BSR/ASHRAE Standard 152-2014 (W)

Intent to Withdraw

Method of Test for Determining the Design and Seasonal Efficiencies of Residential Thermal Distribution Systems

First Withdrawal Review (November 2023)

This standard will be submitted to the American National Standards Institute Board of Standards Review (BSR) with a notice of Intent-to-Withdraw.

This intent-to-withdraw draft has been recommended for public review by the cognizant technical committee and approved by a subcommittee of the Standards Committee. To submit a comment on this proposed withdrawal, go to the ASHRAE website at http://www.ashrae.org/technology/page/331 and access the online comment database. The draft is subject to modification until it is approved for publication by the ASHRAE Board of Directors and ANSI. Until this time, the current edition of the standard (as modified by any published addenda on the ASHRAE Web site) remains in effect. The current edition of any standard may be purchased from the ASHRAE Bookstore at www.ashrae.org or by calling 404-636-8400 or 1-800-527-4723 (for orders in the U.S. or Canada).

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NOTE

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FOREWORD

The objective of this method of test is to provide estimates of the efficiency of thermal distribution systems. This efficiency may be used in energy consumption or system capacity estimates. This method of test provides thermal distribution system efficiencies for both heating and cooling systems. Thermal distribution system efficiency is calculated for seasonal conditions (for energy consumption) or design conditions (for system sizing). This results in a total of four outputs from the method of test. This standard does not address the effectiveness of the tested system to provide comfort in the conditioned space or to deliver the designed or required airflow to individual rooms within the conditioned space.

1. PURPOSE

This standard prescribes a method of test to determine the efficiency of space heating and/or cooling thermal distribution systems under seasonal and design conditions. The objective is to facilitate annual energy calculations and heating and cooling equipment capacity calculations.

2. SCOPE

2.1 This standard applies to single-family detached and attached residences with independent thermal systems.

2.2 This standard applies to air, hydronic, and electric distribution systems.

3. DEFINITIONS

buffer zone: unconditioned part of a building containing some or all of the distribution system.

conditioned space: the portion of a building whose air temperature or operative temperature (combined air and radiant temperatures) is intentionally controlled for human occupancy.

delivery effectiveness: the ratio of the thermal energy transferred to or from the conditioned space to the thermal energy transferred at the equipment-distribution system heat exchanger. Energy delivered to or from the conditioned space includes distribution system losses to the conditioned space.

distribution system efficiency: the ratio between the energy consumption by the equipment if the distribution system had no losses (gains) to the outdoors or effect on the equipment or building loads, and the energy consumed by the same equipment connected to the distribution system under test.

electric distribution system: a thermal distribution system that uses electric wiring as the distribution medium in the building.

equipment: a thermal energy conversion device (furnace, boiler, or water heater) or heat-pumping device (air conditioner or heat pump) that serves all or part of the building.

equipment capacity: the manufacturer's rated capacity at the 35°C (95°F) AHRI rating point for air conditioners and 8°C (47°F) AHRI rating point for heat pumps. Furnace capacity shall be adjusted for altitude effects. For the low-capacity stages of multistaged equipment, consult manufacturers' data.

equipment efficiency: the ratio between the thermal energy transferred at the equipment heat exchanger and the thermal (or its equivalent) energy consumed by the equipment.

equipment factor: the ratio of the equipment efficiency, including the effects of the distribution system to the equipment efficiency without the distribution system.

finned-tube baseboard: a heating-terminal unit that primarily consists of one or more finned tubes and a casing cabinet.

floor area: the conditioned floor area of the building.

forced-air distribution system: forced-air systems are heating and/or cooling systems that use motor-driven blowers to distribute heated, cooled, and otherwise treated air for comfort of individuals in confined spaces.

hydronic distribution system: a thermal distribution system that uses water or a mixture of water and additives as the distribution medium in the building.

infiltration factor: the ratio of the building infiltration load without including distribution effects to the load, including distribution system effects.

radiant barrier: a surface of low emissivity (less than 0.1) placed inside an attic or roof space above (but not touching) the distribution system to reduce radiant heat transfer.

radiant panel: a heating or cooling surface that delivers 50% or more of its heat transfer by radiation that may be either an integral part of the building (e.g., floor or ceiling heating) or detached from the building elements (e.g., suspended ceiling panel).

reduced-absorptivity exterior coating: an exterior finish applied to roof systems in order to reduce the absorption of solar radiation. The solar absorptivity must be 0.4 or less.

thermal regain: the fraction of distribution system losses (gains for cooling) that are returned to the conditioned space.

tile roof: a ventilated barrel tile roofing system.

variable-capacity equipment: some heating and cooling equipment operates in stages of different capacity that depend on building load, e.g., electric furnaces with several separate heater elements.

vented crawlspace: a crawlspace with an open vent area ≥1/150th of its floor area, with vents distributed over all exterior surfaces.

well-vented attic: an attic with an open vent area ≥1/300th of its floor area distributed high and low over attic surfaces.

4. NOMENCLATURE

a_r = leakage factor for return ducts
a_s = leakage factor for supply ducts
A_{floor} = conditioned floor area of building, m^2 (ft^2)
A_p = surface area of radiant panel, m^2 (ft^2)
$A_{p,wall}$ = surface area of radiant panel against exterior surface, m^2 (ft^2)
A_i = surface area of ducts in unconditioned space i, m^2 (ft^2)
A_r = surface area of return duct outside conditioned space, m^2 (ft^2)
A_s = surface area of supply duct outside conditioned space, m^2 (ft^2)
b_r = return duct surface area coefficient
B_r = conduction fraction for return
B_s = conduction fraction for supply
C_s = forced-air duct system flow coefficient, m^3/(s·Pa^n) (cfm/[in. H$_2$O^n])
C_p = specific heat of air, J/(kg·K) (Btu/[lb·°F])
Cv_{pipe} = volumetric heat capacity of pipe, J/(m^3·K) (Btu/[ft^3·°F])
Cv_{water} = volumetric heat capacity of water, J/(m^3·K) (Btu/[ft^3·°F])
Cv_{ins} = volumetric heat capacity of pipe insulation, J/(m^3·K) (Btu/[ft^3·°F])
d_{pipe} = outside diameter of piping, m (ft)
d_{ins} = outside diameter of insulation around piping, m (ft)
DE = delivery effectiveness
DE_{design} = design delivery effectiveness
$\text{DE}_{seasonal}$ = seasonal delivery effectiveness
$\text{DE}_{corr,\ design}$ = design delivery effectiveness corrected for regain
$\text{DE}_{corr,\ seasonal}$ = seasonal delivery effectiveness corrected for regain
E_{cap} = equipment capacity, W (Btu/h) (negative for cooling equipment)
$F_{cycloss}$ = fraction of energy delivered to conditioned space lost due to equipment cycling
F_{equip} = equipment factor
F_{load} = infiltration factor
F_{recov} = thermal loss recovery factor
F_{regain} = thermal regain factor
$F_{regain,\ s}$ = thermal regain factor for supplies
$F_{regain,\ r}$ = thermal regain factor for returns
F_{out} = fraction of supply duct surface area outside conditioned space
$h_{amb,\ r}$ = enthalpy of ambient air for return, J/kg (Btu/lb)
h_{in} = enthalpy of air inside conditioned space, J/kg (Btu/lb)
h_{out} = enthalpy of outside air, J/kg (Btu/lb)
H_a = heat flow from hydronic loop to outside (W, Btu/h)
$H_{b,\ design}$ = design condition heat flow from hydronic loop to the buffer zone(s), W (Btu/h)
$H_{b,\ seasonal}$ = seasonal condition heat flow from hydronic loop to the buffer zone(s), W (Btu/h)
H_c = heat flow from hydronic loop to conditioned space, W (Btu/h)
$H_{del,\ design}$ = heat delivered by hydronic or electric system under design conditions, W (Btu/h)
$H_{del,\ seasonal}$ = heat delivered by hydronic or electric system under seasonal conditions, W (Btu/h)
H_{design} = design building load, W (Btu/h)
H_{loss} = heat lost by hydronic system, W (Btu/h)
$H_{loss,\ design}$ = heat lost by hydronic or electric system under design conditions, W (Btu/h)
$H_{loss,\ seasonal}$ = heat lost by hydronic or electric system under seasonal conditions, W (Btu/h)
H_{ra} = heat flow from hydronic baseboards or radiant panels to outside, W (Btu/h)
$H_{rb,\ design}$ = design condition heat flow from hydronic baseboards to the buffer zone(s), W (Btu/h)
$H_{rb,\ seasonal}$ = seasonal condition heat flow from hydronic baseboards to the buffer zone(s), W (Btu/h)
$H_{rc,\ design}$ = design condition heat flow from hydronic baseboards to the conditioned space, W (Btu/h)
$H_{rc,\ seasonal}$ = seasonal condition heat flow from hydronic baseboards to the conditioned space, W (Btu/h)
$H_{seasonal}$ = seasonal building load, W (Btu/h)
$H_{u,\ design}$ = design condition heat flow from unfinned piping in the conditioned space, W (Btu/h)
$H_{u,\ seasonal}$ = seasonal condition heat flow from unfinned piping in the conditioned space, W (Btu/h)
$H_{ua,\ design}$ = design condition heat flow from unfinned piping in the conditioned space to outside, W (Btu/h)
$H_{ua,\ seasonal}$ = seasonal condition heat flow from unfinned piping in the conditioned space to outside, W (Btu/h)
$H_{uc,\ design}$ = design condition heat flow from unfinned piping in the conditioned space to the conditioned space, W (Btu/h)

$H_{uc,\ seasonal}$ = seasonal condition heat flow from unfinned piping in the conditioned space to the conditioned space, W (Btu/h)

K = thermal conductance of hydronic pipe insulation, W/(m·K) (Btu/[h·ft·°F])

$k_{b,\ ins}$ = thermal conductance for insulated hydronic piping, W/(m·K) (Btu/[h·ft·°F])

$k_{b,\ unins}$ = thermal conductance for uninsulated hydronic piping, W/(m·K) (Btu/[h·ft·°F])

k_{rc} = thermal conductance for heat transfer from baseboards to conditioned space, W/(m·K) (Btu/[h·ft·°F])

k_{ra} = thermal conductance to the outside for baseboards or radiant panels, W/(m·K), (Btu/[h·ft·°F])

k_{ua} = thermal conductance between unfinned piping and outside for baseboards or radiant panels, W/(m·K) (Btu/[h·ft·°F])

k_{uc} = thermal conductance between unfinned piping and conditioned space, W/(m·K), (Btu/[h·ft·°F])

K_r = thermal capacitance per unit pipe length of finned terminal units in the conditioned space, J/(K·m) (Btu/[°F·ft])

K_u = thermal capacitance per unit pipe length of unfinned piping in the conditioned space, J/(K·m) (Btu/[°F·ft])

$K_{b,\ unins}$ = thermal capacitance per unit pipe length of unfinned piping in the buffer space that is uninsulated, J/(K·m) (Btu/[°F·ft])

$K_{b,\ ins}$ = thermal capacitance per unit pipe length of unfinned piping in the buffer space that is insulated, J/(K·m) (Btu/[°F·ft])

K_{fins} = heat capacity of fins per unit length of J/(K·m) (Btu/[°F·ft])

$L_{b,\ unins}$ = length of unfinned piping in the buffer space that is not insulated, m (ft)

$L_{b,ins}$ = length of unfinned piping in the buffer space that is insulated, m (ft)

L_r = total length of finned terminal hydronic or electric baseboard units, m (ft)

$L_{r,\ wall}$ = length of finned terminal hydronic or electric baseboard units mounted against exterior wall, m (ft)

L_u = total length of unfinned piping in the conditioned space

$L_{u,\ wall}$ = length of unfinned piping mounted against exterior wall, m (ft)

n_s = pressure exponent for forced-air duct system

NTU = number of heat transfer units in the piping system

Q_{buffer} = ventilation rate of duct location, m^3/s (cfm)

Q_c = flow from duct location to conditioned space, m^3/s (cfm)

Q_e = flow through air-handler fan at operating conditions, m^3/s (cfm)

Q_{eH_2o} = volumetric circulator flow rate for hydronic systems, m^3/s (cfm)

$Q_{e,\ rated}$ = flow through air-handler fan at manufacturer's efficiency rating conditions, m^3/s (cfm)

Q_{imb} = flow imbalance, m^3/s (cfm)

Q_{inf} = natural infiltration rate for building without duct system, m^3/s (cfm)

Q_{max} = maximum flow obtainable through flowmeter when measuring air-handler flow, m^3/h (cfm)

Q_{net} = net infiltration: combined natural and imbalance flow, m^3/h (cfm)

Q_{off} = air-handler fan off infiltration including duct leakage, m^3/h (cfm)

Q_r = return duct leakage to outside, m^3/h (cfm)

Q_s = supply duct leakage to outside, m^3/h (cfm)

Q_{25} = duct leakage flow to outside at 25 Pa, m^3/h (cfm)

$Q_{25,\ s}$ = supply duct leakage flow to outside at 25 Pa, m^3/h (cfm)

$Q_{25,\ r}$ = return duct leakage flow to outside at 25 Pa, m^3/h (cfm)

$Q_{0.1}$ = duct leakage flow to outside at 0.1 in. H_2O, m^3/s (cfm)

$Q_{0.1,\ s}$ = supply duct leakage flow to outside at 0.1 in. H_2O, m^3/s (cfm)

$Q_{0.1,\ r}$ = return duct leakage flow to outside at 0.1 in. H_2O, m^3/s (cfm)

$Q_{25,\ total}$ = total duct leakage flow at 25 Pa, m^3/s (cfm)

$Q_{0.1,\ total}$ = total duct leakage flow at 0.1 in. H_2O, m^3/s (cfm)

R_r = thermal resistance of return duct, m^2·K/W (h·ft^2·°F/Btu)

R_s = thermal resistance of supply duct, m^2·K/W (h·ft^2·°F/Btu)

R_w = thermal resistance of exterior wall of building next to hydronic or electric systems, m^2·K/W (h·ft^2·°F/Btu)

R_{uc} = thermal resistance of unfinned pipe in conditioned space, m^2·K/W (h·ft^2·°F/Btu)

$t_{amb,\ b}$ = temperature of the buffer space with the conditioning system on, supply and return in the same space, °C (°F)

$t_{amb,\ r}$ = ambient temperature for return ducts, °C (°F)

$t_{amb,\,s}$ = ambient temperature for supply ducts, °C (°F)

t_{attic} = attic air temperature, °C (°F)

$t_{hotwater}$ = nominal or average boiler or water heater water temperature, °C (°F)

$t_{bdesign}$ = design temperature of buffer zone for hydronic system, °C (°F)

$t_{bseasonal}$ = seasonal temperature of buffer zone for hydronic system, °C (°F)

$t_{b,off}$ = temperature of the buffer space with the conditioning system off, °C (°F)

t_{design} = outdoor-air design temperature, °C (°F)

$_{ground}$ = ground temperature, °C (°F)

t_{in} = temperature of indoor air, °C (°F)

t_{out} = outdoor-air temperature, °C (°F)

t_{rp} = return plenum air temperature, °C (°F)

$t_{seasonal}$ = outdoor-air seasonal temperature, °C (°F)

t_{sp} = supply plenum air temperature, °C (°F)

U = thermal conductance, $W/(m^2{\cdot}K)$ $(Btu/[h{\cdot}ft^2{\cdot}°F])$

$U_{conv\,+\,rad}$ = convective plus radiative heat transfer coefficient of the outer pipe surface, $W/(m^2{\cdot}K)$ $(Btu/[h{\cdot}ft^2{\cdot}°F])$

$U_{panel,\,ra}$ = the overall heat transfer between an electric radiant panel and outside unit area of panel, $W/(m^2{\cdot}K)$ $(Btu/[h{\cdot}ft^2{\cdot}°F])$

$U_{panel,\,rc}$ = the overall heat transfer between an electric radiant panel and the conditioned space per unit area of panel, $W/(m^2{\cdot}K)$ $(Btu/[h{\cdot}ft^2{\cdot}°F])$

$(UA)_{in}$ = UA value for the interface between the conditioned space and the buffer space, W/K (Btu/h/°F)

$(UA)_{out}$ = UA value for the interface between the outside and the buffer space, W/K (Btu/h/°F)

$(UA)_{infil}$ = effective UA value for the infiltration rate of outdoor air through the buffer space, W/K (Btu/h/°F)

$(UA)_{ground}$ = UA value for the interface between the ground and the buffer space, W/K (Btu/h/°F)

V = building volume, m^3 (ft^3)

w = humidity ratio, kg H_2O/kg dry air (lb H_2O/lb dry air)

w_{design} = design outdoor humidity ratio, kg H_2O/kg dry air (lb H_2O/lb dry air)

$w_{seasonal}$ = seasonal outdoor humidity ratio, kg H_2O/kg dry air (lb H_2O/lb dry air)

$w_{in,\,design}$ = design indoor humidity ratio, kg H_2O/kg dry air (lb H_2O/lb dry air)

$w_{in,\,seasonal}$ = seasonal indoor humidity ratio, kg H_2O/kg dry air (lb H_2O/lb dry air)

y = height of convector enclosure surrounding finned terminal units, m (ft)

Z_{design} = intermediate calculation for $\tau_{ondesign}$

$Z_{seasonal}$ = intermediate calculation for $\tau_{onseasonal}$

ϕ_{man} = manufacturer's rating for heat transfer between baseboards and conditioned space, W/m (Btu/ft)

γ_{man} = manufacturer's rating for heat transfer between an electric radiant panel and the conditioned space per unit area of panel, W/m^2 $(Btu/h{\cdot}ft^2)$

ΔP_{fan} = pressure difference across air-handler fan, Pa (in. H_2O)

ΔP_r = average pressure difference between return ducts and outside, Pa (in. H_2O)

ΔP_{rp} = pressure difference between return plenum and conditioned space, Pa (in. H_2O)

ΔP_s = average pressure difference between supply ducts and outside, Pa (in. H_2O)

ΔP_{sp} = pressure difference between supply plenum and conditioned space, Pa (in. H_2O)

Δt_e = temperature rise across heat exchanger, °C (°F)

$\Delta t_{\ln}$ = log-mean temperature difference between the piping and conditioned space, °C (°F)

Δt_{man} = manufacturer's temperature difference rating, °C (°F)

Δt_r = temperature difference between indoors and the ambient for the return, °C (°F)

Δt_s = temperature difference between indoors and the ambient for the supply, °C (°F)

$\eta_{dist,\,design}$ = design distribution system efficiency

$\eta_{dist,\,seasonal}$ = seasonal distribution system efficiency

ρ_{in} = density of indoor air, kg/m^3 (lb/ft^3)

ρ_c = density of buffer zone air, kg/m^3 (lb/ft^3)

$\tau_{cycledesign}$ = circulator cycle time (on + off) under design conditions, h

$\tau_{cycleseasonal}$ = circulator cycle time (on + off) under seasonal average conditions, h

$\tau_{offdesign}$ = design circulator off time, h

$\tau_{offseasonal}$ = seasonal circulator off time, h

$\tau_{ondesign}$ = design circulator on time, h

$\tau_{onseasonal}$ = seasonal circulator on time, h

$\tau_{r,f}$ = relaxation time for a finned-tube baseboard, h

$\tau_{r,u}$ = relaxation time for an unfinned-tube baseboard, h

$\tau_{b,ins}$ = relaxation time for insulated piping in a buffer space, h

$\tau_{b,unins}$ = relaxation time for uninsulated piping in a buffer space, h

5. CLASSIFICATIONS AND GENERAL REQUIREMENTS

5.1 Thermal Distribution Systems. This standard covers the following distribution systems:

a. Forced air (Section 6)
b. Hydronic finned-tube baseboards (Section 7)
c. Electric finned-tube baseboards and radiant panels (Section 8)

5.2 Distribution System Efficiency. The thermal distribution system efficiency is determined for the following conditions:

a. Heating under seasonal conditions (for energy consumption estimates)
b. Heating under design conditions (for system sizing)
c. Cooling under seasonal conditions (for energy consumption estimates)
d. Cooling under design conditions (for system sizing)

5.3 Input Data Requirements. This standard includes a complete protocol for specifying the input parameters needed for evaluating distribution system performance in existing buildings. For buildings that have been designed but not yet built, predicted distribution efficiencies may be calculated on the basis of projected or specified input values. However, the building shall not be considered to have been evaluated according to this standard unless the measurements and calculations specified in the standard have been carried out following construction.

The user of this standard shall provide a listing of all input data and their sources, clearly indicating how the input parameters were determined.

6. FORCED-AIR DISTRIBUTION SYSTEMS

6.1 Instrument Specifications. The instruments for the diagnostic measurements shall conform to the following specifications. All flow measurements shall be corrected for temperature and barometric pressure effects, according to the manufacturers' instructions.

6.1.1 Pressure Measurement. All pressure measurements shall be made with measurement systems (i.e., sensor plus data-acquisition system) having an accuracy of ±0.2 Pa (0.0008 in. H_2O) or 1% of reading, whichever is greater, and a resolution of 0.1 Pa (0.0004 in. H_2O) or 1% of reading, whichever is greater. All pressure measurements within the duct system shall be made using static pressure probes.

6.1.2 Length Measurement. Measurements of length shall have an accuracy of at least ±5%.

6.2 Apparatus

6.2.1 Air-Handler Fan Flow Using an Air-Handler Flow Plate Device. The apparatus for measuring the air-handler fan flow using an air-handler flow plate device shall consist of the following:

a. An air-handler flow plate device (i.e., sensor plus data-acquisition system) having an accuracy of ±7% of measured flow
b. A static pressure probe
c. A pressure transducer meeting the specifications described in Section 6.1.1

6.3 Procedure. The calculation procedure in the following sections shall be used to determine distribution system efficiencies based on the following principal input parameters:

a. Duct location
b. Geographic climate
c. Duct insulation
d. Duct surface area
e. Air-handler fan flow
f. Duct leakage
g. Equipment capacity

The following additional parameters shall be used where required:

a. Building volume
b. Building floor area
c. Presence of radiant barriers, reduced absorptivity exterior coatings, or a tile roof
d. Venting condition of attics and/or crawl spaces
e. Insulation of the building structure
f. Number of return registers

6.3.1 Indoor Air Conditions

a. For heating, the indoor air temperature shall be 20°C (68°F).
b. For cooling, the indoor dry-bulb temperature shall be 25.5°C (78°F).
c. For cooling, the indoor humidity ratio, w_{in}, and the indoor air enthalpy shall be taken from Table 6.3.1-1 or Table 6.3.1-2.

6.3.2 Unconditioned Duct Locations. Attic, garage, underslab, and exterior wall temperature conditions, and humidity conditions for all duct locations, shall be obtained from Tables 6.3.2-1 (heating) and 6.3.2-2 (cooling). Crawl space and basement temperature conditions shall be determined both with and without the impact of duct losses using Equations 6-1 through 6-4. Default U-factors for use in these equations may be used and are found in Table 6.3.2-3. In Tables 6.3.2-1 and 6.3.2-2, the heating and cooling temperatures for design and seasonal conditions shall be taken from Tables 6.3.1-1 and 6.3.1-2. Design data in Tables 6.3.1-1 and 6.3.1-2 are from the 1997 *ASHRAE Handbook—Fundamentals*[1], and the seasonal data are calculated from temperature-differential-weighted TMY and TMY2 data.[2]

6.3.2.1 Temperature and Humidity with Conditioning System Off. The temperature of the crawl space or basement with the conditioning system off is:

TABLE 6.3.1-1 Design and Seasonal Temperature, Humidity, and Enthalpy Conditions (SI)

Location	State	Temperature				W_{design}	$W_{seasonal}$	$W_{in, design}$	$W_{in, seasonal}$	Design h_{out}	Seasonal h_{out}	Design h_{in}	Seasonal h_{in}
		Heating Design	Heating Seasonal	Cooling Design	Cooling Seasonal								
Adak	AK	–5.1	3.7										
Annette	AK	–8.4	4.7	21	21	0.0084	0.0094	0.0073	0.0078	42345	47881	44356	45455
Bethel	AK	–31.1	–8.8	20	20	0.0078	0.0067	0.0071	0.0067	39900	39555	43784	42711
Big Delta	AK	–39.5	–13.2	24	24	0.0062	0.0073	0.0065	0.0069	39815	42668	42116	43296
Fairbanks	AK	–34.8	–16.6	26	26	0.0076	0.0067	0.0070	0.0067	45491	40668	43573	42646
Gulkana	AK	–39.3	–11.6	24	24	0.0073	0.0061	0.0069	0.0065	42685	39579	43265	42088
Homer	AK	–15.5	–1.2	17	17	0.0079	0.0094	0.0072	0.0078	37044	44702	43866	45418
Juneau	AK	–13.7	0.8	21	21	0.0084	0.0078	0.0074	0.0071	42429	42464	44390	43746
King Salmon	AK	–28.4	–6.3	19	19	0.0071	0.0102	0.0068	0.0081	37161	50156	43093	46200
Kodiak	AK	–11.4	2.4	18	18	0.0074	0.0115	0.0070	0.0086	36959	52381	43422	47569
McGrath	AK	–40.8	–14.7	23	23	0.0066	0.0070	0.0066	0.0068	39887	40618	42553	42990
Nome	AK	–32.3	–9.4	18	18								
Yakutat	AK	–16.4	0.4	17	17	0.0077	0.0063	0.0071	0.0065	36571	38827	43676	42249
Birmingham	AL	–6	5.9	33	27.7	0.0151	0.0143	0.0100	0.0097	71855	64296	51222	50450
Mobile	AL	–1	9.5	33	27.6	0.0167	0.0157	0.0107	0.0103	75977	67597	52862	51829
Montgomery	AL	–3	7.2	34	28.2	0.0147	0.0150	0.0099	0.0100	71820	66398	50797	51095
Fort Smith	AR	–8	4.1	35	29.2	0.0143	0.0148	0.0097	0.0099	71784	67084	50373	50964
Little Rock	AR	–6	4.6	35	28.8	0.0159	0.0159	0.0103	0.0103	75901	69290	52009	52009
Phoenix	AZ	3	9.2	42	32.8	0.0085	0.0079	0.0074	0.0071	63852	52945	44516	43846
Prescott	AZ	–7	3.6	33	27.7	0.0044	0.0071	0.0058	0.0068	44488	45857	40333	43083
Tucson	AZ	1	8.7	39	30.6	0.0044	0.0076	0.0057	0.0070	50359	49893	40294	43538
Yuma	AZ	6.4	11.2	43	33.1	0.0094	0.0091	0.0078	0.0076	67572	56414	45447	45110
Bakersfield	CA	1.6	8.9	39	30.7	0.0082	0.0076	0.0073	0.0070	60325	50133	44198	43581
Burbank	CA	5.1	11.6	35	27.9	0.0085	0.0089	0.0074	0.0076	56975	50702	44489	44931
Dagget	CA	–0.2	8.5	41	32.1	0.0060	0.0065	0.0064	0.0066	56806	48567	41998	42415
Fresno	CA	0.1	8.1	38	31.1	0.0086	0.0080	0.0074	0.0072	60355	51614	44614	44006
Long Beach	CA	5.8	12.5	31	25.9	0.0088	0.0101	0.0075	0.0080	53753	51479	44833	46084
Los Angeles	CA	7.4	13.2	27	23.9	0.0092	0.0102	0.0077	0.0081	50652	49911	45227	46255
Point Mugu	CA	5	12.0	26	23.8	0.0096	0.0091	0.0078	0.0077	50677	47086	45646	45155
Sacramento	CA	0.6	9.1	36	29.9	0.0081	0.0086	0.0072	0.0074	56947	51785	44072	44564
San Diego	CA	5.3	13.8	31	24.3	0.0101	0.0103	0.0081	0.0081	57089	50507	46162	46319
San Francisco	CA	3.9	10.8	26	25.2	0.0073	0.0073	0.0069	0.0069	44636	43765	43231	43275
Santa Maria	CA	1.4	9.4	28	24.9	0.0076	0.0071	0.0070	0.0069	47550	43052	43580	43107
Colorado Springs	CO	–15.3	1.5	31	27.3	0.0030	0.0072	0.0052	0.0069	38969	45680	38942	43199
Denver	CO	–16.1	0.7	32	27.8	0.0037	0.0061	0.0055	0.0064	41675	43368	39617	42058
Eagle	CO	–21.7	–2.4	30	26.5	0.0034	0.0069	0.0054	0.0068	38986	44201	39352	42904
Grand Junction	CO	–13.8	0.8	34	28.8	0.0040	0.0059	0.0056	0.0064	44467	43859	39922	41833
Pueblo	CO	–15	0.0	35	28.8	0.0047	0.0069	0.0059	0.0067	47389	46261	40680	42827
Hartford	CT	–14.3	0.5	31	27.0	0.0129	0.0117	0.0092	0.0087	64193	56841	48993	47778
Washington	DC	–6.5	2.7	34	27.3	0.0147	0.0137	0.0099	0.0095	71820	62369	50797	49832
Wilmington	DE	–9.9	2.6	32	26.4	0.0140	0.0129	0.0096	0.0091	67943	59169	50076	48937
Apalachicola	FL	1.7	9.9	32	27.6	0.0188	0.0168	0.0115	0.0107	80322	70496	55005	52974
Daytona	FL	3	10.7	32	26.5	0.0171	0.0159	0.0109	0.0104	76015	66987	53290	52022
Jacksonville	FL	0.2	6.7	34	28.1	0.0163	0.0155	0.0105	0.0102	75939	67555	52435	51612
Miami	FL	9.8	12.4	32	26.9	0.0171	0.0160	0.0109	0.0104	76015	67614	53290	52097

TABLE 6.3.1-1 Design and Seasonal Temperature, Humidity, and Enthalpy Conditions (SI) (Continued)

Location	State	Temperature				W_{design}	$W_{seasonal}$	$W_{in,\ design}$	$W_{in,\ seasonal}$	Design h_{out}	Seasonal h_{out}	Design h_{in}	Seasonal h_{in}
		Heating Design	Heating Seasonal	Cooling Design	Cooling Seasonal								
Orlando	FL	5.3	11.9	34	27.5	0.0163	0.0154	0.0105	0.0102	75939	66899	52435	51559
Tallahassee	FL	–2.1	7.5	34	27.4	0.0163	0.0154	0.0105	0.0102	75939	66672	52435	51519
Tampa	FL	4.2	11.4	33	27.3	0.0167	0.0157	0.0107	0.0103	75977	67362	52862	51831
West Palm Beach	FL	8.1	12.1	32	26.9	0.0171	0.0159	0.0109	0.0104	76015	67582	53290	52080
Augusta	GA	–4.1	5.9	34	27.9	0.0147	0.0146	0.0099	0.0098	71820	65109	50797	50705
Atlanta	GA	–4.9	5.8	33	26.9	0.0136	0.0140	0.0094	0.0096	67909	62477	49652	50074
Macon	GA	–2.8	6.5	34	28.1	0.0147	0.0143	0.0099	0.0097	71820	64447	50797	50369
Savanah	GA	–1.6	7.4	34	27.3	0.0163	0.0152	0.0105	0.0101	75939	65984	52435	51291
Barberspoint	HI	16.2	16.7	32	25.7	0.0140	0.0142	0.0096	0.0097	67943	61793	50076	50282
Hilo	HI	17.1	17.8	29	25.0	0.0152	0.0144	0.0101	0.0098	68046	61560	51351	50489
Honolulu	HI	17.2	17.5	31	25.9	0.0144	0.0132	0.0098	0.0093	67977	59432	50500	49261
Lihue	HI	16.6	17.1	29	25.2	0.0168	0.0146	0.0107	0.0099	72000	62488	52929	50764
Burlington	IA	–17.4	–0.6	33	26.9	0.0151	0.0142	0.0100	0.0097	71855	62997	51222	50263
DesMoines	IA	–19.9	–1.5	32	27.0	0.0140	0.0129	0.0096	0.0091	67943	59833	50076	48941
MasonCity	IA	–23.5	–3.4	31	26.8	0.0144	0.0132	0.0098	0.0093	67977	60435	50500	49288
Sioux City	IA	–21.1	–2.8	32	27.5	0.0140	0.0145	0.0096	0.0098	67943	64504	50076	50611
Boise	ID	–12.6	3.2	34	28.8	0.0052	0.0062	0.0061	0.0065	47412	44540	41093	42129
Lewiston	ID	–9.7	3.9	34	29.1	0.0064	0.0065	0.0065	0.0066	50479	45775	42312	42501
Pocatello	ID	–17.7	0.2	32	28.3	0.0048	0.0058	0.0059	0.0063	44509	43161	40745	41789
Chicago	IL	–16.1	0.4	32	27.3	0.0140	0.0115	0.0096	0.0086	67943	56782	50076	47598
Moline	IL	–19.3	–0.8	32	27.2	0.0140	0.0133	0.0096	0.0093	67943	61095	50076	49390
Springfield	IL	–16.6	0.7	33	27.5	0.0151	0.0131	0.0100	0.0093	71855	61005	51222	49234
Evansville	IN	–12.8	2.5	33	27.4	0.0151	0.0137	0.0100	0.0095	71855	62342	51222	49780
Fort Wayne	IN	–16.9	–0.1	31	26.3	0.0144	0.0129	0.0098	0.0091	67977	59109	50500	48934
Indianapolis	IN	–16.1	0.6	31	26.6	0.0144	0.0131	0.0098	0.0092	67977	59986	50500	49181
South Bend	IN	–16.2	0.4	31	26.7	0.0129	0.0123	0.0092	0.0089	64193	57956	48993	48338
Dodge City	KS	–14.7	1.4	36	29.7	0.0094	0.0111	0.0078	0.0084	60415	58106	45449	47163
Goodland	KS	–16.5	0.6	34	29.2	0.0076	0.0095	0.0070	0.0078	53674	53552	43582	45557
Kansas City	KS	–15.4	1.3	34	28.4	0.0147	0.0141	0.0099	0.0096	71820	64316	50797	50156
Topeka	KS	–15.6	0.0	34	27.9	0.0147	0.0145	0.0099	0.0098	71820	64794	50797	50582
Wichita	KS	–13.3	1.1	36	29.7	0.0123	0.0133	0.0089	0.0093	67807	63607	48384	49382
Lexington	KY	–12.4	2.1	31	26.7	0.0144	0.0138	0.0098	0.0095	67977	61955	50500	49910
Louisville	KY	–11.4	2.5	32	27.6	0.0155	0.0136	0.0102	0.0095	71891	62379	51648	49730
Baton Rouge	LA	–0.9	8.9	33	27.8	0.0167	0.0160	0.0107	0.0104	75977	68583	52862	52118
Lake Charles	LA	0.1	9.1	33	27.5	0.0167	0.0164	0.0107	0.0105	75977	69245	52862	52512
New Orleans	LA	3.9	9.6	33	27.4	0.0167	0.0162	0.0107	0.0105	75977	68632	52862	52316
Shreveport	LA	–3.2	7.6	35	28.5	0.0159	0.0155	0.0103	0.0102	75901	67913	52009	51590
Boston	MA	–11.3	2.8	31	26.6	0.0129	0.0111	0.0092	0.0084	64193	54807	48993	47126
Baltimore	MD	–9.2	2.6	33	27.5	0.0136	0.0133	0.0094	0.0093	67909	61526	49652	49439
Patuxent River	MD	–6.2	4.7	32	26.8	0.0155	0.0142	0.0102	0.0097	71891	62954	51648	50301
Bangor	ME	–19	–1.6	29	25.7	0.0110	0.0101	0.0084	0.0080	57146	51474	47002	46147
Caribou	ME	–23.2	–4.1	28	25.1	0.0101	0.0099	0.0080	0.0080	53833	50267	46089	45919
Portland	ME	–16.7	0.0	28	25.2	0.0127	0.0114	0.0091	0.0086	60657	54252	48814	47464
Alpena	MI	–18.6	–1.9	29	26.3	0.0110	0.0119	0.0084	0.0088	57146	56630	47002	47981
Detroit	MI	–15.1	0.8	31	26.7	0.0129	0.0215	0.0092	0.0126	64193	81611	48993	57790

TABLE 6.3.1-1 Design and Seasonal Temperature, Humidity, and Enthalpy Conditions (SI) (Continued)

Location	State	Temperature				W_{design}	$W_{seasonal}$	$W_{in, design}$	$W_{in, seasonal}$	Design h_{out}	Seasonal h_{out}	Design h_{in}	Seasonal h_{in}
		Heating Design	Heating Seasonal	Cooling Design	Cooling Seasonal								
Flint	MI	–16.3	–0.7	30	25.9	0.0133	0.0116	0.0093	0.0086	64225	55398	49416	47639
Grand Rapids	MI	–15.2	–0.1	30	26.4	0.0133	0.0121	0.0093	0.0088	64225	57162	49416	48137
Sault Saint Marie	MI	–21.8	–3.8	27	25.4	0.0118	0.0118	0.0087	0.0087	57203	55368	47845	47836
Traverse City	MI	–16.8	–1.0	30	26.4	0.0119	0.0115	0.0088	0.0086	60596	55782	47969	47586
Duluth	MN	–26.6	–5.5	27	25.3	0.0105	0.0111	0.0082	0.0084	53860	53528	46509	47137
International Falls	MN	–30.8	–8.1	28	24.8	0.0101	0.0107	0.0080	0.0083	53833	52014	46089	46734
Minneapolis	MN	–23.7	–4.4	31	27.3	0.0129	0.0125	0.0092	0.0090	64193	59165	48993	48551
Rochester	MN	–24.4	–4.0	30	25.7	0.0133	0.0126	0.0093	0.0090	64225	57677	49416	48648
Columbia	MO	–14.9	1.1	33	27.6	0.0151	0.0135	0.0100	0.0094	71855	62188	51222	49643
Saint Louis	MO	–13.6	1.5	34	27.8	0.0147	0.0144	0.0099	0.0098	71820	64511	50797	50498
Springfield	MO	–12.8	2.6	33	27.4	0.0151	0.0147	0.0100	0.0099	71855	65018	51222	50847
Jackson	MS	–4.1	8.7	34	27.3	0.0163	0.0150	0.0105	0.0100	75939	65680	52435	51166
Meridian	MS	–3.9	6.5	34	28.5	0.0163	0.0148	0.0105	0.0099	75939	66257	52435	50901
Billings	MT	–21.8	–1.6	32	27.8	0.0060	0.0074	0.0064	0.0070	47458	46671	41919	43363
Cut Bank	MT	–26.4	–3.6	29	26.4	0.0049	0.0067	0.0060	0.0067	41733	43321	40852	42620
Glasgow	MT	–27.1	–5.3	32	28.1	0.0060	0.0079	0.0064	0.0072	47458	48338	41919	43929
Great Falls	MT	–24.8	–1.9	31	27.4	0.0052	0.0064	0.0061	0.0066	44530	43680	41158	42343
Helena	MT	–23.5	–1.6	31	27.6	0.0041	0.0058	0.0056	0.0063	41695	42432	40028	41763
Lewistown	MT	–24.2	–1.4	30	27.2	0.0056	0.0083	0.0062	0.0073	44551	48365	41571	44288
Miles City	MT	–24.7	–4.3	34	29.0	0.0064	0.0068	0.0065	0.0067	50479	46351	42312	42778
Missoula	MT	–18.3	0.8	31	27.6	0.0052	0.0064	0.0061	0.0066	44530	43903	41158	42337
Asheville	NC	–8.8	4.5	30	26.2	0.0133	0.0142	0.0093	0.0097	64225	62438	49416	50343
Cape Hatteras	NC	–1.9	7.6	30	25.9	0.0180	0.0165	0.0112	0.0106	76091	68024	54147	52688
Charlotte	NC	–5.1	4.9	33	27.2	0.0136	0.0130	0.0094	0.0092	67909	60371	49652	49089
Cherry Point	NC	–2.2	7.0	34	26.6	0.0180	0.0153	0.0112	0.0101	80242	65658	54146	51448
Greensboro	NC	–7.2	4.6	32	27.1	0.0140	0.0134	0.0096	0.0094	67943	61283	50076	49515
Raleigh	NC	–6.4	4.7	32	27.1	0.0155	0.0145	0.0102	0.0098	71891	64029	51648	50575
Bismarck	ND	–26.6	–5.6	32	27.6	0.0084	0.0107	0.0074	0.0083	53727	54988	44416	46780
Fargo	ND	–27.3	–7.0	31	27.5	0.0115	0.0120	0.0086	0.0088	60566	58037	47547	48018
Minot	ND	–26.5	–5.6	32	27.2	0.0097	0.0097	0.0079	0.0079	57060	51796	45743	45676
Grand Island	NE	–19.1	–1.7	34	28.3	0.0117	0.0122	0.0087	0.0089	64096	59418	47726	48244
North Platte	NE	–19.8	–1.7	33	28.1	0.0107	0.0109	0.0083	0.0083	60505	55778	46706	46895
Omaha	NE	–18.8	–0.6	33	28.0	0.0151	0.0138	0.0100	0.0095	71855	63265	51222	49905
Scottsbluff	NE	–19.4	–0.9	33	28.5	0.0068	0.0088	0.0067	0.0075	50504	51020	42727	44847
Concord	NH	–18.9	–1.4	30	27.3	0.0119	0.0117	0.0088	0.0087	60596	57194	47969	47785
Lakehurst	NJ	–10.8	2.6	31	27.3	0.0144	0.0131	0.0098	0.0092	67977	60628	50500	49142
Newark	NJ	–10	3.2	32	26.8	0.0140	0.0117	0.0096	0.0087	67943	56638	50076	47776
Albuquerque	NM	–7.6	3.6	34	28.6	0.0040	0.0070	0.0056	0.0068	44467	46581	39922	43021
Clayton	NM	–12.8	2.3	33	26.5	0.0056	0.0088	0.0062	0.0075	47435	48866	41506	44770
Roswell	NM	–6.8	4.3	36	29.7	0.0055	0.0085	0.0062	0.0074	50430	51450	41485	44497
Truth or Consequenses	NM	–3.2	4.6	35	28.4	0.0036	0.0069	0.0054	0.0068	44446	46162	39511	42915
Tucumcari	NM	–9.5	3.6	35	29.4	0.0059	0.0095	0.0064	0.0078	50454	53534	41898	45483
Elko	NV	–17.1	0.0	34	28.8	0.0029	0.0052	0.0052	0.0061	41637	42079	38796	41123
Ely	NV	–17.8	–1.0	31	26.9	0.0020	0.0041	0.0048	0.0056	36347	37256	37897	39997
Las Vegas	NV	–0.9	7.6	41	32.6	0.0048	0.0054	0.0059	0.0062	53490	46356	40685	41317

TABLE 6.3.1-1 Design and Seasonal Temperature, Humidity, and Enthalpy Conditions (SI) (Continued)

Location	State	Temperature				W_{design}	$W_{seasonal}$	$W_{in,\ design}$	$W_{in,\ seasonal}$	Design h_{out}	Seasonal h_{out}	Design h_{in}	Seasonal h_{in}
		Heating Design	Heating Seasonal	Cooling Design	Cooling Seasonal								
Reno	NV	–10.6	2.5	33	28.7	0.0033	0.0055	0.0053	0.0062	41656	42863	39206	41486
Tonopah	NV	–10.8	2.2	33	28.0	0.0022	0.0049	0.0049	0.0060	38934	40487	38123	40840
Winnemucca	NV	–13.7	1.2	35	29.8	0.0025	0.0041	0.0050	0.0056	41617	40240	38387	40000
Albany	NY	–18.8	–0.7	30	26.1	0.0119	0.0112	0.0088	0.0085	60596	54780	47969	47298
Binghamton	NY	–16.6	–1.3	28	25.5	0.0114	0.0125	0.0085	0.0090	57174	57282	47423	48538
Buffalo	NY	–14.8	0.2	29	25.6	0.0123	0.0120	0.0089	0.0088	60627	56222	48391	48080
Massena	NY	–23.2	–3.1	29	26.2	0.0123	0.0120	0.0089	0.0088	60627	56771	48391	48047
New York Central	NY	–9.2	3.6	31	25.5	0.0129	0.0128	0.0092	0.0091	64193	58120	48993	48868
New York LA Guardia	NY	–8.1	3.4	32	26.5	0.0140	0.0127	0.0096	0.0091	67943	58987	50076	48808
Rochester	NY	–15	–0.4	30	26.7	0.0133	0.0131	0.0093	0.0092	64225	60101	49416	49205
Syracuse	NY	–16.4	–0.7	30	25.9	0.0133	0.0124	0.0093	0.0090	64225	57428	49416	48467
Akron	OH	–14.9	0.6	30	25.9	0.0133	0.0130	0.0093	0.0092	64225	59088	49416	49130
Cincinnatti	OH	–11.3	2.0	32	26.8	0.0155	0.0122	0.0102	0.0089	71891	57969	51648	48275
Cleveland	OH	–14.7	0.9	30	26.6	0.0133	0.0124	0.0093	0.0090	64225	58284	49416	48496
Columbus	OH	–14.3	1.7	31	26.9	0.0144	0.0130	0.0098	0.0092	67977	59967	50500	49054
Dayton	OH	–15.2	1.0	31	25.9	0.0144	0.0123	0.0098	0.0089	67977	57190	50500	48345
Toledo	OH	–16.2	0.2	31	26.7	0.0129	0.0138	0.0092	0.0095	64193	61887	48993	49916
Youngstown	OH	–15.4	0.2	29	26.3	0.0123	0.0120	0.0089	0.0088	60627	56744	48391	48029
Oklahoma	OK	–9.6	3.3	36	29.0	0.0138	0.0135	0.0095	0.0094	71748	63467	49949	49599
Tulsa	OK	–10.1	3.3	36	29.0	0.0138	0.0145	0.0095	0.0098	71748	66010	49949	50626
Astoria	OR	–1.8	7.9	22	22	0.0101	0.0099	0.0080	0.0080	47689	51376	46089	45966
Medford	OR	–4.5	5.0	35	28.8	0.0072	0.0078	0.0069	0.0071	53647	48693	43167	43792
North Bend	OR	0.2	9.2	21	21	0.0093	0.0101	0.0077	0.0080	44743	46918	45318	46123
Pendleton	OR	–11.7	3.9	34	28.8	0.0052	0.0062	0.0061	0.0065	47412	44566	41093	42134
Portland	OR	–2.9	7.1	30	26.9	0.0092	0.0091	0.0077	0.0076	53780	49976	45251	45080
Redmond	OR	–12.7	2.8	32	28.3	0.0048	0.0061	0.0059	0.0064	44509	43761	40745	42025
Salem	OR	–4.1	6.9	31	27.1	0.0088	0.0082	0.0075	0.0073	53753	48050	44833	44195
Allentown	PA	–12.3	1.2	31	26.0	0.0129	0.0124	0.0092	0.0089	64193	57447	48993	48428
Erie	PA	–14.1	0.8	28	24.9	0.0127	0.0129	0.0091	0.0091	60657	57643	48814	48941
Harrisburg	PA	–10.7	2.4	32	27.1	0.0140	0.0124	0.0096	0.0089	67943	58627	50076	48434
Philadelphia	PA	–9.7	3.0	32	27.1	0.0140	0.0130	0.0096	0.0092	67943	60151	50076	49043
Pittsburg	PA	–11.9	0.7	31	25.8	0.0115	0.0118	0.0086	0.0087	60566	55934	47547	47878
Providence	RI	–12.3	1.9	30	26.2	0.0133	0.0121	0.0093	0.0088	64225	56964	49416	48140
Charleston	SC	–2	7.5	33	27.1	0.0167	0.0158	0.0107	0.0103	75977	67320	52862	51924
Greenville	SC	–4.8	5.7	33	26.9	0.0136	0.0137	0.0094	0.0095	67909	61799	49652	49800
Columbia	SC	–4.2	6.0	34	28.3	0.0147	0.0141	0.0099	0.0097	71820	64355	50797	50237
Huron	SD	–24.4	–5.7	33	28.3	0.0121	0.0125	0.0088	0.0090	64128	60312	48148	48616
Pierre	SD	–22.5	–3.2	35	29.1	0.0098	0.0113	0.0079	0.0085	60445	57933	45868	47339
Rapid City	SD	–20.6	–1.4	33	28.5	0.0068	0.0091	0.0067	0.0076	50504	51741	42727	45102
Sioux Falls	SD	–23.7	–3.4	32	27.7	0.0125	0.0130	0.0090	0.0092	64161	60861	48570	49091
Chattanooga	TN	–6.9	4.4	33	27.5	0.0151	0.0151	0.0100	0.0100	71855	66032	51222	51213
Knoxville	TN	–7.5	4.1	32	27.0	0.0140	0.0141	0.0096	0.0096	67943	63000	50076	50220
Memphis	TN	–6.3	5.2	34	28.0	0.0163	0.0149	0.0105	0.0100	75939	66078	52435	51042
Nashville	TN	–9	4.6	33	27.5	0.0151	0.0141	0.0100	0.0096	71855	63434	51222	50197

TABLE 6.3.1-1 Design and Seasonal Temperature, Humidity, and Enthalpy Conditions (SI) (Continued)

Location	State	Temperature				W_{design}	$W_{seasonal}$	$W_{in,\ design}$	$W_{in,\ seasonal}$	Design h_{out}	Seasonal h_{out}	Design h_{in}	Seasonal h_{in}
		Heating Design	Heating Seasonal	Cooling Design	Cooling Seasonal								
Abilene	TX	–5.7	5.4	36	29.5	0.0108	0.0125	0.0083	0.0090	64032	61321	46885	48537
Amarillo	TX	–11.3	3.0	34	28.7	0.0076	0.0105	0.0070	0.0082	53674	55455	43582	46512
Austin	TX	–1.3	8.1	36	29.2	0.0123	0.0147	0.0089	0.0099	67807	66706	48384	50806
Brownsville	TX	4.2	10.7	34	27.9	0.0163	0.0166	0.0105	0.0106	75939	70266	52435	52769
Corpus Christie	TX	2.1	9.9	34	28.2	0.0163	0.0170	0.0105	0.0108	75939	71551	52435	53134
DelRio	TX	0.1	8.6	37	29.1	0.0119	0.0135	0.0088	0.0094	67773	63626	47963	49630
El Paso	TX	–3.9	6.6	37	29.5	0.0051	0.0076	0.0061	0.0070	50405	48975	41072	43604
Fort Worth	TX	–4.2	6.5	36	29.7	0.0138	0.0137	0.0095	0.0095	71748	64551	49949	49748
Houston	TX	1	9.2	34	28.1	0.0163	0.0160	0.0105	0.0104	75939	68885	52435	52114
Kingsville	TX	2	10.2	36	28.7	0.0155	0.0169	0.0102	0.0108	75863	71918	51583	53100
Laredo	TX	2.2	10.5	38	30.5	0.0115	0.0142	0.0086	0.0097	67740	66702	47542	50277
Lubbock	TX	–8.3	3.8	35	29.4	0.0085	0.0103	0.0074	0.0081	56975	55770	44489	46358
Lufkin	TX	–2.6	7.1	35	28.8	0.0159	0.0161	0.0103	0.0104	75901	69772	52009	52201
Midland	TX	–5.4	6.0	36	29.1	0.0068	0.0105	0.0067	0.0082	53621	55822	42752	46510
Port Arthur	TX	0.2	9.4	34	27.8	0.0180	0.0169	0.0112	0.0107	80242	70823	54146	53027
San Angelo	TX	–4.4	6.2	36	29.6	0.0094	0.0118	0.0078	0.0087	60415	59679	45449	47846
San Antonio	TX	–1	8.2	35	29.0	0.0127	0.0146	0.0091	0.0098	67841	66269	48806	50711
Waco	TX	–3.2	6.6	37	29.6	0.0134	0.0145	0.0094	0.0098	71712	66669	49526	50609
Wichita Falls	TX	–7.1	4.7	38	30.3	0.0115	0.0140	0.0086	0.0096	67740	66073	47542	50098
Cedarcity	UT	–13.3	1.3	33	27.6	0.0033	0.0059	0.0053	0.0063	41656	42605	39206	41818
Salt Lake City	UT	–11.7	1.6	35	29.8	0.0025	0.0061	0.0050	0.0064	41617	45419	38387	42064
Norfolk	VA	–4.7	5.3	33	27.3	0.0056	0.0146	0.0062	0.0098	47435	64610	41506	50731
Richmond	VA	–7.6	4.2	33	27.2	0.0151	0.0140	0.0100	0.0096	71855	63051	51222	50152
Roanoke	VA	–8.6	3.9	32	27.1	0.0155	0.0128	0.0102	0.0091	71891	59731	51648	48879
Burlington	VT	–21.2	–2.1	29	25.3	0.0137	0.0113	0.0095	0.0085	64257	54138	49840	47359
Olympia	WA	–4.8	6.0	28	25.9	0.0127	0.0082	0.0091	0.0073	60657	46922	48814	44227
Seattle	WA	–2.2	6.9	27	25.6	0.0092	0.0084	0.0077	0.0074	50652	47041	45227	44430
Spokane	WA	–13.8	2.0	32	27.1	0.0048	0.0062	0.0059	0.0065	44509	43040	40745	42197
Yakima	WA	–11.8	2.7	33	28.3	0.0068	0.0068	0.0067	0.0067	50504	45627	42727	42776
EauClair	WI	–24.9	–4.5	31	27.0	0.0129	0.0134	0.0092	0.0094	64193	61185	48993	49515
Green Bay	WI	–21.9	–2.8	30	26.2	0.0133	0.0129	0.0093	0.0092	64225	59231	49416	49027
La Crosse	WI	–22.4	–1.7	31	27.0	0.0144	0.0131	0.0098	0.0092	67977	60417	50500	49171
Madison	WI	–21.2	–2.3	31	26.4	0.0129	0.0123	0.0092	0.0089	64193	57729	48993	48381
Milwaukee	WI	–18.7	–0.4	30	26.1	0.0133	0.0130	0.0093	0.0092	64225	59206	49416	49071
Charleston	WV	–11.5	2.6	31	27.1	0.0144	0.0127	0.0098	0.0091	67977	59369	50500	48746
Huntington	WV	–11.5	2.5	31	26.5	0.0144	0.0134	0.0098	0.0093	67977	60589	50500	49462
Casper	WY	–20.3	–0.8	32	27.9	0.0026	0.0054	0.0051	0.0062	38951	41663	38532	41356
Cheyenne	WY	–17.6	–0.2	29	26.9	0.0038	0.0069	0.0055	0.0068	39004	44593	39763	42900
Rock Springs	WY	–18.7	–1.7	29	26.1	0.0018	0.0043	0.0047	0.0057	33852	37006	37708	40215
Sheridan	WY	–21.9	–0.9	32	27.7	0.0048	0.0081	0.0059	0.0072	44509	48252	40745	44047
Edmonton	AB	–30.5	–6.3	25.6	24.3	0.0080	0.0082	0.0072	0.0073	46110	45200	43983	44195
Montreal	PQ	–22	–3	28.1	24.8	0.0126	0.0124	0.0090	0.0090	60299	56400	48630	48474
Vancouver	BC	–5	6.5	23.2	22.6	0.0103	0.0104	0.0081	0.0082	49498	49200	46322	46437
Toronto	ON	–17	–3.4	28.7	25.8	0.0123	0.0126	0.0089	0.0090	60281	57800	48376	48678
Winnipeg	MN	–31	–8.9	29	26	0.0104	0.0092	0.0082	0.0077	55793	49600	46463	45214

TABLE 6.3.1-2 Design and Seasonal Temperature, Humidity, and Enthalpy Conditions (I-P)

Location	State	Temperature				W_{design}	$W_{seasonal}$	$W_{indesign}$	$W_{inseasonal}$	Design h_{out}	Seasonal h_{ou}	Design h_{in}	Seasonal h_{in}
		Heating Design	Heating Seasonal	Cooling Design	Cooling Seasonal								
Adak	AK	23	39										
Annette	AK	17	40	70	70	0.0084	0.0094	0.0073	0.0078	26	28	27	27
Bethel	AK	–24	16	68	68	0.0078	0.0067	0.0071	0.0067	25	25	27	26
Big Delta	AK	–39	8	75	75	0.0062	0.0073	0.0065	0.0069	25	26	26	26
Fairbanks	AK	–31	2	79	79	0.0076	0.0067	0.0070	0.0067	27	25	26	26
Gulkana	AK	–39	11	75	75	0.0073	0.0061	0.0069	0.0065	26	25	26	26
Homer	AK	4	30	63	63	0.0079	0.0094	0.0072	0.0078	24	27	27	27
Juneau	AK	7	34	70	70	0.0084	0.0078	0.0074	0.0071	26	26	27	27
King Salmon	AK	–19	21	66	66	0.0071	0.0102	0.0068	0.0081	24	29	26	28
Kodiak	AK	11	36	64	64	0.0074	0.0115	0.0070	0.0086	24	30	26	28
McGrath	AK	–41	6	73	73	0.0066	0.0070	0.0066	0.0068	25	25	26	26
Nome	AK	–26	15	64	64							19	19
Yakutat	AK	2	33	63	63	0.0077	0.0063	0.0071	0.0065	23	24	26	26
Birmingham	AL	21	43	91	82	0.0151	0.0143	0.0100	0.0097	39	35	30	29
Mobile	AL	30	49	91	82	0.0167	0.0157	0.0107	0.0103	40	37	30	30
Montgomery	AL	27	45	93	83	0.0147	0.0150	0.0099	0.0100	39	36	30	30
Fort Smith	AR	19	39	95	85	0.0143	0.0148	0.0097	0.0099	39	37	29	30
Little Rock	AR	21	40	95	84	0.0159	0.0159	0.0103	0.0103	40	38	30	30
Phoenix	AZ	38	49	107	91	0.0085	0.0079	0.0074	0.0071	35	31	27	27
Prescott	AZ	20	38	91	82	0.0044	0.0071	0.0058	0.0068	27	27	25	26
Tucson	AZ	34	48	102	87	0.0044	0.0076	0.0057	0.0070	29	29	25	26
Yuma	AZ	44	52	109	92	0.0094	0.0091	0.0078	0.0076	37	32	27	27
Bakersfield	CA	35	48	102	87	0.0082	0.0076	0.0073	0.0070	34	29	27	26
Burbank	CA	41	53	95	82	0.0085	0.0089	0.0074	0.0076	32	30	27	27
Dagget	CA	32	47	106	90	0.0060	0.0065	0.0064	0.0066	32	29	26	26
Fresno	CA	32	47	100	88	0.0086	0.0080	0.0074	0.0072	34	30	27	27
Long Beach	CA	42	55	88	79	0.0088	0.0101	0.0075	0.0080	31	30	27	28
Los Angeles	CA	45	56	81	75	0.0092	0.0102	0.0077	0.0081	29	29	27	28
Point Mugu	CA	41	54	79	75	0.0096	0.0091	0.0078	0.0077	29	28	27	27
Sacramento	CA	33	48	97	86	0.0081	0.0086	0.0072	0.0074	32	30	27	27
San Diego	CA	42	57	88	76	0.0101	0.0103	0.0081	0.0081	32	29	28	28
San Francisco	CA	39	51	79	77	0.0073	0.0073	0.0069	0.0069	27	27	26	26
Santa Maria	CA	35	49	82	77	0.0076	0.0071	0.0070	0.0069	28	26	26	26
Colorado Springs	CO	4	35	88	81	0.0030	0.0072	0.0052	0.0069	24	27	24	26
Denver	CO	3	33	90	82	0.0037	0.0061	0.0055	0.0064	26	26	25	26
Eagle	CO	–7	28	86	80	0.0034	0.0069	0.0054	0.0068	24	27	25	26
Grand Junction	CO	7	34	93	84	0.0040	0.0059	0.0056	0.0064	27	27	25	26
Pueblo	CO	5	32	95	84	0.0047	0.0069	0.0059	0.0067	28	28	25	26
Hartford	CT	6	33	88	81	0.0129	0.0117	0.0092	0.0087	35	32	29	28
Washington	DC	20	37	93	81	0.0147	0.0137	0.0099	0.0095	39	35	30	29
Wilmington	DE	14	37	90	80	0.0140	0.0129	0.0096	0.0091	37	33	29	29
Apalachicola	FL	35	50	90	82	0.0188	0.0168	0.0115	0.0107	42	38	31	30
Daytona	FL	37	51	90	80	0.0171	0.0159	0.0109	0.0104	40	37	31	30
Jacksonville	FL	32	44	93	82	0.0163	0.0155	0.0105	0.0102	40	37	30	30
Miami	FL	50	54	90	80	0.0171	0.0160	0.0109	0.0104	40	37	31	30

TABLE 6.3.1-2 Design and Seasonal Temperature, Humidity, and Enthalpy Conditions (I-P) (Continued)

Location	State	Temperature				W_{design}	$W_{seasonal}$	$W_{indesign}$	$W_{inseasonal}$	Design h_{out}	Seasonal h_{ou}	Design h_{in}	Seasonal h_{in}
		Heating Design	Heating Seasonal	Cooling Design	Cooling Seasonal								
Orlando	FL	42	53	93	82	0.0163	0.0154	0.0105	0.0102	40	37	30	30
Tallahassee	FL	28	46	93	81	0.0163	0.0154	0.0105	0.0102	40	36	30	30
Tampa	FL	40	52	91	81	0.0167	0.0157	0.0107	0.0103	40	37	30	30
West Palm Beach	FL	47	54	90	80	0.0171	0.0159	0.0109	0.0104	40	37	31	30
Augusta	GA	25	43	93	82	0.0147	0.0146	0.0099	0.0098	39	36	30	29
Atlanta	GA	23	43	91	80	0.0136	0.0140	0.0094	0.0096	37	35	29	29
Macon	GA	27	44	93	83	0.0147	0.0143	0.0099	0.0097	39	35	30	29
Savanah	GA	29	45	93	81	0.0163	0.0152	0.0105	0.0101	40	36	30	30
Barberspoint	HI	61	62	90	78	0.0140	0.0142	0.0096	0.0097	37	34	29	29
Hilo	HI	63	64	84	77	0.0152	0.0144	0.0101	0.0098	37	34	30	29
Honolulu	HI	63	64	88	79	0.0144	0.0132	0.0098	0.0093	37	33	29	29
Lihue	HI	62	63	84	77	0.0168	0.0146	0.0107	0.0099	39	35	30	30
Burlington	IA	1	31	91	80	0.0151	0.0142	0.0100	0.0097	39	35	30	29
DesMoines	IA	–4	29	90	81	0.0140	0.0129	0.0096	0.0091	37	33	29	29
MasonCity	IA	–10	26	88	80	0.0144	0.0132	0.0098	0.0093	37	34	29	29
Sioux City	IA	–6	27	90	82	0.0140	0.0145	0.0096	0.0098	37	35	29	29
Boise	ID	9	38	93	84	0.0052	0.0062	0.0061	0.0065	28	27	25	26
Lewiston	ID	15	39	93	84	0.0064	0.0065	0.0065	0.0066	29	27	26	26
Pocatello	ID	0	32	90	83	0.0048	0.0058	0.0059	0.0063	27	26	25	26
Chicago	IL	3	33	90	81	0.0140	0.0115	0.0096	0.0086	37	32	29	28
Moline	IL	–3	31	90	81	0.0140	0.0133	0.0096	0.0093	37	34	29	29
Springfield	IL	2	33	91	81	0.0151	0.0131	0.0100	0.0093	39	34	30	29
Evansville	IN	9	37	91	81	0.0151	0.0137	0.0100	0.0095	39	35	30	29
Fort Wayne	IN	2	32	88	79	0.0144	0.0129	0.0098	0.0091	37	33	29	29
Indianapolis	IN	3	33	88	80	0.0144	0.0131	0.0098	0.0092	37	34	29	29
South Bend	IN	3	33	88	80	0.0129	0.0123	0.0092	0.0089	35	33	29	28
Dodge City	KS	6	35	97	85	0.0094	0.0111	0.0078	0.0084	34	33	27	28
Goodland	KS	2	33	93	85	0.0076	0.0095	0.0070	0.0078	31	31	26	27
Kansas City	KS	4	34	93	83	0.0147	0.0141	0.0099	0.0096	39	35	30	29
Topeka	KS	4	32	93	82	0.0147	0.0145	0.0099	0.0098	39	36	30	29
Wichita	KS	8	34	97	85	0.0123	0.0133	0.0089	0.0093	37	35	28	29
Lexington	KY	10	36	88	80	0.0144	0.0138	0.0098	0.0095	37	34	29	29
Louisville	KY	11	37	90	82	0.0155	0.0136	0.0102	0.0095	39	35	30	29
Baton Rouge	LA	30	48	91	82	0.0167	0.0160	0.0107	0.0104	40	37	30	30
Lake Charles	LA	32	48	91	82	0.0167	0.0164	0.0107	0.0105	40	38	30	30
New Orleans	LA	39	49	91	81	0.0167	0.0162	0.0107	0.0105	40	37	30	30
Shreveport	LA	26	46	95	83	0.0159	0.0155	0.0103	0.0102	40	37	30	30
Boston	MA	12	37	88	80	0.0129	0.0111	0.0092	0.0084	35	31	29	28
Baltimore	MD	15	37	91	81	0.0136	0.0133	0.0094	0.0093	37	34	29	29
Patuxent River	MD	21	41	90	80	0.0155	0.0142	0.0102	0.0097	39	35	30	29
Bangor	ME	–2	29	84	78	0.0110	0.0101	0.0084	0.0080	32	30	28	28
Caribou	ME	–10	25	82	77	0.0101	0.0099	0.0080	0.0080	31	29	28	27
Portland	ME	2	32	82	77	0.0127	0.0114	0.0091	0.0086	34	31	29	28
Alpena	MI	–1	29	84	79	0.0110	0.0119	0.0084	0.0088	32	32	28	28
Detroit	MI	5	34	88	80	0.0129	0.0215	0.0092	0.0126	35	43	29	33

TABLE 6.3.1-2 Design and Seasonal Temperature, Humidity, and Enthalpy Conditions (I-P) (Continued)

Location	State	Temperature				W_{design}	$W_{seasonal}$	$W_{indesign}$	$W_{inseasonal}$	Design h_{out}	Seasonal h_{ou}	Design h_{in}	Seasonal h_{in}
		Heating Design	Heating Seasonal	Cooling Design	Cooling Seasonal								
Flint	MI	3	31	86	79	0.0133	0.0116	0.0093	0.0086	35	32	29	28
Grand Rapids	MI	5	32	86	80	0.0133	0.0121	0.0093	0.0088	35	32	29	28
Sault Saint Marie	MI	–7	25	81	78	0.0118	0.0118	0.0087	0.0087	32	32	28	28
Traverse City	MI	2	30	86	80	0.0119	0.0115	0.0088	0.0086	34	32	28	28
Duluth	MN	–16	22	81	78	0.0105	0.0111	0.0082	0.0084	31	31	28	28
International Falls	MN	–23	17	82	77	0.0101	0.0107	0.0080	0.0083	31	30	28	28
Minneapolis	MN	–11	24	88	81	0.0129	0.0125	0.0092	0.0090	35	33	29	29
Rochester	MN	–12	25	86	78	0.0133	0.0126	0.0093	0.0090	35	33	29	29
Columbia	MO	5	34	91	82	0.0151	0.0135	0.0100	0.0094	39	34	30	29
Saint Louis	MO	8	35	93	82	0.0147	0.0144	0.0099	0.0098	39	35	30	29
Springfield	MO	9	37	91	81	0.0151	0.0147	0.0100	0.0099	39	36	30	30
Jackson	MS	25	48	93	81	0.0163	0.0150	0.0105	0.0100	40	36	30	30
Meridian	MS	25	44	93	83	0.0163	0.0148	0.0105	0.0099	40	36	30	30
Billings	MT	–7	29	90	82	0.0060	0.0074	0.0064	0.0070	28	28	26	26
Cut Bank	MT	–16	26	84	79	0.0049	0.0067	0.0060	0.0067	26	26	25	26
Glasgow	MT	–17	22	90	83	0.0060	0.0079	0.0064	0.0072	28	29	26	27
Great Falls	MT	–13	29	88	81	0.0052	0.0064	0.0061	0.0066	27	27	25	26
Helena	MT	–10	29	88	82	0.0041	0.0058	0.0056	0.0063	26	26	25	26
Lewistown	MT	–12	30	86	81	0.0056	0.0083	0.0062	0.0073	27	29	26	27
Miles City	MT	–12	24	93	84	0.0064	0.0068	0.0065	0.0067	29	28	26	26
Missoula	MT	–1	33	88	82	0.0052	0.0064	0.0061	0.0066	27	27	25	26
Asheville	NC	16	40	86	79	0.0133	0.0142	0.0093	0.0097	35	35	29	29
Cape Hatteras	NC	29	46	86	79	0.0180	0.0165	0.0112	0.0106	40	37	31	30
Charlotte	NC	23	41	91	81	0.0136	0.0130	0.0094	0.0092	37	34	29	29
Cherry Point	NC	28	45	93	80	0.0180	0.0153	0.0112	0.0101	42	36	31	30
Greensboro	NC	19	40	90	81	0.0140	0.0134	0.0096	0.0094	37	34	29	29
Raleigh	NC	20	40	90	81	0.0155	0.0145	0.0102	0.0098	39	35	30	29
Bismarck	ND	–16	22	90	82	0.0084	0.0107	0.0074	0.0083	31	31	27	28
Fargo	ND	–17	19	88	82	0.0115	0.0120	0.0086	0.0088	34	33	28	28
Minot	ND	–16	22	90	81	0.0097	0.0097	0.0079	0.0079	32	30	27	27
Grand Island	NE	–2	29	93	83	0.0117	0.0122	0.0087	0.0089	35	33	28	28
North Platte	NE	–4	29	91	83	0.0107	0.0109	0.0083	0.0083	34	32	28	28
Omaha	NE	–2	31	91	82	0.0151	0.0138	0.0100	0.0095	39	35	30	29
Scottsbluff	NE	–3	30	91	83	0.0068	0.0088	0.0067	0.0075	29	30	26	27
Concord	NH	–2	29	86	81	0.0119	0.0117	0.0088	0.0087	34	32	28	28
Lakehurst	NJ	13	37	88	81	0.0144	0.0131	0.0098	0.0092	37	34	29	29
Newark	NJ	14	38	90	80	0.0140	0.0117	0.0096	0.0087	37	32	29	28
Albuquerque	NM	18	38	93	83	0.0040	0.0070	0.0056	0.0068	27	28	25	26
Clayton	NM	9	36	91	80	0.0056	0.0088	0.0062	0.0075	28	29	26	27
Roswell	NM	20	40	97	86	0.0055	0.0085	0.0062	0.0074	29	30	26	27
Truth or Consequenses	NM	26	40	95	83	0.0036	0.0069	0.0054	0.0068	27	28	25	26
Tucumcari	NM	15	38	95	85	0.0059	0.0095	0.0064	0.0078	29	31	26	27
Elko	NV	1	32	93	84	0.0029	0.0052	0.0052	0.0061	26	26	24	25
Ely	NV	0	30	88	80	0.0020	0.0041	0.0048	0.0056	23	24	24	25
Las Vegas	NV	30	46	106	91	0.0048	0.0054	0.0059	0.0062	31	28	25	25

TABLE 6.3.1-2 Design and Seasonal Temperature, Humidity, and Enthalpy Conditions (I-P) (Continued)

Location	State	Temperature				W_{design}	$W_{seasonal}$	$W_{indesign}$	$W_{inseasonal}$	Design h_{out}	Seasonal h_{ou}	Design h_{in}	Seasonal h_{in}
		Heating Design	Heating Seasonal	Cooling Design	Cooling Seasonal								
Reno	NV	13	36	91	84	0.0033	0.0055	0.0053	0.0062	26	26	25	26
Tonopah	NV	13	36	91	82	0.0022	0.0049	0.0049	0.0060	24	25	24	25
Winnemucca	NV	7	34	95	86	0.0025	0.0041	0.0050	0.0056	26	25	24	25
Albany	NY	–2	31	86	79	0.0119	0.0112	0.0088	0.0085	34	31	28	28
Binghamton	NY	2	30	82	78	0.0114	0.0125	0.0085	0.0090	32	32	28	29
Buffalo	NY	5	32	84	78	0.0123	0.0120	0.0089	0.0088	34	32	29	28
Massena	NY	–10	27	84	79	0.0123	0.0120	0.0089	0.0088	34	32	29	28
New York Central	NY	15	38	88	78	0.0129	0.0128	0.0092	0.0091	35	33	29	29
New York LA Guardia	NY	17	38	90	80	0.0140	0.0127	0.0096	0.0091	37	33	29	29
Rochester	NY	5	31	86	80	0.0133	0.0131	0.0093	0.0092	35	34	29	29
Syracuse	NY	2	31	86	79	0.0133	0.0124	0.0093	0.0090	35	32	29	29
Akron	OH	5	33	86	79	0.0133	0.0130	0.0093	0.0092	35	33	29	29
Cincinnatti	OH	12	36	90	80	0.0155	0.0122	0.0102	0.0089	39	33	30	28
Cleveland	OH	6	34	86	80	0.0133	0.0124	0.0093	0.0090	35	33	29	29
Columbus	OH	6	35	88	80	0.0144	0.0130	0.0098	0.0092	37	34	29	29
Dayton	OH	5	34	88	79	0.0144	0.0123	0.0098	0.0089	37	32	29	28
Toledo	OH	3	32	88	80	0.0129	0.0138	0.0092	0.0095	35	34	29	29
Youngstown	OH	4	32	84	79	0.0123	0.0120	0.0089	0.0088	34	32	29	28
Oklahoma	OK	15	38	97	84	0.0138	0.0135	0.0095	0.0094	39	35	29	29
Tulsa	OK	14	38	97	84	0.0138	0.0145	0.0095	0.0098	39	36	29	29
Astoria	OR	29	46	72	72	0.0101	0.0099	0.0080	0.0080	28	30	28	27
Medford	OR	24	41	95	84	0.0072	0.0078	0.0069	0.0071	31	29	26	27
North Bend	OR	32	48	70	70	0.0093	0.0101	0.0077	0.0080	27	28	27	28
Pendleton	OR	11	39	93	84	0.0052	0.0062	0.0061	0.0065	28	27	25	26
Portland	OR	27	45	86	80	0.0092	0.0091	0.0077	0.0076	31	29	27	27
Redmond	OR	9	37	90	83	0.0048	0.0061	0.0059	0.0064	27	27	25	26
Salem	OR	25	44	88	81	0.0088	0.0082	0.0075	0.0073	31	28	27	27
Allentown	PA	10	34	88	79	0.0129	0.0124	0.0092	0.0089	35	32	29	29
Erie	PA	7	33	82	77	0.0127	0.0129	0.0091	0.0091	34	33	29	29
Harrisburg	PA	13	36	90	81	0.0140	0.0124	0.0096	0.0089	37	33	29	29
Philadelphia	PA	15	37	90	81	0.0140	0.0130	0.0096	0.0092	37	34	29	29
Pittsburg	PA	11	33	88	78	0.0115	0.0118	0.0086	0.0087	34	32	28	28
Providence	RI	10	35	86	79	0.0133	0.0121	0.0093	0.0088	35	32	29	28
Charleston	SC	28	46	91	81	0.0167	0.0158	0.0107	0.0103	40	37	30	30
Greenville	SC	23	42	91	80	0.0136	0.0137	0.0094	0.0095	37	34	29	29
Columbia	SC	24	43	93	83	0.0147	0.0141	0.0099	0.0097	39	35	30	29
Huron	SD	–12	22	91	83	0.0121	0.0125	0.0088	0.0090	35	34	28	29
Pierre	SD	–9	26	95	84	0.0098	0.0113	0.0079	0.0085	34	33	27	28
Rapid City	SD	–5	29	91	83	0.0068	0.0091	0.0067	0.0076	29	30	26	27
Sioux Falls	SD	–11	26	90	82	0.0125	0.0130	0.0090	0.0092	35	34	29	29
Chattanooga	TN	20	40	91	82	0.0151	0.0151	0.0100	0.0100	39	36	30	30
Knoxville	TN	19	39	90	81	0.0140	0.0141	0.0096	0.0096	37	35	29	29
Memphis	TN	21	41	93	82	0.0163	0.0149	0.0105	0.0100	40	36	30	30
Nashville	TN	16	40	91	81	0.0151	0.0141	0.0100	0.0096	39	35	30	29

TABLE 6.3.1-2 Design and Seasonal Temperature, Humidity, and Enthalpy Conditions (I-P) (Continued)

Location	State	Temperature				W_{design}	$W_{seasonal}$	$W_{indesign}$	$W_{inseasonal}$	Design h_{out}	Seasonal h_{ou}	Design h_{in}	Seasonal h_{in}
		Heating Design	Heating Seasonal	Cooling Design	Cooling Seasonal								
Abilene	TX	22	42	97	85	0.0108	0.0125	0.0083	0.0090	35	34	28	29
Amarillo	TX	12	37	93	84	0.0076	0.0105	0.0070	0.0082	31	32	26	28
Austin	TX	30	47	97	85	0.0123	0.0147	0.0089	0.0099	37	36	28	30
Brownsville	TX	40	51	93	82	0.0163	0.0166	0.0105	0.0106	40	38	30	30
Corpus Christie	TX	36	50	93	83	0.0163	0.0170	0.0105	0.0108	40	39	30	31
DelRio	TX	32	47	99	84	0.0119	0.0135	0.0088	0.0094	37	35	28	29
El Paso	TX	25	44	99	85	0.0051	0.0076	0.0061	0.0070	29	29	25	26
Fort Worth	TX	24	44	97	85	0.0138	0.0137	0.0095	0.0095	39	36	29	29
Houston	TX	34	49	93	83	0.0163	0.0160	0.0105	0.0104	40	37	30	30
Kingsville	TX	36	50	97	84	0.0155	0.0169	0.0102	0.0108	40	39	30	31
Laredo	TX	36	51	100	87	0.0115	0.0142	0.0086	0.0097	37	36	28	29
Lubbock	TX	17	39	95	85	0.0085	0.0103	0.0074	0.0081	32	32	27	28
Lufkin	TX	27	45	95	84	0.0159	0.0161	0.0103	0.0104	40	38	30	30
Midland	TX	22	43	97	84	0.0068	0.0105	0.0067	0.0082	31	32	26	28
Port Arthur	TX	32	49	93	82	0.0180	0.0169	0.0112	0.0107	42	38	31	30
San Angelo	TX	24	43	97	85	0.0094	0.0118	0.0078	0.0087	34	33	27	28
San Antonio	TX	30	47	95	84	0.0127	0.0146	0.0091	0.0098	37	36	29	29
Waco	TX	26	44	99	85	0.0134	0.0145	0.0094	0.0098	39	36	29	29
Wichita Falls	TX	19	40	100	87	0.0115	0.0140	0.0086	0.0096	37	36	28	29
Cedarcity	UT	8	34	91	82	0.0033	0.0059	0.0053	0.0063	26	26	25	26
Salt Lake City	UT	11	35	95	86	0.0025	0.0061	0.0050	0.0064	26	27	24	26
Norfolk	VA	24	42	91	81	0.0056	0.0146	0.0062	0.0098	28	36	26	30
Richmond	VA	18	40	91	81	0.0151	0.0140	0.0100	0.0096	39	35	30	29
Roanoke	VA	17	39	90	81	0.0155	0.0128	0.0102	0.0091	39	33	30	29
Burlington	VT	–6	28	84	78	0.0137	0.0113	0.0095	0.0085	35	31	29	28
Olympia	WA	23	43	82	79	0.0127	0.0082	0.0091	0.0073	34	28	29	27
Seattle	WA	28	44	81	78	0.0092	0.0084	0.0077	0.0074	29	28	27	27
Spokane	WA	7	36	90	81	0.0048	0.0062	0.0059	0.0065	27	26	25	26
Yakima	WA	11	37	91	83	0.0068	0.0068	0.0067	0.0067	29	27	26	26
EauClair	WI	–13	24	88	81	0.0129	0.0134	0.0092	0.0094	35	34	29	29
Green Bay	WI	–7	27	86	79	0.0133	0.0129	0.0093	0.0092	35	33	29	29
La Crosse	WI	–8	29	88	81	0.0144	0.0131	0.0098	0.0092	37	34	29	29
Madison	WI	–6	28	88	79	0.0129	0.0123	0.0092	0.0089	35	33	29	28
Milwaukee	WI	–2	31	86	79	0.0133	0.0130	0.0093	0.0092	35	33	29	29
Charleston	WV	11	37	88	81	0.0144	0.0127	0.0098	0.0091	37	33	29	29
Huntington	WV	11	37	88	80	0.0144	0.0134	0.0098	0.0093	37	34	29	29
Casper	WY	–5	30	90	82	0.0026	0.0054	0.0051	0.0062	24	26	24	25
Cheyenne	WY	0	32	84	80	0.0038	0.0069	0.0055	0.0068	24	27	25	26
Rock Springs	WY	–2	29	84	79	0.0018	0.0043	0.0047	0.0057	22	24	24	25
Sheridan	WY	–7	30	90	82	0.0048	0.0081	0.0059	0.0072	27	28	25	27
Edmonton	AB	–23	21	78	76	0.0080	0.0082	0.0072	0.0073	27	27	27	27
Montreal	PQ	–8	27	83	77	0.0126	0.0124	0.0090	0.0090	34	32	29	29
Vancouver	BC	23	44	74	73	0.0103	0.0104	0.0081	0.0082	29	29	28	28
Toronto	ON	1	26	84	78	0.0123	0.0126	0.0089	0.0090	34	33	28	29
Winnipeg	MN	–24	16	84	79	0.0104	0.0092	0.0082	0.0077	32	29	28	27

TABLE 6.3.2-1 Heating System Location Temperatures

Duct Location	Design Conditions		Seasonal Conditions	
	Temperature, °C	Temperature, °F	Temperature, °C	Temperature, °F
Attic	$t_{design} + 6$	$t_{design} + 10$	$t_{seasonal} + 4$	$t_{seasonal} + 7$
Garage	$t_{design} + 7$	$t_{design} + 13$	$t_{seasonal} + 6$	$t_{seasonal} + 11$
Underslab	t_{ground}		t_{ground}	
Exterior walls	$(t_{in} + t_{design})/2$		$(t_{in} + t_{seasonal})/2$	
Crawl space	Equations 6-2 to 6-4, $t_{out} = t_{design}$		Equations 6-2 to 6-4, $t_{out} = t_{seasonal}$	
Basement	Equations 6-2 to 6-4, $t_{out} = t_{design}$		Equations 6-2 to 6-4, $t_{out} = t_{seasonal}$	

TABLE 6.3.2-2 Cooling System Location Conditions

Duct Location	Design Conditions			Seasonal Conditions		
	Temp. Dry Bulb, °C	Temp. Dry Bulb, °F	Humidity	Temp. Dry Bulb, °C	Temp. Dry Bulb, °F	Humidity
Attic (Well Vented)	$t_{design} + 12$	$t_{design} + 22$	w_{design}	$t_{seasonal} + 7$	$t_{seasonal} + 13$	$w_{seasonal}$
Attic (Poorly Vented)	$t_{design} + 20$	$t_{design} + 36$	w_{design}	$t_{seasonal} + 9$	$t_{seasonal} + 16$	$w_{seasonal}$
Garage	$t_{design} + 4$	$t_{design} + 7$	w_{design}	$t_{seasonal} + 4$	$t_{seasonal} + 7$	$w_{seasonal}$
Underslab	t_{ground}		$w_{in,design}$	t_{ground}		$w_{in,seasonal}$
Exterior Walls	$(t_{in} + t_{design})/2$		$w_{in,design}$	$(t_{in} + t_{seasonal})/2$		$w_{in,seasonal}$
Crawl Space	Equations 6-2 to 6-4, $t_{out} = t_{design}$		w_{design}	Equations 6-2 to 6-4, $t_{out} = t_{seasonal}$		$w_{seasonal}$
Basement	Equations 6-2 to 6-4, $t_{out} = t_{design}$		$w_{in,design}$	Equations 6-2 to 6-4, $t_{out} = t_{seasonal}$		$w_{in,seasonal}$

TABLE 6.3.2-3 Default U-Factors for Use in Equations 6-1 through 6-4

Duct Location	Btu/(ft²·°F)				W/(m²·K)			
	U_{in}	U_{out}	U_{ground}	U_{infil}	U_{in}	U_{out}	U_{ground}	U_{infil}
Vented crawl w/insulated floor	0.0667	0.5	0.1	0.3	0.379	2.838	0.568	1.703
Vented crawl w/insulated walls	0.5	0.1	0.1	0.3	2.838	0.568	0.568	1.703
Vented crawl, uninsulated	0.5	0.5	0.1	0.3	2.838	2.838	0.568	1.703
Vented crawl, insulated walls and floor	0.0667	0.1	0.1	0.3	0.379	0.568	0.568	1.703
Unvented crawl w/insulated floor	0.0667	0.5	0.1	0.06	0.379	2.838	0.568	0.341
Unvented crawl w/insulated walls	0.5	0.1	0.1	0.06	2.838	0.568	0.568	0.341
Unvented crawl, uninsulated	0.5	0.5	0.1	0.06	2.838	2.838	0.568	0.341
Unvented crawl, insulated walls and floor	0.0667	0.1	0.1	0.06	0.379	0.568	0.568	0.341
Basement, insulated floor	0.0667	0.1	0.1	0.0144	0.379	0.568	0.568	0.082
Basement, insulated walls	0.5	0.05	0.1	0.0144	2.838	0.284	0.568	0.082
Basement, uninsulated	0.5	0.1	0.1	0.0144	2.838	0.568	0.568	0.082

$$t_{b,off} = \frac{\sum \mathrm{UA}_j T_j}{\sum \mathrm{UA}_j}$$

$$= \frac{(\mathrm{UA})_{in} t_{in} + [(\mathrm{UA})_{out} + (\mathrm{UA})_{infil}] t_{out} + (\mathrm{UA})_{ground} t_{ground}}{(\mathrm{UA})_{in} + (\mathrm{UA})_{out} + (\mathrm{UA})_{infil} + (\mathrm{UA})_{ground}} \tag{6-1}$$

6.3.2.2 Temperature and Humidity with Conditioning System On

6.3.2.3 Supply and Return Ducts in the Same Location. The temperature of the crawl space or basement with the conditioning system on is:

$$t_{amb,b} = \frac{\sum \mathrm{UA}_j t_j + [(1 - a_s B_s)\Delta t_e + a_r(1 - a_s B_s B_r) t_{in}] Q_e \rho_{in} c_p}{\sum \mathrm{UA}_j + a_r(1 - a_s B_s B_r) Q_e \rho_{in} c_p} \tag{6-2}$$

6.3.2.3.1 Supply and Return Ducts in Different Locations. The temperature of a crawl space or basement containing only supply ducts with the conditioning system on is:

$$t_{amb,s} = \frac{\sum \mathrm{UA}_j t_j + \{[1 - a_s B_s][\Delta t_e + a_r B_r t_{in} + (1 - a_r B_r) t_r]\} Q_e \rho_{in} c_p}{\sum \mathrm{UA}_j + (1 - a_s B_s) Q_e \rho_{in} c_p} \tag{6-3}$$

The temperature of a crawl space or basement containing only return ducts with the conditioning system on is:

$$t_{amb,r} = \frac{\sum \mathrm{UA}_j t_j + a_r(1 - B_r) t_{in} Q_e \rho_{in} c_p}{\sum \mathrm{UA}_j + a_r(1 - B_r) Q_e \rho_{in} c_p} \tag{6-4}$$

6.3.3 Geographic Climate Conditions

6.3.3.1 Ground Temperature. The ground temperature shall be determined by averaging winter and summer design temperatures from Table 6.3.1-1 or Table 6.3.1-2, using Equation 6-5:

$$t_{ground} = \frac{t_{winter,design} + t_{summer,design}}{2} \tag{6-5}$$

6.3.3.2 Attic Temperature Reduction Measures. When radiant barriers, reduced-absorptivity exterior coatings, or tiled roofs are installed, Table 6.3.3.2 shall be used to calculate duct ambient temperatures in attics based on the data in Table 6.3.2-3 and Section 6.3.1. For radiant barriers, the duct system must be installed below the radiant barrier and the attic must be well-vented. Note that these temperature reductions only apply to cooling calculations when $t_{attic} > t_{in}$.

6.3.3.3 Enthalpy Calculations for Cooling Systems. The indoor air enthalpy shall be taken from Table 6.3.1-1 or Table 6.3.1-2. Enthalpies shall be calculated for return duct locations using Equation 6-6a or Equation 6-6b. The dry-bulb temperature for those locations shall be determined from Table 6.3.2-3. The humidity ratio shall be either the indoor or outdoor air humidity ratio (from Table 6.3.1-1 or Table 6.3.1-2), depending upon the entries in Table 6.3.2-3. If applicable, the dry-bulb temperatures used for attic humidity calculations shall have the corrections of Section 6.3.3.2. For design conditions, the design dry-bulb temperature and humidity ratio shall be used. For seasonal conditions, the seasonal dry-bulb temperature and humidity ratio shall be used.

$$h = 1.006t + w(2501 + 1.805t) \qquad \text{[SI]} \tag{6-6a}$$

$$h = 0.240t + w(1061 + 0.444t) \qquad \text{[I-P]} \tag{6-6b}$$

6.3.4 Duct-Wall Thermal Resistance. Duct-wall thermal resistance shall be determined by visual observation of the ducts.

6.3.4.1 Marked Ducts. If the ducts have visible manufacturer's marking of duct-wall thermal resistance, then this marking shall be used.

6.3.4.2 Unmarked Ducts. If the ducts are unmarked, then the insulation thickness shall be measured and the type of insulation (e.g., glass fiber) noted. The duct-wall thermal resistance shall then be calculated based on the insulation type and thickness using calculation procedures from the 2009 *ASHRAE Handbook—Fundamentals*[3], or equivalent.

6.3.5 Duct Surface Areas and Locations. Duct surface areas in each duct location (A_i) and fraction of ducts outside conditioned space (F_{out}) shall be determined as specified in Section 6.3.5.1 or 6.3.5.2.

6.3.5.1 Direct Measurement. The surface areas of supply and return ducts in each duct location shall be determined by measuring the length and perimeter of the ducts in each location, with an A_i for each duct location. The supply and return surface areas in each location shall then be summed to obtain A_s and A_r, respectively. The total duct surface area shall be determined by estimating the duct surface areas inside conditioned space based on observations of duct diameter, register placement, and duct runs. F_{out} is the ratio of the duct surface area outside conditioned space ($A_s + A_r$) to the total duct surface area.

6.3.5.2 Default. F_{out} shall be set equal to 1.0 for single-story houses and 0.75 for houses with more than one story. Areas of supply and return ducts outside the conditioned space shall be determined using Equations 6-7a and 6-7b, respectively:

$$A_s = 0.27(F_{out} A_{floor}) \tag{6-7a}$$

$$A_r = b_r F_{out} A_{floor} \tag{6-7b}$$

where b_r shall be taken from Table 6.3.5.2.

These supply and return duct areas shall be apportioned among buffer spaces to calculate the A_i values by estimation based upon visual observation.

6.3.6 Air-Handler Fan Flow. The air-handler fan flow shall be determined using the test procedure in ASTM E1554-07[4] or Appendix A. Any intentional ventilation intakes to the return ducts shall be kept open during the air-handler fan flow testing process. For buildings with both heating and cooling equipment sharing the same ducts, the air-handler fan flow shall be determined individually for heating and for cooling. For systems with variable-capacity equipment that change the air-han-

TABLE 6.3.5.2 Return Duct Surface Area Coefficient, b_r (m^2/m^2 floor area and ft^2/ft^2 floor area)

Number of Return Registers	b_r
1	0.05
2	0.1
3	0.15
4	0.2
5 or more	0.25

TABLE 6.3.8 Effect of Duct Thermal Mass on Energy Delivered to Conditioned Space

Duct Material	F_{cyc}
Nonmetallic (plastic flex duct or duct board)	0.02
Sheet metal	0.05

dler fan flow, the air-handler fan flow shall be measured at both high- and low-speed operating conditions.

6.3.7 Duct Leakage Flow Rate. Any intentional ventilation intakes to return ducts shall be closed or sealed during fan-pressurization and operating-pressure testing.

Q_s and Q_r shall be determined using either test methods A or B in ASTM E1554-07[4]. Test method D in ASTM E1554-07 may be used as an alternative.

Test method D shall only be used for efficiency calculations if the total duct leakage (supply plus return), including any adjustments (see below), is less than 10% of the air-handler flow.

a. If the test is performed without the air-handler installed, then add 2.5% of the air-handler fan flow to the measured leakage.
b. If the test is performed without the register grilles installed, then add 2.5% of the air-handler fan flow to the measured leakage.
c. If the test is performed with neither the air-handler nor register grilles installed, then add 5% of the air-handler fan flow to the measured leakage.

If test method D is used, the pressure difference across the leaks during air-handler fan operation shall be obtained from either:

a. The manufacturer's specification of the air-handler fan pressure difference.
b. A default pressure difference across the air-handler fan of 125 Pa (0.5 inches H_20).

The air-handler fan pressure difference shall be divided equally between the return and supply plenums (i.e., $\Delta P_{rp} = 0.5\Delta P_{fan}$, $\Delta P_{sp} = 0.5\Delta P_{fan}$). For ducts within the conditioned space, some leakage will be to the inside. The fraction of leakage to the outside shall be the same as the ratio of duct area outside the conditioned space to the total duct area (F_{out}), from Section 6.3.5. Should the value of F_{out} from Section 6.3.5 be less than 0.5, a minimum value of 0.5 for F_{out} shall be used in Equation 6.8.

The duct leakage flows for the supply and return (Q_s, Q_r) shall be calculated using Equation 6.8, where $Q_{25,\,total}$ is the test result from test method D of ASTM E1554-07:

Supply

$$Q_s = F_{out}\frac{Q_{25,\,total}}{2}\left(\frac{\Delta P_{sp}}{25}\right)^{0.6} \quad \text{[SI]} \qquad (6\text{-}8a)$$

Return

$$Q_r = F_{out}\frac{Q_{25,\,total}}{2}\left(\frac{\Delta P_{rp}}{25}\right)^{0.6} \quad \text{[SI]} \qquad (6\text{-}8b)$$

Supply

$$Q_s = F_{out}\frac{Q_{0.1,\,total}}{2}\left(\frac{\Delta P_{sp}}{0.1}\right)^{0.6} \quad \text{[I-P]} \qquad (6\text{-}8c)$$

Return

$$Q_r = F_{out}\frac{Q_{0.1,\,total}}{2}\left(\frac{\Delta P_{rp}}{0.1}\right)^{0.6} \quad \text{[I-P]} \qquad (6\text{-}8d)$$

6.3.8 Duct Thermal Mass ($F_{cycloss}$). The cyclic loss factor, F_{cyc}, for different duct materials shall be taken from Table 6.3.8. These cyclic losses are only applied to the fraction of supply ducts outside conditioned space (F_{out}):

$$F_{cycloss} = F_{cyc}F_{out} \qquad (6\text{-}9)$$

6.4 Delivery Effectiveness Calculations. Design delivery effectiveness, DE_{design}, shall be calculated using the design temperatures from Tables 6.3.2-1, 6.3.2-2, or 6.3.2-3.

Seasonal delivery effectiveness, $DE_{seasonal}$, shall be calculated using the seasonal temperatures from Tables 6.3.2-1, 6.3.2-2, or 6.3.2-3.

6.4.1 Calculation of Characteristic Temperatures and Enthalpies Outside Conditioned Space. The temperatures and enthalpies for locations outside the conditioned space shall be determined from Section 6.3.2 for design and seasonal conditions and for heating and cooling. If the distribution system is not in a single location, the ambient temperature to be used in the effectiveness calculations shall be determined using a duct-surface-area weighted average of the location temperatures as given by Equations 6-10 and 6-11:

$$t_{amb,\,s} = \frac{\sum\limits_{i\,=\,\text{location}}^{\substack{\text{all system supply locations}\\ \text{outside conditioned space}}} A_i t_i}{A_s} \qquad (6\text{-}10)$$

$$t_{amb,\,r} = \frac{\sum\limits_{i\,=\,\text{location}}^{\substack{\text{all system supply locations}\\ \text{outside conditioned space}}} A_i t_i}{A_r} \qquad (6\text{-}11)$$

For duct systems, the return ambient temperature, $t_{amb,\,r}$, shall be limited as specified by the following equations:

For *heating, design,* if $t_{amb,\,r} > t_{in}$ then:

$$t_{amb,\,r} = \frac{t_{design} + \dfrac{\sum_{i\,=\,\text{duct location}}^{\substack{\text{all return duct locations}\\\text{outside conditioned space}}} A_i t_i}{A_r}}{2} \qquad (6\text{-}12)$$

For *heating, seasonal,* if $t_{amb,\,r} > t_{in}$ then:

$$t_{amb,\,r} = \frac{t_{seasonal} + \dfrac{\sum_{i\,=\,\text{duct location}}^{\substack{\text{all return duct locations}\\\text{outside conditioned space}}} A_i t_i}{A_r}}{2} \qquad (6\text{-}13)$$

For *cooling, design*, if $t_{amb,\,r} < t_{in}$ then:

$$t_{amb,\,r} = \frac{t_{design} + \dfrac{\sum_{i\,=\,\text{duct location}}^{\substack{\text{all return duct locations}\\\text{outside conditioned space}}} A_i t_i}{A_r}}{2} \qquad (6\text{-}14)$$

For *cooling, seasonal,* if $t_{amb,\text{r}} < t_{in}$ then:

$$t_{amb,\,r} = \frac{t_{seasonal} + \dfrac{\sum_{i\,=\,\text{duct location}}^{\substack{\text{all return duct locations}\\\text{outside conditioned space}}} A_i t_i}{A_r}}{2} \qquad (6\text{-}15)$$

For cooling systems, the enthalpy of the air surrounding return ducts in different locations shall be surface-area-weighted as specified in the following equations:

$$h_{amb,\,r} = \frac{\sum_{i\,=\,\text{duct location}}^{\substack{\text{all return duct locations}\\\text{outside conditioned space}}} A_i h_i}{A_r} \qquad (6\text{-}16)$$

For *cooling, design*, if $h_{amb,\,r} < h_{in}$ then:

$$h_{amb,\,r} = \frac{h_{out} + \dfrac{\sum_{i\,=\,\text{duct location}}^{\substack{\text{all return duct locations}\\\text{outside conditioned space}}} A_i h_i}{A_r}}{2} \qquad (6\text{-}17)$$

where h_{out} is for design conditions from Table 6.3.1-1 or 6.3.1-2.

For *cooling, seasonal*, if $h_{amb,\,r} < h_{in}$, then use Equation 6-13 with h_{out} for seasonal conditions from Table 6.3.1-1 or 6.3.1-2.

6.4.2 Delivery Effectiveness (DE) for Heating Systems. For variable-capacity equipment, DE shall be calculated using high capacity (and air-handler fan flow) for design calculations and low capacity (and air-handler fan flow) for seasonal calculations. For heat pumps with a single air-handler fan flow but with variable capacity, use the same air-handler fan flow for design and seasonal calculations.

The supply and return conduction fractions, B_s and B_r, shall be calculated with the following equations:

$$B_s = \exp\left(\frac{-A_s}{Q_e \rho_{in} C_p R_s}\right) \quad \text{[SI]} \qquad (6\text{-}18)$$

$$B_r = \exp\left(\frac{-A_r}{Q_e \rho_{in} C_p R_r}\right) \quad \text{[SI]} \qquad (6\text{-}19)$$

$$B_s = \exp\left(\frac{-A_s}{60 Q_e \rho_{in} C_p R_s}\right) \quad \text{[I-P]} \qquad (6\text{-}20)$$

$$B_r = \exp\left(\frac{-A_r}{60 Q_e \rho_{in} C_p R_r}\right) \quad \text{[I-P]} \qquad (6\text{-}21)$$

where ρ_{in} is the density of indoor air (use 1.2 kg/m^3 [0.075 lb/ft^3] at sea level), and C_p is the specific heat of air (use 1000 J/[kg·K] [0.24 Btu/{lb·°F}]). The duct leakage factors for the supply and return sides shall be calculated using Equations 6-22 and 6-23:

$$a_s = \frac{Q_e - Q_s}{Q_e} \qquad (6\text{-}22)$$

$$a_r = \frac{Q_e - Q_r}{Q_e} \qquad (6\text{-}23)$$

The temperature rise across the furnace, Δt_e, shall be calculated based on the equipment capacity (adjusted in accordance with manufacturers's instructions), E_{cap}, and the system air flow, Q_e.

$$\Delta t_e = \frac{E_{cap}}{Q_e \rho_{in} C_p} \quad \text{[SI]} \qquad (6\text{-}24)$$

$$\Delta t_e = \frac{E_{cap}}{60 Q_e \rho_{in} C_p} \quad \text{[I-P]} \qquad (6\text{-}25)$$

The difference between the building and the ambient temperature surrounding the supply, Δt_s, and return, Δt_r, shall be calculated with Equations 6-26 and 6-27:

$$\Delta t_s = t_{in} - t_{amb,\,s} \qquad (6\text{-}26)$$

$$\Delta t_r = t_{in} - t_{amb,\,r} \qquad (6\text{-}27)$$

The delivery effectiveness shall be calculated using Equation 6-28:

$$\text{DE} = a_s B_s - a_s B_s (1 - B_r a_r)\frac{\Delta t_r}{\Delta t_e} - a_s (1 - B_s)\frac{\Delta t_s}{\Delta t_e} \qquad (6\text{-}28)$$

TABLE 6.5.1 Equipment Efficiency Factor (F_{equip})

Capacity	Calculation Conditions	Cooling F_{equip} Air Conditioning or Heat Pump		Heating F_{equip} Gas, Oil, or Electric Furnace	Heating F_{equip} Heat Pump[a]
		Thermostatic[b] Control	Orifice Control		
Single	Design and seasonal	$1.62 - 0.62Q_e/Q_{e,\ rated} + 0.647\ \ln(Q_e/Q_{e,\ rated})$	$0.65 + 0.35 \times (Q_e/Q_{e,\ rated})$	1.0	n/a
Variable	Design	$1.62 - 0.62Q_e/Q_{e,rated} + 0.647\ \ln(Q_e/Q_{e,rated})$	$0.65 + 0.35 \times (Q_e/Q_{e,\ rated})$	1.0	1.0
Variable	Seasonal	$(0.82 + 0.18\text{DE}) \times (1.62 - 0.62Q_e/Q_{e,\ rated} + 0.647\ \ln[Q_e/Q_{e,\ rated}])$	$(0.82 + 0.18\text{DE}) \times (0.65 + 0.35 \times [Q_e/Q_{e,rated}])$	0.91 + 0.09DE	0.44 + 0.56DE

a. A heat pump is variable capacity if it has electric resistance (strip) heat.

b. The equations for thermostatic control were developed for $1.0 > Q_e/Q_{e,\ rated} > 0.5$, and use outside these limits is not recommended. When $Q_e > Q_{e,\ rated}$ then set $Q_e = Q_{e,\ rated}$ in this equation.

6.4.3 Delivery Effectiveness (DE) for Cooling Systems. The delivery effectiveness shall be calculated using the system flow rate during cooling, Q_e, from Section 6.3.6.

For variable-capacity equipment, DE shall be calculated using high capacity (and air-handler fan flow) for design calculations and low capacity (and air-handler fan flow) for seasonal calculations**.**

B_s and B_r shall be determined using Equations 6-18 to 6-21; a_s and a_r shall be determined using Equations 6-22 and 6-23. Δt_r shall be determined using Equation 6-27. t_{sp} is the supply plenum dry-bulb temperature, which depends on latent load and shall be calculated using *ACCA Manual S—Residential Equipment Selection*[5] or assumed to be 13°C (55°F). Δt_e shall be calculated using Equations 6-24 and 6-25 for use in the efficiency calculation sections 6.5.4 and 6.5.5. The equipment capacity (E_{cap}) for cooling systems must be negative in Equations 6-24, 6-25, 6-29, and 6-30.

$$\text{DE} = \frac{a_s Q_e \rho_{in}}{E_{cap}} \times \left[\frac{E_{cap}}{Q_e \rho_{in}} + (1 - a_r)(h_{amb,\ r} - h_{in}) + a_r C_p (B_r - 1)\Delta t_r + C_p (B_s - 1)(t_{sp} - t_{amb,\ s})\right] \quad \text{[SI]} \quad (6\text{-}29)$$

$$\text{DE} = \frac{a_s 60 Q_e \rho_{in}}{E_{cap}} \times \left[\frac{E_{cap}}{60 Q_e \rho_{in}} + (1 - a_r)(h_{amb,\ r} - h_{in}) + a_r C_p (B_r - 1)\Delta t_r + C_p (B_s - 1)(t_{sp} - t_{amb,\ s})\right] \quad \text{[I-P]} \quad (6\text{-}30)$$

6.5 Distribution System Efficiency. For variable-capacity equipment, F_{load} and F_{recov} shall be calculated using high capacity (and air-handler fan flow) for design calculations and low capacity (and air-handler fan flow) for seasonal calculations.

6.5.1 Equipment Efficiency Factor (F_{equip}). F_{equip} shall be taken from Table 6.5.1. The air-handler fan flow impacts on compressor-equipment efficiency shall be determined using the measured air-handler fan flow (according to Appendix A), which shall be compared with the manufacturer's rated flow at equipment efficiency rating conditions. The manufacturer's rated flow shall have a default value of 0.0537 $m^3/s/kW$ (0.0333 cfm/Btu/h) if more specific ratings do not exist. These default values are equivalent to 400 cfm/ton, the prevalent flow at equipment rating conditions.

6.5.2 Thermal Regain ($F_{regain,\ s}$ and $F_{regain,\ r}$). A regain factor, F_{regain}, shall be calculated separately for supply and return locations and given the designation $F_{regain,\ s}$ and $F_{regain,\ r}$, respectively. They shall be calculated as:

$$F_{regain} = (\text{UA})_{in} \frac{t_{amb} - t_{b,\ off}}{Q_e \rho_{in} c_p \Delta t_e} \quad (6\text{-}31)$$

6.5.3 Air Infiltration Factor (F_{load}). The natural infiltration rate for these calculations (Q_{inf}) shall be obtained from ANSI/ASHRAE Standard 62.2-2013[6] or shall be calculated assuming a ventilation rate of 0.35 air changes per hour (ACH), using the building volume, V (calculated from building plans or measured interior dimensions), using Equations 6-32 and 6-33:

$$Q_{inf} = \frac{0.35V}{3600} \quad \text{[SI]} \quad (6\text{-}32)$$

$$Q_{inf} = \frac{0.35V}{60} \quad \text{[I-P]} \quad (6\text{-}33)$$

F_{load} shall be calculated for both design and seasonal conditions. For variable-capacity equipment, use high capacity for design calculations and low capacity for seasonal calculations. The imbalance between supply and return leakage shall be calculated using Equation 6-34:

$$Q_{imb} = |Q_s - Q_r| \quad (6\text{-}34)$$

If $Q_s > Q_r$, then Q_{net} shall be calculated using Equation 6-35:

$$Q_{net} = (Q_{inf}^{1.5} + Q_{imb}^{1.5})^{0.67} \quad (6\text{-}35)$$

If $Q_s < Q_r$ and $Q_{imb} > Q_{inf}$, then $Q_{net} = 0$.

If $Q_s < Q_r$ and $Q_{imb} < Q_{inf}$, then Q_{net} shall be calculated using Equation 6-36:

$$Q_{net} = (Q_{inf}^{1.5} - Q_{imb}^{1.5})^{0.67} \qquad (6\text{-}36)$$

For heating, F_{load} shall be calculated using the following equations, where t_{out} is t_{design} for design calculations and $t_{seasonal}$ for seasonal calculations, both of which are tabulated by climate in Table 6.3.1-1.

For heating, Equations 6-37 and 6-38 shall be used.

$$F_{load} = 1 - \frac{\rho_{in} C_p (t_{in} - t_{out})(Q_{net} - Q_{inf})}{E_{cap}\mathrm{DE}} \qquad [\mathrm{SI}]\ (6\text{-}37)$$

$$F_{load} = 1 - \frac{60\rho_{in} C_p (t_{in} - t_{out})(Q_{net} - Q_{inf})}{E_{cap}\mathrm{DE}} \qquad [\mathrm{I\text{-}P}](6\text{-}38)$$

For cooling, Equations 6-39 and 6-40 shall be used, where h_{out} is outdoor air enthalpy and is equal to the seasonal value for seasonal calculations and the design value for design calculations. h_{out} shall be taken from Table 6.3.1-1. E_{cap} must be negative for cooling in Equations 6-39 and 6-40.

$$F_{load} = 1 - \frac{\rho_{in} (h_{in} - h_{out})(Q_{net} - Q_{inf})}{E_{cap}\mathrm{DE}} \qquad [\mathrm{SI}]\ (6\text{-}39)$$

$$F_{load} = 1 - \frac{60\rho_{in} (h_{in} - h_{out})(Q_{net} - Q_{inf})}{E_{cap}\mathrm{DE}} \qquad [\mathrm{I\text{-}P}](6\text{-}40)$$

6.5.4 Seasonal Distribution System Efficiency. The delivery effectiveness corrected for regain, DE_{corr}, shall be calculated using Equation 6-41:

$$\mathrm{DE}_{corr,\,seasonal} = \mathrm{DE}_{seasonal} + F_{regain,\,s} + F_{regain,\,r} \qquad (6\text{-}41)$$

The seasonal distribution system efficiency shall be calculated using Equation 6-42:

$$\eta_{dist,\,seasonal} = \mathrm{DE}_{corr,\,seasonal} F_{equip} F_{load} (1 - F_{cycloss}) \qquad (6\text{-}42)$$

6.5.5 Design Distribution System Efficiency. The delivery effectiveness corrected for regain, DE_{corr}, shall be calculated using Equation 6-43:

$$\mathrm{DE}_{corr,\,design} = \mathrm{DE}_{design} + F_{regain,\,s} + F_{regain,\,r} \qquad (6\text{-}43)$$

The design distribution system efficiency shall be calculated using Equation 6-44:

$$\eta_{dist,\,design} = \mathrm{DE}_{corr,\,design} F_{equip} F_{load} (1 - F_{cycloss}) \qquad (6\text{-}44)$$

7. HYDRONIC DISTRIBUTION SYSTEMS

This section applies to baseboard convectors using single-loop liquid hydronic piping systems for heating only.

7.1 Instrumentation Specifications

7.1.1 Temperature Measurements. Temperatures at specified points in the piping system shall be measured using systems (i.e., sensor plus data-acquisition system) having an accuracy of ±0.25°C (0.5°F).

7.1.2 Linear Dimensions. Linear dimensions of piping shall be measured to an accuracy of ±5%.

7.2 Apparatus. Temperatures shall be measured at a specified point on the pipe by attaching the sensor to the pipe in good thermal contact with it. Sensors that measure inlet and outlet temperatures of the piping loop shall be isolated from the surrounding air using an insulating patch having thermal conductivity less than 0.05 W/m·K (0.03 Btu/h·ft·°F), at least 1 cm (0.4 in.) thick and extending laterally at least 5 cm (2 in.) in all directions.

7.3 Procedure. The calculation procedure for determining delivery effectiveness and distribution system efficiency is based on the following major input parameters:

a. pipe dimensions
b. pipe thermal properties
c. pipe location

7.3.1 Piping Dimensions. A single-loop hydronic distribution system is made up of four basic components:

a. finned-tube baseboards (all assumed in the conditioned space)
b. unfinned piping in the conditioned space
c. unfinned piping in buffer zones that is not insulated
d. unfinned piping in buffer zones that is insulated

The length of pipe in each section is required in the calculation procedure. The lengths are determined from building plans or from diagnostics.

A diagram of the hydronic loop shall be made with notations identifying portions of the loop that fall under each of the four classifications listed in Section 7.3.1. The linear dimensions listed in each category in Section 7.3.1 shall be measured.

7.3.2 Thermal Properties of Piping

7.3.2.1 Thermal Conductances. Piping and terminal units in each of the four categories are characterized by thermal conductance (W/[m·K] or Btu/[h·ft·°F]), either from manufacturer's data or from simple calculations.

7.3.2.1.1 Finned-Tube Baseboards. Thermal conductance to conditioned space (k_{rc}) shall be obtained from manufacturer's data on heat transfer vs. pipe temperature. The ϕ_{man} value at the highest water temperature that is less than $t_{hotwater}$ shall be used. If such data are not available, a value calculated based on fin area may be used, as follows. Measure fin area per unit length of baseboard (fin height × fin depth × number of fins per unit length) [m^2/m or in.^{2}/ft]. Multiply by the coefficient 0.016 Btu/(h·°F·in.^{2}) or 13 W/(K·m^2).

Thermal conductance to outside ambient (k_{ra}) shall equal y/R_w.

7.3.2.1.2 Unfinned Piping in the Buffer Space. The U-factors for insulated and uninsulated piping in the buffer space shall be determined in one of two ways: either from a table or by calculation.

A table shall be used when the piping has one of the nominal diameters listed in this standard and the insulation thickness is between 1.3 and 5.1 cm (0.5 and 2.0 in.). The actual outer diameter of the pipe shall be measured and compared with these values to determine the applicability of table lookup. If the specified pipe and insulation material are in Tables 7.3.2.1-1 or 7.3.2.1-2, the conductivity values, $k_{b,\ ins}$ and $k_{b,\ unins}$, shall be determined from Tables 7.3.2.1-1 or 7.3.2.1-2.

Calculations shall be used if the pipe or insulation values are not listed in Tables 7.3.2.1-1 or 7.3.2.1-2. For bare copper pipe, $U_{conv\ +\ rad}$ shall equal 7 W/(m^2·K) (1.75 Btu/[h·ft^2·°F]). For other bare pipe and for insulated pipe, $U_{conv\ +\ rad}$ shall equal 13.6 W/(m^2·K) (2.4 Btu/[h·ft^2·°F]). If the thermal conductivity, k, of the insulating material is not provided by the manufacturer, then Table 7.3.2.1-3 shall be used. The material, if unspecified, shall be corrugated sheathing. The thermal conductivity of insulated unfinned piping in the buffer space shall be calculated using Equation 7-1. The conductance of uninsulated unfinned piping in the buffer space shall be calculated using Equation 7-2.

$$k_{b,\,ins} = \frac{2\pi}{\frac{1}{k}\ln\left(\frac{d_{ins}}{d_{pipe}}\right) + \frac{2}{d_{ins}U_{conv+rad}}} \tag{7-1}$$

$$k_{b,\,unins} = \pi d_{pipe} U_{conv+rad} \tag{7-2}$$

7.3.2.1.3 Unfinned Piping in Conditioned Space. The thermal conductance values to the conditioned space (k_{uc}) and outside (k_{ua}) shall be calculated using Equations 7-3a and 7-3b, respectively (R_{uc} shall equal 0.4 m^2·K/W [2 ft·^{2}h·°F/Btu]):

$$k_{ua} = \frac{y}{R_w} \tag{7-3a}$$

R_w shall be corrected for any reduction in insulation due to installation of the baseboard (e.g., if the baseboard is recessed into the wall).

$$k_{uc} = \frac{y}{R_{uc}} \tag{7-3b}$$

If piping is in the wall, these values shall be calculated using Equation 7-4.

$$k_{ua} = k_{uc} = \frac{2y}{R_w + R_{uc}} \tag{7-4}$$

R_w shall be corrected for any reduction in insulation due to installation of the baseboard (e.g., if the baseboard is recessed into the wall).

7.3.2.2 Thermal Capacitance per Unit Length. If the system loop is composed of 1/2 in., 3/4 in., or 1 in. nominal copper piping, the thermal capacitances per unit length, expressed in J/(K·m) pipe or Btu/(°F·ft) pipe, for finned and unfinned sections, shall be determined using Table 7.3.2.2. If the table is not applicable, the formulas in Section 7.3.2.2.2 shall be used.

7.3.2.2.1 Thermal Capacitance per Unit Length—Table Lookup. See Table 7.3.2.2.

7.3.2.2.2 Thermal Capacitance per Unit Length—Formula. The following variables are required for the thermal capacitance calculations.

a. Cv_{pipe}, volumetric heat capacity of pipe. The value for copper may be used: 3.4 × 10^6 J/(m^3·K) or 51 Btu/(ft^3·°F). For thermoplastic and rubber compound tubing, use 2.2 × 10^6 J/(m^3·K) or 33 Btu/(ft^3·°F).

b. Cv_{water}, volumetric heat capacity of water: 4.1 × 10^6 J/(m^3·K) or 61 Btu/(ft^3·°F).

c. Cv_{ins}, volumetric heat capacity of pipe insulation. The value for polystyrene may be used: 0.03 × 10^6 J/(m^3·K) or 0.5 Btu/(ft^3·°F).

d. K_{fins}, heat capacity of fins per unit length of pipe. For finned pipe, the value shall be 200 J/(K·m) pipe or 0.03 Btu/(°F·ft) pipe. For unfinned pipe, $K_{fins} = 0$.

The thermal capacitance per unit length, for each of the pipe categories, shall be calculated using Equation 7-5.

$$K_x = \frac{\pi}{4}[(d_{ins}^2 - d_{pipe}^2)Cv_{ins} + d_{pipe}^2(0.19Cv_{pipe} + 0.81Cv_{water})] + K_{fins} \tag{7-5}$$

where $K_x = K_r$, K_u, $K_{b,\ ins}$, and $K_{b,\ unins}$ for each category.

7.3.2.3 Diagnostic Thermal Properties

7.3.2.3.1 Sensor Installation. A temperature sensor meeting the specifications of Sections 7.1 and 7.2 shall be installed on the section of hydronic pipe immediately adjacent to the boiler or water heater, on the outlet from the hydronic system (return to the boiler or water heater).

7.3.2.3.2 Additional Temperature Measurements. The boiler or water heater water temperature, $t_{hotwater}$, shall be set equal to the midpoint of the upper and lower settings on the aquastat.

7.3.2.3.3 Circulator-on Test. Set back the thermostat at least 5°C (9°F) from normal setpoint and allow it to remain there for at least one hour. At the start of the test, increase the thermostat setting by at least 15°C (27°F) so that the circulating pump comes on. Record the hydronic outlet temperature at least once every 10 seconds, until the presence of warm water in the outlet is clearly evidenced by an abrupt rise in temperature.

7.3.2.3.4 Estimation of Water Flow Rate. The water flow rate, $Q_{e,\,H_2O}$, shall be estimated as the ratio of water volume within the hydronic loop to the time required for the initial slug of warm water to emerge from the system. The water volume within the loop shall equal the total length of pipe multiplied by the inner cross-sectional area of the pipe. If pipes of differing inner diameter are represented in the system, the total volume shall be obtained by summing the volumes of each pipe size. The circulation time of the system shall be set equal to the difference between (1) the earliest time (with circulator startup at time-zero) for which the measured outlet temperature exceeds the range of cold-system temperatures observed earlier in the test, and for which the outlet temperature thereafter increases monotonically to a higher range representative of continuous circulator operation, and (2) one-half the time interval between temperature measurements.

7.3.3 Other Thermal Properties. Table 7.3.3 contains values of thermal properties required in the following calculations.

These values shall be used unless alternative values are specified in the building plans.

TABLE 7.3.2.1-1 Thermal Conductances for Common Pipe Sizes, W/(m·K) Pipe

Insulation Material and Thickness	1/2-Inch Nominal I.D. Copper Pipe	3/4-Inch Nominal I.D. Copper Pipe	1-Inch Nominal I.D. Copper Pipe
None	**0.52**	**0.70**	**0.87**
Corrugated, 1.3 cm	0.43	0.53	0.63
Corrugated, 2.5 cm	0.29	0.35	0.41
Corrugated, 5.1 cm	0.21	0.25	0.28
Molded fiber, 1.3 cm	0.27	0.34	0.41
Molded fiber, 2.5 cm	0.19	0.22	0.26
Molded fiber, 5.1 cm	0.14	0.16	0.18
Polymer foam 1.3 cm	0.22	0.28	0.33
Polymer foam 2.5 cm	0.15	0.18	0.21
Polymer foam 5.1 cm	0.11	0.13	0.14

TABLE 7.3.2.1-2 Thermal Conductances for Common Pipe Sizes, Btu/(h·°F·ft) Pipe

Insulation Material and Thickness	1/2-Inch Nominal I.D. Copper Pipe	3/4-Inch Nominal I.D. Copper Pipe	1-Inch Nominal I.D. Copper Pipe
None	**0.30**	**0.40**	**0.50**
Corrugated, 1/2 in.	0.25	0.31	0.37
Corrugated, 1 in.	0.17	0.21	0.24
Corrugated, 2 in.	0.12	0.14	0.16
Molded Fiber, 1/2 in.	0.16	0.20	0.24
Molded Fiber, 1 in.	0.11	0.13	0.15
Molded Fiber, 2 in.	0.08	0.09	0.10
Polymer Foam, 1/2 in.	0.13	0.16	0.19
Polymer Foam, 1 in.	0.09	0.10	0.12
Polymer Foam, 2 in.	0.06	0.07	0.08

TABLE 7.3.2.1-3 Thermal Conductance Values for Piping Insulation

Material Type	*k* (W/[m·K])	*k* (Btu/[h·ft·°F])
Corrugated cardboard sheathing	0.069	0.04
Molded mineral fiber	0.043	0.025
Foamed rubber or polystyrene	0.035	0.02

TABLE 7.3.2.2 Thermal Capacitance per Unit Length for Commonly Specified Pipes

Pipe Size and Type	J/(m·K) pipe	Btu/(°F·ft) pipe
1/2 in. nominal Type K or L, bare, unfinned	750	0.12
3/4 in. nominal Type K or L, bare, unfinned	1500	0.24
1 in. nominal Type K or L, bare, unfinned	2500	0.40
If finned, add	200	0.03
For 1 in. insulation, add	100	0.01
For 2 in. insulation, add	200	0.03

TABLE 7.3.3 Thermal Properties

Symbol	Description	Value
Q_{e, H_2O}	Volumetric circulator flow rate	0.67×10^{-4} m^3/s (8 ft^3/h) (1 U.S. gpm)
$T_{hotwater}$	Nominal or average boiler/water heater temperature	80°C (180°F)
$\tau_{cycledesign}$	Circulator cycle time (on + off) under design conditions	1800 s (0.5 h)
$\tau_{cycleseasonal}$	Circulator cycle time (on + off) under seasonal average conditions	1100 s (0.3 h)

7.4 Calculations

7.4.1 Thermal Parameters

7.4.1.1 Temperatures. The indoor conditions shall be the same as specified in Section 6.3.1.

The design and seasonal temperatures for pipe locations outside conditioned space ($t_{b,\ design}$ and $t_{b,\ seasonal}$) shall be determined using the procedures described in Section 6.3.2. For systems with pipes in more than one location, $t_{b, design}$ and $t_{b,\ seasonal}$ shall be calculated using the pipe surface-area-weighted average of all the buffer zone temperatures (as in Section 6.4.1).

7.4.1.2 Heat Transfer Rates. The number of heat transfer units in the piping system (NTU) shall be given by Equation 7-6:

$$\mathrm{NTU} = \frac{L_r k_{rc} + L_{r,\ wall} k_{ra} + L_u k_{uc} + L_{u,\ wall} k_{ua}}{Cv_{water} Q_{e,\ H_2O}} + \frac{L_{b,\ unins} k_{b,\ unins} + L_{b,\ ins} k_{b,\ ins}}{Cv_{water} Q_{e,\ H_2O}} \tag{7-6}$$

The log-mean temperature difference between the piping and the conditioned space shall be calculated using Equation 7-7:

$$\Delta t_{\ln} = \frac{(t_{hotwater} - t_{in})[1 - \exp(-\mathrm{NTU})]}{\mathrm{NTU}} \tag{7-7}$$

The heat transfer rates (W [Btu/h]) from the hydronic loop to the conditioned space, buffer space, and outside ambient shall be calculated using Equations 7.8a–7.8d.

$$H_c = \Delta t_{\ln} (L_r k_{rc} + L_u k_{uc}) \quad \text{conditioned space} \tag{7-8a}$$

$$H_a = \Delta t_{\ln} (L_{r,\ wall} k_{ra} + L_{u,\ wall} k_{ua}) \quad \text{ambient} \tag{7-8b}$$

$$H_{b,\ design} = [\Delta t_{\ln} + (t_{in} - t_{b,\ design})] \times (L_{b,\ unins} k_{b,\ unins} + L_{b,\ ins} k_{b,\ ins}) \quad \text{buffer space} \tag{7-8c}$$

$$H_{b,\ seasonal} = [\Delta t_{\ln} + (t_{in} - t_{b,\ seasonal})] \times (L_{b,\ unins} k_{b,\ unins} + L_{b,\ ins} k_{b,\ ins}) \quad \text{buffer space} \tag{7-8d}$$

7.4.1.3 Heating Loads. The design heating load, H_{design}, shall be calculated using Chapter 17 of the 2009 *ASHRAE Handbook—Fundamentals*[3] or *ACCA Manual J*[7]. However, the design-heating load so calculated shall not exceed 0.8 H_c. The seasonal-average heating load, $H_{seasonal}$, shall then be set equal to one-third of the design load.

7.4.2 Design and Seasonal Delivery Effectiveness

7.4.2.1 Relaxation Times. The relaxation shall be calculated using Equations 7-9a through 7-9d.

$$\tau_r = \frac{L_r K_r}{L_{r,\ wall} k_{ra} + L_r k_{rc}} \quad \text{finned-tube baseboard} \tag{7-9a}$$

$$\tau_u = \frac{L_u K_u}{L_{u,\ wall} k_{ua} + L_u k_{uc}} \quad \text{unfinned piping} \tag{7-9b}$$

$$\tau_{b,\ ins} = \frac{K_{b,\ ins}}{k_{b,\ ins}} \quad \text{insulated in buffer zone(s)} \tag{7-9c}$$

$$\tau_{b,\ unins} = \frac{K_{b,\ ins}}{k_{b,\ ins}} \quad \text{uninsulated in buffer zone(s)} \tag{7-9d}$$

7.4.2.2 Circulator On-Time and Off-Time. Circulator on-time for design and seasonal conditions shall be calculated using Equations 7-10a and 7-10b.

$$\tau_{ondesign} = \frac{1}{H_c}(0.6\tau_{cycledesign} H_c - L_r K_r \Delta t_{\ln} - Z_{design}) \tag{7-10a}$$

$$\tau_{oneseasonal} = \frac{1}{H_c}(0.2\tau_{cycleseasonal} H_c - L_r K_r \Delta t_{\ln} - Z_{seasonal}) \tag{7-10b}$$

The circulator off-time shall be set equal to the difference between the cycle time and the on-time, as indicated in Equations 7-11a and 7-11b.

$$\tau_{offdesign} = \tau_{cycledesign} - \tau_{onedesign} \tag{7-11a}$$

$$\tau_{offseasonal} = \tau_{cycleseasonal} - \tau_{oneseasonal} \tag{7-11b}$$

7.4.2.3 Circulator-Off Heat Flows. Heat flows to the conditioned space, buffer space, and ambient during the off-cycle shall be calculated separately. Heat flow, H_{rc}, from finned-tube baseboards to the conditioned space shall be calculated using Equations 7-12a and 7-12b.

$$H_{rc,\,design} = L_r K_r \Delta t_{\ln} \frac{1 - \exp\left(\frac{-\tau_{offdesign}}{\tau_r}\right)}{\tau_{cycledesign}} \qquad (7\text{-}12a)$$

$$H_{rc,\,seasonal} = L_r K_r \Delta t_{\ln} \frac{1 - \exp\left(\frac{-\tau_{offseasonal}}{\tau_r}\right)}{\tau_{cycleseasonal}} \qquad (7\text{-}12b)$$

Heat flow, H_{ra}, from finned-tube baseboards to the outside ambient shall be calculated using Equations 7-13a and 7-13b.

$$H_{ra,\,design} = \frac{\Delta t_{\ln}\ \tau_r L_{r,\,wall} k_{ra}}{\tau_{cycledesign}} \qquad (7\text{-}13a)$$

$$H_{ra,\,seasonal} = \frac{\Delta t_{\ln}\ \tau_r L_{r,\,wall} k_{ra}}{\tau_{cycleseasonal}} \qquad (7\text{-}13b)$$

Heat flow, H_{rb}, from piping to the buffer zone(s) shall be calculated using Equation 7-14a and 7-14b.

$$H_{rb,\,design} = \frac{(\Delta t_{\ln} + t_{in} - t_{b,\,design})}{\tau_{cycledesign}}\left\{K_{b,\,ins} L_{b,\,ins}\left[1 - \exp\left(\frac{-\tau_{offdesign}}{\tau_{b,\,ins}}\right)\right] + K_{b,\,unins} L_{b,\,unins}\left[1 - \exp\left(\frac{-\tau_{offdesign}}{\tau_{b,\,unins}}\right)\right]\right\} \qquad (7\text{-}14a)$$

$$H_{rb,\,seasonal} = \frac{(\Delta t_{\ln} + t_{in} - t_{b,\,design})}{\tau_{cycleseasonal}}\left\{K_{b,\,ins} L_{b,\,ins}\left[1 - \exp\left(\frac{-\tau_{offdesign}}{\tau_{b,\,ins}}\right)\right] + K_{b,\,unins} L_{b,\,unins}\left[1 - \exp\left(\frac{-\tau_{offseasonal}}{\tau_{b,\,unins}}\right)\right]\right\} \qquad (7\text{-}14b)$$

Heat flow, H_u, from unfinned piping in the conditioned space shall be calculated using Equations 7-15a and 7-15b.

$$H_{u,\,design} = \frac{K_u L_u \Delta t_{\ln}\left[1 - \exp\left(\frac{-\tau_{offdesign}}{\tau_u}\right)\right]}{\tau_{cycledesign}} \qquad (7\text{-}15a)$$

$$H_{u,\,seasonal} = \frac{K_u L_u \Delta t_{\ln}\left[1 - \exp\left(\frac{-\tau_{offseasonal}}{\tau_u}\right)\right]}{\tau_{cycleseasonal}} \qquad (7\text{-}15b)$$

The fractions of this heat flow to the inside and the outside (H_{uc} and H_{ua}, respectively) shall be calculated using Equations 7-16a through 7-16d.

$$H_{uc,\,design} = H_{u,\,design}\frac{L_u k_{uc}}{L_u k_{uc} + L_{u,\,wall} k_{ua}} \qquad (7\text{-}16a)$$

$$H_{uc,\,seasonal} = H_{u,\,seasonal}\frac{L_u k_{uc}}{L_u k_{uc} + L_{u,\,wall} k_{ua}} \qquad (7\text{-}16b)$$

$$H_{ua,\,design} = H_{u,\,design} - H_{uc,\,design} \qquad (7\text{-}16c)$$

$$H_{ua,\,seasonal} = H_{u,\,seasonal} - H_{uc,\,seasonal} \qquad (7\text{-}16d)$$

7.4.2.4 Loss and Delivery Heat Rates. The rate of heat loss, H_{loss}, and heat delivery, H_{del}, over both the on and off cycles shall be calculated, for design and seasonal conditions, using Equations 7-17a through 7-17d.

$$H_{loss,\,design} = (H_a + H_{b,\,design})\frac{\tau_{ondesign}}{\tau_{cycledesign}} + H_{ra} + H_{ua,\,design} + H_{rb,\,design} \qquad (7\text{-}17a)$$

$$H_{loss,\,seasonal} = (H_a + H_{b,\,seasonal})\frac{\tau_{oneseasonal}}{\tau_{cycleseasonal}} + H_{ra} + H_{ua,\,seasonal} + H_{rb,\,seasonal} \qquad (7\text{-}17b)$$

$$H_{del,\,design} = H_c\frac{\tau_{ondesign}}{\tau_{cycledesign}} + H_{rc,\,design} + H_{uc,\,design} \qquad (7\text{-}17c)$$

$$H_{del,\,seasonal} = H_c\frac{\tau_{oneseasonal}}{\tau_{cycleseasonal}} + H_{rc,\,seasonal} + H_{uc,\,seasonal} \qquad (7\text{-}17d)$$

7.4.2.5 Delivery Effectiveness Calculations. Design delivery effectiveness shall be calculated using Equation 7-18.

$$\mathrm{DE}_{design} = \frac{1}{1 + \frac{H_{loss,\,design}}{H_{del,\,design}}} \qquad (7\text{-}18)$$

The seasonal delivery effectiveness, $DE_{seasonal}$, shall be calculated using Equation 7-19.

$$\mathrm{DE}_{seasonal} = \frac{1}{1 + \frac{H_{loss,\,seasonal}}{H_{del,\,seasonal}}} \qquad (7\text{-}19)$$

7.4.3 Calculation of Design and Seasonal Distribution System Efficiency

7.4.3.1 Thermal Recovery Factor, F_{recov}. The thermal recovery factor shall be determined (using F_{regain} for the buffer space as specified in Section 6.5.2) using Equations 7-20 and 7-21.

$$F_{recov,\,design} = 1 + F_{regain}(1 - \mathrm{DE}_{design}) \qquad (7\text{-}20)$$

$$F_{recov,\,seasonal} = 1 + F_{regain}(1 - \mathrm{DE}_{seasonal}) \qquad (7\text{-}21)$$

7.4.3.2 Distribution System Efficiency Calculations. Design and seasonal distribution efficiency shall be calculated using Equations 7-22 and 7-23.

$$\eta_{dist,\,design} = \mathrm{DE}_{design} F_{recov,\,design} \tag{7-22}$$

$$\eta_{dist,\,seasonal} = \mathrm{DE}_{seasonal} F_{recov,\,seasonal} \tag{7-23}$$

8. ELECTRIC DISTRIBUTION SYSTEMS

8.1 Procedure. The calculation procedure for determining delivery effectiveness and distribution system efficiency is based on the following major input parameters:

a. Effective thermal resistance between baseboard or panel and the conditioned space
b. Effective thermal resistance between baseboard or panel and outside
c. Design and seasonal outside temperatures
d. Electric element operating temperature

8.1.1 Electric Baseboards. The variable k_{rc}, which characterizes the overall heat transfer from the electric baseboard to the conditioned space, shall be obtained from manufacturer's data on heat transfer and element temperature. The given heat transfer rate, ϕ_{man}, (W/m [Btu/{h·ft}]) shall be divided by the element to surrounding temperature difference used in the manufacturer's data sheet (Δt_{man}) to obtain k_{rc}.

$$k_{rc} = \frac{\phi_{man}}{\Delta t_{man}} \tag{8-1}$$

The heat transfer rate, k_{ra}, (W/[m·K] [Btu/{h·ft°·F}]) to the outside from baseboards that are mounted against an exterior wall shall be estimated using the thermal resistance, R_w, of the outside wall and insulation on the back of the baseboards. R_w must account for any reduction in wall insulation due to installation of the baseboards. The value of k_{ra} shall be calculated using Equation 8-2:

$$k_{ra} = \frac{y}{R_w} \tag{8-2}$$

R_w shall be corrected for any reduction in insulation due to installation of the baseboard (e.g., if the baseboard is recessed into the wall).

8.1.2 Electric Panels. The variable $U_{panel,\,rc}$ (W/[m²·K] [Btu/{h·ft²·°F}]), which characterizes the overall heat transfer between the electric panel and the conditioned space per unit area of panel, shall be obtained from manufacturer's data γ_{man} (W/m² [Btu/h·ft²]) on heat transfer as a function of element temperature. The manufacturer shall have adjusted heat transfer mean temperature data according to the given or applicable design conditions, such as panel construction or panel surface coverings. The γ_{man} value closest to 50°C (122°F) shall be used for heating. Equation 8-3 shall be used to calculate $U_{panel,\,rc}$ using γ_{man} obtained from manufacturer's data and the coincident panel-to-surrounding temperature difference, Δt_{man}. A surround temperature of 18°C (64°F) shall be used.

$$U_{panel,\,rc} = \frac{\gamma_{man}}{\Delta t_{man}} \tag{8-3}$$

The heat transfer rate per unit panel area, $U_{panel,\,ra}$ (W/[m²·K] [Btu/{h·ft²·°F}]), to the outside from panels that are mounted against an exterior wall, floor, or ceiling shall be estimated using the combined thermal resistance, R_w, of the building envelope and insulation on the back of the panels. Note that R_w must account for any reduction in wall insulation due to installation of the electric panels. The value of $U_{panel,\,ra}$ shall be calculated using Equation 8-4:

$$U_{panel,\,ra} = \frac{1}{R_w} \tag{8-4}$$

R_w shall be corrected for any reduction in insulation due to installation of the panel (e.g., if the panel is recessed into the wall).

8.2 Calculations

8.2.1 Design and Seasonal Temperatures. The design and seasonal temperatures, t_{design}, shall be taken from Table 6.3.1-1 or 6.3.1-2, and the indoor temperatures shall be taken from Section 6.3.1.

8.2.2 Heat Transfer Rates for Baseboards. The rate of heat loss, H_{loss}, and heat delivery, H_{del}, shall be calculated, for design and seasonal conditions, using Equations 8-5 through 8-8.

Design Delivery

$$H_{del,\,design} = \phi_{man}\left\{L_r + L_{r,\,wall}\left[\frac{k_{rc}\Delta t_{man}}{k_{rc}\Delta t_{man} + k_{ra}(\Delta t_{man} + t_{in} - t_{design})} - 1\right]\right\} \tag{8-5}$$

Seasonal Delivery

$$H_{del,\,seasonal} = \phi_{man}\left\{L_r + L_{r,\,wall}\left[\frac{k_{rc}\Delta t_{man}}{k_{rc}\Delta t_{man} + k_{ra}(\Delta t_{man} + t_{in} - t_{seasonal})} - 1\right]\right\} \tag{8-6}$$

Design Loss

$$H_{loss,\,design} = \phi_{man} L_{r,\,wall}\frac{k_{ra}(\Delta t_{man} + t_{in} + t_{design})}{k_{rc}\Delta t_{man} + k_{ra}(\Delta t_{man} + t_{in} - t_{design})} \tag{8-7}$$

Seasonal Loss

$$H_{loss,\,seasonal} = \phi_{man} L_{r,\,wall}\frac{k_{ra}(\Delta t_{man} + t_{in} + t_{seasonal})}{k_{rc}\Delta t_{man} + k_{ra}(\Delta t_{man} + t_{in} - t_{seasonal})} \tag{8-8}$$

8.2.3 Heat Transfer Rates for Electric Panels. The rate of heat loss, H_{loss}, and heat delivery, H_{del}, shall be calculated, for design and seasonal conditions, using Equations 8-9 through 8-12.

Design Delivery

$$H_{del,\,design} = \gamma_{man}\{A_p + A_{p,\,wall}\left[\frac{U_{panel,\,rc}\Delta t_{man}}{U_{panel,\,rc}\Delta t_{man} + U_{panel,\,ra}(\Delta t_{man} + t_{in} - t_{design})} - 1\right]\} \tag{8-9}$$

Seasonal Delivery

$$H_{del,\,seasonal} = \gamma_{man}\{A_p + A_{p,\,wall}\left[\frac{U_{panel,\,rc}\Delta t_{man}}{U_{panel,\,rc}\Delta t_{man} + U_{panel,\,ra}(\Delta t_{man} + t_{in} - t_{seasonal})} - 1\right]\} \tag{8-10}$$

Design Losses

$$H_{loss,\,design} = \gamma_{man}A_{p,\,wall} \times \frac{U_{panel,\,ra}(\Delta t_{man} + t_{in} - t_{design})}{U_{panel,\,rc}\Delta t_{man} + U_{panel,\,ra}(\Delta t_{man} + t_{in} - t_{design})} \tag{8-11}$$

Seasonal Losses

$$H_{loss,\,seasonal} = \gamma_{man}A_{p,\,wall} \times \frac{U_{panel,\,ra}(\Delta t_{man} + t_{in} - t_{seasonal})}{U_{panel,\,rc}\Delta t_{man} + U_{panel,\,ra}(\Delta t_{man} + t_{in} - t_{seasonal})} \tag{8-12}$$

8.2.4 Design and Seasonal Distribution System Efficiency. The design and seasonal distribution system efficiency shall be calculated using Equations 8-13 and 8-14, respectively.

$$\eta_{dist,\,design} = \frac{1}{1 + \frac{H_{loss,\,design}}{H_{del,\,design}}} \tag{8-13}$$

$$\eta_{dist,\,seasonal} = \frac{1}{1 + \frac{H_{loss,\,seasonal}}{H_{del,\,seasonal}}} \tag{8-14}$$

9. REFERENCES

1. ASHRAE. 1997. *ASHRAE Handbook—Fundamentals*. Atlanta: ASHRAE.
2. Los Alamos National Laboratory. 1984. *Passive Solar Heating Analysis Design Manual*. Los Alamos, NM: LANL.
3. ASHRAE. 2009. *ASHRAE Handbook—Fundamentals*. Atlanta: ASHRAE.
4. ASTM. 2007. ASTM E1554, *Standard Test Methods for Determining Air Leakage of Air Distribution Systems by Fan Pressurization*. West Conshohocken, PA: ASTM.
5. ACCA. 2004. *ACCA Manual S—Residential Equipment Selection*, 3rd Edition. Washington, DC: ACCA.
6. ASHRAE. 2013. ANSI/ASHRAE Standard 62.2-2013, *Ventilation and Acceptable Air Quality in Low-Rise Residential Buildings*. Atlanta: ASHRAE.
7. ACCA. 2004. *ACCA Manual J—Residential Load Calculation*, 7th Edition. Washington, DC: ACCA.

(This is a normative appendix and is part of this standard.)

NORMATIVE APPENDIX A
AIR-HANDLER FAN FLOW MEASUREMENT USING AN AIR-HANDLER FLOW PLATE DEVICE

In this procedure, the system filter is replaced by a flowmeter. The flow measured by the flowmeter is adjusted to account for the change in flow due to the flowmeter and filter having different resistances. Any intentional ventilation intakes to the return ducts shall be kept open during the air-handler fan flow measurement process.

a. Install a static pressure probe in the supply plenum. It must be attached firmly to ensure that it does not move during the air-handler fan flow test. Insert the static pressure probe with the tip facing into the airflow. Keep the probe clear of the direct air-handler fan discharge in the supply plenum or any point in the plenum where a venturi or excessive turbulence may be found. Should a negative reading be found in the supply plenum, select another measurement location, preferably further away from the air-handler fan. If the supply plenum is inaccessible, or if the pressure measured there is excessively noisy, the probe may be installed in a supply duct. If supply plenum and ducts are inaccessible, a probe may be installed to measure the total pressure drop across a supply register.

b. With the air-handler fan on and a clean filter installed, measure the pressure difference between the static pressure probe and the conditioned space (ΔP_{sp1}).

c. Replace the filter with the appropriate flow plate and ensure that it is sealed in place so that all the air must go through the plate.

d. Turn the air-handler fan on and measure the new pressure at the static pressure probe (ΔP_{sp2}).

e. Record the flow going through the flow plate, Q.

f. Calculate and record the air-handler fan flow at operating conditions given by Equation A-1:

$$Q_e = Q\left(\frac{\Delta P_{sp1}}{\Delta P_{sp2}}\right)^{0.5} \tag{A-1}$$

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