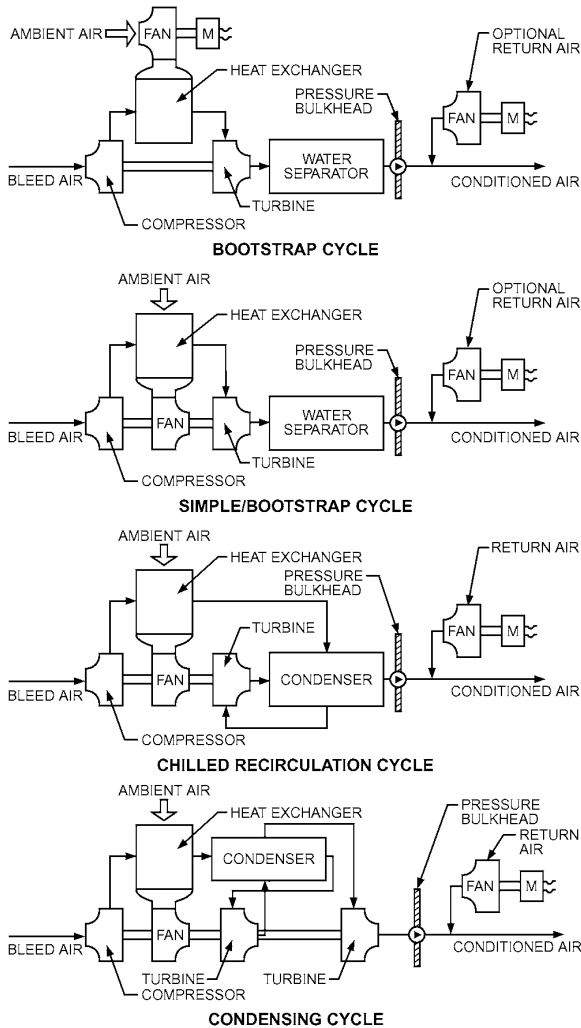


Fig. 11 Some Aircraft Refrigeration Cycles

increases pack cooling capacity by depressing the ram air heat sink temperature.

The **high-pressure water separator** condenses and removes moisture at high pressure upstream of the cooling turbine. A heat exchanger uses turbine discharge air to cool the high-pressure air sufficiently to condense most of the moisture present in the bleed air supply. The moisture is collected and sprayed into the ram airstream.

In the condensing cycle one turbine removes the high-pressure water and the second turbine does the final expansion to subfreezing temperature air that is to be mixed with filtered, recirculated cabin air. Separating these functions recovers the heat of condensation, which results in a higher cycle efficiency. It also eliminates condenser freezing problems because the condensing heat exchanger is operated above freezing conditions.

The air-conditioning packs are located in unpressurized areas of the aircraft to minimize structural requirements of the ram air circuit that provides the necessary heat sink for the air-conditioning cycle. This location also provides protection against cabin depressurization in the event of a bleed or ram air duct rupture. The most common areas for the air-conditioning packs are the underwing/wheel

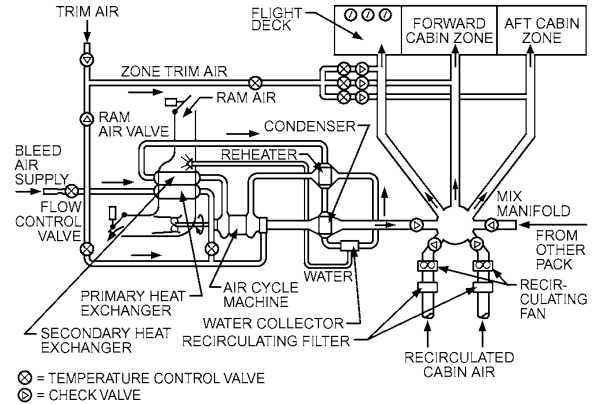


Fig. 12 Aircraft Air-Conditioning Schematic

well area and the tail cone area aft of the rear pressure bulkhead. Other areas include the areas adjacent to the nose wheel and overwing fairing. The temperature control components and recirculating fans are located throughout the distribution system in the pressurized compartments. The electronic pack and zone temperature controllers are located in the electrical/electronic (E/E) bay. The air-conditioning control panel is located in the flight deck. A schematic of a typical air-conditioning system is shown in Figure 12.

Cabin Pressure Control

Cabin pressure is controlled by modulating airflow discharged from the pressurized cabin through one or more cabin outflow valves. The cabin pressure control includes the outflow valves, controller, selector panel, and redundant positive-pressure relief valves. Provisions for negative-pressure relief are incorporated in the relief valves and/or included in the aircraft structure (door). The system controls the cabin ascent and descent rates to acceptable comfort levels, and maintains cabin pressure altitude in accordance with cabin-to-ambient differential pressure schedules. Modern controls usually set landing field altitude, if not available from the flight management system (FMS), and monitor aircraft flight through the FMS and the air data computer (ADC) to minimize cabin pressure altitude and rate of change.

The cabin-pressure-modulating and safety valves (positive-pressure relief valves) are located either on the aircraft skin, in the case of large commercial aircraft, or on the fuselage pressure bulkhead, in the case of commuter, business, and military aircraft. Locating outflow valves on the aircraft skin precludes handling of large airflows in the unpressurized tailcone or nose areas and provides some thrust recovery; however, these double-gate valves are more complex than the butterfly or poppet-type valves used for bulkhead installations. Safety valves are poppet-type valves for either installation. Most commercial aircraft have electronic controllers located in the E/E bay. The cabin pressure selector panel is located in the flight deck.

2. TYPICAL FLIGHT

A typical flight scenario from London's Heathrow Airport to Los Angeles International Airport would be as follows:

While the aircraft is at the gate and the engines have not been started yet, the ECS can be powered by compressed air supplied by the auxiliary power unit (APU), or bleed air from a ground cart. The APU or ground-cart bleed air is ducted directly to the bleed air manifold upstream of the air-conditioning packs. Once started, the

engines become the compressed air source and the ground carts are disconnected.

Taxiing from the gate at Heathrow, the outside air temperature is 59°F with an atmospheric pressure of 14.7 psia. The aircraft engines are at low thrust, pushing the aircraft slowly along the taxiway.

Engine Bleed Air Control

As air from outside enters the compressor stages of the engine, it is compressed to 32 psig and a temperature of 330°F. Some of this air is then extracted from the engine core through one of two openings (bleed ports) in the side of the engine. Which bleed port extracts the air depends on the positioning of valves that control the ports. One bleed port is at a higher engine compressor stage (e.g., fifteenth stage), commonly called high stage. The second is at a lower compressor stage (e.g., eighth stage), commonly called low stage or intermediate stage. The exact stage varies depending on engine type. At low engine power, the high stage is the only source of air at sufficient pressure to meet the needs of the bleed system. Bleed stage selection is totally automatic, except for a shutoff selection available to the pilots on the overhead panel in the flight deck.

As the aircraft turns onto the runway, the pilots advance the engine thrust to takeoff power. The engine's high stage compresses the air to 1200°F and 430 psia. This energy level exceeds the requirements for the air-conditioning packs and other pneumatic services; approximately 50% of the total energy available at the high-stage port cannot be used, so the bleed system automatically switches to the low-stage port to conserve energy.

Because the engine must cope with widely varying conditions from ground level to flight at an altitude of up to 43,100 ft, during all seasons and throughout the world, air at the high or low stage of the engine compressor seldom exactly matches the pneumatic systems' needs. Excess energy must be discarded as waste heat. The bleed system constantly monitors engine conditions and selects the least wasteful port. Even so, bleed port temperatures often exceed fuel auto-ignition temperatures. The precooler automatically discharges excess energy to the atmosphere to ensure that the temperature of the pneumatic manifold is well below that which could ignite fuel in the event of a fuel leak.

The aircraft climbs to a cruise altitude of 39,000 ft, where the outside air temperature is -70°F at an atmospheric pressure of 2.9 psia, and the partial pressure of oxygen is 0.6 psi. Until the start of descent to Los Angeles, the low-stage compressor is able to compress the low-pressure cold outdoor air to more than 30 psia and above 400°F. This conditioning of the air is all accomplished through the heat of compression: fuel is added only after the air has passed through the compressor stages of the engine core.

Figure 13 shows the temperature of the air leaving the bleed system (labeled "to airplane" in Figure 10) from the time of departure to the time of arrival at Los Angeles.

The air then passes through an ozone converter on its way to the air-conditioning packs located under the wing at the center of the aircraft.

Ozone Protection

While flying at 39,000 ft, several ozone plumes are encountered. Some have ozone concentrations as high as 0.8 ppm, or 0.62 ppm sea-level equivalent (SLE). This assumes a worst-case flight during the month of April, when ozone concentrations are highest. If this concentration of ozone were introduced into the cabin, passengers and crew could experience chest pain, coughing, shortness of breath, fatigue, headache, nasal congestion, and eye irritation.

Atmospheric ozone dissociation occurs when ozone goes through the compressor stages of the engine, the ozone catalytic converter (which is on aircraft with a route structure that can encounter high ozone concentrations), and the air-conditioning packs. The ozone further dissociates when contacting ducts, interior surfaces, and the

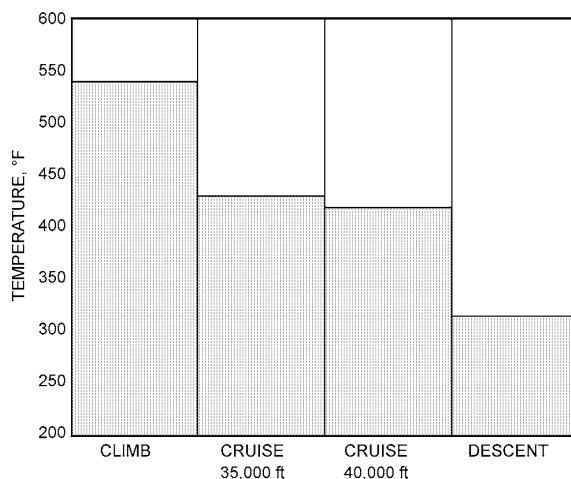


Fig. 13 Bleed Air Temperatures

recirculation system. The ozone converter dissociates ozone to oxygen molecules by using a noble catalyst such as palladium. A new converter dissociates approximately 95% of the ozone entering the converter to oxygen. It has a useful life of about 12,000 flight hours.

As the air leaves the ozone converter, it is still at 400°F and a pressure of 30 psia. Assuming a worst case when the converter is approaching the end of its useful life, with an ozone conversion efficiency of 60%, the ozone concentration leaving the converter is about 0.25 ppm SLE. This air goes through the air-conditioning packs and enters the cabin. The ozone concentration in the cabin is about 0.09 ppm. As mentioned in the section on Regulations, the FAA sets a 3 h time-weighted average ozone concentration limit in the cabin of 0.1 ppm and a peak ozone concentration limit of 0.25 ppm.

Air Conditioning and Temperature Control

Air next enters the air-conditioning packs, which provide essentially dry, sterile, and dust-free conditioned air to the airplane cabin at the proper temperature, flow rate, and pressure to satisfy pressurization and temperature control requirements. For most aircraft, this is approximately 5 cfm per passenger. To ensure redundancy, typically two (or more) air-conditioning packs provide a total of about 10 cfm of conditioned air per passenger. An equal quantity of filtered, recirculated air is mixed with air from the air-conditioning packs for a total of approximately 20 cfm per passenger. Automatic control for the air-conditioning packs constantly monitors airplane flight parameters, the flight crew's selection for temperature zones, cabin zone temperature, and mixed distribution air temperature. The control automatically adjusts the various valves for a comfortable environment under normal conditions. The pilot's controls are located on the overhead panel in the flight deck, along with the bleed system controls. Normally, pilots are required only to periodically monitor the compartment temperatures from the overhead panel. Temperatures can be adjusted based on flight attendant reports of passengers being too hot or too cold. Various selections are available to the pilots to accommodate abnormal operational situations.

Air Recirculation

The air has now been cooled and leaves the air-conditioning packs. It leaves the packs at 60°F and 11.8 psi. The relative humidity is less than 1% and ozone concentration is less than 0.25 ppm. The

carbon dioxide concentration remains unchanged from that of the outside air at about 350 ppm. As this air enters a mixing chamber, it is combined with recirculated air.

The recirculated air is filtered before entering the mix manifold. Over 99.9% of the bacteria and viruses that reach the recirculation filters are removed from recirculated air by HEPA filters, which are used on most modern aircraft.

Air Distribution

The filtered and bleed air mixture leaves the mixing chamber on its way through the air distribution system. At this time, its humidity has increased relative to bleed air by about 5 to 10% rh. The temperature of the mixture is determined by the cooling requirements of the dominant zone. Control for the remaining zones is achieved by adding hot air to the zone supply. The hot-air source is the same bleed supply as the packs, so very small amounts of air are required to adjust the temperature.

Carbon dioxide levels in the distribution system are about half-way between the levels in bleed air and in the cabin. At a 6000 ft cabin altitude, the level is about 1000 ppm in the distribution system.

The mixture leaves the air distribution system and enters the cabin through high-velocity diffusers. The diffusers run the length of the cabin. In order to minimize fore-to-aft flow and mixing between zones, flow is provided at a uniform amount per unit length of cabin. Even though the air change rates are high compared to buildings, they are low when looking at the plug flow velocity. If ventilation air were provided uniformly across the cabin, as in plug flow, the velocity would be less than 5 fpm. Momentum from the diffusers increases velocity up to comfortable levels of 15 to 65 fpm.

Once the air mixes with the air in the cabin, the humidity rises by another 5 to 10% rh to stabilize at 10 to 20% rh, and the carbon dioxide level rests at about 1700 ppm (at 6000 ft cabin altitude).

Cabin Pressure Control

The cabin pressure control system continuously monitors ground and flight modes, altitude, climb, cruise or descent modes, and the airplane's holding patterns at various altitudes. It uses this information to position the cabin pressure outflow valve to maintain cabin pressure as close to sea level as practical, without exceeding a cabin-to-outside pressure differential of 8.60 psi. At a 39,000 ft cruise altitude, the cabin pressure is equivalent to 6900 ft or a pressure of 11.5 psia. In addition, the outflow valve repositions itself to allow more or less air to escape as the airplane changes altitude. The resulting cabin altitude is consistent with airplane altitude within the constraints of keeping pressure changes comfortable for passengers. The cabin pressure control system panel is located in the pilot's overhead panel near the other air-conditioning controls. Normally, the cabin pressure control system is totally automatic, requiring no attention from the pilots.

Finally, as descent to LAX begins, the cabin pressure controller follows a prescribed schedule for repressurization. The cabin altitude eventually reaches sea level, the doors can then be opened at the gate, and passengers depart.

3. AIR QUALITY

Factors Affecting Perceived Air Quality

Several factors can influence comfort and *perceived* cabin air quality. These cabin environmental parameters, in combination with maintenance-, operations-, individual-, and job-related factors, collectively influence the cabin crew and passenger perceptions of the cabin environment. **Cabin environmental quality (CEQ)** must be differentiated from **cabin air quality (CAQ)**, because many symptoms, such as eye irritation, for example, may be caused by humidity (CEQ) as well as contaminants (CAQ).

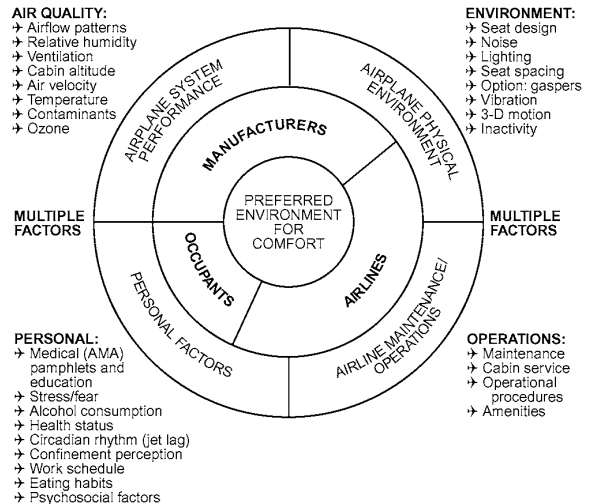


Fig. 14 Multiple Comfort Factors

(Adapted, with permission, from STP 1393—Air Quality and Comfort in Airliner Cabins, copyright ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428)

Strictly, air quality is a measure of pollutant levels. Aircraft cabin air quality is function of many variables including: the quantity of ventilation flow, ambient air quality, the design of the cabin volume, the design of the ventilation and pressurization systems, the way the systems are operated and maintained, the presence of sources of contaminants, and the strength of such sources.

Figure 14 depicts the three groups that can influence cabin environmental quality: manufacturers, airlines, and the occupants themselves. Airplane manufacturers influence the physical environment by the design of the environmental control system integrated with the rest of the systems on the airplane. Airlines affect the environmental conditions in the cabin by seating configuration, amenities offered, and procedures for maintaining and operating the aircraft. Finally, cabin environmental comfort is influenced by the individual and job-related activities of the cabin crew and passengers.

Factors that can individually or collectively affect aircraft cabin air quality are discussed in the following sections.

Airflow

The airflow per unit length of the airplane is typically the same for all sections. However, economy class has a lower airflow per passenger because of its greater seating density compared to first class and business class.

The flight deck is provided with a higher airflow per person than the cabin in order to (1) maintain a positive pressure in the cockpit to prevent smoke ingress from adjacent areas (abnormal condition), (2) provide cooling for electrical equipment, and (3) account for increased solar loads and night heat loss through the airplane skin and windows.

The bleed or outdoor air quantity supplied on some aircraft models can be reduced by shutting off one air-conditioning pack. The flight crew has control of these packs to provide flexibility in case of a system failure or for special use of the aircraft. However, packs should be in full operation whenever passengers are on board.

Air Changes

Confusion abounds over the use of air exchange rate (also called "air change rate") when making comparisons between dissimilar systems. Further, there is no air quality equivalence in the compar-

ison of systems unless the occupied volumes are equal. This is because high air exchange rates can be achieved in two ways. As airflow increases, the air change rate increases; however, as volume decreases, the air change rate also increases but without a proportionate increase in air quality. Air exchange rate is the ratio of ventilation flow to volume:

$$ACR = \frac{Q}{V}$$

where

ACR = air change rate, h⁻¹

Q = flow, ft³/h

V = volume, ft³

A close inspection of the definition reveals the subtle relationship between air quality $c = q/Q$ (steady state) and air exchange rate:

$$c = \text{Air quality} = q/(ACR)V$$

where

c = contaminant levels

q = contaminant generation rate

It is incorrect to assume that a smaller, single-aisle aircraft has better air quality than a larger, double-aisle aircraft simply because the air exchange rate is higher. Similarly, comparisons of buildings are in error. Remember, air quality is related to flow, which is the product of air change and volume.

The air exchange rate (bleed air to volume ratio) for an airplane cabin is typically between 11 and 15 ach [air changes per hour (ACH)]. Dilution rates for these air changes are between 25 and 18 min for replacement of 99% of the air. The particulate equivalent of an air exchange rate (total ventilation to volume ratio, where total ventilation = bleed + HEPA filtered recirculation) is between 20 and 30 equivalent air changes per hour.

Ozone

Ozone is present in the atmosphere as a consequence of the photochemical conversion of oxygen by solar ultraviolet radiation. Ozone levels vary with season, altitude, latitude, and weather systems. A marked and progressive increase in ozone concentration occurs in the flight altitude of commercial aircraft. The mean ambient ozone concentration increases with increasing latitude, is maximal during the spring (fall season for southern latitudes), and often varies when weather causes high ozone plumes to descend.

Residual cabin ozone concentration is a function of the ambient concentration; design, operation, and maintenance of the air distribution system; and whether catalytic ozone converters are installed.

Cabin ozone limits are set by FAR *Standards* 121.578 and 25.832. Catalytic ozone converters are generally required on airplanes flying mission profiles where the cabin ozone levels are predicted to exceed these limits (refer to the FAA Code of Federal Regulations for other compliance methods).

Microbial Aerosols

Biologically derived particles that become airborne include viruses, bacteria, actinomycetes, fungal spores and hyphae, arthropod fragments and droppings, and animal and human dander. One study has documented the occurrence of an outbreak of infectious disease related to airplane use. In 1977, because of an engine malfunction, an airliner with 54 persons onboard was delayed on the ground for 3 h, during which the airplane ventilation system was reportedly turned off. Within 3 days of the incident, 72% of the passengers became ill with influenza. One passenger (the index case) was ill while the airplane was delayed. With the ventilation system shut off, no bleed air was introduced into the cabin to dilute microbial aerosols and CO₂ or to control cabin temperatures.

The airplane ventilation system should never be shut off when passengers are on board, although the air packs (but not recirculation fans) may be shut off for a short time during takeoff only.

To remove particulates and biological particles from the recirculated air, use filter assemblies that contain a HEPA filter with a minimum efficiency of 99.97% on a dioctyl phthalate (DOP) test, as measured by MIL-STD-282. A HEPA filter is rated using 0.3 μm size particles. A filter's efficiency increases over time as particulates become trapped by the filter. However, system performance degrades because of increased pressure drop. Overlapping capture mechanisms in a filter also increase efficiency for particles smaller and larger than the most penetrating particle size (MPPS). For an airplane filter, the MPPS is about 0.1 to 0.2 μm.

Viruses typically range from about 0.01 to 0.2 μm, and are effectively removed by the air filtration mechanism of diffusional interception. Bacteria are typically about 0.5 to 1.5 μm, and are effectively removed by inertial impaction.

Activity Levels

Respiratory rates (also called minute ventilation) and, hence, air contaminant doses vary with activity level. Elevated activity levels increase respiration rate, and thereby may increase the dose of some airborne contaminants. Breathing rates range from approximately 0.3 cfm for a seated passenger to 0.6 cfm for a working flight attendant.

Volatile Organic Compounds

Volatile organic compounds (VOCs) can be emitted by material used in furnishings, pesticides, disinfectants, cleaning fluids, and food and beverages.

Carbon Dioxide

Carbon dioxide is the product of normal human metabolism, which is CO₂'s predominant source in aircraft cabins. Concentration in the cabin varies with bleed-air flow rate, number of people present, and their individual rates of CO₂ production, which vary with activity and, to a smaller degree, with diet and health. CO₂ has been widely used as an indicator of indoor air quality, typically serving the function of a surrogate. According to the DOT (1989), measured cabin CO₂ values of 92 randomly selected smoking and nonsmoking flights averaged 1500 ppm.

The environmental exposure limit adopted by the Association of German Engineers (VDI 2004) and the American Conference of Governmental Industrial Hygienists (ACGIH) is 5000 ppm as the time-weighted average (TWA) limit for CO₂; this value corresponds to a bleed air ventilation rate of about 2.3 cfm per person at sea level, if the only source of CO₂ is the occupants at rest. Other sources of CO₂ within the cabin or cargo (e.g., dry ice) would of course require more ventilation. 14CFR/CS/JAR 25.831 also limits CO₂ to 5000 ppm (0.5%).

4. REGULATIONS

The Federal Aviation Administration (FAA) regulates the design of transport category aircraft for operation in the United States under section 14 of the Code of Federal Regulation (CFR) Part 25 (commonly referred to as the Federal Aviation Regulations [FARs]). ECS equipment and systems must meet these requirements, which are primarily related to safety of the occupants. Certification and operation of these aircraft in the United States is regulated by the FAA in FAR Part 121. Similar regulations are applied to European nations by the European Aviation Safety Agency (EASA), which represents the combined requirements of the airworthiness authorities of the participating nations; the current equivalent design regulation is Certification Specification (CS) 25, although many airplanes were designed and certified to the former Joint Aviation Regulations (JARs) Part 25. Operating rules based on FAA or EASA regulations are applied in-

dividually by the nation of registry. Regulatory agencies may impose special conditions on the design, and compliance is mandatory.

Several 14 CFR and CS/JAR Part 25 paragraphs apply directly to transport category aircraft ECS. Those most germane to the ECS design requirements of this chapter are as follows:

- 14CFR/CS/JAR 25.831 Ventilation
- 14CFR/CS 25.832 Cabin ozone concentration
- 14CFR/CS/JAR 25.841 Pressurized cabins
- 14CFR/CS/JAR 25.1301 Function and installation
- 14CFR/CS/JAR 25.1309 Equipment, systems, and installations
- 14CFR/CS/JAR 25.1438 Pressurization and pneumatic systems
- 14CFR/CS/JAR 25.1461 Equipment containing high energy rotors

These regulatory requirements are summarized in the following sections; however, the applicable FAR, CS and JAR paragraphs, amendments and advisory material should be consulted for the latest revisions and full extent of the rules.

14 CFR/CS/JAR Paragraph 25.831: Ventilation

- Each passenger and crew compartment must be ventilated.
- Each crew member must have enough bleed air to perform their duties without undue fatigue or discomfort (minimum of 10 cfm).
- Crew and passenger compartment air must be free from hazardous concentration of gases and vapors:
 - CO limit is 1 part in 20,000 parts of air
 - CO₂ limit is 0.5% by volume, sea level equivalent. Many airplanes were designed/certified to a carbon dioxide limit of 3% by volume (the former requirement)
 - CO and CO₂ limits must be met after reasonably probable failures
- Smoke evacuation from the cockpit must be readily accomplished without depressurization.
- Occupants of the flight deck, crew rest area, and other isolated areas must be able to control the temperature and quantity of ventilating air to their compartments independently.

14 CFR 25.831, Amendment 25-87 (specifies new requirements)

- Under normal operating conditions, the ventilation system must be designed to provide each occupant with airflow containing at least 0.55 lb of bleed air per minute (or about 10 cfm at 8000 ft).
- The maximum exposure at any given temperature is specified as a function of the temperature exposure.

FAA Advisory Circular (AC) 25-20/ Acceptable Means of Compliance/Advisory Circular-Joint 25.831

- The ventilation system should be designed to provide enough fresh air to prevent accumulation of odors and pollutants such as carbon dioxide.
- In the event of loss of one source or probable failure conditions, the supply of bleed air should not be less than 0.4 lb/min per person for any period exceeding 5 min. This is derived from the ventilation rate procedure of ASHRAE *Standard* 62-1981. However, temporary reductions below this flow rate may be accepted if the compartment environment can be maintained at a level that is not hazardous to the occupant.

14 CFR/CS 25.832: Cabin Ozone Concentration

Specifies the cabin ozone concentration during flight must be shown not to exceed the following:

- 0.25 ppm by volume, sea level equivalent, at any time above flight level 320 (32,000 ft)

- 0.10 ppm by volume, sea level equivalent, time-weighted average during any 3 h interval above flight level 270 (27,000 ft)

At present, JAR 25 has no requirement for cabin ozone concentration.

14 CFR/CS/JAR 25.841: Pressurized Cabins

- Maximum cabin pressure altitude is limited to 8000 ft at the maximum aircraft operating altitude under normal operating conditions.
- For operation above 25,000 ft, a cabin pressure altitude of not more than 15,000 ft must be maintained in the event of any reasonably probable failure or malfunction in the pressurization system.
- The makeup of the cabin pressure control components, instruments, and warning indication is specified to ensure the necessary redundancy and flight crew information.

14 CFR Amendment 25-87

This revision imposes additional rules for high-altitude operation.

14 CFR/CS/JAR 25.1301: Function and Installation

Each item of installed equipment must be of a kind and design appropriate to its intended function, be properly labeled, be installed according to limitations specified for that equipment, and function properly.

14 CFR/CS/JAR 25.1309: Equipment, Systems, and Installations

- Systems and associated components must be designed such that any failure that would prevent continued safe flight and landing is extremely improbable, and any other failure that reduces the ability of the aircraft or crew to cope with adverse operating conditions is improbable.
- Warning information must be provided to alert the crew to unsafe system operating conditions so they can take corrective action.
- Analysis in compliance with these requirements must consider possible failure modes, probability of multiple failures, undetected failures, current operating condition, crew warning, and fault detection.

FAR *Advisory Circular* AC 25.1309-1A, CS AMJ 25.1309, and JAR ACJs 1 to 25.1309 define the required failure probabilities for the various failure classifications: probable, improbable, and extremely improbable for the FAR requirements; and frequent, reasonably probable, remote, and extremely remote for the CS/JAR requirements.

14 CFR/CS 25.1438: Pressurization and Pneumatic Systems

This standard specifies the proof and burst pressure factors for pressurization and pneumatic systems as follows:

- Pressurization system elements
 - Proof pressure: 1.5 times max normal pressure
 - Burst pressure: 2.0 times maximum normal pressure
- Pneumatic system elements
 - Proof pressure: 1.5 times maximum normal pressure
 - Burst pressure: 3.0 times maximum normal pressure

CS/JAR 25.1438 and AMJ/ACJ 25.1438 specify the proof and burst pressure factors for pressurization and pneumatic systems as follows:

- Proof pressure
 - 1.5 times worst normal operation
 - 1.33 times worst reasonable probable failure
 - 1.0 times worst remote failure

- Burst pressure
 - 3.0 times worst normal operation
 - 2.66 times worst reasonably probable failure
 - 2.0 times worst remote failure
 - 1.0 times worst extremely remote failure

14 CFR/CS/JAR 25.1461: Equipment Containing High-Energy Rotors

Equipment must comply with at least one of the following three requirements:

- High-energy rotors contained in equipment must be able to withstand damage caused by malfunctions, vibration, and abnormal temperatures.
 - Auxiliary rotor cases must be able to contain damage caused by high-energy rotor blades.
 - Equipment control devices must reasonably ensure that operating limitations affecting the integrity of high-energy rotors will not be exceeded in service.
- Testing must show that equipment containing high-energy rotors can contain any failure that occurs at the highest speed attainable with normal speed control devices inoperative.
- Equipment containing high-energy rotors must be located where rotor failure will neither endanger the occupants nor adversely affect continued safe flight.

Categories and Definitions

Commercial users categorize their ECS equipment in accordance with the Air Transport Association of America (ATAA) *Specification 100*. The following ATAA chapters define ECS functions and components:

- **Chapter 21**, Air Conditioning, discusses heating, cooling, moisture/contaminant control, temperature control, distribution, and cabin pressure control. Common system names are the air-conditioning system (ACS) and the cabin pressure control system (CPCS).
- **Chapter 30**, Ice and Rain Protection, covers airfoil ice protection; engine cowl ice protection; and windshield ice, frost, or rain protection.
- **Chapter 35**, Oxygen, includes components that store, regulate, and deliver oxygen to the passengers and crew.
- **Chapter 36**, Pneumatic, covers ducts and components that deliver compressed (bleed) air from a power source (main engine or auxiliary power unit) to connecting points for the using systems (which are detailed in Chapters 21, 30, and 80). The pneumatic system is also commonly called the engine bleed air system (EBAS).

REFERENCES

ASHRAE members can access *ASHRAE Journal* articles and ASHRAE research project final reports at technologyportal.ashrae.org. Articles and reports are also available for purchase by nonmembers in the online ASHRAE Bookstore at www.ashrae.org/bookstore.

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CHAPTER 66

CODES AND STANDARDS

THE codes and standards and other publications listed here represent practices, methods, or standard published by the organizations indicated. They are useful guides for the practicing engineer in determining test methods, ratings, performance requirements, and limits of HVAC&R equipment. Copies of these publications can be obtained from most of the organizations listed in the Publisher column, from Global Engineering Documents at global.ihs.com, or from Techstreet at techstreet.com. Addresses of the organizations are given at the end of the chapter.

Selected Codes and Standards Published by Various Societies and Associations

Subject	Title	Publisher	Reference
<i>Air Conditioners</i>	Commercial Systems Overview	ACCA	ACCA Manual CS-1993
	Residential Equipment Selection, 2nd ed.	ACCA	ANSI/ACCA 3 Manual S®-2014
	HVAC Quality Installation Specification	ACCA	ANSI/ACCA 5 QI-2015
	Technician's Guide & Workbook for Quality Installations	ACCA	ACCA 2015
	Laboratory Methods of Testing Air Terminal Units	ASHRAE	ANSI/ASHRAE 130-2016
	Non-Ducted Air Conditioners and Heat Pumps—Testing and Rating for Performance	ISO	ISO 5151:2017
	Ducted Air-Conditioners and Air-to-Air Heat Pumps—Testing and Rating for Performance	ISO	ISO 13253:2017
	Guidelines for Roof Mounted Outdoor Air-Conditioner Installations	SMACNA	SMACNA 1997
	Heating and Cooling Equipment	UL/CSA	ANSI/UL 1995-2011/C22.2 No. 236-11
	Performance Standard for Split-System and Single-Package Central Air Conditioners and Heat Pumps	CSA	CAN/CSA C656-14
Gas-Fired	Energy Performance Rating for Large and Single Packaged Vertical Air Conditioners and Heat Pumps	CSA	CAN/CSA C746-2017
	Commercial Systems Overview	ACCA	ACCA Manual CS-1993
	Residential Equipment Selection, 2nd ed.	ACCA	ANSI/ACCA 3 Manual S-2014
	Home Evaluation and Performance Improvement	ACCA	ANSI/ACCA 12 QH-2018
	Technician's Guide & Workbook for Home Evaluation and Performance Improvement	ACCA	ACCA 2014
	Gas-Fired, Heat Activated Air Conditioning and Heat Pump Appliances	CSA	ANSI Z21.40.1-1996/CGA 2.91-M96 (R2017)
	Gas-Fired Work Activated Air Conditioning and Heat Pump Appliances (Internal Combustion)	CSA	ANSI Z21.40.2-1996/CGA 2.92-M96 (R2017)
	Performance Testing and Rating of Gas-Fired Air Conditioning and Heat Pump Appliances	CSA	ANSI Z21.40.4a-1998/CGA 2.94a-M98 (R2017)
	Packaged Terminal Air-Conditioners and Heat Pumps	AHRI/CSA	AHRI 310/380-2017/CSA C744-2017
	Room Air Conditioners	AHAM	ANSI/AHAM RAC-1-2015
Packaged Terminal Room	Method of Testing for Rating Room Air Conditioners and Packaged Terminal Air Conditioners	ASHRAE	ANSI/ASHRAE 16-2016
	Method of Testing for Rating Room Air Conditioner and Packaged Terminal Air Conditioner Heating Capacity	ASHRAE	ANSI/ASHRAE 58-1986 (RA14)
	Method of Testing for Rating Fan-Coil Conditioners	ASHRAE	ANSI/ASHRAE 79-2015
	Energy Performance of Room Air Conditioners	CSA	CAN/CSA C368.1-14
	Room Air Conditioners	CSA	C22.2 No. 117-1970 (R2016)
	Room Air Conditioners, Ed. 7	UL	ANSI/UL 484-2014
	Commercial Systems Overview	ACCA	ACCA Manual CS-1993
	Residential Equipment Selection, 2nd ed.	ACCA	ANSI/ACCA 3 Manual S-2014
	Unitary Air-Conditioning and Air-Source Heat Pump Equipment	AHRI	ANSI/AHRI 210/240-2017
	Sound Rating of Outdoor Unitary Equipment	AHRI	AHRI 270-2015
Unitary	Application of Sound Rating Levels of Outdoor Unitary Equipment	AHRI	AHRI 275-2010
	Commercial and Industrial Unitary Air-Conditioning and Heat Pump Equipment	AHRI	AHRI 340/360-2015
	Methods of Testing for Rating Electrically Driven Unitary Air-Conditioning and Heat Pump Equipment	ASHRAE	ANSI/ASHRAE 37-2009
	Methods of Testing for Rating Heat Operated Unitary Air-Conditioning and Heat-Pump Equipment	ASHRAE	ANSI/ASHRAE 40-2014
	Methods of Testing for Rating Seasonal Efficiency of Unitary Air Conditioners and Heat Pumps	ASHRAE	ANSI/ASHRAE 116-2010
	Method of Testing for Rating Computer and Data Processing Room Unitary Air Conditioners	ASHRAE	ANSI/ASHRAE 127-2012
	Method of Rating Unitary Spot Air Conditioners	ASHRAE	ANSI/ASHRAE 128-2011

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Selected Codes and Standards Published by Various Societies and Associations (*Continued*)

Subject	Title	Publisher	Reference
Ships	Specification for Mechanically Refrigerated Shipboard Air Conditioner	ASTM	ASTM F1433-97 (2010)
Accessories	Flashing and Stand Combination for Air Conditioning Units (Unit Curb)	IAPMO	IAPMO PS 120-2004
Air Conditioning	Commercial Systems Overview	ACCA	ACCA Manual CS-1993
	Heat Pump Systems	ACCA	ACCA Manual H-1984
	Residential Load Calculation, 8th ed.	ACCA	ANSI/ACCA 2 Manual J-2016
	Commercial Load Calculation, 5th ed.	ACCA	ACCA Manual N-2012
	Comfort, Air Quality, and Efficiency by Design	ACCA	ACCA Manual RS-1997
	HVAC Quality Installation Specification	ACCA	ANSI/ACCA 5 QI-2015
	Technician's Guide & Workbook for Quality Installations	ACCA	ACCA 2015
	Peak Cooling and Heating Load Calculations in Buildings Except Low-Rise Residential Buildings	ASHRAE/ ACCA	ANSI/ASHRAE/ACCA 183-2007 (RA 2017)
	Environmental Systems Technology, 2nd ed. (1999)	NEBB	NEBB
	Installation of Air-Conditioning and Ventilating Systems	NFPA	NFPA 90A-2018
	Standard of Purity for Use in Mobile Air-Conditioning Systems	SAE	SAE J1991-2011
	HVAC Systems Applications, 2nd ed.	SMACNA	SMACNA 2010
	HVAC Systems—Duct Design, 4th ed.	SMACNA	SMACNA 2006
	Heating and Cooling Equipment	UL/CSA	ANSI/UL 1995-2015/C22.2 No. 236-15
Aircraft	Air Conditioning of Aircraft Cargo	SAE	SAE AIR806B-1997 (R2015)
	Aircraft Fuel Weight Penalty Due to Air Conditioning	SAE	SAE AIR1168/8-2011
	Air Conditioning Systems for Subsonic Airplanes	SAE	SAE ARP85F-2012
	Environmental Control Systems Terminology	SAE	SAE ARP147E-2001 (R2017)
	Testing of Airplane Installed Environmental Control Systems (ECS)	SAE	SAE ARP217D-1999 (R2016)
	Guide for Qualification Testing of Aircraft Air Valves	SAE	SAE ARP986D-2015
	Control of Excess Humidity in Avionics Cooling	SAE	SAE ARP987B-2015
	Engine Bleed Air Systems for Aircraft	SAE	SAE ARP1796B-2015
	Aircraft Ground Air Conditioning Service Connection	SAE	SAE AS4262B-2012
	Air Cycle Air Conditioning Systems for Military Air Vehicles	SAE	SAE AS4073A-2013
Automotive	Refrigerant 12 Automotive Air-Conditioning Hose	SAE	SAE J51-2015
	Design Guidelines for Air Conditioning Systems for Off-Road Operator Enclosures	SAE	SAE J169-1985
	Test Method for Measuring Power Consumption of Air Conditioning and Brake Compressors for Trucks and Buses	SAE	SAE J1340-2011
	Information Relating to Duty Cycles and Average Power Requirements of Truck and Bus Engine Accessories	SAE	SAE J1343-2000
	Rating Air-Conditioner Evaporator Air Delivery and Cooling Capacities	SAE	SAE J1487-2013
	Recovery and Recycle Equipment for Mobile Automotive Air-Conditioning Systems	SAE	SAE J1990-2011
	R134a Refrigerant Automotive Air-Conditioning Hose	SAE	SAE J2064-2015
	Service Hose for Automotive Air Conditioning	SAE	SAE J2196-2011
Ships	Mechanical Refrigeration and Air-Conditioning Installations Aboard Ship	ASHRAE	ANSI/ASHRAE 26-2010
	Practice for Mechanical Symbols, Shipboard Heating, Ventilation, and Air Conditioning (HVAC)	ASTM	ASTM F856-97 (2014)
Air Curtains	Laboratory Methods of Testing Air Curtains for Aerodynamic Performance	AMCA	AMCA 220-05 (R2012)
	Air Terminals	AHRI	AHRI 880-2017
	Standard Methods for Laboratory Airflow Measurement	ASHRAE	ANSI/ASHRAE 41.2-1987 (RA92)
	Method of Testing the Performance of Air Outlets and Inlets	ASHRAE	ANSI/ASHRAE 70-2006 (RA11)
	Residential Mechanical Ventilating Systems	CSA	CAN/CSA F326-M91 (R2014)
	Air Curtains for Entranceways in Food and Food Service Establishments	NSF	ANSI/NSF 37-2017
Air Diffusion	Air Distribution Basics for Residential and Small Commercial Buildings	ACCA	ACCA Manual T-2001
	Balancing and Testing Air and Hydronic Systems	ACCA	ACCA Manual B-2009
	Method of Testing the Performance of Air Outlets and Inlets	ASHRAE	ANSI/ASHRAE 70-2006 (RA11)
	Method of Testing for Room Air Diffusion	ASHRAE	ANSI/ASHRAE 113-2013
Air Filters	Comfort, Air Quality, and Efficiency by Design	ACCA	ACCA Manual RS-1997
	Home Evaluation and Performance Improvement	ACCA	ANSI/ACCA 12 QH-2018
	Technician's Guide & Workbook for Home Evaluation and Performance Improvement	ACCA	ACCA 2015
	Balancing and Testing Air and Hydronic Systems	ACCA	ACCA Manual B-2009
	Industrial Ventilation: A Manual of Recommended Practice, 29th ed. (2016)	ACGIH	ACGIH
	Portable Electric Room Air Cleaners	AHAM	ANSI/AHAM AC-1-2015
	Residential Air Filter Equipment	AHRI	ANSI/AHRI 680-2017
	Commercial and Industrial Air Filter Equipment	AHRI	ANSI/AHRI 850-2013
	Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size	ASHRAE	ANSI/ASHRAE 52.2-2017

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Subject	Title	Publisher	Reference
	Laboratory Test Method for Assessing the Performance of Gas-Phase Air Cleaning Systems: Loose Granular Media	ASHRAE	ANSI/ASHRAE 145.1-2015
	Laboratory Test Method for Assessing the Performance of Gas-Phase Air Cleaning Systems: Air Cleaning Devices	ASHRAE	ANSI/ASHRAE 145.2-2016
	Code on Nuclear Air and Gas Treatment	ASME	ASME AG-1-2017
	Nuclear Power Plant Air-Cleaning Units and Components	ASME	ASME N509-1989 (R1996)
	In-Service Testing of Nuclear Air Treatment, Heating, Ventilating, and Air-Conditioning Systems	ASME	ASME N511-2007
	Specification for Filters Used in Air or Nitrogen Systems	ASTM	ASTM F1791-00 (2013)
	Method for Sodium Flame Test for Air Filters	BSI	BS 3928:1969 (R2014)
	Particulate Air Filters for General Ventilation: Determination of Filtration Performance	BSI	BS EN 779:2012
	Electrostatic Air Cleaners	UL	ANSI/UL 867-2011
	High-Efficiency, Particulate, Air Filter Units	UL	ANSI/UL 586-2009
	Air Filter Units	UL	ANSI/UL 900-2015
	Exhaust Hoods for Commercial Cooking Equipment	UL	UL 710-2012
	Grease Filters for Exhaust Ducts	UL	UL 1046-2010
Air-Handling Units	Commercial Systems Overview	ACCA	ACCA Manual CS-1993
	Residential Equipment Selection	ACCA	ANSI/ACCA 3 Manual S-2014
	Central Station Air-Handling Units	AHRI	ANSI/AHRI 430-2014
	Non-Recirculating Direct Gas-Fired Industrial Air Heaters	CSA	ANSI Z83.4-2017/CSA 3.7-2017
Air Leakage	Technician's Guide & Workbook for Duct Diagnostics and Repair	ACCA	ACCA 2016
	HVAC Quality Installation Specification	ACCA	ANSI/ACCA 5 QI-2015
	Technician's Guide & Workbook for Quality Installations	ACCA	ACCA 2015
	Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings	ASHRAE	ANSI/ASHRAE 62.2-2016
	Method of Test for Determining the Airtightness of HVAC Equipment	ASHRAE	ANSI/ASHRAE 193-2010 (RA14)
	Test Method for Determining Air Change in a Single Zone by Means of a Tracer Gas Dilution	ASTM	ASTM E741-11 (2017)
	Test Method for Determining Air Leakage Rate by Fan Pressurization	ASTM	ASTM E779-10
	Test Method for Field Measurement of Air Leakage Through Installed Exterior Window and Doors	ASTM	ASTM E783-02 (2010)
	Practices for Air Leakage Site Detection in Building Envelopes and Air Barrier Systems	ASTM	ASTM E1186-2017
	Test Method for Determining the Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure and Temperature Differences Across the Specimen	ASTM	ASTM E1424-91 (2016)
	Test Methods for Determining Airtightness of Buildings Using an Orifice Blower Door	ASTM	ASTM E1827-11 (2017)
	Practice for Determining the Effects of Temperature Cycling on Fenestration Products	ASTM	ASTM E2264-05 (2013)
	Test Method for Determining Air Flow Through the Face and Sides of Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen	ASTM	ASTM E2319-04 (2011)
	Test Method for Determining Air Leakage of Air Barrier Assemblies	ASTM	ASTM E2357-17
	HVAC Air Duct Leakage Test Manual, 2nd ed.	SMACNA	SMACNA 2012
Boilers	Packaged Boiler Engineering Manual (1998)	ABMA	ABMA 100
	Selected Codes and Standards of the Boiler Industry (2001)	ABMA	ABMA 103
	Operation and Maintenance Safety Manual (1995)	ABMA	ABMA 106
	Fluidized Bed Combustion Guidelines (1995)	ABMA	ABMA 200
	Guide to Clean and Efficient Operation of Coal Stoker-Fired Boilers (2002)	ABMA	ABMA 203
	Guideline for Performance Evaluation of Heat Recovery Steam Generating Equipment (1995)	ABMA	ABMA 300
	Guidelines for Industrial Boiler Performance Improvement (1999)	ABMA	ABMA 302
	Measurement of Sound from Steam Generators (1995)	ABMA	ABMA 304
	Guideline for Gas and Oil Emission Factors for Industrial, Commercial, and Institutional Boilers (1997)	ABMA	ABMA 305
	Combustion Control Guidelines for Single Burner Firetube and Watertube Industrial/Commercial/Institutional Boilers (1999)	ABMA	ABMA 307
	Combustion Control Guidelines for Multiple-Burner Boilers (2001)	ABMA	ABMA 308
	Boiler Water Quality Requirements and Associated Steam Quality for ICI Boilers (2012)	ABMA	ABMA 402
	HVAC Quality Installation Specification	ACCA	ANSI/ACCA 5 QI-2015
	Technician's Guide & Workbook for Quality Installations	ACCA	ACCA 2015
	Residential Equipment Selection	ACCA	ANSI/ACCA 3 Manual S 2014
	Commercial Systems Overview	ACCA	ACCA Manual CS-1993

Selected Codes and Standards Published by Various Societies and Associations (*Continued*)

Subject	Title	Publisher	Reference
Gas or Oil	Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers	ASHRAE	ANSI/ASHRAE 103-2017
	Boiler and Pressure Vessel Code—Section I: Power Boilers; Section IV: Heating Boilers	ASME	BPVC-2017
	Fired Steam Generators	ASME	ASME PTC 4-2013
	Boiler, Pressure Vessel, and Pressure Piping Code	CSA	CSA B51-14
	Testing Standard, Method to Determine Efficiency of Commercial Heating Boilers, 2nd ed. (2007)	HYDI	HYDI BTS-2000
	Rating Procedure for Heating Boilers, 6th ed. (2005)	HYDI	IBR
	Single Burner Boiler Operations	NFPA	ANSI/NFPA 8501-97
	Prevention of Furnace Explosions/Implosions in Multiple Burner Boilers	NFPA	ANSI/NFPA 8502-99
	Heating, Water Supply, and Power Boilers—Electric	UL	ANSI/UL 834-2004
	Boiler and Combustion Systems Hazards Code	NFPA	NFPA 85-2015
	Home Evaluation and Performance Improvement	ACCA	ANSI/ACCA 12 QH-2018
	Technician's Guide & Workbook for Home Evaluation and Performance Improvement	ACCA	ACCA 2015
	Controls and Safety Devices for Automatically Fired Boilers	ASME	ASME CSD-1-2015
	Gas-Fired Low-Pressure Steam and Hot Water Boilers	CSA	ANSI Z21.13-2017/CSA 4.9-2017
	Industrial and Commercial Gas-Fired Package Boilers	CSA	CAN 1-3.1-77 (R2016)
	Oil-Burning Equipment: Steam and Hot-Water Boilers	CSA	B140.7-05 (R2014)
	Oil-Fired Boiler Assemblies	UL	UL 726-1995
	Commercial-Industrial Gas Heating Equipment	UL	UL 795-2016
	Standards and Typical Specifications for Tray Type Deaerators, 10th ed. (2016)	HEI	HEI 120
	Ultimate Boiler Industry Lexicon: Handbook of Power Utility and Boiler Terms and Phrases, 6th ed. (2001)	ABMA	ABMA 101
Building Codes	ASTM Standards Used in Building Codes	ASTM	ASTM
	Practice for Conducting Visual Assessments for Lead Hazards in Buildings	ASTM	ASTM E2255M-13
	Standard Practice for Periodic Inspection of Building Facades for Unsafe Conditions	ASTM	ASTM E2270-14
	Standard Practice for Building Enclosure Commissioning	ASTM	ASTM E2813-12
	Structural Welding Code—Steel	AWS	AWS D1.1M/D1.1:2015
	BOCA National Building Code, 14th ed. (1999)	BOCA	BNBC
	Uniform Building Code, vol. 1, 2, and 3 (1997)	ICBO	UBC V1, V2, V3
	International Building Code® (2018)	ICC	IBC
	International Code Council Performance Code® for Buildings and Facilities (2018)	ICC	ICC PC
	International Existing Building Code® (2018)	ICC	IEBC
	International Energy Conservation Code® (2018)	ICC	IECC
	International Property Maintenance Code® (2018)	ICC	IPMC
	International Residential Code® (2018)	ICC	IRC
	Building Construction and Safety Code®	NFPA	ANSI/NFPA 5000-2018
	National Building Code of Canada (2015)	NRC	NRC
	Standard Building Code (1999)	SBCCI	SBC
	Safety Code for Elevators and Escalators	ASME	ASME A17.1-2016
	Natural Gas and Propane Installation Code	CSA	CAN/CSA B149.1-10
	Propane Storage and Handling Code	CSA	CAN/CSA B149.2-10
	Uniform Mechanical Code (2018)	IAPMO	IAPMO
Mechanical	International Mechanical Code® (2018)	ICC	IMC
	International Fuel Gas Code® (2018)	ICC	IFGC
	Standard Gas Code (1999)	SBCCI	SBC
Burners	Domestic Gas Conversion Burners	CSA	ANSI Z21.17-1998/CSA 2.7-M98 (R2014)
	Installation of Domestic Gas Conversion Burners	CSA	ANSI Z21.8-1994 (R2017)
	Installation Code for Oil Burning Equipment	CSA	CAN/CSA B139-09 (R2014)
	Oil-Burning Equipment: General Requirements	CSA	CAN/CSA B140.0-03 (R2013)
	Vapourizing-Type Oil Burners	CSA	B140.1-1966 (R2015)
	Atomizing-Type Oil Burners	CSA	CAN/CSA B140.2.1-10 (R2014)
	Pressure Atomizing Oil Burner Nozzles	CSA	B140.2.2-1971 (R2015)
	Oil Burners	UL	ANSI/UL 296-2017
	Waste Oil-Burning Air-Heating Appliances	UL	ANSI/UL 296A-1995
	Commercial-Industrial Gas Heating Equipment	UL	UL 795-2016
	Commercial/Industrial Gas and/or Oil-Burning Assemblies with Emission Reduction Equipment	UL	UL 2096-2006
Chillers	Commercial Systems Overview	ACCA	ACCA Manual CS-1993
	Absorption Water Chilling and Water Heating Packages	AHRI	ANSI/AHRI 560-2000

Selected Codes and Standards Published by Various Societies and Associations (*Continued*)

Subject	Title	Publisher	Reference
	Water-Chilling and Heat Pump Water-Heating Packages Using the Vapor Compression Cycle	AHRI	ANSI/AHRI 550/590-2015
	Method of Testing Liquid-Chilling Packages	ASHRAE	ANSI/ASHRAE 30-2017
	Method of Testing Absorption Water-Chilling and Water-Heating Packages	ASHRAE	ANSI/ASHRAE 182-2008 (RA13)
	Performance Standard for Rating Packaged Water Chillers	CSA	CAN/CSA C743-09 (R2014)
Chimneys	Specification for Clay Flue Liners	ASTM	ASTM C315-07 (2016)
	Specification for Industrial Chimney Lining Brick	ASTM	ASTM C980-17
	Practice for Installing Clay Flue Lining	ASTM	ASTM C1283-15
	Guide for Design and Construction of Brick Liners for Industrial Chimneys	ASTM	ASTM C1298-95 (2013)
	Guide for Design, Fabrication, and Erection of Fiberglass Reinforced Plastic (FRP) Chimney Liners with Coal-Fired Units	ASTM	ASTM D5364-14
	Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances	NFPA	ANSI/NFPA 211-2016
	Medium Heat Appliance Factory-Built Chimneys	UL	ANSI/UL 959-2010
	Factory-Built Chimneys for Residential Type and Building Heating Appliance	UL	ANSI/UL 103-2010
Cleanrooms	Practice for Cleaning and Maintaining Controlled Areas and Clean Rooms	ASTM	ASTM E2042/E2042M-09 (2016)
	Practice for Design and Construction of Aerospace Cleanrooms and Contamination Controlled Areas	ASTM	ASTM E2217-12
	Practice for Tests of Cleanroom Materials	ASTM	ASTM E2312-11
	Practice for Aerospace Cleanrooms and Associated Controlled Environments—Cleanroom Operations	ASTM	ASTM E2352-04 (2010)
	Test Method for Sizing and Counting Airborne Particulate Contamination in Clean Rooms and Other Dust-Controlled Areas Designed for Electronic and Similar Applications	ASTM	ASTM F25/F25M-09 (2015)
	Practice for Continuous Sizing and Counting of Airborne Particles in Dust-Controlled Areas and Clean Rooms Using Instruments Capable of Detecting Single Sub-Micrometre and Larger Particles	ASTM	ASTM F50-12 (2015)
	Procedural Standards for Certified Testing of Cleanrooms, 3rd ed. (2009)	NEBB	NEBB
Climate Data	Residential Load Calculations	ACCA	ANSI/ACCA 2 Manual J-2016
	Commercial Load Calculations	ACCA	ACCA Manual N-2012
	Climatic Data for Building Design Standards	ASHRAE	ANSI/ASHRAE 169-2013
Coils	Forced-Circulation Air-Cooling and Air-Heating Coils	AHRI	AHRI 410-2001
	Methods of Testing Forced Circulation Air Cooling and Air Heating Coils	ASHRAE	ANSI/ASHRAE 33-2016
Comfort Conditions	Threshold Limit Values for Physical Agents (updated annually)	ACGIH	ACGIH
	Comfort, Air Quality, and Efficiency by Design	ACCA	ACCA Manual RS-1997
	Thermal Environmental Conditions for Human Occupancy	ASHRAE	ANSI/ASHRAE 55-2017
	Classification for Serviceability of an Office Facility for Thermal Environment and Indoor Air Conditions	ASTM	ASTM E2320-04 (2012)
	Hot Environments—Estimation of the Heat Stress on Working Man, Based on the WBGT Index (Wet Bulb Globe Temperature)	ISO	ISO 7243:2017
	Ergonomics of the Thermal Environment—Analytical Determination and Interpretation of Thermal Comfort Using Calculation of the PMV and PPD Indices and Local Thermal Comfort Criteria	ISO	ISO 7730:2005
	Ergonomics of the Thermal Environment—Determination of Metabolic Rate	ISO	ISO 8996:2004
	Ergonomics of the Thermal Environment—Estimation of the Thermal Insulation and Water Vapour Resistance of a Clothing Ensemble	ISO	ISO 9920:2007
Commissioning	HVAC Quality Installation Specification	ACCA	ANSI/ACCA 5 QI-2015
	HVAC Quality Installation Verification Protocols	ACCA	ANSI/ACCA 9 QIvp-2016
	Technician's Guide & Workbook for Quality Installations	ACCA	ACCA 2015
	The Commissioning Process	ASHRAE	ASHRAE <i>Guideline</i> 0-2013
	HVAC&R Technical Requirements for the Commissioning Process	ASHRAE	ASHRAE <i>Guideline</i> 1.1-2007
	Commissioning Process for Buildings and Systems	ASHRAE	ASHRAE 202-2013
	Standard Practice for Building Enclosure Commissioning	ASTM	ASTM E2813-12
	HVAC Systems—Commissioning Manual, 2nd ed.	SMACNA	SMACNA 2013
Compressors	Displacement Compressors, Vacuum Pumps and Blowers	ASME	ASME PTC 9-1970
	Performance Test Code on Compressors and Exhausters	ASME	ASME PTC 10-1997 (RA14)
	Compressed Air and Gas Handbook, 6th ed. (2003)	CAGI	CAGI
Refrigerant	Positive Displacement Condensing Units	AHRI	ANSI/AHRI 520-2004
	Positive Displacement Refrigerant Compressors and Compressor Units	AHRI	CAN/ANSI/AHRI 540-2015
	Safety Standard for Refrigeration Systems	ASHRAE	ANSI/ASHRAE 15-2016
	Methods of Testing for Rating Positive Displacement Refrigerant Compressors and Condensing Units That Operate at Subcritical Temperatures of the Refrigerant	ASHRAE	ANSI/ASHRAE 23.1-2010

Selected Codes and Standards Published by Various Societies and Associations (*Continued*)

Subject	Title	Publisher	Reference
	Hermetic Refrigerant Motor-Compressors	UL/CSA	UL 984-1996/C22.2 No.140.2-96 (R2016)
Computers	Method of Testing for Rating Computer and Data Processing Room Unitary Air Conditioners	ASHRAE	ANSI/ASHRAE 127-2012
	Method of Test for the Evaluation of Building Energy Analysis Computer Programs	ASHRAE	ANSI/ASHRAE 140-2017
	Fire Protection of Information Technology Equipment	NFPA	NFPA 75-2017
Condensers	Commercial Systems Overview	ACCA	ACCA Manual CS-1993
	Residential Equipment Selection, 2nd ed.	ACCA	ANSI/ACCA 3 Manual S-2014
	Water-Cooled Refrigerant Condensers, Remote Type	AHRI	AHRI 450-2007
	Remote Mechanical-Draft Air-Cooled Refrigerant Condensers	AHRI	ANSI/AHRI 460-2005
	Remote Mechanical Draft Evaporative Refrigerant Condensers	AHRI	ANSI/AHRI 490-2011
	Safety Standard for Refrigeration Systems	ASHRAE	ANSI/ASHRAE 15-2016
	Methods of Testing for Rating Remote Mechanical-Draft Air-Cooled Refrigerant Condensers	ASHRAE	ANSI/ASHRAE 20-1997 (RA06)
	Methods of Testing for Rating Liquid Water-Cooled Refrigerant Condensers	ASHRAE	ANSI/ASHRAE 22-2014
	Methods of Testing for Rating Positive Displacement Refrigerant Compressors and Condensing Units That Operate at Subcritical Temperatures of the Refrigerant	ASHRAE	ANSI/ASHRAE 23.1-2010
	Methods of Laboratory Testing Remote Mechanical-Draft Evaporative Refrigerant Condensers	ASHRAE	ANSI/ASHRAE 64-2011
	Steam Surface Condensers	ASME	ASME PTC 12.2-2010
	Standards for Steam Surface Condensers, 12th ed. (2017)	HEI	HEI 118
	Standards for Direct Contact Barometric and Low Level Condensers, 9th ed. (2014)	HEI	HEI 117
Condensing Units	Refrigerant-Containing Components and Accessories, Nonelectrical	UL	ANSI/UL 207-2009
	Commercial Systems Overview	ACCA	ACCA Manual CS-1993
	Residential Equipment Selection, 2nd ed.	ACCA	ANSI/ACCA 3 Manual S-2014
	Commercial and Industrial Unitary Air-Conditioning Condensing Units	AHRI	ANSI/AHRI 365-2009
	Methods of Testing for Rating Positive Displacement Refrigerant Compressors and Condensing Units	ASHRAE	ANSI/ASHRAE 23.1-2010
Containers	Heating and Cooling Equipment	UL/CSA	ANSI/UL 1995-2015/C22.2 No. 236-15
	Series 1 Freight Containers—Classifications, Dimensions, and Ratings	ISO	ISO 668:2013
	Series 1 Freight Containers—Specifications and Testing; Part 2: Thermal Containers	ISO	ISO 1496-2:2008
Controls	Animal Environment in Cargo Compartments	SAE	SAE AIR1600-1996 (R2015)
	Temperature Control Systems (2002)	AABC	National Standards, Ch. 12
	Field Testing of HVAC Controls Components	ASHRAE	ASHRAE <i>Guideline</i> 11-2009
	Specifying Direct Digital Control Systems	ASHRAE	ASHRAE <i>Guideline</i> 13-2015
	BACnet™—A Data Communication Protocol for Building Automation and Control Networks	ASHRAE	ANSI/ASHRAE 135-2016
	Method of Test for Conformance to BACnet®	ASHRAE	ANSI/ASHRAE 135.1-2013
	Method of Test for Rating Air Terminal Unit Controls	ASHRAE	ASHRAE 195-2013
	Temperature-Indicating and Regulating Equipment	CSA	C22.2 No. 24-15
	Performance Requirements for Thermostats Used with Individual Room Electric Space Heating Devices	CSA	CAN/CSA C828-13
	Solid-State Controls for Appliances	UL	UL 244A-2003
	Limit Controls	UL	ANSI/UL 353-1994
	Primary Safety Controls for Gas- and Oil-Fired Appliances	UL	ANSI/UL 372-1994
	Temperature-Indicating and -Regulating Equipment	UL	UL 873-2007
	Tests for Safety-Related Controls Employing Solid-State Devices	UL	UL 991-2004
	Automatic Electrical Controls; Part 1: General Requirements	UL	UL 60730-1-2016
Commercial and Industrial	Guidelines for Boiler Control Systems (Gas/Oil Fired Boilers) (1998)	ABMA	ABMA 301
	Guideline for the Integration of Boilers and Automated Control Systems in Heating Applications (1998)	ABMA	ABMA 306
	Industrial Control and Systems: General Requirements	NEMA	NEMA ICS 1-2000 (R2015)
	Preventive Maintenance of Industrial Control and Systems Equipment	NEMA	NEMA ICS 1.3-1986 (R2015)
	Industrial Control and Systems, Controllers, Contactors, and Overload Relays Rated Not More than 2000 Volts AC or 750 Volts DC	NEMA	NEMA ICS 2-2000 (R2005)
Residential	Industrial Control and Systems: Instructions for the Handling, Installation, Operation and Maintenance of Motor Control Centers Rated Not More than 600 Volts	NEMA	NEMA ICS 2.3-1995 (R2008)
	Industrial Control Equipment	UL	ANSI/UL 508-1999
	Manually Operated Gas Valves for Appliances, Appliance Connector Valves and Hose End Valves	CSA	ANSI Z21.15-2009 (R2017)/CSA 9.1-2009 (R2017)
	Gas Appliance Pressure Regulators	CSA	ANSI Z21.18-2007 (R2017)/CSA 6.3-2007 (R2016)

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Subject	Title	Publisher	Reference
	Automatic Gas Ignition Systems and Components	CSA	ANSI Z21.20-2005 (R2016)
	Gas Appliance Thermostats	CSA	ANSI Z21.23-2010 (R2015)
	Manually-Operated Piezo-Electric Spark Gas Ignition Systems and Components	CSA	ANSI Z21.77-2005/CSA 6.23-2005 (R2015)
	Manually Operated Electric Gas Ignition Systems and Components	CSA	ANSI Z21.92-2001 (R2016)/CSA 6.29-2001 (R2016)
	Residential Controls—Electrical Wall-Mounted Room Thermostats	NEMA	NEMA DC 3-2008
	Residential Controls—Surface Type Controls for Electric Storage Water Heaters	NEMA	NEMA DC 5-1989 (R2008)
	Residential Controls—Temperature Limit Controls for Electric Baseboard Heaters	NEMA	NEMA DC 10-2009 (2014)
	Residential Controls—Hot-Water Immersion Controls	NEMA	NEMA DC 12-1985 (R2008)
	Line-Voltage Integrally Mounted Thermostats for Electric Heaters	NEMA	NEMA DC 13-1979 (R2013)
	Residential Controls—Class 2 Transformers	NEMA	NEMA DC 20-1992 (R2014)
	Safety Guidelines for the Application, Installation, and Maintenance of Solid State Controls	NEMA	NEMA ICS 1.1-1984 (R2015)
	Electrical Quick-Connect Terminals	UL	ANSI/UL 310-2014
Coolers	Refrigeration Equipment	CSA	CAN/CSA C22.2 No. 120-13
	Unit Coolers for Refrigeration	AHRI	ANSI/AHRI 420-2016
	Quality Maintenance of Commercial Refrigeration Systems	ACCA	ANSI/ACCA 14 QMref-2015
	Refrigeration Unit Coolers	UL	ANSI/UL 412-2011
Air	Methods of Testing Forced Convection and Natural Convection Air Coolers for Refrigeration	ASHRAE	ANSI/ASHRAE 25-2001 (RA06)
	Methods of Testing for Rating Drinking-Water Coolers with Self-Contained	ASHRAE	ANSI/ASHRAE 18-2008 (RA13)
Drinking Water	Mechanical Refrigeration		
	Drinking-Water Coolers	UL	ANSI/UL 399-2017
	Drinking Water System Components—Health Effects	NSF	ANSI/NSF 61-2017
Evaporative	Method of Testing Direct Evaporative Air Coolers	ASHRAE	ANSI/ASHRAE 133-2015
	Method of Test for Rating Indirect Evaporative Coolers	ASHRAE	ANSI/ASHRAE 143-2015
Food and Beverage	Milking Machine Installations—Vocabulary	ASABE	ANSI/ASABE AD3918-2007 (R2011)
	Methods of Testing for Rating Vending Machines for Sealed Beverages	ASHRAE	ANSI/ASHRAE 32.1-2017
	Methods of Testing for Rating Pre-Mix and Post-Mix Beverage Dispensing Equipment	ASHRAE	ANSI/ASHRAE 32.2-2003 (RA11)
	Manual Food and Beverage Dispensing Equipment	NSF	ANSI/NSF 18-2016
	Commercial Bulk Milk Dispensing Equipment	NSF	ANSI/NSF 20-2016
Liquid	Refrigerated Vending Machines	UL	ANSI/UL 541-2016
	Refrigerant-Cooled Liquid Coolers, Remote Type	AHRI	AHRI 480-2007
	Methods of Testing for Rating Liquid Coolers	ASHRAE	ANSI/ASHRAE 24-2013
	Liquid Cooling Systems	SAE	SAE AIR1811A-1997 (R2015)
Cooling Towers	Cooling Tower Testing (2002)	AABC	National Standards, Ch 13
	Commercial Systems Overview	ACCA	ACCA Manual CS-1993
	Bioaerosols: Assessment and Control (1999)	ACGIH	ACGIH
	Atmospheric Water Cooling Equipment	ASME	ASME PTC 23-2003 (RA14)
	Water-Cooling Towers	NFPA	NFPA 214-2016
	Acceptance Test Code for Water-Cooling Towers	CTI	CTI ATC-105 (2000)
	Code for Measurement of Sound from Water Cooling Towers	CTI	CTI ATC-128 (2014)
	Nomenclature for Industrial Water Cooling Towers	CTI	CTI BUL-109 (2015)
	Recommended Practice for Airflow Testing of Cooling Towers	CTI	CTI PFM-143 (1994)
	Fiberglass-Reinforced Plastic Panels	CTI	CTI STD-131 (2009)
	Certification of Water Cooling Tower Thermal Performance	CTI	CTI STD-201RS (2017)
Crop Drying	Density, Specific Gravity, and Mass-Moisture Relationships of Grain for Storage	ASABE	ANSI/ASAE D241.4-1992 (R2012)
	Thermal Properties of Grain and Grain Products	ASABE	ASAE D243.4-2003 (R2012)
	Moisture Relationships of Plant-Based Agricultural Products	ASABE	ASAE D245.6-2007 (R2012)
	Dielectric Properties of Grain and Seed	ASABE	ASAE D293.4-2012
	Construction and Rating of Equipment for Drying Farm Crops	ASABE	ASAE S248.3-1976 (R2010)
	Resistance to Airflow of Grains, Seeds, Other Agricultural Products, and Perforated Metal Sheets	ASABE	ASAE D272.3-1996 (R2011)
	Shelled Corn Storage Time for 0.5% Dry Matter Loss	ASABE	ASAE D535-2005 (R2010)
	Moisture Measurement—Unground Grain and Seeds	ASABE	ASAE S352.2-1998 (R2012)
	Moisture Measurement—Meat and Meat Products	ASABE	ASAE S353-1972 (R2012)
	Moisture Measurement—Forages	ASABE	ANSI/ASAE S358.3-2012
	Moisture Measurement—Peanuts	ASABE	ASAE S410.2-2010
	Thin-Layer Drying of Agricultural Crops	ASABE	ANSI/ASAE S448.1-2001 (R2012)
	Moisture Measurement—Tobacco	ASABE	ASAE S487-1987 (R2012)
	Energy Efficiency of Peanut Drying Systems	ASABE	ASAE S488.1-2013
	Temperature Sensor Locations for Seed-Cotton Drying Systems	ASABE	ASAE S530.1-2007 (R2012)

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Subject	Title	Publisher	Reference
Dampers	Laboratory Methods of Testing Dampers for Rating Selecting Outdoor, Return, and Relief Dampers for Air-Side Economizer Systems	AMCA ASHRAE	AMCA 500-D-12 ASHRAE <i>Guideline</i> 16-2014
Dehumidifiers	Commercial Systems Overview Bioaerosols: Assessment and Control (1999) Dehumidifiers Method of Testing for Rating Desiccant Dehumidifiers Utilizing Heat for the Regeneration Process Criteria for Moisture-Control Design Analysis in Buildings Method of Test for Rating Desiccant-Based Dehumidification Equipment Method of Testing for Rating Indoor Pool Dehumidifiers Method of Testing for Rating DX-Dedicated Outdoor Air Systems for Moisture Removal Capacity and Moisture Removal Efficiency Moisture Separator Reheaters Dehumidifiers Performance of Dehumidifiers Dehumidifiers	ACCA ACGIH AHAM ASHRAE ASHRAE ASHRAE ASHRAE ASHRAE ASME CSA CSA UL	ACCA Manual CS-1993 ACGIH ANSI/AHAM DH-1-2008 ANSI/ASHRAE 139-2015 ANSI/ASHRAE 160-2016 ANSI/ASHRAE 174-2009 ANSI/ASHRAE 190-2013 ANSI/ASHRAE 198-2013 PTC 12.4-1992 (RA14) C22.2 No. 92-15 CAN/CSA C749-15 ANSI/UL 474-2015
Desiccants	Method of Testing Desiccants for Refrigerant Drying	ASHRAE	ANSI/ASHRAE 35-2014
Driers	Liquid-Line Driers Method of Testing Liquid Line Refrigerant Driers Refrigerant-Containing Components and Accessories, Nonelectrical	AHRI ASHRAE UL	ANSI/AHRI 710-2009 ANSI/ASHRAE 63.1-1995 (RA01) ANSI/UL 207-2009
Ducts and Fittings	Hose, Air Duct, Flexible Nonmetallic, Aircraft Ducted Electric Heat Guide for Air Handling Systems, 2nd ed. Factory-Made Air Ducts and Air Connectors	SAE SMACNA UL	SAE AS1501C-1994 (R2013) SMACNA 1994 ANSI/UL 181-2013
Construction	Industrial Ventilation: A Manual of Recommended Practice, 29th ed. (2016) Preferred Metric Sizes for Flat, Round, Square, Rectangular, and Hexagonal Metal Products Sheet Metal Welding Code Fibrous Glass Duct Construction Standards, 5th ed. Residential Fibrous Glass Duct Construction Standards, 3rd ed. Thermoplastic Duct (PVC) Construction Manual, 2nd ed. Accepted Industry Practices for Sheet Metal Lagging, 1st ed. Fibrous Glass Duct Construction Standards, 7th ed. Round Industrial Duct Construction Standards, 2nd ed. Rectangular Industrial Duct Construction Standards, 2nd ed.	ACGIH ASME AWS NAIMA NAIMA SMACNA SMACNA SMACNA SMACNA SMACNA	ACGIH ASME B32.100-2016 AWS D9.1M/D9.1:2018 NAIMA AH116 NAIMA AH119 SMACNA 1995 SMACNA 2002 SMACNA 2003 SMACNA 1999 SMACNA 2004
Installation	Flexible Duct Performance and Installation Standards, 5th ed. HVAC Quality Installation Specification HVAC Quality Installation Verification Protocols Technician's Guide & Workbook for Duct Diagnostics and Repair Installation of Air-Conditioning and Ventilating Systems Installation of Warm Air Heating and Air-Conditioning Systems	ADC ACCA ACCA ACCA NFPA NFPA	ADC-91 ANSI/ACCA 5 QI-2015 ANSI/ACCA 9 QIvp-2016 ACCA 2016 NFPA 90A-2018 NFPA 90B-2018
Material Specifications	Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet and Strip Specification for Steel, Sheet, Carbon, Structural, and High-Strength, Low-Alloy, Hot- Rolled and Cold-Rolled, General Requirements for Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dipped Process Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low- Alloy, High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Bake Hardenable Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength Practice for Measuring Flatness Characteristics of Coated Sheet Products	ASTM ASTM ASTM ASTM ASTM ASTM	ASTM A480/A480M-17 ASTM A568/A568M-17a ASTM A653/A653M-17 ASTM A924/A924M-17a ASTM A1008/A1008M-16 ASTM A1011/A1011M-17a
System Design	Installation Techniques for Perimeter Heating and Cooling Residential Duct Systems Commercial Low Pressure, Low Velocity Duct System Design Air Distribution Basics for Residential and Small Commercial Buildings Method of Test for Determining the Design and Seasonal Efficiencies of Residential Thermal Distribution Systems Closure Systems for Use with Rigid Air Ducts Closure Systems for Use with Flexible Air Ducts and Air Connectors	ASTM ACCA ACCA ACCA ACCA ASHRAE UL UL	ASTM A1030/A1030M-16 ACCA Manual 4-1990 ANSI/ACCA Manual D-2016 ACCA Manual Q-1990 ACCA Manual T-2001 ANSI/ASHRAE 152-2014 ANSI/UL 181A-2013 ANSI/UL 181B-2013
Testing	Duct Leakage Testing (2002)	AABC	National Standards, Ch 5

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Subject	Title	Publisher	Reference
	Balancing and Testing Air and Hydronic Systems	ACCA	ACCA Manual B 2009
	HVAC Quality Installation Specification	ACCA	ANSI/ACCA 5 QI-2015
	HVAC Quality Installation Verification Protocols	ACCA	ANSI/ACCA 9 QIvp-2016
	Technician's Guide & Workbook for Quality Installations	ACCA	ACCA 2015
	Technician's Guide & Workbook for Duct Diagnostics and Repair	ACCA	ACCA 2016
	Flexible Duct Test Code, 3rd ed.	ADC	ADC FD 72-R1
	Test Method for Measuring Acoustical and Airflow Performance of Duct Liner Materials and Prefabricated Silencers	ASTM	ASTM E477-13
	Method of Testing to Determine Flow Resistance of HVAC Ducts and Fittings	ASHRAE	ANSI/ASHRAE 120-2017
	Method of Testing HVAC Air Ducts	ASHRAE	ANSI/ASHRAE/SMACNA 126-2016
	HVAC Air Duct Leakage Test Manual, 2nd ed.	SMACNA	SMACNA 2012
	HVAC Duct Systems Inspection Guide, 3rd ed.	SMACNA	SMACNA 2006
Economizers	Selecting Outdoor, Return, and Relief Dampers for Air-Side Economizer Systems	ASHRAE	ASHRAE <i>Guideline</i> 16-2014
Electrical	Electrical Power Systems and Equipment—Voltage Ratings	ANSI	ANSI C84.1-2011
	Test Method for Bond Strength of Electrical Insulating Varnishes by the Helical Coil Test	ASTM	ASTM D2519-07 (2012)
	Standard Specification for Shelter, Electrical Equipment, Lightweight	ASTM	ASTM E2377-10
	Canadian Electrical Code (24th ed.), Safety Standard for Electrical Installations	CSA	CSA C22.1-18
	ICC Electrical Code, Administrative Provisions (2006)	ICC	ICCEC
	Low Voltage Cartridge Fuses	NEMA	NEMA FU 1-2012
	Industrial Control and Systems: Terminal Blocks	NEMA	NEMA ICS 4-2015
	Industrial Control and Systems: Enclosures	NEMA	ANSI/NEMA ICS 6-1993 (R2016)
	Application Guide for Ground Fault Protective Devices for Equipment	NEMA	ANSI/NEMA PB 2.2-2014
	General Color Requirements for Wiring Devices	NEMA	NEMA WD 1-1999 (R2015)
	Wiring Devices—Dimensional Specifications	NEMA	ANSI/NEMA WD 6-2016
	National Electrical Code®	NFPA	NFPA 70-2017
	National Fire Alarm and Signaling Code	NFPA	NFPA 72-2016
	Compatibility of Electrical Connectors and Wiring	SAE	SAE AIR1329-2014
	Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures	UL	ANSI/UL 489-2016
Energy	Air-Conditioning and Refrigerating Equipment Nameplate Voltages	AHRI	ANSI/AHRI 110-2016
	Comfort, Air Quality, and Efficiency by Design	ACCA	ACCA Manual RS-1997
	Thermal Energy Storage	ACCA	ACCA 2005
	Measurement of Energy and Demand Savings	ASHRAE	ASHRAE <i>Guideline</i> 14-2014
	Energy Standard for Buildings Except Low-Rise Residential Buildings	ASHRAE	ANSI/ASHRAE/IES 90.1-2016
	Energy-Efficient Design of Low-Rise Residential Buildings	ASHRAE	ANSI/ASHRAE/IES 90.2-2007
	Energy Conservation in Existing Buildings	ASHRAE	ANSI/ASHRAE/IES 100-2015
	Methods of Determining, Expressing, and Comparing Building Energy Performance and Greenhouse Gas Emissions	ASHRAE	ANSI/ASHRAE 105-2014
	Method of Test for the Evaluation of Building Energy Analysis Computer Programs	ASHRAE	ANSI/ASHRAE 140-2017
	Method of Test for Determining the Design and Seasonal Efficiencies of Residential Thermal Distribution Systems	ASHRAE	ANSI/ASHRAE 152-2014
	Standard for the Design of High-Performance, Green Buildings Except Low-Rise Residential Buildings	ASHRAE/USGBC	ANSI/ASHRAE/USGBC/IES 189.1-2014
	National Green Building Standard	ICC/ASHRAE	ICC/ASHRAE 700-2015
	Fuel Cell Power Systems Performance	ASME	PTC 50-2002 (RA14)
	International Energy Conservation Code® (2018)	ICC	IECC
	International Green Construction Code™ (2015)	ICC	IGCC
	Uniform Solar Energy and Hydronics Code (2015)	IAPMO	IAPMO
	Energy Management Guide for Selection and Use of Fixed Frequency Medium AC Squirrel-Cage Polyphase Induction Motors	NEMA	NEMA MG 10-2017
	Energy Management Guide for Selection and Use of Single-Phase Motors	NEMA	NEMA MG 11-1977 (R2012)
	HVAC Systems—Commissioning Manual, 2nd ed.	SMACNA	SMACNA 2013
	Building Systems Analysis and Retrofit Manual, 2nd ed.	SMACNA	SMACNA 2011
	Energy Systems Analysis and Management, 2nd ed.	SMACNA	SMACNA 2014
	Energy Management Equipment	UL	UL 916-2015
Exhaust Systems	Fan Systems: Supply/Return/Relief/Exhaust (2002)	AABC	National Standards, Ch 10
	Commercial Systems Overview	ACCA	ACCA Manual CS-1993
	Industrial Ventilation: A Manual of Recommended Practice, 29th ed. (2016)	ACGIH	ACGIH
	Fundamentals Governing the Design and Operation of Local Exhaust Ventilation Systems	AIHA	ANSI/AIHA Z9.2-2012
	Spray Finishing Operations: Safety Code for Design, Construction, and Ventilation	AIHA	ANSI/AIHA Z9.3-2007

Selected Codes and Standards Published by Various Societies and Associations (Continued)

Subject	Title	Publisher	Reference
	Laboratory Ventilation	AIHA	ANSI/AIHA Z9.5-2012
	Recirculation of Air from Industrial Process Exhaust Systems	AIHA	ANSI/AIHA Z9.7-2007
	Method of Testing Performance of Laboratory Fume Hoods	ASHRAE	ANSI/ASHRAE 110-2016
	Ventilation for Commercial Cooking Operations	ASHRAE	ANSI/ASHRAE 154-2016
	Performance Test Code on Compressors and Exhausters	ASME	PTC 10-1997 (RA14)
	Flue and Exhaust Gas Analyses	ASME	PTC 19.10-1981
	Mechanical Flue-Gas Exhausters	CSA	CAN B255-16
	Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Particulate Solids	NFPA	ANSI/NFPA 91-2015
	Draft Equipment	UL	UL 378-2006
Expansion Valves	Thermostatic Refrigerant Expansion Valves	AHRI	ANSI/AHRI 750-2016
	Method of Testing Capacity of Thermostatic Refrigerant Expansion Valves	ASHRAE	ANSI/ASHRAE 17-2015
Fan-Coil Units	Industrial Ventilation: A Manual of Recommended Practice, 29th ed. (2016)	ACGIH	ACGIH
	Room Fan-Coils	AHRI	ANSI/AHRI 440-2008
	Methods of Testing for Rating Fan-Coil Conditioners	ASHRAE	ANSI/ASHRAE 79-2015
	Heating and Cooling Equipment	UL/CSA	ANSI/UL 1995-2015/C22.2 No. 236-15
Fans	Residential Duct Systems	ACCA	ANSI/ACCA 1 Manual D-2016
	Commercial Low Pressure, Low Velocity Duct System Design	ACCA	ACCA Manual Q-2003
	Balancing and Testing Air and Hydronic Systems	ACCA	ACCA Manual B-2009
	HVAC Quality Installation Specifications	ACCA	ANSI/ACCA 5 QI-2015
	Technician's Guide & Workbook for Quality Installations	ACCA	ACCA 2015
	Industrial Ventilation: A Manual of Recommended Practice, 29th ed. (2016)	ACGIH	ACGIH
	Standards Handbook	AMCA	AMCA 99-16
	Air Systems	AMCA	AMCA 200-95 (R2011)
	Fans and Systems	AMCA	AMCA 201-02 (R2011)
	Troubleshooting	AMCA	AMCA 202-17
	Field Performance Measurement of Fan Systems	AMCA	AMCA 203-90 (R2011)
	Balance Quality and Vibration Levels for Fans	AMCA	ANSI/AMCA 204-05 (R2012)
	Laboratory Methods of Testing Air Circulator Fans for Rating and Certification	AMCA	ANSI/AMCA 230-15
	Laboratory Method of Testing Positive Pressure Ventilators for Rating	AMCA	ANSI/AMCA 240-15
	Reverberant Room Method for Sound Testing of Fans	AMCA	AMCA 300-14
	Methods for Calculating Fan Sound Ratings from Laboratory Test Data	AMCA	AMCA 301-14
	Application of Sone Ratings for Non-Ducted Air Moving Devices	AMCA	AMCA 302-73 (R2012)
	Application of Sound Power Level Ratings for Fans	AMCA	AMCA 303-79 (R2012)
	Recommended Safety Practices for Users and Installers of Industrial and Commercial Fans	AMCA	AMCA 410-96
	Industrial Process/Power Generation Fans: Site Performance Test Standard	AMCA	AMCA 803-02 (R2008)
	Home Evaluation and Performance Improvement	ACCA	ANSI/ACCA 12 QH-2018
	Technician's Guide & Workbook for Home Evaluation and Performance Improvement	ACCA	ACCA 2015
	Mechanical Balance of Impellers for Fans	AHRI	AHRI Guideline G-2016
	Acoustics—Measurement of Airborne Noise Emitted and Structure-Borne Vibration Induced by Small Air-Moving Devices—Part 1: Airborne Noise Measurement	ASA	ANSI/ASA S12.11-2013-Part 1/ISO 10302-1:2013
	Part 2: Structure-Borne Vibration	ASA	ANSI/ASA S12.11-2013-Part 2/ISO 10302-2:2013
	Laboratory Methods of Testing Fans for Aerodynamic Performance Rating	ASHRAE/ AMCA	ANSI/ASHRAE 51-2016 ANSI/AMCA 210-16
	Laboratory Methods of Testing Fans Used to Exhaust Smoke in Smoke Management Systems	ASHRAE	ANSI/ASHRAE 149-2013
	Ventilation for Commercial Cooking Operations	ASHRAE	ANSI/ASHRAE 154-2016
	Fans	ASME	ANSI/ASME PTC 11-2008
	Fans and Ventilators	CSA	C22.2 No. 113-15
	Energy Performance of Ceiling Fans	CSA	CAN/CSA C814-10 (R2015)
	Residential Mechanical Ventilating Systems	CSA	CAN/CSA F326-M91 (R2014)
	Electric Fans	UL	ANSI/UL 507-2017
	Power Ventilators	UL	ANSI/UL 705-2017
Fenestration	Practice for Calculation of Photometric Transmittance and Reflectance of Materials to Solar Radiation	ASTM	ASTM E971-11
	Test Method for Solar Photometric Transmittance of Sheet Materials Using Sunlight	ASTM	ASTM E972-96 (2013)
	Test Method for Solar Transmittance (Terrestrial) of Sheet Materials Using Sunlight	ASTM	ASTM E1084-86 (2015)
	Practice for Determining Load Resistance of Glass in Buildings	ASTM	ASTM E1300-16
	Practice for Installation of Exterior Windows, Doors and Skylights	ASTM	ASTM E2112-07 (2016)
	Test Method for Insulating Glass Unit Performance	ASTM	ASTM E2188-10
	Test Method for Testing Resistance to Fogging Insulating Glass Units	ASTM	ASTM E2189-10e1
	Specification for Insulating Glass Unit Performance and Evaluation	ASTM	ASTM E2190-10

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Subject	Title	Publisher	Reference
	Guide for Assessing the Durability of Absorptive Electrochemical Coatings within Sealed Insulating Glass Units	ASTM	ASTM E2354-10
	Tables for Reference Solar Spectral Irradiance: Direct Normal and Hemispherical on 37° Tilted Surface	ASTM	ASTM G173-03 (2012)
	Windows	CSA	CSA A440-00 (R2005)
	Fenestration Energy Performance	CSA	CSA A440.2-14
	Window, Door, and Skylight Installation	CSA	CSA A440.4-07 (R2016)
Filter-Driers	Flow-Capacity Rating of Suction-Line Filters and Suction-Line Filter-Driers	AHRI	AHRI 730-2013
	Method of Testing Liquid Line Filter-Drier Filtration Capability	ASHRAE	ANSI/ASHRAE 63.2-2017
	Method of Testing Flow Capacity of Suction Line Filters and Filter-Driers	ASHRAE	ANSI/ASHRAE 78-1985 (RA 2017)
Fireplaces	Factory-Built Fireplaces	UL	ANSI/UL 127-2011
	Fireplace Stoves	UL	ANSI/UL 737-2011
Fire Protection	Test Method for Surface Burning Characteristics of Building Materials	ASTM/NFPA	ASTM E84-17a
	Test Methods for Fire Test of Building Construction and Materials	ASTM	ASTM E119-16a
	Test Method for Room Fire Test of Wall and Ceiling Materials and Assemblies	ASTM	ASTM E2257-17
	Test Method for Determining Fire Resistance of Perimeter Fire Barriers Using Intermediate-Scale Multi-Story Test Apparatus	ASTM	ASTM E2307-15
	Guide for Laboratory Monitors	ASTM	ASTM E2335-17
	Test Method for Fire Resistance Grease Duct Enclosure Systems	ASTM	ASTM E2336-16
	Practice for Specimen Preparation and Mounting of Textile, Paper or Polymeric (Including Vinyl) and Wood Wall or Ceiling Coverings, Facings, and Veneers, to Assess Surface Burning Characteristics	ASTM	ASTM E2404-17
	BOCA National Fire Prevention Code, 11th ed. (1999)	BOCA	BNFPC
	Uniform Fire Code	IFCI	UFC 1997
	International Fire Code® (2018)	ICC	IFC
	International Mechanical Code® (2018)	ICC	IMC
	International Urban-Wildland Interface Code® (2018)	ICC	IUWIC
	Fire-Resistance Tests—Elements of Building Construction; Part 1: Gen. Requirements	ISO	ISO 834-1:1999
	Fire-Resistance Tests—Door and Shutter Assemblies	ISO	ISO 3008:2007
	Reaction to Fire Tests—Ignitability of Building Products Using a Radiant Heat Source	ISO	ISO 5657:1997
	Fire Containment—Elements of Building Construction—Part 1: Ventilation Ducts	ISO	ISO 6944-1:2008
	Fire Service Annunciator and Interface	NEMA	NEMA SB 30-2005
	Fire Protection Handbook (2008)	NFPA	NFPA
	National Fire Codes® (issued annually)	NFPA	NFPA
	Fire Protection Guide to Hazardous Materials	NFPA	NFPA HAZ-2010
	Fire Code	NFPA	NFPA 1-2018
	Installation of Sprinkler Systems	NFPA	NFPA 13-2016
	Flammable and Combustible Liquids Code	NFPA	NFPA 30-2018
	Fire Protection for Laboratories Using Chemicals	NFPA	NFPA 45-2015
	National Fire Alarm Code	NFPA	NFPA 72-2016
	Fire Doors and Other Opening Protectives	NFPA	NFPA 80-2016
	Health Care Facilities	NFPA	NFPA 99-2018
	Life Safety Code®	NFPA	NFPA 101-2018
	Methods of Fire Tests of Door Assemblies	NFPA	NFPA 252-2017
	Fire, Smoke and Radiation Damper Installation Guide for HVAC Systems, 5th ed.	SMACNA	SMACNA 2002
	Fire Tests of Door Assemblies	UL	ANSI/UL 10B-2008
	Heat Responsive Links for Fire-Protection Service	UL	ANSI/UL 33-2010
	Fire Tests of Building Construction and Materials	UL	ANSI/UL 263-2011
	Fire Dampers	UL	ANSI/UL 555-2006
	Fire Tests of Through-Penetration Firestops	UL	ANSI/UL 1479-2015
Smoke Management	The Commissioning Process for Smoke Control Systems	ASHRAE	ASHRAE <i>Guideline</i> 1.5-2012
	Laboratory Methods of Testing Fans Used to Exhaust Smoke in Smoke Management Systems	ASHRAE	ANSI/ASHRAE 149-2013
	Smoke-Control Systems Utilizing Barriers and Pressure Differences	NFPA	NFPA 92A-2009
	Smoke Management Systems in Malls, Atria, and Large Spaces	NFPA	NFPA 92B-2009
	Ceiling Dampers	UL	ANSI/UL 555C-2014
	Smoke Dampers	UL	ANSI/UL 555S-2014
Freezers	Quality Maintenance of Commercial Refrigeration Systems	ACCA	ANSI/ACCA 14 QMref-2015
	Energy Performance and Capacity of Household Refrigerators, Refrigerator-Freezers, Freezers, and Wine Chillers	CSA	C300-15
	Energy Performance of Food Service Refrigerators and Freezers	CSA	C827-10 (R2015)
	Refrigeration Equipment	CSA	CAN/CSA C22.2 No. 120-13

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Subject	Title	Publisher	Reference
Commercial	Dispensing Freezers	NSF	ANSI/NSF 6-2016
	Commercial Refrigerators and Freezers	NSF	ANSI/NSF 7-2016
	Commercial Refrigerators and Freezers	UL	ANSI/UL 471-2010
	Ice Makers	UL	ANSI/UL 563-2009
	Ice Cream Makers	UL	ANSI/UL 621-2010
	Energy and Volume Refrigerating Appliances	AHAM	ANSI/AHAM HRF-1-2016
Household	Energy Performance and Capacity of Household Refrigerators, Refrigerator-Freezers, Freezers, and Wine Chillers	CSA	C300-15
Fuels	Threshold Limit Values for Chemical Substances (updated annually)	ACGIH	ACGIH
	National Gas Fuel Code	NFPA	ANSI Z223.1/NFPA 54-2015
	Reporting of Fuel Properties when Testing Diesel Engines with Biobased Fuels	ASABE	ASABE EP552.1-2017
	Coal Pulverizers	ASME	PTC 4.2 1969 (R2016)
	Classification of Coals by Rank	ASTM	ASTM D388-18
	Specification for Fuel Oils	ASTM	ASTM D396-17a
	Specification for Diesel Fuel Oils	ASTM	ASTM D975-17a
	Specification for Gas Turbine Fuel Oils	ASTM	ASTM D2880-15
	Specification for Kerosine	ASTM	ASTM D3699-13be1
	Practice for Receipt, Storage and Handling of Fuels for Gas Turbines	ASTM	ASTM D4418-17
	Test Method for Determination of Yield Stress and Apparent Viscosity of Used Engine Oils at Low Temperature	ASTM	ASTM D6896-17
	Test Method for Total Sulfur in Naphthas, Distillates, Reformulated Gasolines, Diesels, Biodiesels, and Motor Fuels by Oxidative Combustion and Electrochemical Detection	ASTM	ASTM D6920-13
	Test Method for Determination of Homogeneity and Miscibility in Automotive Engine Oils	ASTM	ASTM D6922-13
	Test Method for Measurement of Hindered Phenolic and Aromatic Amine Antioxidant Content in Non-Zinc Turbine Oils by Linear Sweep Voltammetry	ASTM	ASTM D6971-09 (2014)
	Practice for Enumeration of Viable Bacteria and Fungi in Liquid Fuels—Filtration and Culture Procedures	ASTM	ASTM D6974-16
	Test Method for Evaluation of Automotive Engine Oils in the Sequence IIIF, Spark-Ignition Engine	ASTM	ASTM D6984-17a
	Test Method for Determination of Ignition Delay and Derived Cetane Number (DCN) of Diesel Fuel Oils by Combustion in a Constant Volume Chamber	ASTM	ASTM D6890-16e1
	Test Method for Determination of Total Sulfur in Liquid Hydrocarbons and Hydrocarbon-Oxygenate Blends by Gas Chromatography with Flame Photometric Detection	ASTM	ASTM D7041-16
	Test Method for Sulfur in Gasoline, Diesel Fuel, Jet Fuel, Kerosine, Biodiesel, Biodiesel Blends, and Gasoline-Ethanol Blends by Monochromatic Wavelength Dispersive X-Ray Fluorescence Spectrometry	ASTM	ASTM D7039-15a
	Test Method for Flash Point by Modified Continuously Closed Cup (MCCCFP) Tester	ASTM	ASTM D7094-17a
	Test Method for Determining the Viscosity-Temperature Relationship of Used and Soot-Containing Engine Oils at Low Temperatures	ASTM	ASTM D7110-15
	Test Method for Determination of Trace Elements in Middle Distillate Fuels by Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-AES)	ASTM	ASTM D7111-16
	Test Method for Determining Stability and Compatibility of Heavy Fuel Oils and Crude Oils by Heavy Fuel Oil Stability Analyzer (Optical Detection)	ASTM	ASTM D7112-12 (2017)
	Test Method for Determination of Intrinsic Stability of Asphaltene-Containing Residues, Heavy Fuel Oils, and Crude Oils (<i>n</i> -Heptane Phase Separation; Optical Detection)	ASTM	ASTM D7157-12
	Test Method for Hydrogen Content of Middle Distillate Petroleum Products by Low-Resolution Pulsed Nuclear Magnetic Resonance Spectroscopy	ASTM	ASTM D7171-16
	Gas-Fired Central Furnaces	CSA	ANSI Z21.47-2016/CSA 2.3-2016
	Gas Unit Heaters, Gas Packaged Heaters, Gas Utility Heaters and Gas-Fired Duct Furnaces	CSA	ANSI Z83.8-2016/CSA 2.6-2016
	Uniform Mechanical Code (2018)	IAPMO	Chapter 13
	Uniform Plumbing Code (2018)	IAPMO	Chapter 12
	International Fuel Gas Code® (2018)	ICC	IFGC
	Standard Gas Code (1999)	SBCCI	SGC
	Commercial-Industrial Gas Heating Equipment (2011)	UL	UL 795-2016
Furnaces	Commercial Systems Overview	ACCA	ACCA Manual CS-1993
	Residential Equipment Selection, 2nd ed.	ACCA	ANSI/ACCA 3 Manual S-2014
	HVAC Quality Installation Specification	ACCA	ANSI/ACCA 5 QI-2015
	Technician's Guide & Workbook for Quality Installations	ACCA	ACCA 2015
	Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Furnaces and Boilers	ASHRAE	ANSI/ASHRAE 103-2017

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Subject	Title	Publisher	Reference
Gas	Prevention of Furnace Explosions/Implosions in Multiple Burner Boilers	NFPA	NFPA 8502-99
	Residential Gas Detectors	UL	ANSI/UL 1484-2016
	Heating and Cooling Equipment	UL/CSA	ANSI/UL 1995-2015/C22.2 No. 236-15
	Single and Multiple Station Carbon Monoxide Alarms	UL	ANSI/UL 2034-2017
	National Fuel Gas Code	AGA/NFPA	ANSI Z223.1/NFPA 54-2018
	Gas-Fired Central Furnaces	CSA	ANSI Z21.47-2016/CSA 2.3-2016
	Gas Unit Heaters, Gas Packaged Heaters, Gas Utility Heaters and Gas-Fired Duct Furnaces	CSA	ANSI Z83.8-2016/CSA 2.6-2016
	Thermal Efficiencies of Industrial and Commercial Gas-Fired Package Furnaces	CSA	CAN/CSA P.8-09 (R2014)
	International Fuel Gas Code® (2018)	ICC	IFGC
	Standard Gas Code (1999)	SBCCI	SGC
Oil	Commercial-Industrial Gas Heating Equipment	UL	UL 795-2016
	Specification for Fuel Oils	ASTM	ASTM D396-17a
	Specification for Diesel Fuel Oils	ASTM	ASTM D975-17a
	Test Method for Smoke Density in Flue Gases from Burning Distillate Fuels	ASTM	ASTM D2156-09 (2013)
	Standard Test Method for Vapor Pressure of Liquefied Petroleum Gases (LPG) (Expansion Method)	ASTM	ASTM D6897-16
	Oil Burning Stoves and Water Heaters	CSA	B140.3-1962 (R2015)
	Oil-Fired Warm Air Furnaces	CSA	B140.4-04 (R2014)
	Installation of Oil-Burning Equipment	NFPA	NFPA 31-2016
	Oil-Fired Central Furnaces	UL	UL 727-2018
	Oil-Fired Floor Furnaces	UL	ANSI/UL 729-2003
Solid Fuel	Oil-Fired Wall Furnaces	UL	ANSI/UL 730-2003
	Installation Code for Solid-Fuel-Burning Appliances and Equipment	CSA	CSA B365-10 (R2015)
	Solid-Fuel-Fired Central Heating Appliances	CSA	CAN/CSA B366.1-11 (R2015)
	Solid-Fuel and Combination-Fuel Central and Supplementary Furnaces	UL	ANSI/UL 391-2010
Green Buildings	Standard for the Design of High-Performance, Green Buildings Except Low-Rise Residential Buildings	ASHRAE/USGBC	ANSI/ASHRAE/USGBC/IES 189.1-2014
	National Green Building Standard	ICC/ASHRAE	ICC/ASHRAE 700-2015
	International Green Construction Code™ (2015)	ICC	IGCC
	Building Systems Analysis and Retrofit Manual, 2nd ed.	SMACNA	SMACNA 2011
Heaters	Gas-Fired High-Intensity Infrared Heaters	CSA	ANSI Z83.19-2017/CSA 2.35-2017
	Gas-fired Tubular and Low-Intensity Infrared Heaters	CSA	ANSI Z83.20-2016/CSA 2.34-2016
	Threshold Limit Values for Chemical Substances (updated annually)	ACGIH	ACGIH
	Industrial Ventilation: A Manual of Recommended Practice, 29th ed. (2016)	ACGIH	ACGIH
	Thermal Performance Testing of Solar Ambient Air Heaters	ASABE	ANSI/ASAE S423-1991 (R2012)
	Air Heaters	ASME	ASME PTC 4.3-2017
	Guide for Construction of Solid Fuel Burning Masonry Heaters	ASTM	ASTM E1602-03 (2017)
	Non-Recirculating Direct Gas-Fired Industrial Air Heaters	CSA	ANSI Z83.4-2017/CSA 3.7-2017
	Electric Duct Heaters	CSA	C22.2 No. 155-M1986 (R2017)
	Portable Kerosene-Fired Heaters	CSA	CAN3-B140.9.3-M86 (R2015)
	Standards for Closed Feedwater Heaters, 9th ed. (2015)	HEI	HEI 2622
	Electric Heating Appliances	UL	ANSI/UL 499-2014
	Electric Oil Heaters	UL	ANSI/UL 574-2003
	Oil-Fired Air Heaters and Direct-Fired Heaters	UL	UL 733-1993
	Electric Dry Bath Heaters	UL	ANSI/UL 875-2009
	Oil-Burning Stoves	UL	ANSI/UL 896-1993
Engine	Electric Engine Preheaters and Battery Warmers for Diesel Engines	SAE	SAE J1310-2011
	Selection and Application Guidelines for Diesel, Gasoline, and Propane Fired Liquid Cooled Engine Pre-Heaters	SAE	SAE J1350-2011
	Fuel Warmer—Diesel Engines	SAE	SAE J1422-2011
Nonresidential	Installation of Electric Infrared Brooding Equipment	ASABE	ASAE EP258.4-2014
	Gas-Fired Construction Heaters	CSA	ANSI Z83.7-2017/CSA 2.14-2017
	Recirculating Direct Gas-Fired Heating and Forced Ventilation Appliances for Commercial and Industrial Applications	CSA	ANSI Z83.18-2017
	Portable Industrial Oil-Fired Heaters	CSA	B140.8-1967 (R2015)
	Fuel-Fired Heaters—Air Heating—for Construction and Industrial Machinery	SAE	SAE J1024-2011
	Commercial-Industrial Gas Heating Equipment	UL	UL 795-2016
	Electric Heaters for Use in Hazardous (Classified) Locations	UL	ANSI/UL 823-2006
Pool	HVAC Design for Swimming Pools and Spas	ACCA	ANSI/ACCA 10 SPS-2010
	Methods of Testing and Rating Pool Heaters	ASHRAE	ANSI/ASHRAE 146-2011

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Subject	Title	Publisher	Reference
Room	Gas-Fired Pool Heaters	CSA	ANSI Z21.56-2017/CSA 4.7-2017
	Oil-Fired Service Water Heaters and Swimming Pool Heaters	CSA	B140.12-03 (R2013)
	Specification for Room Heaters, Pellet Fuel-Burning Type	ASTM	ASTM E1509-12 (2017)
	Gas-Fired Room Heaters, Vol. II, Unvented Room Heaters	CSA	ANSI Z21.11.2-2016
	Gas-Fired Unvented Catalytic Room Heaters for Use with Propane Gas	CSA	ANSI Z21.76-2016
	Vented Gas-Fired Space Heating Appliances	CSA	ANSI Z21.86-2016/CSA 2.32-2016
	Vented Gas Fireplace Heaters	CSA	ANSI Z21.88-2017/CSA 2.33-2017
	Unvented Kerosene-Fired Room Heaters and Portable Heaters	UL	UL 647-1993
	Movable and Wall- or Ceiling-Hung Electric Room Heaters	UL	UL 1278-2014
	Fixed and Location-Dedicated Electric Room Heaters	UL	UL 2021-2015
Transport	Solid Fuel-Type Room Heaters	UL	ANSI/UL 1482-2011
	Heater, Airplane, Engine Exhaust Gas to Air Heat Exchanger Type	SAE	SAE ARP86-2011
	Heater, Aircraft Internal Combustion Heat Exchanger Type	SAE	SAE AS8040B-2013
	Motor Vehicle Heater Test Procedure	SAE	SAE J638-2011
Unit	Gas Unit Heaters, Gas Packaged Heaters, Gas Utility Heaters and Gas-Fired Duct Furnaces	CSA	ANSI Z83.8-2016/CSA 2.6-2016
	Oil-Fired Unit Heaters	UL	ANSI/UL 731-2018
Heat Exchangers	Remote Mechanical-Draft Evaporative Refrigerant Condensers	AHRI	ANSI/AHRI 490-2011
	Method of Testing Air-to-Air Heat/Energy Exchangers	ASHRAE	ANSI/ASHRAE 84-2013
	Boiler and Pressure Vessel Code—Section VIII, Division 1: Pressure Vessels	ASME	ASME BPVC-2017
	Single Phase Heat Exchangers	ASME	ASME PTC 12.5-2000 (R2015)
	Air Cooled Heat Exchangers	ASME	ASME PTC 30-1991 (RA11)
	Laboratory Methods of Test for Rating the Performance of Heat/Energy-Recovery Ventilators	CSA	C439-18
	Standards for Gasketed Plate Heat Exchangers, 1st ed. (2014)	HEI	HEI 126
	Standards for Shell and Tube Heat Exchangers, 5th ed. (2013)	HEI	HEI 129
	Standards of Tubular Exchanger Manufacturers Association, 9th ed. (2007)	TEMA	TEMA
	Refrigerant-Containing Components and Accessories, Nonelectrical	UL	ANSI/UL 207-2009
Heating	Commercial Systems Overview	ACCA	ACCA Manual CS-1993
	HVAC Quality Installation Specification	ACCA	ANSI/ACCA 5 QI-2015
	Technician's Guide & Workbook for Quality Installations	ACCA	ACCA 2015
	Residential Load Calculations	ACCA	ANSI/ACCA 2 Manual J-2016
	Comfort, Air Quality, and Efficiency by Design	ACCA	ACCA Manual RS-1997
	Residential Equipment Selection, 2nd ed.	ACCA	ANSI/ACCA 3 Manual S-2014
	Heating, Ventilating and Cooling Greenhouses	ASABE	ANSI/ASAE EP406.4-2003 (R2008)
	Peak Cooling and Heating Load Calculations in Buildings Except Low-Rise Residential Buildings	ASHRAE/ ACCA	ANSI/ASHRAE/ACCA 183-2007 (RA 2017)
	Heater Elements	CSA	C22.2 No. 72-10 (R2014)
	Determining the Required Capacity of Residential Space Heating and Cooling Appliances	CSA	F280-12 (R2017)
	Heat Loss Calculation Guide (2001)	HYDI	HYDI H-22
	Residential Hydronic Heating Installation Design Guide	HYDI	IBR Guide
	Radiant Floor Heating (1995)	HYDI	HYDI 004
	Advanced Installation Guide (Commercial) for Hot Water Heating Systems (2001)	HYDI	HYDI 250
	Environmental Systems Technology, 2nd ed. (1999)	NEBB	NEBB
	Pulverized Fuel Systems	NFPA	NFPA 8503-97
	Aircraft Electrical Heating Systems	SAE	SAE AIR860B-2011
	Heating Value of Fuels	SAE	SAE J1498-2017
	Performance Test for Air-Conditioned, Heated, and Ventilated Off-Road Self-Propelled Work Machines	SAE	SAE J1503-2004
	HVAC Systems Applications, 2nd ed.	SMACNA	SMACNA 2010
	Electric Baseboard Heating Equipment	UL	ANSI/UL 1042-2009
	Electric Duct Heaters	UL	ANSI/UL 1996-2009
	Heating and Cooling Equipment	UL/CSA	ANSI/UL 1995-2015/C22.2 No. 236-15
Heat Pumps	Commercial Systems Overview	ACCA	ACCA Manual CS-1993
	Geothermal Heat Pump Training Certification Program	ACCA	ACCA Training Manual
	Heat Pumps Systems, Principles and Applications, 2nd ed.	ACCA	ACCA Manual H-1984
	Residential Equipment Selection, 2nd ed.	ACCA	ANSI/ACCA 3 Manual S-2014
	Industrial Ventilation: A Manual of Recommended Practice, 29th ed. (2016)	ACGIH	ACGIH
	Performance Rating of Unitary Air-Conditioning and Air-Source Heat Pump Equipment	AHRI	ANSI/AHRI 210/240-2017
	Commercial and Industrial Unitary Air-Conditioning and Heat Pump Equipment	AHRI	ANSI/AHRI 340/360-2015
	Single Package Vertical Air-Conditioner and Heat Pumps	AHRI	ANSI/AHRI 390-2003

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Subject	Title	Publisher	Reference
Gas-Fired	Direct Geoechange Heat Pumps	AHRI	ANSI/AHRI 870-2016
	Variable Refrigerant Flow (VRF) Multi-Split Air-Conditioning and Heat Pump Equipment	AHRI	ANSI/AHRI 1230-2014
	Methods of Testing for Rating Electrically Driven Unitary Air-Conditioning and Heat Pump Equipment	ASHRAE	ANSI/ASHRAE 37-2009
	Methods of Testing for Rating Seasonal Efficiency of Unitary Air-Conditioners and Heat Pumps	ASHRAE	ANSI/ASHRAE 116-2010
	Method of Test for Direct-Expansion Ground Source Heat Pumps	ASHRAE	ANSI/ASHRAE 194-2017
	Method of Testing for Rating of Multi-Purpose Heat Pumps for Residential Space Conditioning and Water Heating	ASHRAE	ANSI/ASHRAE 206-2013
	Performance Standard for Split-System and Single-Package Central Air Conditioners and Heat Pumps	CSA	CAN/CSA C656-14
	Installation of Air-Source Heat Pumps and Air Conditioners	CSA	CAN/CSA C273.5-11 (R2015)
	Performance of Direct-Expansion (DX) Ground-Source Heat Pumps	CSA	C748-13
	Water-Source Heat Pumps—Testing and Rating for Performance, Part 1: Water-to-Air and Brine-to-Air Heat Pumps	CSA	CAN/CSA C13256-1-01 (R2016)
	Part 2: Water-to-Water and Brine-to-Water Heat Pumps	CSA	CAN/CSA C13256-2-01 (R2015)
	Heating and Cooling Equipment (2011)	UL/CSA	ANSI/UL 1995/C22.2 No. 236-15
	Gas-Fired, Heat Activated Air Conditioning and Heat Pump Appliances	CSA	ANSI Z21.40.1-1996/CGA 2.91-M96 (R2017)
	Gas-Fired, Work Activated Air Conditioning and Heat Pump Appliances (Internal Combustion)	CSA	ANSI Z21.40.2-1996/CGA 2.92-M96 (R2017)
	Performance Testing and Rating of Gas-Fired Air Conditioning and Heat Pump Appliances	CSA	ANSI Z21.40.4-1998/CGA 2.94-M98 (R2017)
Heat Recovery	Gas Turbine Heat Recovery Steam Generators	ASME	ANSI/ASME PTC 4.4-2008 (R2013)
	Water Heaters, Hot Water Supply Boilers, and Heat Recovery Equipment	NSF	ANSI/NSF 5-2016
High-Performance Buildings	Sustainable, High Performance Operations and Maintenance	ASHRAE	ASHRAE <i>Guideline</i> 32-2012
	Standard for the Design of High-Performance, Green Buildings Except Low-Rise Residential Buildings	ASHRAE/USGBC	ANSI/ASHRAE/USGBC/IES 189.1-2014
	International Green Construction Code™ (2015)	ICC	IGCC
Humidifiers	Commercial Systems Overview	ACCA	ACCA Manual CS-1993
	Residential Equipment Selection	ACCA	ANSI/ACCA 3 Manual S-2014
	Comfort, Air Quality, and Efficiency by Design	ACCA	ACCA Manual RS-1997
	Bioaerosols: Assessment and Control (1999)	ACGIH	ACGIH
	Portable Household Humidifiers	AHAM	AHAM HU-1-2016
	Central System Humidifiers for Residential Applications	AHRI	ANSI/AHRI 610-2014
	Self-Contained Humidifiers for Residential Applications	AHRI	ANSI/AHRI 620-2014
	Commercial and Industrial Humidifiers	AHRI	ANSI/AHRI 640-2017
	Method of Test for Residential Central-System Humidifiers	ASHRAE	ANSI/ASHRAE 164.1-2012
HVAC Load Calculations	Humidifiers	UL/CSA	C22.2 No. 104-11 (R2015)
	Residential Load Calculations	ACCA	ANSI/ACCA 2 Manual J-2016
	Commercial Load Calculations	ACCA	ACCA Manual N-2012
	Peak Cooling and Heating Load Calculations in Buildings Except Low-Rise Residential Buildings	ASHRAE/ACCA	ANSI/ASHRAE/ACCA 183-2007 (RA 2017)
Ice Makers	Quality Maintenance of Commercial Refrigeration Systems	ACCA	ANSI/ACCA 14 QMref-2015
	Performance Rating of Automatic Commercial Ice Makers	AHRI	ANSI/AHRI 810-2016
	Ice Storage Bins	AHRI	ANSI/AHRI 820-2017
	Methods of Testing Automatic Ice Makers	ASHRAE	ANSI/ASHRAE 29-2015
	Refrigeration Equipment	CSA	C22.2 No. 120-13
	Energy Performance of Automatic Ice Makers and Ice Storage Bins	CSA	CAN/CSA C742-15
	Automatic Ice Making Equipment	NSF	ANSI/NSF 12-2017
	Ice Makers	UL	ANSI/UL 563-2009
Incinerators	Incinerators and Waste and Linen Handling Systems and Equipment	NFPA	NFPA 82-2014
	Residential Incinerators	UL	UL 791-2006
Indoor Air Quality	Good HVAC Practices for Residential and Commercial Buildings (2003)	ACCA	ACCA
	Comfort, Air Quality, and Efficiency by Design	ACCA	ACCA Manual RS-1997
	Bioaerosols: Assessment and Control (1999)	ACGIH	ACGIH
	Interactions Affecting the Achievement of Acceptable Indoor Environments	ASHRAE	ASHRAE <i>Guideline</i> 10-2016
	Ventilation for Acceptable Indoor Air Quality	ASHRAE	ANSI/ASHRAE 62.1-2016
	Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings	ASHRAE	ANSI/ASHRAE 62.2-2016

Selected Codes and Standards Published by Various Societies and Associations (*Continued*)

Subject	Title	Publisher	Reference
	Test Method for Determination of Volatile Organic Chemicals in Atmospheres (Canister Sampling Methodology)	ASTM	ASTM D5466-15
	Guide for Using Probability Sampling Methods in Studies of Indoor Air Quality in Buildings	ASTM	ASTM D5791-95 (2017)
	Guide for Using Indoor Carbon Dioxide Concentrations to Evaluate Indoor Air Quality and Ventilation	ASTM	ASTM D6245-12
	Guide for Placement and Use of Diffusive Samplers for Gaseous Pollutants in Indoor Air	ASTM	ASTM D6306-17
	Test Method for Determination of Metals and Metalloids in Airborne Particulate Matter by Inductively Coupled Plasma Atomic Emissions Spectrometry (ICP-AES)	ASTM	ASTM D7035-16
	Test Method for Metalworking Fluid Aerosol in Workplace Atmospheres	ASTM	ASTM D7049-17
	Practice for Emission Cells for the Determination of Volatile Organic Emissions from Indoor Materials/Products	ASTM	ASTM D7143-17
	Practice for Collection of Surface Dust by Micro-Vacuum Sampling for Subsequent Metals Determination	ASTM	ASTM D7144-05a (2016)
	Test Method for Determination of Beryllium in the Workplace by Extraction and Optical Fluorescence Detection	ASTM	ASTM D7202-15
	Practice for Referencing Suprathreshold Odor Intensity	ASTM	ASTM E544-10
	Guide for Specifying and Evaluating Performance of a Single Family Attached and Detached Dwelling—Indoor Air Quality	ASTM	ASTM E2267-04 (2013)
	Classification for Serviceability of an Office Facility for Thermal Environment and Indoor Air Conditions	ASTM	ASTM E2320-04 (2012)
	Practice for Continuous Sizing and Counting of Airborne Particles in Dust-Controlled Areas and Clean Rooms Using Instruments Capable of Detecting Single Sub-Micrometre and Larger Particles	ASTM	ASTM F50-12 (2015)
	Ambient Air—Determination of Mass Concentration of Nitrogen Dioxide—Modified Griess-Saltzman Method	ISO	ISO 6768:1998
	Air Quality—Exchange of Data—Part 1: General Data Format	ISO	ISO 7168-1:1999
	Part 2: Condensed Data Format	ISO	ISO 7168-2:1999
	Environmental Tobacco Smoke—Estimation of Its Contribution to Respirable Suspended Particles—Determination of Particulate Matter by Ultraviolet Absorbance and by Fluorescence	ISO	ISO 15593:2001
	Indoor Air—Part 3: Determination of Formaldehyde and Other Carbonyl Compounds in Indoor Air and Test Chamber Air—Active Sampling Method	ISO	ISO 16000-3:2011
	Workplace Air Quality—Sampling and Analysis of Volatile Organic Compounds by Solvent Desorption/Gas Chromatography—Part 1: Pumped Sampling Method	ISO	ISO 16200-1:2001
	Part 2: Diffusive Sampling Method	ISO	ISO 16200-2:2000
	Workplace Air Quality—Determination of Total Organic Isocyanate Groups in Air Using 1-(2-Methoxyphenyl) Piperazine and Liquid Chromatography	ISO	ISO 16702:2007
	Installation of Carbon Monoxide (CO) Detection and Warning Equipment	NFPA	NFPA 720-2015
	Indoor Air Quality—A Systems Approach, 3rd ed.	SMACNA	SMACNA 1998
	IAQ Guidelines for Occupied Buildings Under Construction, 2nd ed.	SMACNA	ANSI/SMACNA 008-2007
	Single and Multiple Station Carbon Monoxide Alarms	UL	ANSI/UL 2034-2017
Aircraft	Air Quality Within Commercial Aircraft	ASHRAE	ASHRAE <i>Guideline</i> 28-2016
	Air Quality Within Commercial Aircraft	ASHRAE	ANSI/ASHRAE 161-2018
	Guide for Selecting Instruments and Methods for Measuring Air Quality in Aircraft Cabins	ASTM	ASTM D6399-10
	Guide for Deriving Acceptable Levels of Airborne Chemical Contaminants in Aircraft Cabins Based on Health and Comfort Considerations	ASTM	ASTM D7034-11
Modeling	Guideline for Documenting Indoor Airflow and Contaminant Transport Modeling	ASHRAE	ASHRAE <i>Guideline</i> 33-2013
Insulation	Home Evaluation and Performance Improvement	ACCA	ANSI/ACCA 12 QH-2018
	Technician's Guide & Workbook for Home Evaluation and Performance Improvement	ACCA	ACCA 2014
	Guidelines for Use of Thermal Insulation in Agricultural Buildings	ASABE	ANSI/ASAE S401.2-1993 (R2012)
	Terminology Relating to Thermal Insulation	ASTM	ASTM C168-17
	Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus	ASTM	ASTM C177-13
	Test Method for Steady-State Heat Transfer Properties of Pipe Insulations	ASTM	ASTM C335/C335M-17
	Practice for Fabrication of Thermal Insulating Fitting Covers for NPS Piping and Vessel Lagging	ASTM	ASTM C450-17
	Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus	ASTM	ASTM C518-17
	Specification for Preformed Flexible Elastomeric Cellular Thermal Insulation in Sheet and Tubular Form	ASTM	ASTM C534/C534M-16
	Specification for Cellular Glass Thermal Insulation	ASTM	ASTM C552-17
	Specification for Rigid, Cellular Polystyrene Thermal Insulation	ASTM	ASTM C578-17a

Selected Codes and Standards Published by Various Societies and Associations (Continued)

Subject	Title	Publisher	Reference
	Practice for Inner and Outer Diameters of Thermal Insulation for Nominal Sizes of Pipe and Tubing	ASTM	ASTM C585-10 (2016)
	Specification for Unfaced Preformed Rigid Cellular Polyisocyanurate Thermal Insulation	ASTM	ASTM C591-17
	Practice for Estimate of the Heat Gain or Loss and the Surface Temperatures of Insulated Flat, Cylindrical, and Spherical Systems by Use of Computer Programs	ASTM	ASTM C680-14
	Specification for Adhesives for Duct Thermal Insulation	ASTM	ASTM C916-14
	Classification of Potential Health and Safety Concerns Associated with Thermal Insulation Materials and Accessories	ASTM	ASTM C930-18
	Practice for Thermographic Inspection of Insulation Installations in Envelope Cavities of Frame Buildings	ASTM	ASTM C1060-11a (2015)
	Specification for Fibrous Glass Duct Lining Insulation (Thermal and Sound Absorbing Material)	ASTM	ASTM C1071-16
	Specification for Faced or Unfaced Rigid Cellular Phenolic Thermal Insulation	ASTM	ASTM C1126-15
	Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus	ASTM	ASTM C1363-11
	Specification for Perpendicularly Oriented Mineral Fiber Roll and Sheet Thermal Insulation for Pipes and Tanks	ASTM	ASTM C1393-14
	Guide for Measuring and Estimating Quantities of Insulated Piping and Components	ASTM	ASTM C1409-12
	Specification for Cellular Melamine Thermal and Sound-Absorbing Insulation	ASTM	ASTM C1410-17
	Guide for Selecting Jacketing Materials for Thermal Insulation	ASTM	ASTM C1423-16
	Specification for Extruded Preformed Flexible Cellular Polyolefin Thermal Insulation in Sheet and Tubular Form	ASTM	ASTM C1427-16
	Specification for Polyimide Flexible Cellular Thermal and Sound Absorbing Insulation	ASTM	ASTM C1482-17
	Specification for Cellulosic Fiber Stabilized Thermal Insulation	ASTM	ASTM C1497-16
	Test Method for Characterizing the Effect of Exposure to Environmental Cycling on Thermal Performance of Insulation Products	ASTM	ASTM C1512-10 (2015)e1
	Specification for Flexible Polymeric Foam Sheet Insulation Used as a Thermal and Sound Absorbing Liner for Duct Systems	ASTM	ASTM C1534-18
	Standard Guide for Development of Standard Data Records for Computerization of Thermal Transmission Test Data for Thermal Insulation	ASTM	ASTM C1558-16
	Guide for Determining Blown Density of Pneumatically Applied Loose Fill Mineral Fiber Thermal Insulation	ASTM	ASTM C1574-04 (2013)
	Test Method for Determining the Moisture Content of Organic and Inorganic Insulation Materials by Weight	ASTM	ASTM C1616-07 (2012)
	Classification for Rating Sound Insulation	ASTM	ASTM E413-16
	Test Method for Determining the Drainage Efficiency of Exterior Insulation and Finish Systems (EIFS) Clad Wall Assemblies	ASTM	ASTM E2273-03 (2011)
	Practice for Use of Test Methods E96/E96M for Determining the Water Vapor Transmission (WVT) of Exterior Insulation and Finish Systems	ASTM	ASTM E2321-03 (2011)
	Thermal Insulation—Vocabulary	ISO	ISO 9229:2007
	National Commercial and Industrial Insulation Standards, 8th ed.	MICA	MICA
	Accepted Industry Practices for Sheet Metal Lagging, 1st ed.	SMACNA	SMACNA 2002
Legionellosis	Minimizing the Risk of Legionellosis Associated with Building Water Systems	ASHRAE	ASHRAE Guideline 12-2000
	Legionellosis: Risk Management for Building Water Systems	ASHRAE	ANSI/ASHRAE 188-2015
Louvers	Laboratory Methods of Testing Dampers for Rating	AMCA	AMCA 500-D-12
	Laboratory Methods of Testing Louvers for Rating	AMCA	AMCA 500-L-12 (R2015)
Lubricants	Methods of Testing the Floc Point of Refrigeration Grade Oils	ASHRAE	ANSI/ASHRAE 86-2013
	Refrigeration Oil Description	ASHRAE	ANSI/ASHRAE 99-2006
	Test Method for Pour Point of Petroleum Products	ASTM	ASTM D97-17b
	Classification of Industrial Fluid Lubricants by Viscosity System	ASTM	ASTM D2422-97 (2013)
	Test Method for Relative Molecular Weight (Relative Molecular Mass) of Hydrocarbons by Thermoelectric Measurement of Vapor Pressure	ASTM	ASTM D2503-92 (2016)
	Test Method for Determination of Moderately High Temperature Piston Deposits by Thermo-Oxidation Engine Oil Simulation Test—TEOST MHT	ASTM	ASTM D7097-16a
	Petroleum Products—Corrosiveness to Copper—Copper Strip Test	ISO	ISO 2160:1998
Measurement	Industrial Ventilation: A Manual of Recommended Practice, 29th ed. (2016)	ACGIH	ACGIH
	Engineering Analysis of Experimental Data	ASHRAE	ASHRAE Guideline 2-2010 (R2014)
	Instrumentation for Monitoring Central Chilled Water Plant Efficiency	ASHRAE	ASHRAE Guideline 22-2012
	Standard Method for Measuring the Proportion of Lubricant in Liquid Refrigerant	ASHRAE	ANSI/ASHRAE 41.4-2015
	Standard Method for Measurement of Moist Air Properties	ASHRAE	ANSI/ASHRAE 41.6-2014
	Methods of Determining, Expressing, and Comparing Building Energy Performance and Greenhouse Gas Emissions	ASHRAE	ANSI/ASHRAE 105-2014

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Subject	Title	Publisher	Reference
Energy Fluid Flow	Method for Establishing Installation Effects on Flowmeters	ASME	ASME MFC-10M-2000 (R2011)
	Test Uncertainty	ASME	ASME PTC 19.1-2013
	Measurement of Industrial Sound	ASME	ANSI/ASME PTC 36-2004 (R2013)
	Test Methods for Water Vapor Transmission of Materials	ASTM	ASTM E96/E96M-16
	Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples	ASTM	ASTM E230/E230M-17
	Practice for Continuous Sizing and Counting of Airborne Particles in Dust-Controlled Areas and Clean Rooms Using Instruments Capable of Detecting Single Sub-Micrometre and Larger Particles	ASTM	ASTM F50-12 (2015)
	Ergonomics of the Thermal Environment—Instruments for Measuring Physical Quantities	ISO	ISO 7726:1998
	Ergonomics of the Thermal Environment—Determination of Metabolic Rate	ISO	ISO 8996:2004
	Ergonomics of the Thermal Environment—Estimation of the Thermal Insulation and Water Vapour Resistance of a Clothing Ensemble	ISO	ISO 9920:2007
	Measurement of Energy and Demand Savings	ASHRAE	ASHRAE Guideline 14-2014
	Standard Methods for Liquid in Flow Measurement	ASHRAE	ANSI/ASHRAE 41.8-2016
	Methods for Volatile-Refrigerant Mass Flow Measurements Using Calorimeters	ASHRAE	ANSI/ASHRAE 41.9-2011
	Flow Measurement	ASME	ASME PTC 19.5-2004 (R2013)
	Glossary of Terms Used in the Measurement of Fluid Flow in Pipes	ASME	ASME MFC-1M-2014
	Measurement Uncertainty for Fluid Flow in Closed Conduits	ASME	ANSI/ASME MFC-2M-1983 (R2013)
	Measurement of Fluid Flow in Pipes Using Orifice, Nozzle, and Venturi	ASME	ASME MFC-3M-2004 (R2017)
	Measurement of Fluid Flow in Pipes Using Vortex Flowmeters	ASME	ASME MFC-6M-2013
	Fluid Flow in Closed Conduits: Connections for Pressure Signal Transmissions Between Primary and Secondary Devices	ASME	ASME MFC-8M-2001 (R2016)
	Measurement of Liquid Flow in Closed Conduits by Weighing Method	ASME	ASME MFC-9M-1988 (R2011)
	Measurement of Fluid Flow Using Small Bore Precision Orifice Meters	ASME	ASME MFC-14M-2003 (R2008)
	Measurement of Fluid Flow in Closed Conduits by Means of Electromagnetic Flowmeters	ASME	ASME MFC-16-2014
	Measurement of Fluid Flow Using Variable Area Meters	ASME	ASME MFC-18M-2001 (R2016)
	Test Method for Determining the Moisture Content of Inorganic Insulation Materials by Weight	ASTM	ASTM C1616-07 (2012)
	Test Method for Indicating Wear Characteristics of Petroleum Hydraulic Fluids in a High Pressure Constant Volume Vane Pump	ASTM	ASTM D6973-14
	Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)	ASTM	ASTM D7042-16e3
	Test Method for Indicating Wear Characteristics of Non-Petroleum and Petroleum Hydraulic Fluids in a Constant Volume Vane Pump	ASTM	ASTM D7043-17
	Practice for Calculating Viscosity of a Blend of Petroleum Products	ASTM	ASTM D7152-11 (2016)
	Test Method for Same-Different Test	ASTM	ASTM E2139-05 (2011)
	Practice for Field Use of Pyranometers, Pyrheliometers, and UV Radiometers	ASTM	ASTM G183-15
Gas Flow	Standard Methods for Laboratory Airflow Measurement	ASHRAE	ANSI/ASHRAE 41.2-1987 (R1992)
	Method of Test for Measurement of Flow of Gas	ASHRAE	ANSI/ASHRAE 41.7-2015
	Measurement of Gas Flow by Turbine Meters	ASME	ANSI/ASME MFC-4M-1986 (R2016)
Pressure	Measurement of Gas Flow by Means of Critical Flow Venturi Nozzles	ASME	ANSI/ASME MFC-7M-2016
	Standard Method for Pressure Measurement	ASHRAE	ANSI/ASHRAE 41.3-2014
	Pressure Gauges and Gauge Attachments	ASME	ASME B40.100-2013
	Pressure Measurement	ASME	ANSI/ASME PTC 19.2-2010 (R2015)
Temperature	Standard Method for Temperature Measurement	ASHRAE	ANSI/ASHRAE 41.1-2013
	Thermometers, Direct Reading and Remote Reading	ASME	ASME B40.200-2008 (R2013)
Thermal	Temperature Measurement	ASME	ASME PTC 19.3-1974 (R2004)
	Total Temperature Measuring Instruments (Turbine Powered Subsonic Aircraft)	SAE	SAE AS793A-2001 (R2008)
	Method of Testing Thermal Energy Meters for Liquid Streams in HVAC Systems	ASHRAE	ANSI/ASHRAE 125-2016
	Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus	ASTM	ASTM C177-13
	Test Method for Steady-State Heat Flux Measurements Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus	ASTM	ASTM C518-17
	Practice for In-Situ Measurement of Heat Flux and Temperature on Building Envelope Components	ASTM	ASTM C1046-95 (2013)
	Practice for Determining Thermal Resistance of Building Envelope Components from In-Situ Data	ASTM	ASTM C1155-95 (2013)
	Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus	ASTM	ASTM C1363-11

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Subject	Title	Publisher	Reference
Mobile Homes and Recreational Vehicles	Residential Load Calculation, 8th ed.	ACCA	ANSI/ACCA Manual J-2016
	Recreational Vehicle Cooking Gas Appliances	CSA	ANSI Z21.57-2010
	Oil-Fired Warm Air Heating Appliances for Mobile Housing and Recreational Vehicles	CSA	B140.10-06 (R2015)
	Manufactured Homes	CSA	CAN/CSA Z240 MH Series-16
	Recreational Vehicles	CSA	CAN/CSA Z240 RV Series-14
	Gas Supply Connectors for Manufactured Homes	IAPMO	IAPMO TS 9-2003
	Fuel Supply: Manufactured/Mobile Home Parks & Recreational Vehicle Parks	IAPMO	Chapter 13, Part II
	Manufactured Housing Construction and Safety Standards	ICC/ANSI	HUD 24 CFR Part 3280 (2008)
	Manufactured Housing	NFPA	NFPA 501-2017
	Recreational Vehicles	NFPA	NFPA 1192-2018
	Plumbing System Components for Recreational Vehicles	NSF	ANSI/NSF 24-2016
	Low Voltage Lighting Fixtures for Use in Recreational Vehicles	UL	ANSI/UL 234-2005
	Liquid Fuel-Burning Heating Appliances for Manufactured Homes and Recreational Vehicles	UL	ANSI/UL 307A-2009
	Gas-Burning Heating Appliances for Manufactured Homes and Recreational Vehicles	UL	UL 307B-2006
Motors and Generators	Installation and Maintenance of Farm Standby Electric Power	ASABE	ANSI/ASABE EP364.4-2013
	Nuclear Power Plant Air-Cleaning Units and Components	ASME	ASME N509-2002 (R2008)
	In-Service Testing of Nuclear Air Treatment Systems	ASME	ASME N511-2007 (R2013)
	Fired Steam Generators	ASME	ASME PTC 4-2013
	Gas Turbine Heat Recovery Steam Generators	ASME	ASME PTC 4.4-2008 (R2013)
	Test Methods for Film-Insulated Magnet Wire	ASTM	ASTM D1676-17
	Test Method for Evaluation of Engine Oils in a High Speed, Single-Cylinder Diesel Engine—Caterpillar 1R Test Procedure	ASTM	ASTM D6923-17
	Test Method for Evaluation of Diesel Engine Oils in the T-11 Exhaust Gas Recirculation Diesel Engine	ASTM	ASTM D7156-17
	Test Methods, Marking Requirements, and Energy Efficiency Levels for Three-Phase Induction Motors	CSA	CSA C390-10 (R2015)
	Motors and Generators	CSA	C22.2 No. 100-14
	Emergency Electrical Power Supply for Buildings	CSA	CSA C282-15
	Energy Efficiency Test Methods for Small Motors	CSA	CAN/CSA C747-09 (R2014)
	Standard Test Procedure for Polyphase Induction Motors and Generators	IEEE	IEEE 112-2017
	Motors and Generators	NEMA	NEMA MG 1-2016
	Energy Management Guide for Selection and Use of Fixed Frequency Medium AC Squirrel-Cage Polyphase Industrial Motors	NEMA	NEMA MG 10-2017
	Energy Management Guide for Selection and Use of Single-Phase Motors	NEMA	NEMA MG 11-1977 (R2012)
	Magnet Wire	NEMA	ANSI/NEMA MW 1000-2016
	Motion/Position Control Motors, Controls, and Feedback Devices	NEMA	NEMA ICS 16-2001
	Rotating Electrical Machines—General Requirements	UL	UL 1004-1-2012
	Electric Motors and Generators for Use in Hazardous (Classified) Locations	UL	ANSI/UL 674-2011
	Overheating Protection for Motors	UL	ANSI/UL 2111-1997
Operation and Maintenance	Maintenance of Residential HVAC Systems	ACCA	ANSI/ACCA 4 QM-2013
	Preparation of Operating and Maintenance Documentation for Building Systems	ASHRAE	ASHRAE Guideline 4-2008 (RA13)
	Sustainable, High Performance Operations and Maintenance	ASHRAE	ASHRAE Guideline 32-2012
	Inspection and Maintenance of Commercial-Building HVAC Systems	ASHRAE/ACCA	ANSI/ASHRAE/ACCA 180-2012
	International Property Maintenance Code® (2018)	ICC	IPMC
Panel Heating and Cooling	Method of Testing for Rating Ceiling Panels for Sensible Heating and Cooling	ASHRAE	ANSI/ASHRAE 138-2013
Pipe, Tubing, and Fittings	Scheme for the Identification of Piping Systems	ASME	ASME A13.1-2015
	Pipe Threads, General Purpose (Inch)	ASME	ANSI/ASME B1.20.1-2013
	Wrought Copper and Copper Alloy Braze-Joint Pressure Fittings	ASME	ASME B16.50-2013
	Power Piping	ASME	ASME B31.1-2016
	Process Piping	ASME	ASME B31.3-2016
	Refrigeration Piping and Heat Transfer Components	ASME	ASME B31.5-2016
	Building Services Piping	ASME	ASME B31.9-2017
	Practice for Obtaining Hydrostatic or Pressure Design Basis for “Fiberglass” (Glass-Fiber-Reinforced Thermosetting-Resin) Pipe and Fittings	ASTM	ASTM D2992-12
	Specification for Welding of Austenitic Stainless Steel Tube and Piping Systems in Sanitary Applications	AWS	AWS D18.1:2009
	Standards of the Expansion Joint Manufacturers Association, 10th ed.	EJMA	EJMA
	Pipe Hangers and Supports—Materials, Design and Manufacture	MSS	ANSI/MSS SP-58-2009
	Pipe Hangers and Supports—Selection and Application	MSS	ANSI/MSS SP-69-2003

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Subject	Title	Publisher	Reference
Plastic	General Welding Guidelines (2009)	NCPWB	NCPWB
	National Fuel Gas Code	AGA/NFPA	ANSI Z223.1/NFPA 54-2018
	Refrigeration Tube Fittings—General Specifications	SAE	SAE J513-1999
	Seismic Restraint Manual—Guidelines for Mechanical Systems, 3rd ed.	SMACNA	ANSI/SMACNA 001-2008
	Tube Fittings for Flammable and Combustible Fluids, Refrigeration Service, and Marine Use	UL	ANSI/UL 109-1997
	Specification for Poly (Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120	ASTM	ASTM D1785-12
	Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials or Pressure Design Basis for Thermoplastic Pipe Products	ASTM	ASTM D2837-13e1
	Specification for Perfluoroalkoxy (PFA)-Fluoropolymer Tubing	ASTM	ASTM D6867-03 (2014)
	Specification for Polyethylene Stay in Place Form System for End Walls for Drainage Pipe	ASTM	ASTM D7082-15
	Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80	ASTM	ASTM F441/F441M-15
	Test Method for Evaluating the Oxidative Resistance of Polyethylene (PE) Pipe to Chlorinated Water	ASTM	ASTM F2263-14
	Specification for 12 to 60 in. [300 to 1500 mm] Annular Corrugated Profile-Wall Polyethylene (PE) Pipe and Fittings for Gravity-Flow Storm Sewer and Subsurface Drainage Applications	ASTM	ASTM F2306/F2306M-14
	Test Method for Determining Chemical Compatibility of Substances in Contact with Thermoplastic Pipe and Fittings Materials	ASTM	ASTM F2331-11 (2016)
	Test Method for Determining Thermoplastic Pipe Wall Stiffness	ASTM	ASTM F2433-05 (2013)
	Specification for Steel Reinforced Polyethylene (PE) Corrugated Pipe	ASTM	ASTM F2435-15
	Electrical Polyvinyl Chloride (PVC) Tubing and Conduit	NEMA	NEMA TC 2-2013
	PVC Plastic Utilities Duct for Underground Installation	NEMA	NEMA TC 6 and 8-2013
	Smooth Wall Coilable Polyethylene Electrical Plastic Duct	NEMA	NEMA TC 7-2016
	Fittings for PVC Plastic Utilities Duct for Underground Installation	NEMA	NEMA TC 9-2004 (R2012)
	Electrical Nonmetallic Tubing (ENT)	NEMA	NEMA TC 13-2014
	Plastics Piping System Components and Related Materials	NSF	ANSI/NSF 14-2016b
Metal	Rubber Gasketed Fittings	UL	ANSI/UL 213-2004
	Welded and Seamless Wrought Steel Pipe	ASME	ASME B36.10M-2015
	Stainless Steel Pipe	ASME	ASME B36.19M-2004 (R2015)
	Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless	ASTM	ASTM A53/53M-12
	Specification for Seamless Carbon Steel Pipe for High-Temperature Service	ASTM	ASTM A106/A106M-15
	Specification for Seamless Copper Pipe, Standard Sizes	ASTM	ASTM B42-15a
	Specification for Seamless Copper Tube	ASTM	ASTM B75/B75M-11
	Specification for Seamless Copper Water Tube	ASTM	ASTM B88-16
	Specification for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service	ASTM	ASTM B280-16
	Specification for Hard-Drawn Copper Capillary Tube for Restrictor Applications	ASTM	ASTM B360-15
	Specification for Welded Copper Tube for Air Conditioning and Refrigeration Service	ASTM	ASTM B640-12a
	Specification for Copper-Beryllium Seamless Tube (UNS Nos. C17500 and C17510)	ASTM	ASTM B937-15
	Test Method for Rapid Determination of Corrosiveness to Copper from Petroleum Products Using a Disposable Copper Foil Strip	ASTM	ASTM D7095-17
	Thickness Design of Ductile-Iron Pipe	AWWA	ANSI/AWWA C150/A21.50-14
	Fittings, Cast Metal Boxes, and Conduit Bodies for Conduit, Electrical Metallic Tubing, and Cable	NEMA	NEMA FB 1-2014
	Polyvinyl-Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit	NEMA	NEMA RN 1-2005 (R2013)
Plumbing	Backwater Valves	ASME	ASME A112.14.1-2003 (R2017)
	Plumbing Supply Fittings	ASME	ASME A112.18.1-2012 (R2017)
	Plumbing Waste Fittings	ASME	ASME A112.18.2-2015
	Performance Requirements for Backflow Protection Devices and Systems in Plumbing Fixture Fittings	ASME	ASME A112.18.3-2002 (R2017)
	Uniform Plumbing Code (2018)	IAPMO	IAPMO
	International Plumbing Code® (2018)	ICC	IPC
	International Private Sewage Disposal Code® (2018)	ICC	IPSDC
	2018 National Standard Illustrated Plumbing Code—Illustrated	PHCC	PHCC 2012
Pumps	Standard Plumbing Code (1997)	SBCCI	SPC
	Balancing and Testing Air and Hydronic Systems	ACCA	ACCA Manual B-2009
	Centrifugal Pumps	ASME	ASME PTC 8.2-1990
	Specification for Horizontal End Suction Centrifugal Pumps for Chemical Process	ASME	ASME B73.1-2012
	Specification for Vertical-in-Line Centrifugal Pumps for Chemical Process	ASME	ASME B73.2-2016

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Subject	Title	Publisher	Reference
	Specification for Sealless Horizontal End Suction Metallic Centrifugal Pumps for Chemical Process	ASME	ASME B73.3-2015
	Specification for Thermoplastic and Thermoset Polymer Material Horizontal End Suction Centrifugal Pumps for Chemical Process	ASME	ASME B73.5M-1995 (R2007)
	Liquid Pumps	CSA	CAN/CSA C22.2 No. 108-14
	Performance Standard for Liquid Ring Vacuum Pumps, 5th ed. (2017)	HEI	HEI 119
	Rotodynamic (Centrifugal) Pumps for Nomenclature and Definitions	HI	ANSI/HI 1.1-1.2-2014
	Rotodynamic (Centrifugal) Pumps for Design and Application	HI	ANSI/HI 1.3-2013
	Rotodynamic (Centrifugal) Pumps for Manuals Describing Installation, Operation and Maintenance	HI	ANSI/HI 1.4-2014
	Rotodynamic (Vertical) Nomenclature	HI	ANSI/HI 2.1-2.2-2014
	Rotodynamic (Vertical) Application	HI	ANSI/HI 2.3-2013
	Rotodynamic (Vertical) Operations	HI	ANSI/HI 2.4-2014
	Rotary Pumps for Nomenclature, Definitions, Application, and Operation	HI	ANSI/HI 3.1-3.5-2015
	Sealless, Magnetically Driven Rotary Pumps for Nomenclature, Definitions, Application, Operation, and Test	HI	ANSI/HI 4.1-4.6-2017
	Sealless Rotodynamic Pumps for Nomenclature, Definitions, Application, Operation, and Test	HI	ANSI/HI 5.1-5.6-2016
	Reciprocating Pumps for Nomenclature, Definitions, Application, and Operation	HI	ANSI/HI 6.1-6.5-2015
	Direct Acting (Steam) Pumps for Nomenclature, Definitions, Application, and Operation	HI	ANSI/HI 8.1-8.5-2015
	Pumps—General Guidelines for Types, Definitions, Application, Sound Measurement and Decontamination	HI	ANSI/HI 9.1-9.5-2015
	Rotodynamic Pumps for Assessment of Allowable Nozzle Loads	HI	ANSI/HI 9.6.2-2015
	Centrifugal and Vertical Pumps for Allowable Operating Region	HI	ANSI/HI 9.6.3-2017
	Rotodynamic Pumps for Vibration Measurements and Allowable Values	HI	ANSI/HI 9.6.4-2016
	Rotodynamic (Centrifugal and Vertical) Pumps Guideline for Condition Monitoring	HI	ANSI/HI 9.6.5-2016
	Intake Design for Rotodynamic Pumps	HI	ANSI/HI 9.8-2016
	Engineering Data Book, 2nd ed.	HI	HI (1990)
	Equipment for Swimming Pools, Spas, Hot Tubs and Other Recreational Water Facilities	NSF	ANSI/NSF 50-2016a
	Pumps for Oil-Burning Appliances	UL	UL 343-2008
	Motor-Operated Water Pumps	UL	ANSI/UL 778-2016
	Swimming Pool Pumps, Filters, and Chlorinators	UL	ANSI/UL 1081-2016
Radiators	Balancing and Testing Air and Hydronic Systems	ACCA	ACCA Manual B-2009
	Testing and Rating Standard for Baseboard Radiation, 8th ed. (2005)	HYDI	IBR
	Testing and Rating Standard for Finned Tube (Commercial) Radiation, 6th ed. (2005)	HYDI	IBR
Receivers	Refrigerant Liquid Receivers	AHRI	ANSI/AHRI 495-2005
	Refrigerant-Containing Components and Accessories, Nonelectrical	UL	ANSI/UL 207-2009
Refrigerants	Threshold Limit Values for Chemical Substances (updated annually)	ACGIH	ACGIH
	Specifications for Refrigerants	AHRI	AHRI 700-2017
	Refrigerant Recovery Equipment and Recovery/Recycling Equipment	AHRI	AHRI 740-2016
	Refrigerant Information Recommended for Product Development and Standards	ASHRAE	ASHRAE Guideline 6-2015
	Method of Testing Flow Capacity of Refrigerant Capillary Tubes	ASHRAE	ANSI/ASHRAE 28-1996 (RA10)
	Designation and Safety Classification of Refrigerants	ASHRAE	ANSI/ASHRAE 34-2016
	Sealed Glass Tube Method to Test the Chemical Stability of Materials for Use Within Refrigerant Systems	ASHRAE	ANSI/ASHRAE 97-2007 (RA 2017)
	Refrigeration Oil Description	ASHRAE	ANSI/ASHRAE 99-2006
	Reducing the Release of Halogenated Refrigerants from Refrigerating and Air-Conditioning Equipment and Systems	ASHRAE	ANSI/ASHRAE 147-2013
	Methods of Testing Capacity for Refrigerant Pressure Regulators	ASHRAE	ANSI/ASHRAE 158.2-2011
	Method of Test to Determine the Performance of Halocarbon Refrigerant Leak Detectors	ASHRAE	ANSI/ASHRAE 173-2012
	Test Method for Acid Number of Petroleum Products by Potentiometric Titration	ASTM	ASTM D664-17
	Test Method for Concentration Limits of Flammability of Chemical (Vapors and Gases)	ASTM	ASTM E681-09 (2015)
	Refrigerant-Containing Components for Use in Electrical Equipment	CSA	C22.2 No. 140.3-15
	Refrigerants—Designation System	ISO	ISO 817:2014
	Procedure Retrofitting CFC-12 (R-12) Mobile Air-Conditioning Systems to HFC-134a (R-134a)	SAE	SAE J1661-2011
	Recommended Service Procedure for the Containment of CFC-12 (R-12)	SAE	SAE J1989-2011
	Standard of Purity for Recycled R-134a (HFC-134a) and R-1234yf (HFO-1234yf) for Use in Mobile Air-Conditioning Systems	SAE	SAE J2099-2012
	HFC-134a (R-134a) Service Hose Fittings for Automotive Air-Conditioning Service Equipment	SAE	SAE J2197-2011

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Subject	Title	Publisher	Reference
	CFC-12 (R-12) Refrigerant Recovery Equipment for Mobile Automotive Air-Conditioning Systems	SAE	SAE J2209-2011
	Recommended Service Procedure for the Containment of HFC-134a	SAE	SAE J2211-2011
	Refrigerant-Containing Components and Accessories, Nonelectrical	UL	ANSI/UL 207-2009
	Refrigerant Recovery/Recycling Equipment	UL	ANSI/UL 1963-2011
	Refrigerants	UL	ANSI/UL 2182-2006
Refrigeration	Quality Maintenance of Commercial Refrigeration Systems	ACCA	ANSI/ACCA 14 QMref-2015
	Safety Standard for Refrigeration Systems	ASHRAE	ANSI/ASHRAE 15-2016
	Mechanical Refrigeration Code	CSA	B52-13
	Refrigeration Equipment	CSA	CAN/CSA C22.2 No. 120-13
	Safe Design of Closed-Circuit Ammonia Refrigeration Systems	IIAR	ANSI/IIAR 2-2014
	Refrigerated Medical Equipment	UL	ANSI/UL 416-1993
Refrigeration Systems	Ejectors	ASME	ASME PTC 24-1976 (R1982)
	Safety Standard for Refrigeration Systems	ASHRAE	ANSI/ASHRAE 15-2016
	Designation and Safety Classification of Refrigerants	ASHRAE	ANSI/ASHRAE 34-2016
	Reducing the Release of Halogenated Refrigerants from Refrigerating and Air-Conditioning Equipment and Systems	ASHRAE	ANSI/ASHRAE 147-2013
	Testing of Refrigerating Systems	ISO	ISO 916-1968
	Standards for Steam Jet Vacuum Systems, 7th ed. (2012)	HEI	HEI 125
Transport	Mechanical Transport Refrigeration Units	AHRI	ANSI/AHRI 1110-2013
	Mechanical Refrigeration and Air-Conditioning Installations Aboard Ship	ASHRAE	ANSI/ASHRAE 26-2010
	General Requirements for Application of Vapor Cycle Refrigeration Systems for Aircraft	SAE	SAE ARP731C-2003 (R2015)
	Safety Standard for Motor Vehicle Refrigerant Vapor Compression Systems	SAE	SAE J639-2011
Refrigerators			
Commercial	Quality Maintenance of Commercial Refrigeration Systems	ACCA	ANSI/ACCA 14 QMref-2015
	Method of Testing Commercial Refrigerators and Freezers	ASHRAE	ANSI/ASHRAE 72-2014
	Energy Performance Standard for Commercial Refrigeration Equipment	CSA	CAN/CSA C657-15
	Energy Performance of Food Service Refrigerators and Freezers	CSA	C827-10 (R2015)
	Gas Food Service Equipment	CSA	ANSI Z83.11-2016/CSA 1.8-2016
	Food Equipment	NSF	ANSI/NSF 2-2015
	Commercial Refrigerators and Freezers	NSF	ANSI/NSF 7-2016
	Mobile Food Carts	NSF	ANSI/NSF 59-2012
	Refrigeration Unit Coolers	UL	ANSI/UL 412-2011
	Refrigerating Units	UL	ANSI/UL 427-2011
	Commercial Refrigerators and Freezers	UL	ANSI/UL 471-2010
Household	Energy and Volume Refrigerating Appliances	AHAM	ANSI/AHAM HRF-1-2016
	Refrigerators Using Gas Fuel	CSA	ANSI Z21.19-2014/CSA 1.4-2014
	Energy Performance and Capacity of Household Refrigerators, Refrigerator-Freezers, Freezers, and Wine Chillers	CSA	C300-15
Retrofitting			
Building	Home Evaluation and Performance Improvement	ACCA	ANSI/ACCA 12 QH-2018
	Technician's Guide & Workbook for Home Evaluation and Performance Improvement	ACCA	ACCA 2015
	Technician's Guide & Workbook for Duct Diagnostics and Repair	ACCA	ACCA 2016
	Bob's House	ACCA	ACCA 2008
	Good HVAC Practices for Residential and Commercial Buildings	ACCA	ACCA 2003
	Building Systems Analysis and Retrofit Manual, 2nd ed.	SMACNA	SMACNA 2011
Refrigerant	Procedure for Retrofitting CFC-12 (R-12) Mobile Air Conditioning Systems to HFC-134a (R-134a)	SAE	SAE J1661-2011
Roof Ventilators	Commercial Low Pressure, Low Velocity Duct System Design	ACCA	ACCA Manual Q-1990
	Power Ventilators	UL	ANSI/UL 705-2017
Safety	Guideline for Risk Management of Public Health and Safety in Buildings	ASHRAE	ASHRAE Guideline 29-2009
Seismic Restraint	Method of Test of Seismic Restraint Devices for HVAC&R Equipment	ASHRAE	ANSI/ASHRAE 171-2017
	Seismic Restraint Manual—Guidelines for Mechanical Systems, 3rd ed.	SMACNA	ANSI/SMACNA 001-2008
Smoke Control Systems	The Commissioning Process for Smoke Management Systems	ASHRAE	ASHRAE Guideline 1.5-2012
	Laboratory Methods of Testing Fans Used to Exhaust Smoke in Smoke Management Systems	ASHRAE	ANSI/ASHRAE 149-2013
	Smoke-Control Systems Utilizing Barriers and Pressure Differences	NFPA	NFPA 92A-2009
	Smoke Management Systems in Malls, Atria, and Large Spaces	NFPA	NFPA 92B-2009
	Ceiling Dampers	UL	ANSI/UL 555C-2014
	Smoke Dampers	UL	ANSI/UL 555S-2014

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Subject	Title	Publisher	Reference
Solar Equipment	Thermal Performance Testing of Solar Ambient Air Heaters	ASABE	ANSI/ASAE S423-1991 (R2012)
	Testing and Reporting Solar Cooker Performance	ASABE	ASAE S580.1-2013
	Method of Measuring Solar-Optical Properties of Materials	ASHRAE	ASHRAE 74-1988
	Methods of Testing to Determine the Thermal Performance of Solar Collectors	ASHRAE	ANSI/ASHRAE 93-2010 (RA14)
	Methods of Testing to Determine the Thermal Performance of Solar Domestic Water Heating Systems	ASHRAE	ANSI/ASHRAE 95-1981 (RA87)
	Methods of Testing to Determine the Thermal Performance of Unglazed Flat-Plate Liquid-Type Solar Collectors	ASHRAE	ANSI/ASHRAE 96-1980 (RA89)
	Practice for Installation and Service of Solar Space Heating Systems for One and Two Family Dwellings	ASTM	ASTM E683-91 (2013)
	Practice for Evaluating Thermal Insulation Materials for Use in Solar Collectors	ASTM	ASTM E861-13
	Practice for Installation and Service of Solar Domestic Water Heating Systems for One and Two Family Dwellings	ASTM	ASTM E1056-13
	Reference Solar Spectral Irradiance at the Ground at Different Receiving Conditions—Part 1: Direct Normal and Hemispherical Solar Irradiance for Air Mass 1.5	ISO	ISO 9845-1:1992
	Solar Collectors	CSA	CAN/CSA F378 Series-11 (R2016)
	Packaged Solar Domestic Hot Water Systems (Liquid to Liquid Heat Transfer)	CSA	CAN/CSA F379 Series-09 (R2013)
	Installation Code for Solar Domestic Hot Water Systems	CSA	CAN/CSA F383-08 (R2013)
	Solar Heating—Domestic Water Heating Systems—Part 2: Outdoor Test Methods for System Performance Characterization and Yearly Performance Prediction of Solar-Only Systems	ISO	ISO 9459-2:1995
	Solar Energy—Solar Thermal Collectors—Test Methods	ISO	ISO 9806:2017
	Solar Water Heaters—Elastomeric Materials for Absorbers, Connecting Pipes and Fittings—Method of Assessment	ISO	ISO 9808:1990
	Solar Energy—Calibration of a Pyranometer Using a Pyrhelimeter	ISO	ISO 9846:1993
Solenoid Valves	Solenoid Valves for Use with Volatile Refrigerants	AHRI	ANSI/AHRI 760-2014
	Methods of Testing Capacity of Refrigerant Solenoid Valves	ASHRAE	ANSI/ASHRAE 158.1-2012
	Electrically Operated Valves	UL	UL 429-2013
Sound Measurement	Threshold Limit Values for Physical Agents (updated annually)	ACGIH	ACGIH
	Electroacoustics—Sound Level Meters—Part 3: Periodic Tests	ASA	ANSI/ASA S1.4 Part 3-2014
	Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters	ASA	ANSI S1.11-2014
	Microphones, Part 1: Specifications for Laboratory Standard Microphones	ASA	ANSI S1.15-1997/Part 1 (R2016)
	Part 2: Primary Method for Pressure Calibration of Laboratory Standard Microphones by the Reciprocity Technique	ASA	ANSI S1.15-2005/Part 2 (R2015)
	Specification for Acoustical Calibrators	ASA	ANSI S1.40-2006 (R2016)
	Measurement of Industrial Sound	ASME	ASME PTC 36-2004 (RA13)
	Test Method for Measuring Acoustical and Airflow Performance of Duct Liner Materials and Prefabricated Silencers	ASTM	ASTM E477-13
	Test Method for Determination of Decay Rates for Use in Sound Insulation Test Methods	ASTM	ASTM E2235-04 (2012)
	Procedural Standards for the Measurement of Sound and Vibration, 2nd ed. (2006)	NEBB	NEBB
	HVAC Systems Sound and Vibration Procedural Guide, 1st ed.	SMACNA	SMACNA 2013
	Reverberant Room Method for Sound Testing of Fans	AMCA	AMCA 300-14
	Methods for Calculating Fan Sound Ratings from Laboratory Test Data	AMCA	AMCA 301-14
Fans	Application of Sone Ratings for Non-Ducted Air Moving Devices	AMCA	AMCA 302-73 (R2008)
	Application of Sound Power Level Ratings for Fans	AMCA	AMCA 303-79 (R2008)
	Acoustics—Measurement of Airborne Noise Emitted and Structure-Borne Vibration Induced by Small Air-Moving Devices—Part 1: Airborne Noise Measurement	ASA	ANSI/ASA S12.11-1-2013/ISO 10302-1:2013
	Part 2: Structure-Borne Vibration	ASA	ANSI/ASA S12.11-2-2013/ISO 10302-2:2013
Other Equipment	Sound Rating of Outdoor Unitary Equipment	AHRI	AHRI 270-2015
	Application of Sound Rating Levels of Outdoor Unitary Equipment	AHRI	ANSI/AHRI 275-2010
	Sound Rating and Sound Transmission Loss of Packaged Terminal Equipment	AHRI	ANSI/AHRI 300-2015
	Sound Rating of Non-Ducted Indoor Air-Conditioning Equipment	AHRI	ANSI/AHRI 350-2015
	Sound Rating of Large Air-Cooled Outdoor Refrigerating and Air-Conditioning Equipment	AHRI	ANSI/AHRI 370-2015
	Method of Rating Sound and Vibration of Refrigerant Compressors	AHRI	ANSI/AHRI 530-2011
	Method of Measuring Machinery Sound Within an Equipment Space	AHRI	ANSI/AHRI 575-2017
	Statistical Methods for Determining and Verifying Stated Noise Emission Values of Machinery and Equipment	ASA	ANSI S12.3-1985 (R2016)
Techniques	Sound Level Prediction for Installed Rotating Electrical Machines	NEMA	NEMA MG 3-1974 (R2014)
	Preferred Frequencies and Filter Band Frequencies for Acoustical Measurements	ASA	ANSI/ASA S1.6-2016
	Reference Values for Levels Used in Acoustics and Vibrations	ASA	ANSI/ASA S1.8-2016
	Measurement of Sound Pressure Levels in Air	ASA	ANSI/ASA S1.13-2005 (R2010)

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Subject	Title	Publisher	Reference
	Procedure for the Computation of Loudness of Steady Sound	ASA	ANSI/ASA S3.4-2007 (R2017)
	Criteria for Evaluating Room Noise	ASA	ANSI/ASA S12.2-2008
	Methods for Determining the Insertion Loss of Outdoor Noise Barriers	ASA	ANSI/ASA S12.8-1998 (R2013)
	Engineering Method for the Determination of Sound Power Levels of Noise Sources Using Sound Intensity	ASA	ANSI/ASA S12.12-1992 (R2017)
	Procedures for Outdoor Measurement of Sound Pressure Level	ASA	ANSI/ASA S12.18-1994 (R2009)
	Methods for Measurement of Sound Emitted by Machinery and Equipment at Workstations and Other Specified Positions	ASA	ANSI/ASA S12.43-1997 (R2017)
	Methods for Calculation of Sound Emitted by Machinery and Equipment at Workstations and Other Specified Positions from Sound Power Level	ASA	ANSI/ASA S12.44-1997 (R2017)
	Acoustics—Determination of Sound Power Levels and Sound Energy Levels of Noise Sources Using Sound Pressure—Precision Method for Reverberation Test Rooms	ASA	ANSI/ASA S12.51-2012/ISO 3741:2012 (R2017)
	Acoustics—Determination of Sound Power Levels of Noise Sources Using Sound Pressure—Engineering Methods for Small, Movable Sources in Reverberant Fields—Part 1: Comparison Method for Hard-Walled Test Rooms	ASA	ANSI/ASA S12.53/Part 1-2011/ISO 3743-1:2011 (R2016)
	Part 2: Methods for Special Reverberation Test Rooms	ASA	ANSI/ASA S12.53/Part 2-1999 (R2015)/ISO 3743-2:1999 (R2015)
	Acoustics—Determination of Sound Power Levels and Sound Energy Levels of Noise Sources Using Sound Pressure—Engineering Methods for an Essentially Free Field over a Reflecting Plane	ASA	ANSI/ASA S12.54-2011/ISO 3744:2011 (R2016)
	Acoustics—Determination of Sound Power Levels and Sound Energy Levels of Noise Sources Using Sound Pressure—Survey Method Using an Enveloping Measurement Surface over a Reflecting Plane	ASA	ANSI/ASA S12.56-2011/ISO 3746:2011 (R2016)
	Test Method for Impedance and Absorption of Acoustical Materials by the Impedance Tube Method	ASTM	ASTM C384-04 (2016)
	Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method	ASTM	ASTM C423-17
	Test Method for Measurement of Airborne Sound Attenuation Between Rooms in Buildings	ASTM	ASTM E336-17a
	Test Method for Impedance and Absorption of Acoustical Materials Using a Tube, Two Microphones and a Digital Frequency Analysis System	ASTM	ASTM E1050-12
	Test Method for Measurement and Reporting of Masking Sound Levels Using A-Weighted and One-Third-Octave-Band Sound Pressure Levels	ASTM	ASTM E1573-18
	Test Method for Measurement of Sound in Residential Spaces	ASTM	ASTM E1574-98 (2014)
	Acoustics—Methods for Calculating Loudness—Part 1: Zwicker method	ISO	ISO 532:2017
	Part 2: Moore-Glasberg method	ISO	ISO 532-2:2017
	Acoustics—Determination of Sound Power Levels of Noise Sources Using Sound Intensity; Part 1: Measurement at Discrete Points	ISO	ISO 9614-1:1993
	Part 2: Measurement by Scanning	ISO	ISO 9614-2:1996
	Procedural Standards for the Measurement of Sound and Vibration, 2nd ed. (2006)	NEBB	NEBB
	Terminology Acoustical Terminology	ASA	ANSI S1.1-2013
	Terminology Relating to Building and Environmental Acoustics	ASTM	ASTM C634-13
Space Heaters	Methods of Testing for Rating Combination Space-Heating and Water-Heating Appliances	ASHRAE	ANSI/ASHRAE 124-2007
	Gas-Fired Room Heaters, Vol. II, Unvented Room Heaters	CSA	ANSI Z21.11.2-2016
	Vented Gas-Fired Space Heating Appliances	CSA	ANSI Z21.86-2016/CSA 2.32-2016
	Movable and Wall- or Ceiling-Hung Electric Room Heaters	UL	UL 1278-2014
	Fixed and Location-Dedicated Electric Room Heaters	UL	UL 2021-2015
Sustainability	Sustainable, High Performance Operations and Maintenance	ASHRAE	ASHRAE Guideline 32-2012
	Standard for the Design of High-Performance, Green Buildings Except Low-Rise Residential Buildings	ASHRAE/USGBC	ANSI/ASHRAE/USGBC/IES 189.1-2014
	International Green Construction Code™ (2015)	ICC	IGCC
Symbols	Graphic Symbols for Heating, Ventilating, Air-Conditioning, and Refrigerating Systems	ASHRAE	ANSI/ASHRAE 134-2005 (RA14)
	Graphical Symbols for Plumbing Fixtures for Diagrams Used in Architecture and Building Construction	ASME	ANSI/ASME Y32.4-1977 (RA04)
	Symbols for Mechanical and Acoustical Elements as Used in Schematic Diagrams	ASME	ANSI/ASME Y32.18-1972 (RA13)
	Practice for Mechanical Symbols, Shipboard Heating, Ventilation, and Air Conditioning (HVAC)	ASTM	ASTM F856-97 (2014)
	Standard Symbols for Welding, Brazing, and Nondestructive Examination	AWS	AWS A2.4:2012
	Graphic Symbols for Electrical and Electronics Diagrams	IEEE	ANSI/CSA/IEEE 315-1975 (R1993)
	Standard for Logic Circuit Diagrams	IEEE	IEEE 991-1986 (R1994)
	American National Standard for Metric Practice	IEEE/ASTM	IEEE/ASTM SI 10-2016
	Abbreviations and Acronyms for Use on Drawings and Related Documents	ASME	ASME Y14.38-2007 (R2013)
	Engineering Drawing Practices	ASME	ASME Y14.100-2017
	American National Standard for Safety Colors	NEMA	ANSI/NEMA Z535.1-2006 (R2011)

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Subject	Title	Publisher	Reference
Terminals, Wiring	Electrical Quick-Connect Terminals	UL	ANSI/UL 310-2014
	Wire Connectors	UL	ANSI/UL 486A-486B-2013
	Splicing Wire Connectors	UL	ANSI/UL 486C-2018
	Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors	UL	ANSI/UL 486E-2015
Testing and Balancing	AABC National Standards for Total System Balance (2002)	AABC	AABC
	Balancing and Testing Air and Hydronic Systems	ACCA	ACCA Manual B-2009
	Industrial Process/Power Generation Fans: Site Performance Test Standard	AMCA	AMCA 803-02 (R2008)
	Guidelines for Measuring and Reporting Environmental Parameters for Plant Experiments in Growth Chambers	ASABE	ANSI/ASAE EP411.5-2012
	HVAC&R Technical Requirements for the Commissioning Process	ASHRAE	ASHRAE Guideline 1.1-2007
	Measurement, Testing, Adjusting, and Balancing of Building HVAC Systems	ASHRAE	ANSI/ASHRAE 111-2008 (RA 2017)
	Rotary Pump Tests	HI	ANSI/HI 3.6-2016
	Air-Operated Pump Tests	HI	ANSI/HI 10.6-2016
	Pumps—General Guidelines for Types, Definitions, Application, Sound Measurement and Decontamination	HI	HI 9.1-9.5-2015
	Rotodynamic Submersible Pumps: for Hydraulic Performance, Hydrostatic Pressure, Mechanical and Electrical Acceptance Tests	HI	ANSI/HI 11.6-2017
	Procedural Standards for Certified Testing of Cleanrooms, 3rd ed. (2009)	NEBB	NEBB
	Procedural Standards for TAB Environmental Systems, 8th ed. (2015)	NEBB	NEBB
Thermal Storage	HVAC Systems Testing, Adjusting and Balancing, 3rd ed.	SMACNA	SMACNA 2002
	Thermal Energy Storage: A Guide for Commercial HVAC Contractors	ACCA	ACCA 2005
	Method of Testing Thermal Storage Devices with Electrical Input and Thermal Output Based on Thermal Performance	ASHRAE	ANSI/ASHRAE 94.2-2010
	Measurement, Testing, Adjusting, and Balancing of Building HVAC Systems	ASHRAE	ANSI/ASHRAE 111-2008 (R2017)
Transformers	Method of Testing the Performance of Cool Storage Systems	ASHRAE	ANSI/ASHRAE 150-2000 (R2014)
	Minimum Efficiency Values for Liquid-Filled Distribution Transformers	CSA	CAN/CSA C802.1-13
	Minimum Efficiency Values for Dry-Type Transformers	CSA	CAN/CSA C802.2-12 (R2017)
	Minimum Efficiency Values for Power Transformers	CSA	CAN/CSA C802.3-15
Turbines	Guide for Determining Energy Efficiency of Distribution Transformers	NEMA	NEMA TP-1-2002
	Steam Turbines	ASME	ASME PTC 6-2004 (R2014)
	Steam Turbines in Combined Cycle	ASME	ASME PTC 6.2-2011 (R2016)
	Hydraulic Turbines and Pump-Turbines	ASME	ASME PTC 18-2011
	Gas Turbines	ASME	ASME PTC 22-2014
	Wind Turbines	ASME	ASME PTC 42-1988 (R2004)
	Specification for Stainless Steel Bars for Compressor and Turbine Airfoils	ASTM	ASTM A1028-03 (2015)
	Specification for Gas Turbine Fuel Oils	ASTM	ASTM D2880-15
	Steam Turbines for Mechanical Drive Service	NEMA	NEMA SM 23-1991 (R2002)
	Land Based Steam Turbine Generator Sets, 0 to 33,000 kW	NEMA	NEMA SM 24-1991 (R2002)
Valves	Face-to-Face and End-to-End Dimensions of Valves	ASME	ASME B16.10-2017
	Valves—Flanged, Threaded, and Welding End	ASME	ASME B16.34-2017
	Manually Operated Metallic Gas Valves for Use in Aboveground Piping Systems up to 5 psi	ASME	ASME B16.44-2012
	Pressure Relief Devices	ASME	ASME PTC 25-2014
	Methods of Testing Capacity of Refrigerant Solenoid Valves	ASHRAE	ANSI/ASHRAE 158.1-2012
	Relief Valves for Hot Water Supply Systems	CSA	ANSI Z21.22-2015/CSA 4.4-2015
	Control Valve Capacity Test Procedures	ISA	ANSI/ISA-S75.02.01-2008
	Metal Valves for Use in Flanged Pipe Systems—Face-to-Face and Centre-to-Face Dimensions	ISO	ISO 5752:1982
	Safety Valves for Protection Against Excessive Pressure, Part 1: Safety Valves	ISO	ISO 4126-1:2013
	Oxygen System Fill/Check Valve	SAE	SAE AS1225A-1997 (R2017)
	Flow Control Valves for Anhydrous Ammonia and LP-Gas	UL	ANSI/UL 125-2014
	Safety Relief Valves for Anhydrous Ammonia and LP-Gas	UL	ANSI/UL 132-2015
	LP-Gas Regulators	UL	ANSI/UL 144-2012
	Electrically Operated Valves	UL	UL 429-2013
	Valves for Flammable Fluids	UL	ANSI/UL 842-2015
Gas	Manually Operated Metallic Gas Valves for Use in Gas Piping Systems up to 175 psig (Sizes NPS 1/2 through 2)	ASME	ASME B16.33-2012
	Large Metallic Valves for Gas Distribution (Manually Operated, NPS-2 1/2 to 12, 125 psig Maximum)	ASME	ANSI/ASME B16.38-2012
	Manually Operated Thermoplastic Gas Shutoffs and Valves in Gas Distribution Systems	ASME	ASME B16.40-2013
	Manually Operated Gas Valves for Appliances, Appliance Connection Valves, and Hose End Valves	CSA	ANSI Z21.15-2009/CGA 9.1-2009 (R2014)
	Automatic Valves for Gas Appliances	CSA	ANSI Z21.21-2015/CSA 6.5-2015

Selected Codes and Standards Published by Various Societies and Associations (*Continued*)

Subject	Title	Publisher	Reference
Refrigerant	Combination Gas Controls for Gas Appliances	CSA	ANSI Z21.78-2010/CGA 6.20-2010 (R2015)
	Gas Convenience Outlets and Optional Enclosures	CSA	ANSI Z21.90-2015/CSA 6.24-2015
	Thermostatic Refrigerant Expansion Valves	AHRI	ANSI/AHRI 750-2016
	Solenoid Valves for Use with Volatile Refrigerants	AHRI	ANSI/AHRI 760-2014
	Refrigerant Pressure Regulating Valves	AHRI	ANSI/AHRI 770-2014
	Method of Testing Thermostatic Refrigerant Expansion Valves	ASHRAE	ANSI/ASHRAE 17-2008
Vapor Retarders	Methods of Testing Capacity of Refrigerant Solenoid Valves	ASHRAE	ANSI/ASHRAE 158.1-2012
	Practice for Selection of Water Vapor Retarders for Thermal Insulation	ASTM	ASTM C755-10 (2015)e1
	Practice for Determining the Properties of Jacketing Materials for Thermal Insulation	ASTM	ASTM C921-10 (2015)
Vending Machines	Specification for Flexible, Low Permeance Vapor Retarders for Thermal Insulation	ASTM	ASTM C1136-17a
	Methods of Testing for Rating Vending Machines for Sealed Beverages	ASHRAE	ANSI/ASHRAE 32.1-2017
	Methods of Testing for Rating Pre-Mix and Post-Mix Beverage Dispensing Equipment	ASHRAE	ANSI/ASHRAE 32.2-2003 (RA11)
	Vending Machines	CSA	C22.2 No. 128-16
	Energy Performance of Vending Machines	CSA	CAN/CSA C804-09 (R2014)
	Vending Machines for Food and Beverages	NSF	ANSI/NSF 25-2012
	Refrigerated Vending Machines	UL	ANSI/UL 541-2016
Vent Dampers	Vending Machines	UL	ANSI/UL 751-2016
	Automatic Damper Devices for Use with Gas-Fired Appliances	CSA	ANSI Z21.66-2015/CSA 6.14-2015
Ventilation	Vent or Chimney Connector Dampers for Oil-Fired Appliances	UL	ANSI/UL 17-2008
	Commercial Systems Overview	ACCA	ACCA Manual CS-1993
	Residential Equipment Selection	ACCA	ANSI/ACCA 3 Manual S-2014
	Residential Duct Systems	ACCA	ANSI/ACCA 1 Manual D-2016
	Commercial Low Pressure, Low Velocity Duct System Design	ACCA	ACCA Manual Q-1990
	Comfort, Air Quality, and Efficiency by Design	ACCA	ACCA Manual RS-1997
	Guide for Testing Ventilation Systems (1991)	ACGIH	ACGIH
	Industrial Ventilation: A Manual of Recommended Practice, 29th ed. (2016)	ACGIH	ACGIH
	Design of Ventilation Systems for Poultry and Livestock Shelters	ASABE	ASAE EP270.5-1986 (R2012)
	Design Values for Emergency Ventilation and Care of Livestock and Poultry	ASABE	ANSI/ASAE EP282.2-1993 (R2013)
	Heating, Ventilating and Cooling Greenhouses	ASABE	ANSI/ASAE EP406.4-2003 (R2008)
	Guidelines for Selection of Energy Efficient Agricultural Ventilation Fans	ASABE	ASAE EP566.2-2012
	Uniform Terminology for Livestock Production Facilities	ASABE	ASAE S501-1990 (R2011)
	Agricultural Ventilation Constant Speed Fan Test Standard	ASABE	ASAE S565-2005 (R2011)
	Guide for the Ventilation and Thermal Management of Batteries for Stationary Applications	ASHRAE/IEEE	ASHRAE Guideline 21-2012/IEEE 1635-2012
	Ventilation for Acceptable Indoor Air Quality	ASHRAE	ANSI/ASHRAE 62.1-2016
	Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings	ASHRAE	ANSI/ASHRAE 62.2-2016
	Method of Testing for Room Air Diffusion	ASHRAE	ANSI/ASHRAE 113-2013
	Measuring Air Change Effectiveness	ASHRAE	ANSI/ASHRAE 129-1997 (RA02)
	Ventilation for Commercial Cooking Operations	ASHRAE	ANSI/ASHRAE 154-2016
	Ventilation of Health Care Facilities	ASHRAE/ASHE	ANSI/ASHRAE/ASHE 170-2017
	Residential Mechanical Ventilation Systems	CSA	CAN/CSA F326-M91 (R2014)
	Parking Structures	NFPA	NFPA 88A-2015
	Installation of Air-Conditioning and Ventilating Systems	NFPA	NFPA 90A-2018
	Ventilation Control and Fire Protection of Commercial Cooking Operations	NFPA	NFPA 96-2017
	Food Equipment	NSF	ANSI/NSF 2-2015
	Biosafety Cabinetry: Design, Construction, Performance, and Field Certification	NSF	ANSI/NSF 49-2016
	Aerothermodynamic Systems Engineering and Design	SAE	SAE AIR1168/3-1989 (R2011)
	Heater, Airplane, Engine Exhaust Gas to Air Heat Exchanger Type	SAE	SAE ARP86-2011
	Test Procedure for Battery Flame Retardant Venting Systems	SAE	SAE J1495-2013
Venting	Commercial Systems Overview	ACCA	ACCA Manual CS-1993
	Draft Hoods	CSA	ANSI Z21.12-1990 (R2015)
	National Fuel Gas Code	AGA/NFPA	ANSI Z223.1/NFPA 54-2018
	Explosion Prevention Systems	NFPA	NFPA 69-2014
	Smoke and Heat Venting	NFPA	NFPA 204-2018
	Chimneys, Fireplaces, Vents and Solid Fuel-Burning Appliances	NFPA	NFPA 211-2016
	Guide for Free Standing Steel Stack Construction, 2nd ed.	SMACNA	SMACNA 2011
	Guyed Steel Stacks	SMACNA	SMACNA 2011
	Draft Equipment	UL	UL 378-2006
	Gas Vents	UL	ANSI/UL 441-2016

Selected Codes and Standards Published by Various Societies and Associations (Continued)

Subject	Title	Publisher	Reference
	Type L Low-Temperature Venting Systems	UL	ANSI/UL 641-2010
Vibration	Balance Quality and Vibration Levels for Fans	AMCA	ANSI/AMCA 204-05 (R2012)
	Techniques of Machinery Vibration Measurement	ASA	ANSI/ASA S2.17-1980 (R2004)
	Mechanical Vibration and Shock—Resilient Mounting Systems—Part 1: Technical Information to Be Exchanged for the Application of Isolation Systems	ISO	ISO 2017-1:2005
	Evaluation of Human Exposure to Whole-Body Vibration—Part 2: Vibration in Buildings (1 Hz to 80 Hz)	ISO	ISO 2631-2:2003
	Guidelines for the Evaluation of the Response of Occupants of Fixed Structures, Especially Buildings and Off-Shore Structures, to Low-Frequency Horizontal Motion (0.063 to 1 Hz)	ISO	ISO 6897:1984
	Procedural Standards for the Measurement of Sound and Vibration, 2nd ed. (2006)	NEBB	NEBB
	HVAC Systems Sound and Vibration Procedural Guide, 1st ed.	SMACNA	SMACNA 2013
Water Heaters	Desuperheater/Water Heaters	AHRI	ANSI/AHRI 470-2006
	Safety for Electrically Heated Livestock Waterers	ASABE	ASAE EP342.3-2010
	Methods of Testing to Determine the Thermal Performance of Solar Domestic Water Heating Systems	ASHRAE	ANSI/ASHRAE 95-1981 (RA87)
	Method of Testing for Rating Commercial Gas, Electric, and Oil Service Water Heating Equipment	ASHRAE	ANSI/ASHRAE 118.1-2012
	Method of Testing for Rating Residential Water Heaters	ASHRAE	ANSI/ASHRAE 118.2-2006 (RA15)
	Methods of Testing for Rating Combination Space-Heating and Water-Heating Appliances	ASHRAE	ANSI/ASHRAE 124-2007
	Methods of Testing for Efficiency of Space-Conditioning/Water-Heating Appliances That Include a Desuperheater Water Heater	ASHRAE	ANSI/ASHRAE 137-2013 (RA 2017)
	Method of Testing Absorption Water-Chilling and Water-Heating Packages	ASHRAE	ANSI/ASHRAE 182-2008 (RA13)
	Legionellosis: Risk Management for Building Water Systems	ASHRAE	ANSI/ASHRAE 188-2015
	Boiler and Pressure Vessel Code—Section IV: Heating Boilers	ASME	BPVC-2017
	Section VI: Recommended Rules for the Care and Operation of Heating Boilers	ASME	BPVC-2017
	Gas Water Heaters—Vol. I: Storage Water Heaters with Input Ratings of 75,000 Btu per Hour or Less	CSA	ANSI Z21.10.1-2017/CSA 4.1-2017
	Vol. III: Storage Water Heaters with Input Ratings Above 75,000 Btu per Hour, Circulating and Instantaneous	CSA	ANSI Z21.10.3-2017/CSA 4.3-2017
	Oil Burning Stoves and Water Heaters	CSA	B140.3-1962 (R2015)
	Oil-Fired Service Water Heaters and Swimming Pool Heaters	CSA	B140.12-03 (R2013)
	Construction and Test of Electric Storage-Tank Water Heaters	CSA	CAN/CSA C22.2 No. 110-94 (R2014)
	Performance of Electric Storage Tank Water Heaters for Domestic Hot Water Service	CSA	CSA C191-13
	Energy Efficiency of Electric Storage Tank Water Heaters and Heat Pump Water Heaters	CSA	CSA C745-03 (R2014)
	Water Heaters, Hot Water Supply Boilers, and Heat Recovery Equipment	NSF	ANSI/NSF 5-2016
	Household Electric Storage Tank Water Heaters	UL	ANSI/UL 174-2004
	Oil-Fired Storage Tank Water Heaters	UL	ANSI/UL 732-2018
	Commercial-Industrial Gas Heating Equipment	UL	UL 795-2016
	Electric Booster and Commercial Storage Tank Water Heaters	UL	ANSI/UL 1453-2016
Welding and Brazing	Boiler and Pressure Vessel Code—Section IX: Welding and Brazing Qualifications	ASME	BPVC-2017
	Structural Welding Code—Steel	AWS	AWS D1.1M/D1.1:2015
	Specification for Welding of Austenitic Stainless Steel Tube and Piping Systems in Sanitary Applications	AWS	AWS D18.1:2009
Wood-Burning Appliances	Threshold Limit Values for Chemical Substances (updated annually)	ACGIH	ACGIH
	Specification for Room Heaters, Pellet Fuel Burning Type	ASTM	ASTM E1509-12 (2017)
	Guide for Construction of Solid Fuel Burning Masonry Heaters	ASTM	ASTM E1602-03 (2017)
	Installation Code for Solid-Fuel-Burning Appliances and Equipment	CSA	CAN/CSA B365-10 (R2015)
	Solid-Fuel-Fired Central Heating Appliances	CSA	CAN/CSA B366.1-11 (R2015)
	Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances	NFPA	ANSI/NFPA 211-2016
	Commercial Cooking, Rethermalization and Powered Hot Food Holding and Transport Equipment	NSF	ANSI/NSF 4-2016

ORGANIZATIONS

Abbrev.	Organization	Address	Telephone	URL
AABC	Associated Air Balance Council	1518 K Street NW, Suite 503 Washington, D.C. 20005	(202) 737-0202	aabc.com
ABMA	American Boiler Manufacturers Association	8221 Old Courthouse Road, Suite 202 Vienna, VA 22182	(703) 356-7172	abma.com
ACCA	Air Conditioning Contractors of America	2800 S. Shirlington Road, Suite 300 Arlington, VA 22206	(703) 575-4477	acca.org
ACGIH	American Conference of Governmental Industrial Hygienists	1330 Kemper Meadow Drive Cincinnati, OH 45240	(513) 742-2020	acgi.org
ADC	Air Diffusion Council	1901 N. Roselle Road, Suite 800 Schaumburg, IL 60195	(847) 706-6750	flexibleduct.org
AGA	American Gas Association	400 N. Capitol Street NW Washington, D.C. 20001	(202) 824-7000	aga.org
AHAM	Association of Home Appliance Manufacturers	1111 19th Street NW, Suite 402 Washington, D.C. 20036	(202) 872-5955	aham.org
AHRI	Air-Conditioning, Heating, and Refrigeration Institute	2111 Wilson Boulevard, Suite 500 Arlington, VA 22201	(703) 524-8800	ahrinet.org
AIHA	American Industrial Hygiene Association	3141 Fairview Park Dr, Suite 777 Falls Church, VA 22042	(703) 207-3561	aiha.org
AMCA	Air Movement and Control Association International	30 West University Drive Arlington Heights, IL 60004	(847) 394-0150	amca.org
ANSI	American National Standards Institute	1899 L Street NW, 11th Floor Washington, D.C. 20036	(202) 293-8020	ansi.org
ASA	Acoustical Society of America	1305 Walt Whitman Road, Suite 300 Melville, NY 11747-4502	(516) 576-2360	acousticalsociety.org
ASABE	American Society of Agricultural and Biological Engineers	2950 Niles Road St. Joseph, MI 49085	(269) 429-0300	asabe.org
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers	1791 Tullie Circle, NE Atlanta, GA 30329	(404) 636-8400	ashrae.org
ASME	American Society of Mechanical Engineers	Two Park Avenue New York, NY 10016-5990	(973) 882-1170	asme.org
ASTM	ASTM International	100 Barr Harbor Drive West Conshohocken, PA 19428-2959	(610) 832-9585	astm.org
AWS	American Welding Society	8669 NW 36 Street, #130 Miami, FL 33166	(305) 443-9353	aws.org
AWWA	American Water Works Association	6666 W. Quincy Avenue Denver, CO 80235	(303) 794-7711	awwa.org
BOCA	Building Officials and Code Administrators International	(see ICC)		
BSI	British Standards Institution	389 Chiswick High Road London W4 4AL, UK	44 020 8996 9000	bsigroup.com
CAGI	Compressed Air and Gas Institute	1300 Sumner Avenue Cleveland, OH 44115	(216) 241-7333	cagi.org
CSA	Canadian Standards Association International	178 Rexdale Boulevard Toronto, ON M9W 1R3, Canada	(416) 747-4000	csagroup.org
CTI	Cooling Technology Institute	P.O. Box 681807 Houston, TX 77268	(281) 583-4087	cti.org
EJMA	Expansion Joint Manufacturers Association	25 North Broadway Tarrytown, NY 10591	(914) 332-0040	ejma.org
HEI	Heat Exchange Institute	1300 Sumner Avenue Cleveland, OH 44115	(216) 241-7333	heatexchange.org
HI	Hydraulic Institute	6 Campus Drive, First Floor North Parsippany, NJ 07054-4406	(973) 267-9700	pumps.org
HYDI	Hydronics Institute Division of AHRI	(see AHRI)		
IAPMO	International Association of Plumbing and Mechanical Officials	4755 E. Philadelphia Street Ontario, CA 91761	(909) 472-4100	iapmo.org
ICBO	International Conference of Building Officials	(see ICC)		

ORGANIZATIONS (Continued)

Abbrev.	Organization	Address	Telephone	URL
ICC	International Code Council	500 New Jersey Ave NW, 6th Floor Washington, D.C. 20001	(888) 422-7233	iccsafe.org
IEEE	Institute of Electrical and Electronics Engineers	3 Park Avenue, 17th Floor New York, NY 10016-5997	(732) 981-0060	ieee.org
IES	Illuminating Engineering Society	120 Wall Street, Floor 17 New York, NY 10005-4001	(212) 248-5000	ies.org
IFCI	International Fire Code Institute	(see ICC)		
IIAR	International Institute of Ammonia Refrigeration	1001 N. Fairfax St, Suite 503 Alexandria, VA 22314	(703) 312-4200	iiar.org
ISA	International Society of Automation	67 T.W. Alexander Drive, P.O. Box 12277 Research Triangle Park, NC 27709	(919) 549-8411	isa.org
ISO	International Organization for Standardization	Chemin de Blandonnet 8, CP 401 1214 Vernier, Geneva, Switzerland	41 22 749 01 11	iso.org
MCAA	Mechanical Contractors Association of America	1385 Piccard Drive Rockville, MD 20850	(301) 869-5800	mcaa.org
MICA	Midwest Insulation Contractors Association	16712 Elm Circle Omaha, NE 68130	(402) 342-3463	micainsulation.org
MSS	Manufacturers Standardization Society of the Valve and Fittings Industry	127 Park Street NE Vienna, VA 22180-4602	(703) 281-6613	mss-hq.com
NAIMA	North American Insulation Manufacturers Association	11 Canal Center Plaza, Suite 103 Alexandria, VA 22314	(703) 684-0084	insulationinstitute.org
NCPWB	National Certified Pipe Welding Bureau	1385 Piccard Drive Rockville, MD 20850	(301) 869-5800	mcaa.org/ncpwb
NEBB	National Environmental Balancing Bureau	8575 Grovemont Circle Gaithersburg, MD 20877	(301) 977-3698	nebb.org
NEMA	Association of Electrical and Medical Imaging Equipment Manufacturers	1300 North 17th Street, Suite 900 Arlington, VA 22209	(703) 841-3200	nema.org
NFPA	National Fire Protection Association	1 Batterymarch Park Quincy, MA 02169-7471	(617) 770-3000	nfpa.org
NRC	National Research Council of Canada, Institute for Research in Construction	1200 Montreal Road, Bldg M-58 Ottawa, ON K1A 0R6, Canada	(613) 993-9101	nrc-cnrc.ca
NSF	NSF International	P.O. Box 130140, 789 N. Dixboro Road Ann Arbor, MI 48105	(734) 769-8010	nsf.org
PHCC	Plumbing-Heating-Cooling Contractors Association	180 S. Washington Street, Suite 100 Falls Church, VA 22046	(703) 237-8100	phccweb.org
SAE	SAE International	400 Commonwealth Drive Warrendale, PA 15096	(724) 776-4841	sae.org
SBCCI	Southern Building Code Congress International	(see ICC)		
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association	4201 Lafayette Center Drive Chantilly, VA 20151-1219	(703) 803-2980	smacna.org
TEMA	Tubular Exchanger Manufacturers Association	25 North Broadway Tarrytown, NY 10591	(914) 332-0040	tema.org
UL	Underwriters Laboratories	333 Pfingsten Road Northbrook, IL 60062-2096	(847) 272-8800	ul.com
USGBC	U.S. Green Building Council	2101 L Street NW, Suite 500 Washington, D.C. 20037	(202) 742-3792	usgbc.org

Related Commercial Resources

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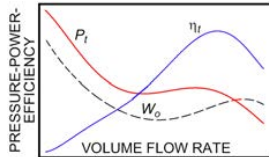
Additions and Corrections

The following presents additional information and technical errors found between June 15, 2016, and March 29, 2019, in the I-P editions of the 2016, 2017, and 2018 *ASHRAE Handbook* volumes. Occasional typographical errors and nonstandard symbol labels will be corrected in future volumes. The most current list of Handbook additions and corrections is on the ASHRAE web site (www.ashrae.org).

The authors and editor encourage you to notify them if you find other technical errors. Please send corrections to: Handbook Editor, ASHRAE, 1791 Tullie Circle NE, Atlanta, GA 30329, or e-mail hkennedy@ashrae.org.

2016 HVAC Systems and Equipment

p. 21.3, Table 1. The performance curve for propeller fans should be as follows:



p. 38.37, Eq. (24). Remove “x” from end of equation.

2017 Fundamentals

p. 1.13, Eq. (23). Following the equation, add the following text: “where μ is degree of saturation W/W_s , dimensionless.”

p. 4.3, Table 2, 1st equation for hollow sphere. In the denominator, change the + to a –.

p. 4.20, Table 9. For Eq. (T9.10) for horizontal cylinder, the range should be $10^{-6} < Ra < 10^{13}$.

p. 4.21, Example 11. In list item number 1, the equation should be $t_f = (t_s + t_\infty)/2$.

p. 11.13, 2nd col. Change “Guideline 27” to “proposed Guideline 27P.”

p. 14.12, Examples 7 and 8. In Example 7, in the equation for $E_{t,r}$, change “+ $\cos(68.62^\circ)$ ” to “– $\cos(90^\circ)$ ” and the result to 29 Btu/h·ft². In Example 8, in the equation for $E_{t,r}$, change “ $\cos(68.64^\circ)$ ” to “ $\cos(30^\circ)$ ” and the result to 4 Btu/h·ft².

p. 18.21, Eqs. (24) and (25). In Eq. (24), change $Z_{i,0}$ to $X_{i,0}$. The following paragraph should read “Equation (24) shows the need to separate $X_{i,0}$ because the contribution of current surface temperature to conductive flux cannot be collected with the other historical terms involving that temperature.” In Eq. (25), change $T_{si,j}$ to $T_{so,i,j}$.

p. 18.39, 1st col, definitions. The mention of Figure 18 of Chapter 34 of the 2011 *ASHRAE Handbook—HVAC Applications* should refer to that figure in the 2015 edition.

p. 19.6, Example 1. In the last equation, change “14,000” to “14,400.” The result remains the same.

p. 24.4, Eq. (2). Change “/2.152” to “× 2.151.”

COMPOSITE INDEX

ASHRAE HANDBOOK SERIES

This index covers the current Handbook series published by ASHRAE. The four volumes in the series are identified as follows:

- S = 2016 HVAC Systems and Equipment
- F = 2017 Fundamentals
- R = 2018 Refrigeration
- A = 2019 HVAC Applications

Alphabetization of the index is letter by letter; for example, **Heat-** precedes **Heat exchangers**, and **Floors** precedes **Floor slabs**.

The page reference for an index entry includes the book letter and the chapter number, which may be followed by a decimal point and the beginning page in the chapter. For example, the page number F30.6 means the information may be found in the 2017 HVAC Fundamentals volume, Chapter 30, beginning on page 6.

Each Handbook volume is revised and updated on a four-year cycle. Because technology and the interests of ASHRAE members change, some topics are not included in the current Handbook series but may be found in the earlier Handbook editions cited in the index.

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