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ASHRAE POCKET GUIDE

for Air Conditioning, Heating, Ventilation, Refrigeration (I-P Edition)

7th Edition

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Errata noted in the list dated 8/9/12 have been corrected.

AIR-CONDITIONING LOAD DATA

Cooling Loads. Obtain appropriate weather data and select design conditions. In addition to the conventional dry-bulb with mean coincident wet-bulb, also consider dew-point with mean coincident dry-bulb, particularly with spaces requiring large amounts of outdoor air or close control of moisture. Select indoor dry-bulb, wet-bulb, and ventilation rate, including permissible variations and control limits. Consider proposed schedules of occupancy, lighting, and processes that contribute to the internal load. Several different times of day and months must frequently be analyzed to determine the peak load time.

ANSI/ASHRAE/ACCA Standard 183-2007 sets the minimum standards for nonresidential load calculations.

Currently there are two ASHRAE cooling load calculation methods. The first is the heat balance method whose equations are coded in a generic computer program, linked to a user interface program. The source code for these programs is in the ASHRAE Load Calculation Toolkit.

The second method is the radiant time series method, a simplification of the heat balance method, still requiring a complex computer program for a multi-room building.

Due to the variation in heat transfer coefficients, precision of construction, and manner of actual building operation, a cooling load calculation can never be more than a good estimate of the actual load.

For preliminary estimation of the cooling load the figures herein are a very rough guide. The approximate cooling load calculation methods presented herein are useful to the experienced designer.

To design and size components of central air-conditioning systems more than the cooling load is needed. Type of system, fan energy and location, direct heat loss and gain, duct leakage, heat extracted from lights, and type of return system must all be considered.

Heating Loads. Similar calculations to cooling load are made, but temperatures outside conditional spaces are usually lower than space temperatures maintained. Solar heat gains, and internal heat gains are not included and thermal storage of building structure or content is usually ignored. This is usually sufficient to cope with a worst-case situation. There is very often need for cooling in cold months, for perimeter spaces with high solar heat gain and interior spaces with significant heat gain.

Cooling Load Check Figures

Classifications	Occupancy Sq Ft/Person			Lights and Other Electrical Watts/Sq Ft			Refrigeration Sq Ft/Ton‡			Supply Air Rate CFM/Sq Ft East-South-West			North			Internal		
	Lo	Av	Hi	Lo	Av	Hi	Lo	Av	Hi	Lo	Av	Hi	Lo	Av	Hi	Lo	Av	Hi
Apartment, High Rise	325	175	100	0.7	0.9	1.1	450	400	350	0.8	1.2	1.7	0.5	0.8	1.3	–	–	–
Auditoriums, Churches, Theaters	15	11	6	0.5	0.7	0.9	400	250	90	–	–	–	–	–	–	1.0	2.0	3.0
Educational Facilities	30	25	20	0.75	1.0	1.1	240	185	150	1.0	1.6	2.2	0.9	1.3	2.0	0.8	1.2	1.9
Schools, Colleges, Universities																		
Factories Assembly Areas	50	35	23	2.5†	4.0†	5.5†	240	150	90	–	–	–	–	–	–	2.0	3.6	5.5
Light Manufacturing	200	150	100	7.5†	9†	11†	200	150	100	–	–	–	–	–	–	1.6	2.5	3.8
Heavy Manufacturing*	200	250	300	12†	25†	30†	100	80	60	–	–	–	–	–	–	2.5	4.0	6.5
Hospitals Patient Rooms	70	50	25	0.5	0.75	1.0	275	220	165	1.0	1.5	2.0	0.8	1.2	1.4	0.7	1.0	1.3
Public Areas	100	80	50	0.5	0.75	1.0	175	140	110	1.0	1.25	1.45	1.0	1.1	1.2	0.95	1.0	1.1
Hotels, Motels, Dormitories	200	150	100	0.5	0.75	1.0	350	300	220	1.0	1.40	1.5	0.9	1.2	1.4	–	–	–
Libraries and Museums	80	60	40	0.5	0.75	1.0	340	280	200	1.0	1.6	2.1	0.9	1.1	1.3	0.9	1.0	1.1
Office Buildings (General)	130	110	80	2†	2.5†	4†	360	280	190	1.0	1.6	2.2	0.9	1.3	2.0	0.8	1.0	1.2
Private Offices	150	125	100	0.5	0.75	1.0	–	–	–	1.2	1.8	2.4	1.1	1.5	1.8	0.8	1.2	1.4
Stenographic Department	100	85	70	1.0	1.25	1.5	–	–	–	–	–	–	–	–	–	0.9	1.3	2.0
Residential Large	600	400	200	0.5	1.0	1.5	600	500	380	0.8	1.2	1.6	0.5	0.8	1.3	–	–	–
Medium	600	360	200	0.5	1.0	1.5	700	550	400	0.7	1.1	1.4	0.5	0.7	1.2	-	-	-
Restaurants Large	17	15	13	0.5	1.0	1.5	135	100	80	1.8	2.4	3.7	1.2	1.6	2.1	0.9	1.1	1.4
Medium							150	120	100	1.5	2.0	3.0	1.1	1.4	1.8	0.9	1.0	1.3
Shopping Centers, Department Stores and Specialty Shops																		
Beauty and Barber Shops	45	40	25	3.0†	5.0†	9.0†	240	160	105	1.5	2.6	4.2	1.1	1.7	2.6	0.9	1.3	2.0
Malls	100	75	50	1.0	1.5	2.0	365	230	160	–	–	–	–	–	–	1.1	1.8	2.5
Refrigeration for Central Heating and Cooling Plant																		
Urban Districts						475	380	285										
College Campuses						400	320	240										
Commercial Centers						330	265	200										
Residential Centers						625	500	375										

Refrigeration and air quantities for applications listed in this table of cooling load check figures are based on all-air system and normal outdoor air quantities for ventilation except as noted.

Notes: †Refrigeration loads are for entire application

*Air quantities for heavy manufacturing areas are based on supplementary means to remove excessive heat.

Summary of Load Sources and Equations for Estimating Space Design Cooling Load

Load Source	Equation	Reference, Table, Description
External Roof	$q = UA$(CLTD)	Design heat transmission coefficients, pp. 144-149 Areas calculated from plans CLTD, pp. 150-151
Walls	$q = UA$(CLTD)	Design heat transmission coefficients, pp. 144-149 Areas calculated from plans CLTD, pp. 152-154
Glass Conduction	$q = UA$(TD)	Glass area calculated from plans U-factors p. 141
Glass Solar	$q = A$(SC)SCL	Solar Cooling Load factors, pp. 155-156 Shading coefficients for combination of glass and internal shading, p. 157 Compute shaded area from building projections Externally shaded glass: use north orientation data
Partitions, Ceilings, Floors	$q = UA$(TD)	Design heat transmission coefficients, pp. 144-149 Area calculated from plans
Internal Lights	q = INPUT	Input rating from electrical plans or lighting fixture data, pp. 159-161
People Sensible	q_s = No. (Sens. H.G.)	Number of people in space Sensible heat gain from occupants, Btu/h, p. 158
Latent	q_l = No. (Lat. H.G.)	Latent heat gain from occupants, Btu/h
Equipment and Appliances	q_s = HEAT GAIN	Recommended rate of heat gain—pp. 161-170
Power	q = HEAT GAIN	p. 162
Infiltration Air		
Sensible	$q_s = 1.10\ CFM\ (\Delta t)$	Inside-outside air temperature difference, °F
Latent	$q_l = 4840\ CFM\ (\Delta W)$	Inside-outside air humidity ratio difference, grains/lbda
Total	$q = 4.5\ CFM\ (\Delta h)$	Inside-outside air enthalpy difference, Btu/lbda

CAUTION: Approximate data—Use for preliminary computations only. See *ASHRAE Cooling and Heating Load Calculation Applications Manual* (Spitler 2008), and *ASHRAE Load Calculation Toolkit.*

Heat Flow (Q) Through Building Materials

(In addition to heat flow through building materials the resistance of surfaces and air spaces must be included in calculating U-factors.)

$$Q(\text{Btu/h}) = U \times \text{Area (ft}^2) \times \text{(temperature difference (°F)}$$

where U = overall coefficient of heat transmission, Btu/h·ft^2·°F) of materials + interior and exterior resistances

$$1/U = \Sigma R \text{ (resistance of components)}$$

For multiple layers of homogeneous materials, R values are added in series:

$$1/U = R_{\text{cold surface}} + R_1 + R_2 + R_n \ldots + R_{\text{warm surface}}$$

For wood stud walls, studs 16" on center (series and parallel):

$$1/U = R_{\text{cold surface}} + \left\{ \frac{+0.25\ R_{\text{stud}}}{+0.75\ R_{\text{stud space}}} \right\} + R_{\text{warm surface}}$$

(Plus, in series, $R_{\text{insulation}}$, R_{siding}, $R_{\text{wallboard}}$, etc.)

For metal framed construction, heat flow through the metal causes thermal bridging increasing the U value significantly.

Conductive Heat Flow Through Glazing

Solar radiation gain through glazing is usually more significant in cooling load calculations than conductive heat gain. Solar heat gain is neglected in heating load calculations.

Conductive heat flow through glazing including surface resistance (approximate data)

Single glazing	U = 1.1
Double glazing	U = 0.55
Triple glazing	U = 0.33

Air Space Coefficients for Horizontal Heat Flow

Air Space Thickness, in.	Air Space Temp., °F	Air Temp. Diff., °F	Air Space Coefficient h_s, Btu/h·ft^2·°F Effective Emittance *E* 0.82	0.20	0.05
0.5	5	10	0.88	0.46	0.35
		55	1.00	0.57	0.47
		90	1.10	0.67	0.57
	32	10	1.00	0.50	0.38
		55	1.08	0.57	0.45
		90	1.17	0.67	0.54
	50	10	1.09	0.53	0.39
		55	1.14	0.58	0.44
		90	1.23	0.67	0.53
	85	10	1.28	0.59	0.42
		55	1.30	0.62	0.45
		90	1.36	0.67	0.51
	120	10	1.48	0.66	0.46
		55	1.50	0.67	0.47
		90	1.53	0.70	0.50
0.2	5	<90	1.36	0.93	0.83
	32	<90	1.50	1.00	0.88
	50	<90	1.61	1.05	0.91
	85	<90	1.83	1.14	0.97
	120	<90	2.07	1.24	1.04

Surface Conductances and Resistances for Air

Position of Surface	Direction of Heat Flow	Surface Emittance, ε: Non-reflective ε = 0.90 h_i	R	Reflective ε = 0.20 h_i	R	Reflective ε = 0.05 h_i	R
STILL AIR							
Horizontal	Upward	1.63	0.61	0.91	1.10	0.76	1.32
Sloping—45°	Upward	1.60	0.62	0.88	1.14	0.73	1.37
Vertical	Horizontal	1.46	0.68	0.74	1.35	0.59	1.70
Sloping—45°	Downward	1.32	0.76	0.60	1.67	0.45	2.22
Horizontal	Downward	1.08	0.92	0.37	2.70	0.22	4.55
MOVING AIR (Any position)		h_o	R				
15-mph Wind (for winter)	Any	6.00	0.17	—	—	—	—
7.5-mph Wind (for summer)	Any	4.00	0.25	—	—	—	—

Notes:
1. Surface conductance h_i and h_o measured in Btu/h·ft²·°F; resistance R in °F·ft²·h/Btu.
2. No surface has both an air space resistance value and a surface resistance value.
3. Conductances are for surfaces of the stated emittance facing virtual blackbody surroundings at the same temperature as the ambient air. Values are based on a surface-air temperature difference of 10°F and for surface temperatures of 70°F.
4. Condensate can have a significant impact on surface emittance.

Emittance Values of Various Surfaces and Effective Emittances of Air Spaces[a]

Surface	Average Emittance ε	Effective Emittance ε_{eff} of Air Space: One Surface Emittance ε; Other, 0.9	Both Surfaces Emittance ε
Aluminum foil, bright	0.05	0.05	0.03
Aluminum foil, with condensate just visible (> 0.7 gr/ft²)	0.30	0.29	—
Aluminum foil, with condensate clearly visible (> 2.9 gr/ft²)	0.70	0.65	—
Aluminum sheet	0.12	0.12	0.06
Aluminum coated paper, polished	0.20	0.20	0.11
Steel, galvanized, bright	0.25	0.24	0.15
Aluminum paint	0.50	0.47	0.35
Building materials: wood, paper, masonry, nonmetallic paints	0.90	0.82	0.82
Regular glass	0.84	0.77	0.72

[a]These values apply in the 4 to 40 μm range of the electromagnetic spectrum.

Effective Thermal Resistance of Ventilated Attics[a] (Summer Condition)

Part A. Nonreflective Surfaces

Ventilation rate columns: Not Ventilation[b] (0); Natural Ventilation (0.1); Power Ventilation[c] (0.5, 1.0, 1.5). Ventilation Rate, cfm/ft²; Ceiling Resistance R[d], °F·ft²·h/Btu.

Ventilation Air Temperature, °F	Sol-Air[e] Temperature, °F	0: 10	0: 20	0.1: 10	0.1: 20	0.5: 10	0.5: 20	1.0: 10	1.0: 20	1.5: 10	1.5: 20
80	120	1.9	1.9	2.8	3.4	6.3	9.3	9.6	16	11	20
	140	1.9	1.9	2.8	3.5	6.5	10	9.8	17	12	21
	160	1.9	1.9	2.8	3.6	6.7	11	10	18	13	22
100	120	1.9	1.9	2.2	2.3	3.3	4.4	4.0	6.0	4.1	6.9
	140	1.9	1.9	2.4	2.7	4.2	6.1	5.8	8.7	6.5	10
	160	1.9	1.9	2.6	3.2	5.0	7.6	7.2	11	8.3	13
Part B. Reflective Surfaces[f]											
80	120	6.5	6.5	8.1	8.8	13	17	17	25	19	30
	140	6.5	6.5	8.2	9.0	14	18	18	26	20	31
	160	6.5	6.5	8.3	9.2	15	18	19	27	21	32
100	120	6.5	6.5	7.0	7.4	8.0	10	8.5	12	8.8	12
	140	6.5	6.5	7.3	7.8	10	12	11	15	12	16
	160	6.5	6.5	7.6	8.2	11	14	13	18	15	20

[a]Although the term effective resistance is commonly used when there is attic ventilation, this table includes values for situations with no ventilation. The effective resistance of the attic added to the resistance (1/U) of the ceiling yields the effective resistance of this combination based on sol-air and room temperatures. These values apply to wood frame construction with a roof deck and roofing that has a conductance of 1.0 Btu/h·ft²·°F.
[b]This condition cannot be achieved in the field unless extreme measures are taken to tightly seal the attic.
[c]Based on air discharging outward from attic.
[d]When determining ceiling resistance, do not add the effect of a reflective surface facing the attic, as it is accounted for in part B of this table.
[e]Roof surface temperature rather than sol-air temperature can be used if 0.25 is subtracted from the attic resistance shown.
[f]Surfaces with effective emittance ε_{eff} = 0.05 between ceiling joists facing attic space.

Typical Thermal Properties of Common Building and Insulating Materials—Design Values

Description	Density, lb/ft³	Conductivity (*k*), Btu·in / h·ft²·°F	Conductance (*C*), Btu / h·ft²·°F	Resistance (*R*): Per Inch Thickness (1/*k*), °F·ft²·h / Btu·in	Resistance (*R*): For Thickness Listed (1/*C*), °F·ft²·h / Btu	Specific Heat, Btu / lb·°F
BUILDING BOARD						
Gypsum or plaster board .... 0.5 in.	50	—	2.22	—	0.45	
Plywood (Douglas Fir) .... 0.5 in.	34	—	1.60	—	0.62	
Plywood or wood panels .... 0.75 in.	34	—	1.07	—	0.93	0.29
Vegetable fiber board						
Sheathing, regular density .... 0.5 in.	18	—	0.76	—	1.32	0.31
.... 0.78125 in.	18	—	0.49	—	2.06	
Nail-base sheathing .... 0.5 in.	25	—	0.94	—	1.06	0.31
Shingle backer .... 0.375 in.	18	—	1.06	—	0.94	0.31
Shingle backer .... 0.3125 in.	18	—	1.28	—	0.78	
Tile and lay-in panels, plain or acoustic	18	0.40	—	2.50	—	0.14
.... 0.5 in.	18	—	0.80	—	1.25	
.... 0.75 in.	18	—	0.53	—	1.89	
Hardboard						
High density, service-tempered grade and service grade	55	0.82	—	1.22	—	0.32
Particleboard						
Medium density	50	0.94	—	1.06	—	0.31
BUILDING MEMBRANE						
Vapor—permeable felt	—	—	16.70	—	0.06	
Vapor—seal, 2 layers of mopped 15-lb felt	—	—	8.35	—	0.12	
Vapor—seal, plastic film	—	—	—	—	Negl.	
FINISH FLOORING MATERIALS						
Carpet and fibrous pad	—	—	0.48	—	2.08	0.34
Tile—asphalt, linoleum, vinyl, rubber	—	—	20.00	—	0.05	0.30
ceramic						0.19

Typical Thermal Properties of Common Building and Insulating Materials—Design Values (Continued)

Description	Density, lb/ft³	Conductivity (*k*), Btu·in / h·ft²·°F	Conductance (*C*), Btu / h·ft²·°F	Resistance (*R*): Per Inch Thickness (1/*k*), °F·ft²·h / Btu·in	Resistance (*R*): For Thickness Listed (1/*C*), °F·ft²·h / Btu	Specific Heat, Btu / lb·°F
Wood, hardwood finish .... 0.75 in.	—	—	1.47	—	0.68	
INSULATING MATERIALS						
Blanket and Batt						
Mineral fiber, fibrous form processed from rock, slag, or glass approx. 8.25-10 in.	0.4-2.0	—	0.033	—	30	
Board and Slabs						
Cellular glass	8.0	0.33	—	3.03	—	0.18
Glass fiber, organic bonded	4.0-9.0	0.25	—	4.00	—	0.23
Expanded perlite, organic bonded	1.0	0.36	—	2.78	—	0.30
Expanded rubber (rigid)	4.5	0.22	—	4.55	—	0.40
Expanded polystyrene, extruded (smooth skin surface) (HCFC-142b exp.)	1.8-3.5	0.20	—	5.00	—	0.29
Expanded polystyrene, molded beads	1.0	0.26	—	3.85	—	—
	1.25	0.25	—	4.00	—	—
	1.5	0.24	—	4.17	—	—
Cellular phenolic (open cell)	1.8-2.2	0.23	—	4.40	—	—
Mineral fiber with resin binder	15.0	0.29	—	3.45	—	0.17
Mineral fiberboard, wet felted						
Core or roof insulation	16-17	0.34	—	2.94	—	—
Acoustical tile	18.0	0.35	—	2.86	—	0.19
Mineral fiberboard, wet molded						
Acoustical tile	23.0	0.42	—	2.38	—	0.14
Cement fiber slabs (shredded wood with Portland cement binder)	25-27.0	0.50-0.53		2.0-1.89	—	

Typical Thermal Properties of Common Building and Insulating Materials—Design Values (Continued)

Description	Density, lb/ft³	Conductivity (k), Btu·in / h·ft²·°F	Conductance (C), Btu / h·ft²·°F	Resistance (R): Per Inch Thickness (1/k), °F·ft²·h / Btu·in	Resistance (R): For Thickness Listed (1/C), °F·ft²·h / Btu	Specific Heat, Btu / lb·°F
Loose Fill						
Cellulosic insulation (milled paper or wood pulp)........	2.3-3.2	0.27-0.32	—	3.70-3.13	—	0.33
Perlite, expanded	2.0-4.1	0.27-0.31	—	3.7-3.3	—	0.26
	4.1-7.4	0.31-0.36	—	3.3-2.8	—	—
	7.4-11.0	0.36-0.42	—	2.8-2.4	—	—
Mineral fiber (rock, slag, or glass)						
approx. 3.75-5 in.	0.6-2.0	—	—	—	11.0	0.17
approx. 6.5-8.75 in.	0.6-2.0	—	—	—	19.0	—
Vermiculite, exfoliated	7.0-8.2	0.47	—	2.13	—	0.32
	4.0-6.0	0.44	—	2.27	—	—
ROOFING						
Built-up roofing........ 0.375 in.	70	—	3.00	—	0.33	0.35
Slate .... 0.5 in.	—	—	20.00	—	0.05	0.30
Wood shingles, plain and plastic film faced	—	—	1.06	—	0.94	0.31
PLASTERING MATERIALS						
Cement plaster, sand aggregate	116	5.0	—	0.20	—	0.20
Gypsum plaster:						
Lightweight aggregate .... 0.5 in.	45	—	3.12	—	0.32	—
Perlite aggregate	45	1.5	—	0.67	—	0.32
Sand aggregate	105	5.6	—	0.18	—	0.20
Sand aggregate on metal lath .... 0.75 in.	—	—	7.70	—	0.13	—
Vermiculite aggregate	45	1.7	—	0.59	—	—
MASONRY MATERIALS						
Masonry Units						

Typical Thermal Properties of Common Building and Insulating Materials—Design Values (Continued)

Description	Density, lb/ft³	Conductivity (*k*), Btu·in / h·ft²·°F	Conductance (*C*), Btu / h·ft²·°F	Resistance (*R*): Per Inch Thickness (1/*k*), °F·ft²·h / Btu·in	Resistance (*R*): For Thickness Listed (1/*C*), °F·ft²·h / Btu	Specific Heat, Btu / lb·°F
Brick, fired clay	150	8.4-10.2	—	0.12-0.10	—	—
Clay tile, hollow						
1 cell deep ... 4 in.	—	—	0.90	—	1.11	—
2 cells deep ... 8 in.	—	—	0.54	—	1.85	—
3 cells deep ... 12 in.	—	—	0.40	—	2.50	—
Concrete blocks						
Medium weight aggregate (combinations of normal weight and lightweight aggregate)						
8 in., 26-29 lb, 97-112 lb/ft³ concrete, 2 or 3 cores	—	—	0.58-0.78	—	1.71-1.28	—
Same with perlite filled cores	—	—	0.27-0.44	—	3.7-2.3	—
Lightweight aggregate (expanded shale, clay, slate or slag, pumice)						
6 in., 16-17 lb 85-87 lb/ft³ concrete, 2 or 3 cores	—	—	0.52-0.61	—	1.93-1.65	—
Same with perlite filled cores	—	—	0.24	—	4.2	—
Same with vermiculite filled cores	—	—	0.33	—	3.0	—
8 in., 19-22 lb, 72-86 lb/ft³ concrete	—	—	0.32-0.54	—	3.2-1.90	0.21
Same with perlite filled cores	—	—	0.15-0.23	—	6.8-4.4	—
Same with vermiculite filled cores	—	—	0.19-0.26	—	5.3-3.9	—
Same with molded EPS (beads) filled cores	—	—	0.21	—	4.8	—
Same with UF foam filled cores	—	—	0.22	—	4.5	—
Same with molded EPS inserts in cores	—	—	0.29	—	3.5	—
Stone, lime, or sand	180	72	—	0.01	—	—
Quartzitic and sandstone	140	24	—	0.04	—	—
Calcitic, dolomitic, limestone, marble, and granite	180	30	—	0.03	—	—
	140	16	—	0.06	—	—
Gypsum partition tile						
3 by 12 by 30 in., solid	—	—	0.79	—	1.26	0.19

Typical Thermal Properties of Common Building and Insulating Materials—Design Values (Continued)

Description	Density, lb/ft³	Conductivity (k), Btu·in / h·ft²·°F	Conductance (C), Btu / h·ft²·°F	Resistance (R) Per Inch Thickness (1/k), °F·ft²·h / Btu·in	Resistance (R) For Thickness Listed (1/C), °F·ft²·h / Btu	Specific Heat, Btu / lb·°F
Concretes						
Sand and gravel or stone aggregate concretes (concretes with more than 50% quartz or quartzite sand have conductivities in the higher end of the range)	150	10.0-20.0	—	0.10-0.05	—	—
	140	9.0-18.0	—	0.11-0.06	—	0.19-0.24
	130	7.0-13.0	—	0.14-0.08	—	—
Limestone concretes	140	11.1	—	0.09	—	—
	120	7.9	—	0.13	—	—
Gypsum-fiber concrete (87.5% gypsum, 12.5% wood chips)	51	1.66	—	0.60	—	0.21
Cement/lime, mortar, and stucco	120	9.7	—	0.10	—	—
Lightweight aggregate concretes						
Expanded shale, clay, or slate; expanded slags; cinders; pumice (with density up to 100 lb/ft³); and scoria (sanded concretes have conductivities in the higher end of the range)	120	6.4-9.1	—	0.16-0.11	—	—
	60	2.1-2.5	—	0.48-0.40	—	—
Perlite, vermiculite, and polystyrene beads	50	1.8-1.9	—	0.55-0.53	—	—
	30	1.1	—	0.91	—	—
Foam concretes	120	5.4	—	0.19	—	—
SIDING MATERIALS (on flat surface)						
Shingles						
Wood, 16 in., 7.5 exposure	—	—	1.15	—	0.87	0.31
Wood, double, 16-in., 12-in. exposure	—	—	0.84	—	1.19	0.28
Siding						
Asphalt roll siding	—	—	6.50	—	0.15	0.35
Asphalt insulating siding (0.5 in. bed.)	—	—	0.69	—	1.46	0.35
Hardboard siding, 0.4375 in.	—	—	1.49	—	0.67	0.28
Wood, drop, 1 by 8 in.	—	—	1.27	—	0.79	0.28
Wood, bevel, 0.5 by 8 in., lapped	—	—	1.23	—	0.81	0.28

Typical Thermal Properties of Common Building and Insulating Materials—Design Values (Continued)

Description	Density, lb/ft³	Conductivity (*k*), Btu·in/h·ft²·°F	Conductance (*C*), Btu/h·ft²·°F	Resistance (*R*): Per Inch Thickness (1/*k*), °F·ft²·h/Btu·in	Resistance (*R*): For Thickness Listed (1/*C*), °F·ft²·h/Btu	Specific Heat, Btu/lb·°F
Wood, plywood, 0.375 in., lapped	—	—	1.69	—	0.59	0.29
Aluminum, steel, or vinyl, over sheathing						
Hollow-backed	—	—	1.64	—	0.61	0.29[q]
Insulating-board backed nominal 0.375 in.	—	—	0.55	—	1.82	0.32
Insulating-board backed nominal 0.375 in., foil backed	—	—	0.34	—	2.96	—
Architectural (soda-lime float) glass	158	6.9	—	—	—	0.21
WOODS (12% moisture content)[e,r]						
Hardwoods						0.39[s]
Oak	41.2-46.8	1.12-1.25	—	0.89-0.80	—	
Birch	42.6-45.4	1.16-1.22	—	0.87-0.82	—	
Maple	39.8-44.0	1.09-1.19	—	0.92-0.84	—	
Ash	38.4-41.9	1.06-1.14	—	0.94-0.88	—	
Softwoods						0.39[s]
Southern Pine	35.6-41.2	1.00-1.12	—	1.00-0.89	—	
Douglas Fir-Larch	33.5-36.3	0.95-1.01	—	1.06-0.99	—	
Southern Cypress	31.4-32.1	0.90-0.92	—	1.11-1.09	—	
Hem-Fir, Spruce-Pine-Fir	24.5-31.4	0.74-0.90	—	1.35-1.11	—	
West Coast Woods, Cedars	21.7-31.4	0.68-0.90	—	1.48-1.11	—	
California Redwood	24.5-28.0	0.74-0.82	—	1.35-1.22	—	

Cooling Load Temperature Differences for Flat Roofs--24°N Latitude, July

Roof No	Solar time, h: 2	4	6	8	10	12	14	16	18	20	22	24
1	−2	−5	−6	9	44	76	92	86	58	23	8	2
2	0	−4	−6	1	30	64	86	89	70	36	14	5
3	8	2	−2	3	22	47	68	77	68	47	29	16
4	11	3	−2	−4	5	27	55	75	80	67	43	23
5	16	8	3	1	10	30	52	68	70	59	41	27
8	24	17	11	9	14	27	43	54	58	52	42	32
9	25	16	9	4	5	17	36	54	65	63	51	37
10	31	22	15	9	8	16	30	45	56	59	52	41
13	31	25	20	16	16	23	33	43	49	49	43	37
14	32	27	23	19	19	24	32	40	45	45	42	37

Cooling Load Temperature Differences for Flat Roofs--36°N Latitude, July

Roof No.	Solar time, h: 2	4	6	8	10	12	14	16	18	20	22	24
1	−2	−5	−6	12	45	75	90	84	60	26	9	2
2	0	−4	−6	4	32	63	84	87	70	39	15	5
3	8	2	−2	4	24	47	67	75	68	48	30	17
4	11	3	−1	−3	7	29	55	74	79	67	45	24
5	16	8	3	2	12	31	52	67	70	59	42	27
8	25	17	12	9	15	28	42	54	58	53	43	33
9	26	16	9	4	7	19	37	54	64	63	52	38
10	32	23	15	10	9	17	30	45	56	58	52	42
13	31	25	20	16	17	24	33	43	49	49	44	37
14	32	28	23	20	20	25	32	40	45	46	42	37

Cooling Load Temperature Differences for Flat Roofs--48°N Latitude, July

Roof No.	Solar time, h: 2	4	6	8	10	12	14	16	18	20	22	24
1	−2	−5	−5	15	44	69	83	79	59	29	9	2
2	0	−4	−5	6	32	60	78	81	68	41	16	5
3	8	2	−1	6	24	45	63	71	65	48	30	17
4	12	3	−1	−2	8	29	52	69	74	65	45	25
5	16	8	3	3	13	31	49	63	66	58	42	27
8	24	17	11	10	16	27	40	51	55	51	42	32
9	26	16	9	5	8	19	35	51	60	61	51	38
10	31	22	15	10	10	17	29	43	53	56	51	41
13	30	25	20	16	18	24	32	41	47	47	43	37
14	32	27	23	20	20	24	31	38	43	44	41	36

CAUTION: Approximate data--Use for preliminary computations only.
Also, see notes on next page.

Notes for CLTD Data for Flat Roofs

1. Data applies directly to: (1) dark surface, (2) indoor temperature is 78°F, (3) outdoor maximum temperature of 95°F with mean temperature of 85°F and daily range of 21°F, (4) solar radiation typical of clear day on 21st day of month, (5) outside surface film resistance of 0.333 $(h \cdot ft^2 \cdot °F)/Btu$, and (6) inside surface resistance of 0.685 $(h \cdot ft^2 \cdot °F)/Btu$.

2. Adjustments to design temperatures

$$\text{Corr. CLTD} = \text{CLTD} + (78 - t_r) + (t_m - 85)$$

where t_r = inside temperature and t_m = mean outdoor temperature, or t_m = maximum outdoor temperature − (daily range)/2

No adjustment recommended for color or for ventilation of air space above a ceiling.

For design purposes, the data suffices for plus or minus 2 weeks from the 21st day of given month.

Roof Classifications for Use with CLTD Tables for Flat Roofs

Mass Location	Suspended Ceiling	R-Factor, $h \cdot ft^2 \cdot °F/Btu$	Wood 1 in.	2 in. (heavyweight) Concrete	Steel Deck	AtticCeiling Comb.
Mass inside insul.	Without	0 to 10	*	2	*	*
		10 to 20	*	4	*	*
		20 to 25	*	5	*	*
	With	0 to 5	*	5	*	*
		5 to 10	*	8	*	*
		10 to 20	*	13	*	*
		20 to 25	*	14	*	*
Mass evenly placed	Without	0 to 5	1	2	1	1
		5 to 15	2	*	1	2
		15 to 25	4	*	2	2
	With	0 to 5	*	3	1	*
		5 to 10	4	*	1	*
		10 to 15	5	*	2	
		15 to 20	9	*	2	*
		20 to 25	10	*	4	*
Mass outside insul.	Without	0 to 5	*	2	*	*
		5 to 10	*	3	*	*
		10 to 15	*	4	*	*
		15 to 25	*	5	*	*
	With	0 to 10	*	3	*	*
		10 to 15	*	4	*	*
		15 to 20	*	5	*	*

* Denotes roof that is not possible with the chosen parameters

Approximate Cooling Load Temperature Differences (CLTDs) for Sunlit Walls—24°N Latitude, July

Wall Facing	Solar time, h								Solar time, h								Solar time, h							
	6	8	10	12	14	16	18	20	6	8	10	12	14	16	18	20	6	8	10	12	14	16	18	20
	Low Mass, Low R-Factor Wall								**Low Mass, Medium R-Factor Wall**								**Low Mass, High R-Factor Wall**							
N	−2	13	18	22	28	32	34	17	1	0	6	13	18	23	28	30	−2	2	12	18	23	28	32	29
NE	0	39	53	39	30	30	24	13	0	3	20	36	39	35	32	27	−2	9	36	46	38	32	29	22
E	0	44	63	48	32	30	24	13	1	3	22	43	46	40	34	28	−2	10	42	55	44	35	30	23
SE	−2	25	44	42	32	30	24	13	0	1	13	28	35	35	32	27	−2	4	26	40	38	33	29	22
S	−3	3	12	24	31	30	23	13	0	−1	1	7	16	24	27	25	−2	−1	4	13	24	29	28	22
SW	−3	3	13	22	40	58	52	20	1	−1	1	7	15	29	43	47	−2	−1	5	13	24	42	54	44
W	−3	3	13	22	42	73	75	27	2	0	2	7	15	30	52	61	−1	−1	5	13	23	46	69	61
NW	−3	3	13	22	37	62	67	25	1	0	2	7	15	27	45	54	−1	−1	5	13	22	40	60	55
	High Mass, Low R-Value Wall								**High Mass, Medium R-Value Wall**								**High Mass, High R-Value Wall**							
N	3	3	7	12	16	21	25	27	10	8	8	10	12	15	18	21	12	9	8	8	10	13	16	19
NE	3	6	20	31	33	32	31	27	11	9	14	21	25	26	27	26	13	10	10	15	21	24	27	27
E	4	6	22	36	39	36	33	29	12	10	15	24	29	30	30	29	14	11	11	17	24	28	30	31
SE	3	4	14	25	30	30	30	26	10	8	11	17	21	24	25	25	13	10	9	12	17	21	24	25
S	3	1	3	7	14	20	23	22	8	6	5	6	10	14	17	18	10	8	6	5	7	10	14	17
SW	5	3	4	8	14	26	38	40	13	10	9	9	11	17	24	30	17	13	10	8	9	12	18	25
W	7	4	4	8	15	28	45	51	17	13	11	11	13	18	28	36	21	16	12	10	11	13	20	30
NW	6	3	4	8	14	25	40	46	15	12	10	10	12	17	25	32	19	14	11	9	10	12	18	26

CAUTION: Approximate data—Use for preliminary computations only.

Approximate Cooling Load Temperature Differences (CLTDs) for Sunlit Walls—36°N Latitude, July

Wall Facing	Solar time, h								Solar time, h								Solar time, h							
	6	8	10	12	14	16	18	20	6	8	10	12	14	16	18	20	6	8	10	12	14	16	18	20
	Low Mass, Low R-Factor Wall								**Low Mass, Medium R-Factor Wall**								**Low Mass, High R-Factor Wall**							
N	–1	12	14	21	28	29	30	17	0	0	5	10	16	22	26	27	–2	3	9	15	21	27	28	27
NE	1	41	46	30	29	29	24	14	0	4	21	33	33	31	30	27	–2	12	36	39	32	30	28	23
E	1	49	64	48	31	30	24	14	1	4	26	45	47	40	34	29	–2	14	46	56	45	34	30	23
SE	–1	31	52	52	36	30	24	14	1	2	16	34	44	41	35	29	–2	7	31	48	47	37	31	23
S	–3	4	18	39	47	40	25	14	0	–1	2	11	25	36	38	32	–2	–1	6	21	37	44	37	25
SW	–2	4	13	23	50	67	59	23	1	0	2	8	17	34	51	54	–1	–1	5	13	28	50	62	51
W	–2	4	13	21	42	73	78	31	2	0	2	8	15	30	52	63	–1	–1	5	13	23	46	69	65
NW	–2	4	13	21	29	53	65	28	1	0	2	8	15	24	39	51	–2	–1	5	13	21	33	53	55
	High Mass, Low R-Factor Wall								**High Mass, Medium R-Factor Wall**								**High Mass, High R-Factor Wall**							
N	3	3	6	10	15	20	23	25	9	7	8	9	11	14	17	19	11	9	7	7	9	11	14	17
NE	3	7	20	28	29	29	29	26	10	9	14	20	23	24	25	25	13	10	10	15	19	22	24	25
E	4	8	25	38	40	37	34	29	12	11	17	25	30	31	31	30	15	11	12	18	25	30	31	31
SE	4	5	17	30	37	36	33	29	12	10	13	20	26	29	29	28	14	11	10	14	20	26	29	30
S	3	2	4	11	22	31	33	29	10	8	7	9	14	20	24	25	13	10	7	7	10	15	21	24
SW	6	3	4	8	16	31	44	46	15	12	10	10	13	19	28	34	19	15	11	10	10	14	21	29
W	7	4	5	9	15	28	46	54	17	14	12	11	13	18	28	37	22	17	13	11	11	14	20	30
NW	6	3	4	8	14	22	35	43	14	11	10	10	12	15	22	30	18	14	11	9	10	12	17	24

CAUTION: Approximate data—Use for preliminary computations only.

Approximate Cooling Load Temperature Differences (CLTDs) for Sunlit Walls—48°N Latitude, July

CAUTION: Approximate data--Use for preliminary computations only.

Wall Facing	Solar time, h								Solar time, h								Solar time, h							
	6	8	10	12	14	16	18	20	6	8	10	12	14	16	18	20	6	8	10	12	14	16	18	20
	Low Mass, Low R-Factor Wall								**Low Mass, Medium R-Factor Wall**								**Low Mass, High R-Factor Wall**							
N	3	10	13	21	27	28	27	21	1	2	6	10	16	21	25	26	–1	5	9	14	21	26	27	27
NE	10	42	38	26	28	29	24	15	1	7	23	31	30	29	28	26	0	18	36	34	28	28	28	23
E	10	54	64	47	31	29	25	15	1	8	30	47	48	40	34	29	0	20	49	57	44	34	29	23
SE	4	36	59	61	45	31	25	15	1	4	20	40	51	49	40	32	–1	11	36	55	56	43	33	24
S	–2	5	28	52	62	51	29	15	1	0	3	16	34	48	50	40	–1	0	9	30	50	57	47	30
SW	–1	5	12	29	59	75	65	29	2	0	3	8	20	40	58	61	–1	0	6	14	33	58	69	57
W	–1	5	13	21	41	72	80	41	2	0	3	8	15	29	51	64	–1	0	6	13	22	45	69	69
NW	–2	5	12	21	27	45	62	37	2	0	2	8	14	22	34	47	–1	0	5	13	20	29	46	54
	High Mass, Low R-Factor Wall								**High Mass, Medium R-Factor Wall**								**High Mass, High R-Factor Wall**							
N	3	4	6	10	14	19	22	24	9	8	8	9	11	14	17	19	12	9	8	8	9	11	14	17
NE	4	10	22	26	26	27	27	25	10	10	15	20	22	23	24	24	13	10	12	16	19	22	23	24
E	4	11	28	40	40	37	34	29	12	12	19	27	32	32	32	30	15	12	14	20	27	31	32	32
SE	4	7	20	35	43	42	38	32	13	12	15	23	30	34	34	32	16	12	12	17	24	30	34	34
S	5	3	6	16	31	41	43	37	13	10	9	12	19	27	32	33	16	12	10	10	14	21	28	32
SW	7	4	5	9	19	36	50	52	18	14	12	12	15	23	32	39	22	17	13	11	12	16	24	33
W	8	5	6	9	15	27	45	55	19	15	12	12	14	19	28	38	23	18	14	12	12	14	20	30
NW	6	4	5	8	14	20	31	41	14	11	10	10	12	15	20	28	18	14	11	9	10	12	16	22

Note 1. Apply data directly to (1) dark surface, (2) indoor temperature of 78°F, (3) outdoor maximum temperature of 95°F with mean temperature of 85°F and daily range of 21°F, (4) outside surface film resistance of 0.333 (h·ft^2·°F)/Btu, and (5) inside surface resistance of 0.685 (h·ft^2·°F)/Btu.

Note 2. Adjustments to design temperatures:

Corr. CLTD = CLTD + $(78 - t_r) + (t_m - 85)$

where t_r = inside temperature and t_m = mean outdoor temperature, or t_m = maximum outdoor temperature – (daily range)/2

Note 3. Adjustments to months other than July: For design purposes, the data suffices for plus or minus 2 weeks from the 21st day of given month

Solar Cooling Load For Sunlit Glass (SCL)

Tables do not consider zone type and are conservative. Use for preliminary computations only.

24°N Latitude, July

Glass Facing	Solar time, h																	
	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
N	0	19	35	36	36	38	40	42	42	40	38	39	43	32	11	6	3	1
NE	0	54	124	150	144	115	78	58	49	44	38	32	25	14	6	3	1	1
E	0	57	139	177	180	154	107	68	54	46	40	33	25	14	6	3	1	1
SE	0	26	74	104	114	106	83	59	50	44	38	32	25	14	6	3	1	1
S	0	5	15	23	30	35	40	43	43	40	37	32	24	14	6	3	1	1
SW	0	5	15	23	30	35	39	42	61	88	110	118	105	62	24	12	6	3
W	0	5	15	23	30	35	39	41	67	116	160	186	184	118	44	21	11	5
NW	0	5	15	23	30	35	39	41	51	83	122	151	158	106	39	19	9	5
Hor	0	10	55	113	170	218	253	271	273	258	225	176	115	54	24	12	6	3

36°N Latitude, July

Glass Facing	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
N	0	25	29	28	32	36	39	40	41	39	36	32	33	36	12	6	3	1
NE	0	79	129	139	120	84	58	50	45	41	37	32	26	17	7	3	2	1
E	0	86	153	184	182	155	107	67	54	45	39	33	26	17	7	3	2	1
SE	0	42	90	125	142	140	119	86	58	48	40	34	27	17	7	3	2	1
S	0	8	17	24	36	53	70	80	79	68	52	38	29	18	7	3	2	1
SW	0	8	17	24	30	35	38	57	90	122	141	144	127	85	32	15	8	4
W	0	8	17	24	30	35	38	40	66	115	159	188	191	149	53	25	12	6
NW	0	8	17	24	30	35	38	40	40	56	93	129	148	127	43	21	10	5
Hor	0	20	66	120	171	215	246	263	265	251	221	178	124	66	28	13	7	3

Solar Cooling Load for Sunlit Glass (SCL) (*Concluded*)

48°N Latitude, July

Glass Facing	Solar time, h																	
	5	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
N	14	28	24	27	31	34	37	38	38	37	35	31	27	34	25	9	4	2
NE	32	101	130	126	95	61	49	44	41	38	35	31	26	19	10	4	2	1
E	31	112	165	188	182	153	104	65	51	43	38	32	27	19	10	4	2	1
SE	11	58	106	143	164	168	152	119	77	54	43	35	28	20	10	4	2	1
S	3	11	18	30	58	90	116	130	130	116	88	56	37	24	12	5	3	1
SW	3	11	18	24	30	34	46	82	122	152	168	166	146	106	50	22	11	5
W	3	11	18	24	30	34	36	38	64	112	156	186	193	167	89	36	17	9
NW	3	11	18	24	30	34	36	38	38	40	67	106	134	134	76	30	14	7
Hor	5	32	73	120	163	200	226	241	242	230	205	170	125	76	35	16	8	4

Tables do not consider zone type and are conservation. Data apply directly to: (1) standard double strength glass with no inside shade, and (2) clear sky, 21st day of month.

Adjustments to table data

- Latitudes other than 24, 36 and 48°N
  Linear interpolation is acceptable.
- Months other than July
  For design purposes, data will suffice for plus or minus 2 weeks from the 21st day of given month.
- Other types of glass and internal shade
  Use shading coefficients as multiplier.
- Externally shaded glass
  Use north orientation

Shading Coefficients* for Single Glass with Indoor Shading by Venetian Blinds or Roller Shades

Type of Glass	Nominal Thickness,[a] in.	Solar Transmittance[b]	Type of Shading: Venetian Blinds, Medium	Venetian Blinds, Light	Roller Shade, Opaque, Dark	Roller Shade, Opaque, White	Roller Shade, Translucent, Light
Clear	3/32[c]	0.87 to 0.80	0.74[d] (0.63)[e]	0.67[d] (0.58)[e]	0.81	0.39	0.44
Clear	1/4 to 1/2	0.80 to 0.71					
Clear pattern	1/8 to 1/2	0.87 to 0.79					
Heat-absorbing pattern	1/8	—					
Tinted	3/16, 7/32	0.74, 0.71					
Heat-absorbing[f]	3/16, 1/4	0.46					
Heat-absorbing pattern	3/16, 1/4	—	0.57	0.53	0.45	0.30	0.36
Tinted	1/8, 7/32	0.59, 0.45					
Heat-absorbing or pattern	—	0.44 to 0.30	0.54	0.52	0.40	0.28	0.32
Heat-absorbing[f]	3/8	0.34					
Heat-absorbing or pattern		0.29 to 0.15					
	—	0.24	0.42	0.40	0.36	0.28	0.31
Reflective coated glass	S.C. = 0.30[g]		0.25	0.23			
	= 0.40		0.33	0.29			
	= 0.50		0.42	0.38			
	= 0.60		0.50	0.44			

[a]Refer to manufacturers' literature for values.
[b]For vertical blinds with opaque white and beige louvers in the tightly closed position, SC is 0.25 and 0.29 when used with glass of 0.71 to 0.80 transmittance.
[c]Typical residential glass thickness.
[d]From Van Dyck and Konen (1982), for 45° open venetian blinds, 35° solar incidence, and 35° profile angle.
[e]Values for closed venetian blinds. Use these values only when operation is automated for solar gain reduction (as opposed to daylight use).
[f]Refers to gray, bronze, and green tinted heat-absorbing glass.
[g]SC for glass with no shading device.

*Note: Shading Coefficient (SC) has been superseded by solar heat gain coefficient (SHGC) including the effect of incident angle of solar radiation on the glass, and the effect of type of framing. This shading coefficient table is sufficiently accurate for the approximate cooling load calculations of this publication. For the glazing portion of single-pane clear and tinted fenestration,

$$SC = \frac{SHGC}{0.87}$$

This does not include frame effects.

Rates of Heat Gain from Occupants of Conditioned Spaces

Degree of Activity		Total Heat, Btu/h: Adult Male	Total Heat, Btu/h: Adjusted, M/F[a]	Sensible Heat, Btu/h	Latent Heat, Btu/h	% Sensible Heat that is Radiant[b]: Low V	% Sensible Heat that is Radiant[b]: High V
Seated at theater	Theater, matinee	390	330	225	105		
Seated at theater, night	Theater, night	390	350	245	105	60	27
Seated, very light work	Offices, hotels, apartments	450	400	245	155		
Moderately active office work	Offices, hotels, apartments	475	450	250	200		
Standing, light work; walking	Department store; retail store	550	450	250	200	58	38
Walking, standing	Drug store, bank	550	500	250	250		
Sedentary work	Restaurant[c]	490	550	275	275		
Light bench work	Factory	800	750	275	475		
Moderate dancing	Dance hall	900	850	305	545	49	35
Walking 3 mph; light machine work	Factory	1000	1000	375	625		
Bowling[d]	Bowling alley	1500	1450	580	870		
Heavy work	Factory	1500	1450	580	870	54	19
Heavy machine work; lifting	Factory	1600	1600	635	965		
Athletics	Gymnasium	2000	1800	710	1090		

Notes:
1. Tabulated values are based on 75°F room dry-bulb temperature. For 80°F room dry bulb, the total heat remains the same, but the sensible heat values should be decreased by approximately 20%, and the latent heat values increased accordingly.
2. Also refer to Table 4, Chapter 8, for additional rates of metabolic heat generation.
3. All values are rounded to nearest 5 Btu/h.

[a]Adjusted heat gain is based on normal percentage of men, women, and children for the application listed, with the postulate that the gain from an adult female is 85% of that for an adult male, and that the gain from a child is 75% of that for an adult male.
[b]Values approximated from data in Table 6, Chapter 8, where is air velocity with limits shown in that table.
[c]Adjusted heat gain includes 60 Btu/h for food per individual (30 Btu/h sensible and 30 Btu/h latent).
[d]Figure one person per alley actually bowling, and all others as sitting (400 Btu/h) or standing or walking slowly (550 Btu/h).

Heat Gain from Lighting

The energy absorbed by the structure and contents contributes to space cooling load only after a time lag, some still reradiating after the heat sources have been switched off. This may make load lower than instantaneous heat gain, thus affecting the peak load.

Instantaneous rate of heat gain from lights, q_{el} Btu/h:

$$q_{el} = 3.41\ W\ F_{ue}\ F_{sa}$$

where

W = total lights wattage installed
F_{ue} = lighting use factor (proportion in use)
F_{sa} = lighting special allowance factor

The **total light wattage** is obtained from the ratings of all lamps installed, both for general illumination and for display use. Ballasts are not included, but are addressed by a separate factor. Wattages of magnetic ballasts are significant; the energy consumption of high-efficiency electronic ballasts might be insignificant compared to that of the lamps.

The **lighting use factor** is the ratio of wattage in use, for the conditions under which the load estimate is being made, to total installed wattage. For commercial applications such as stores, the use factor is generally 1.0.

The **special allowance factor** is the ratio of the lighting fixtures' power consumption, including lamps and ballast, to the nominal power consumption of the lamps. For incandescent lights, this factor is 1. For fluorescent lights, it accounts for power consumed by the ballast as well as the ballast's effect on lamp power consumption. The special allowance factor can be less than 1 for electronic ballasts that lower electricity consumption below the lamp's rated power consumption. Use manufacturers' values for system (lamps + ballast) power, when available.

For high-intensity-discharge lamps (e.g. metal halide, mercury vapor, high- and low-pressure sodium vapor lamps), the actual lighting system power consumption should be available from the manufacturer of the fixture or ballast. Ballasts available for metal halide and high pressure sodium vapor lamps may have special allowance factors from about 1.3 (for low-wattage lamps) down to 1.1 (for high-wattage lamps).

An alternative procedure is to estimate the lighting heat gain on a per square foot basis. Such an approach may be required when final lighting plans are not available. Table 2 shows the maximum lighting power density (LPD) (lighting heat gain per square foot) allowed by ASHRAE *Standard* 90.1-2007 for a range of space types.

Lighting Power Densities Using Space-by-Space Method

Common Space Types*	LPD, W/ft²	Building-Specific Space Types	LPD, W/ft²
Office—enclosed	1.1	Gymnasium/exercise center	
Office—open plan	1.1	Playing Area	1.4
Conference/meeting/multipurpose	1.3	Exercise Area	0.9
Classroom/lecture/training	1.4	Courthouse/police station/penitentiary	
For penitentiary	1.3	Courtroom	1.9
Lobby	1.3	Confinement cells	0.9
For hotel	1.1	Judges' chambers	1.3
For performing arts theater	3.3	Fire Stations	
For motion picture theater	1.1	Engine room	0.8
Audience/seating Area	0.9	Sleeping quarters	0.3
For gymnasium	0.4	Post office—sorting area	1.2
For exercise center	0.3	Convention center—exhibit space	1.3
For convention center	0.7	Library	
For penitentiary	0.7	Card file and cataloging	1.1
For religious buildings	1.7	Stacks	1.7
For sports arena	0.4	Reading area	1.2
For performing arts theater	2.6	Hospital	
For motion picture theater	1.2	Emergency	2.7
For transportation	0.5	Recovery	0.8

Lighting Power Densities Using Space-by-Space Method (Continued)

Atrium—first three floors	0.6	Nurses' station	1.0
Atrium—each additional floor	0.2	Exam/treatment	1.5
Lounge/recreation	1.2	Pharmacy	1.2
For hospital	0.8	Patient room	0.7
Dining Area	0.9	Operating room	2.2
For penitentiary	1.3	Nursery	0.6
For hotel	1.3	Medical supply	1.4
For motel	1.2	Physical therapy	0.9
For bar lounge/leisure dining	1.4	Radiology	0.4
For family dining	2.1	Laundry—washing	0.6
Food preparation	1.2	Automotive—service/repair	0.7
Laboratory	1.4	Manufacturing	
Restrooms	0.9	Low bay (<25 ft floor to ceiling height)	1.2
Dressing/locker/fitting room	0.6	High bay (≥25 ft7.6 m floor to ceiling height)	1.7
Corridor/transition	0.5	Detailed manufacturing	2.1
For hospital	1.0	Equipment room	1.2
For manufacturing facility	0.5	Control room	0.5
Stairs—active	0.6	Hotel/motel guest rooms	1.1
Active storage	0.8	Dormitory—living quarters	1.1
For hospital	0.9	Museum	
Inactive storage	0.3	General exhibition	1.0
For museum	0.8	Restoration	1.7
Electrical/mechanical	1.5	Bank/office—banking activity area	1.5
Workshop	1.9	Religious buildings	
Sales area [for accent lighting, see Section 9.6.2(B) of ASHRAE *Standard* 90.1]	1.7	Worship pulpit, choir	2.4
		Fellowship hall	0.9
		Retail	
		Sales area for accent lighting, see Section 9.6.3(C) of ASHRAE *Standard* 90.1]	1.7
		Mall concourse	1.7
		Sports arena	
		Ring sports area	2.7
		Court sports area	2.3
		Indoor playing field area	1.4
		Warehouse	
		Fine material storage	1.4
		Medium/bulky material storage	0.9
		Parking garage—garage area	0.2
		Transportation	
		Airport—concourse	0.6
		Air/train/bus—baggage area	1.0
		Terminal—ticket counter	1.5

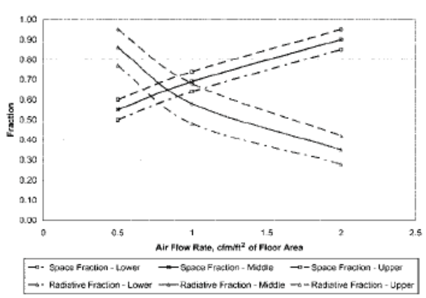
Source: ASHRAE *Standard* 90.1-2007.
*In cases where both a common space type and a building-specific type are listed, the building-specific space type applies.

Lighting Heat Gain Parameters for Typical Operating Conditions

Luminaire Category	Space Fraction	Radiative Fraction	Notes
Recessed fluorescent luminaire without lens	0.64 to 0.74	0.48 to 0.68	• Use middle values in most situations • May use higher space fraction, and lower radiative fraction for luminaire with side-slot returns • May use lower values of both fractions for direct/ indirect luminaire • May use higher values of both fractions for ducted returns
Recessed fluorescent luminaire with lens	0.40 to 0.50	0.61 to 0.73	• May adjust values in the same way as for recessed fluorescent luminaire without lens
Downlight compact fluorescent luminaire	0.12 to 0.24	0.95 to 1.0	• Use middle or high values if detailed features are unknown • Use low value for space fraction and high value for radiative fraction if there are large holes in luminaire's reflector
Downlight incandescent luminaire	0.70 to 0.80	0.95 to 1.0	• Use middle values if lamp type is unknown • Use low value for space fraction if standard lamp (i.e. A-lamp) is used • Use high value for space fraction if reflector lamp (i.e. BR-lamp) is used
Non-in-ceiling fluorescent luminaire	1.0	0.5 to 0.57	• Use lower value for radiative fraction for surface-mounted luminaire • Use higher value for radiative fraction for pendant luminaire

Source: Fisher and Chantrasrisalai (2006).

The table above provides a range of design data under typical operating conditions: airflow 1 cfm/ft², supply air between 59°F and 62°F, room temperature between 72°F and 75°F, and lighting heat input in a range from 0.9 to 2.6 W/ft². For a fluorescent luminaire without lens, the figure below gives more precise data. The data should be used with judgement.



Lighting Heat Gain Parameters for Recessed Fluorescent Luminaire Without Lens

Heat Gain from Motors and their Loads

Instantaneous rate of heat gain from equipment operated by electric motors within a conditioned space.

$$q_{em} = 2545\,(P/E_m)\,F_{um}\,F_{LM}$$

where

q_{em} = heat equivalent of equipment operation
P = motor power rating, hp
E_m = motor efficiency, decimal fraction < 1.0
F_{um} = motor use factor 1.0 or <1.0 (proportion operating)
F_{LM} = motor load factor 1.0 or <1.0

When motor is outside the conditioned space, but load is inside,

$$q_{em} = 2545\,P\,F_{um}\,F_{LM}$$

When motor is inside the conditioned space, but load is outside,

$$q_{em} = 2545P\left(\frac{1.0 - E_m}{E_m}\right)F_{um}\,F_{em}$$

Minimum Nominal Efficiency for General Purpose Design A and Design B Motors

	Minimum Nominal Full-Load Efficiency, %					
	Open Motors			Enclosed Motors		
Number of Poles ⇒	2	4	6	2	4	6
Synchronous Speed (RPM) ⇒	3600	1800	1200	3600	1800	1200
Motor Horsepower						
1	—	82.5	80.0	75.5	82.5	80.0
1.5	82.5	84.0	84.0	82.5	84.0	85.5
2	84.0	84.0	85.5	84.0	84.0	86.5
3	84.0	86.5	86.5	85.5	87.5	87.5
5	85.5	87.5	87.5	87.5	87.5	87.5
7.5	87.5	88.5	88.5	88.5	89.5	89.5
10	88.5	89.5	90.2	89.5	89.5	89.5
15	89.5	91.0	90.2	90.2	91.0	90.2
20	90.2	91.0	91.0	90.2	91.0	90.2
25	91.0	91.7	91.7	91.0	92.4	91.7
30	91.0	92.4	92.4	91.0	92.4	91.7
40	91.7	93.0	93.0	91.7	93.0	93.0
50	92.4	93.0	93.0	92.4	93.0	93.0
60	93.0	93.6	93.6	93.0	93.6	93.6
75	93.0	94.1	93.6	93.0	94.1	93.6
100	93.0	94.1	94.1	93.6	94.5	94.1
125	93.6	94.5	94.1	94.5	94.5	94.1
150	93.6	95.0	94.5	94.5	95.0	95.0
200	94.5	95.0	94.5	95.0	95.0	95.0

Heat output of a motor is generally proportional to motor load, within rated overload limits. Because of typically high no-load motor current, fixed losses, and other reasons, F_{LM} is generally assumed to be unity, and no adjustment should be made for underloading or overloading unless the situation is fixed and can be accurately established, and reduced-load efficiency data can be obtained from the motor manufacturer. Unless the manufacturer's technical literature indicates otherwise, motor heat gain normally should be equally divided between radiant and convective components for the subsequent cooling load calculations.

Cooking Appliances

Heat gain: $q_s = q_{input} F_U F_R$, where F_U is the usage factor and F_R is the radiation factor.

Recommended Rates of Radiant and Convective Heat Gain from Unhooded Electric Appliances During Idle (Ready-to-Cook) Conditions

	Energy Rate, Btu/h		Rate of Heat Gain, Btu/h					
Appliance	Rated	Standby	Sensible Radiant	Sensible Convective	Latent	Total	Usage Factor F_u	Radiation Factor F_r
Cabinet: hot serving (large), insulated*	6,800	1,200	400	800	0	1,200	0.18	0.33
Cabinet: hot serving (large), uninsulated	6,800	3,500	700	2,800	0	3,500	0.51	0.2
Cabinet: proofing (large)*	17,400	1,400	1,200	0	200	1,400	0.08	0.86
Cabinet: proofing (small-15 shelf)	14,300	3,900	0	900	3,000	3,900	0.27	0
Coffee brewing urn	13,000	1,200	200	300	700	1,200	0.09	0.17
Drawer warmers, 2-drawer (moist holding)*	4,100	500	0	0	200	200	0.12	0
Egg cooker	10,900	700	300	400	0	700	0.06	0.43
Espresso machine*	8,200	1,200	400	800	0	1,200	0.15	0.33
Food warmer: steam table (2-well-type)	5,100	3,500	300	600	2,600	3,500	0.69	0.09
Freezer (small)	2,700	1,100	500	600	0	1,100	0.41	0.45
Hot dog roller*	3,400	2,400	900	1,500	0	2,400	0.71	0.38
Hot plate: single burner, high speed	3,800	3,000	900	2,100	0	3,000	0.79	0.3
Hot-food case (dry holding)*	31,100	2,500	900	1,600	0	2,500	0.08	0.36
Hot-food case (moist holding)*	31,100	3,300	900	1,800	600	3,300	0.11	0.27
Microwave oven: commercial (heavy duty)	10,900	0	0	0	0	0	0	0
Oven: countertop conveyorized bake/finishing*	20,500	12,600	2,200	10,400	0	12,600	0.61	0.17
Panini*	5,800	3,200	1,200	2,000	0	3,200	0.55	0.38
Popcorn popper*	2,000	200	100	100	0	200	0.1	0.5
Rapid-cook oven (quartz-halogen)*	41,000	0	0	0	0	0	0	0
Rapid-cook oven (microwave/convection)*	24,900	4,100	1,000	3,100	0	1,000	0.16	0.24
Reach-in refrigerator*	4,800	1,200	300	900	0	1,200	0.25	0.25
Refrigerated prep table*	2,000	900	600	300	0	900	0.45	0.67
Steamer (bun)	5,100	700	600	100	0	700	0.14	0.86
Toaster: 4-slice pop up (large): cooking	6,100	3,000	200	1,400	1,000	2,600	0.49	0.07
Toaster: contact (vertical)	11,300	5,300	2,700	2,600	0	5,300	0.47	0.51
Toaster: conveyor (large)	32,800	10,300	3,000	7,300	0	10,300	0.31	0.29
Toaster: small conveyor	5,800	3,700	400	3,300	0	3,700	0.64	0.11
Waffle iron	3,100	1,200	800	400	0	1,200	0.39	0.67

Recommended Rates of Radiant Heat Gain from Hooded Electric Appliances During Idle (Ready-to-Cook) Conditions

	Energy Rate, Btu/h		Rate of Heat Gain, Btu/h		
Appliance	**Rated**	**Standby**	**Sensible Radiant**	**Usage Factor F_u**	**Radiation Factor F_r**
Broiler: underfired 3 ft	36,900	30,900	10,800	0.84	0.35
Cheesemelter*	12,300	11,900	4,600	0.97	0.39
Fryer: kettle	99,000	1,800	500	0.02	0.28
Fryer: open deep-fat, 1-vat	47,800	2,800	1,000	0.06	0.36
Fryer: pressure	46,100	2,700	500	0.06	0.19
Griddle: double sided 3 ft (clamshell down)*	72,400	6,900	1,400	0.1	0.2
Griddle: double sided 3 ft (clamshell up)*	72,400	11,500	3,600	0.16	0.31
Griddle: flat 3 ft	58,400	11,500	4,500	0.2	0.39
Griddle-small 3 ft*	30,700	6,100	2,700	0.2	0.44
Induction cooktop*	71,700	0	0	0	0
Induction wok*	11,900	0	0	0	0
Oven: combi: combi-mode*	56,000	5,500	800	0.1	0.15
Oven: combi: convection mode	56,000	5,500	1,400	0.1	0.25
Oven: convection full-size	41,300	6,700	1,500	0.16	0.22
Oven: convection half-size*	18,800	3,700	500	0.2	0.14
Pasta cooker*	75,100	8,500	0	0.11	0
Range top: top off/oven on*	16,600	4,000	1,000	0.24	0.25
Range top: 3 elements on/oven off	51,200	15,400	6,300	0.3	0.41
Range top: 6 elements on/oven off	51,200	33,200	13,900	0.65	0.42
Range top: 6 elements on/oven on	67,800	36,400	14,500	0.54	0.4
Range: hot-top	54,000	51,300	11,800	0.95	0.23
Rotisserie*	37,900	13,800	4,500	0.36	0.33
Salamander*	23,900	23,300	7,000	0.97	0.3
Steam kettle: large (60 gal) simmer lid down*	110,600	2,600	100	0.02	0.04
Steam kettle: small (40 gal) simmer lid down*	73,700	1,800	300	0.02	0.17
Steamer: compartment: atmospheric*	33,400	15,300	200	0.46	0.01
Tilting skillet/braising pan	32,900	5,300	0	0.16	0

Recommended Rates of Radiant Heat Gain from Hooded Gas Appliances During Idle (Ready-to-Cook) Conditions

Appliance	Energy Rate, Btu/h		Rate of Heat Gain, Btu/h		
	Rated	Standby	Sensible Radiant	Usage Factor F_u	Radiation Factor F_r
Broiler: batch*	95,000	69,200	8,100	0.73	0.12
Broiler: chain (conveyor)	132,000	96,700	13,200	0.73	0.14
Broiler: overfired (upright)*	100,000	87,900	2,500	0.88	0.03
Broiler: underfired 3 ft	96,000	73,900	9,000	0.77	0.12
Fryer: doughnut	44,000	12,400	2,900	0.28	0.23
Fryer: open deep-fat, 1 vat	80,000	4,700	1,100	0.06	0.23
Fryer: pressure	80,000	9,000	800	0.11	0.09
Griddle: double sided 3 ft (clamshell down)*	108,200	8,000	1,800	0.07	0.23
Griddle: double sided 3 ft (clamshell up)*	108,200	14,700	4,900	0.14	0.33
Griddle: flat 3 ft	90,000	20,400	3,700	0.23	0.18
Oven: combi: combi-mode*	75,700	6,000	400	0.08	0.07
Oven: combi: convection mode	75,700	5,800	1,000	0.08	0.17
Oven: convection full-size	44,000	11,900	1,000	0.27	0.08
Oven: conveyor (pizza)	170,000	68,300	7,800	0.4	0.11
Oven: deck	105,000	20,500	3,500	0.2	0.17
Oven: rack mini-rotating*	56,300	4,500	1,100	0.08	0.24
Pasta cooker*	80,000	23,700	0	0.3	0
Range top: top off/oven on*	25,000	7,400	2,000	0.3	0.27
Range top: 3 burners on/oven off	120,000	60,100	7,100	0.5	0.12
Range top: 6 burners on/oven off	120,000	120,800	11,500	1.01	0.1
Range top: 6 burners on/oven on	145,000	122,900	13,600	0.85	0.11
Range: wok*	99,000	87,400	5,200	0.88	0.06
Rethermalizer*	90,000	23,300	11,500	0.26	0.49
Rice cooker*	35,000	500	300	0.01	0.6
Salamander*	35,000	33,300	5,300	0.95	0.16
Steam kettle: large (60 gal) simmer lid down*	145,000	5,400	0	0.04	0
Steam kettle: small (10 gal) simmer lid down*	52,000	3,300	300	0.06	0.09
Steam kettle: small (40 gal) simmer lid down	100,000	4,300	0	0.04	0
Steamer: compartment: atmospheric *	26,000	8,300	0	0.32	0
Tilting skillet/braising pan	104,000	10,400	400	0.1	0.04

Recommended Rates of Radiant Heat Gain from Hooded Solid Fuel Appliances During Idle (Ready-to-Cook) Conditions

	Energy Rate, Btu/h	Rate of Heat Gain, Btu/h			
Appliance	Rated	Standby	Sensible	Usage Factor F_u	Radiation Factor F_r
Broiler: solid fuel: charcoal	40 lb	42,000	6200	N/A	0.15
Broiler: solid fuel: wood (mesquite)*	40 lb	49,600	7000	N/A	0.14

Recommended Rates of Radiant and Convective Heat Gain from Warewashing Equipment During Idle (Standby) or Washing Conditions

	Energy Rate, Btu/h		Rate of Heat Gain, Btu/h						
			Unhooded				Hooded		
Appliance	Rated	Standby/ Washing	Sensible Radiant	Sensible Convective	Latent	Total	Sensible Radiant	Usage Factor F_u	Radiation Factor F_r
Dishwasher (conveyor type, chemical sanitizing)	46,800	5700/43,600	0	4450	13490	17940	0	0.36	0
Dishwasher (conveyor type, hot-water sanitizing) standby	46,800	5700/N/A	0	4750	16970	21720	0	N/A	0
Dishwasher (door-type, chemical sanitizing) washing	18,400	1200/13,300	0	1980	2790	4770	0	0.26	0
Dishwasher (door-type, hot-water sanitizing) washing	18,400	1200/13,300	0	1980	2790	4770	0	0.26	0
Dishwasher* (under-counter type, chemical sanitizing) standby	26,600	1200/18,700	0	2280	4170	6450	0	0.35	0.00
Dishwasher* (under-counter type, hot-water sanitizing) standby	26,600	1700/19,700	800	1040	3010	4850	800	0.27	0.34
Booster heater*	130,000	0	500	0	0	0	500	0	N/A

Note: Heat load values are prorated for 30% washing and 70% standby.

Hospital and Laboratory Equipment

Heat gain varies significantly. In a laboratory, heat gain ranges from 15 to 70 Btuh/ft^2. Medical equipment is highly varied in type and application. The table is relevant for portable and bench-type equipment. For large equipment, such as MRI, obtain heat gain from the manufacturer.

Recommended Heat Gain from Typical Medical Equipment

Equipment	Nameplate, W	Peak, W	Average, W
Anesthesia system	250	177	166
Blanket warmer	500	504	221
Blood pressure meter	180	33	29
Blood warmer	360	204	114
ECG/RESP	1440	54	50
Electrosurgery	1000	147	109
Endoscope	1688	605	596
Harmonical scalpel	230	60	59
Hysteroscopic pump	180	35	34
Laser sonics	1200	256	229
Optical microscope	330	65	63
Pulse oximeter	72	21	20
Stress treadmill	N/A	198	173
Ultrasound system	1800	1063	1050
Vacuum suction	621	337	302
X-ray system	968		82
	1725	534	480
	2070		18

Recommended Heat Gain from Miscellaneous Office Equipment

Appliance	Maximum Input Rating, W	Recommended Rate of Heat Gain, W
Mail-processing equipment		
Folding machine	125	80
Inserting machine, 3,600 to 6,800 pieces/h	600 to 3,300	390 to 2,150
Labeling machine, 1,500 to 30,000 pieces/h	600 to 6,600	390 to 4,300
Postage meter	230	150
Vending machines		
Cigarette	72	72
Cold food/beverage	1,150 to 1,920	575 to 960
Hot beverage	1,725	862
Snack	240 to 275	240 to 275
Other		
Bar code printer	440	370
Cash registers	60	48
Check processing workstation, 12 pockets	4,800	2,470
Coffee maker, 10 cups	1,500	1,050 W sens., 1,540 Btu/h latent
Microfiche reader	85	85
Microfilm reader	520	520
Microfilm reader/printer	1,150	1,150
Microwave oven, 1 ft^3	600	400
Paper shredder	250 to 3,000	200 to 2,420
Water cooler, 32 qt/h	700	350

Recommended Load Factors for Various Types of Offices

Load Density of Office	Load Factor, W/ft^2	Description
Light	0.5	Assumes 167 ft^2/workstation (6 workstations per 1000 ft^2) with computer and monitor at each plus printer and fax. Computer, monitor, and fax diversity 0.67, printer diversity 0.33.
Medium	1	Assumes 125 ft^2/workstation (8 workstations per 1000 ft^2) with computer and monitor at each plus printer and fax. Computer, monitor, and fax diversity 0.75, printer diversity 0.50.
Medium/ Heavy	1.5	Assumes 100 ft^2/workstation (10 workstations per 1000 ft^2) with computer and monitor at each plus printer and fax. Computer and monitor diversity 0.75, printer and fax diversity 0.50.
Heavy	2	Assumes 83 ft^2/workstation (12 workstations per 1000 ft^2) with computer and monitor at each plus printer and fax. Computer and monitor diversity 1.0, printer and fax diversity 0.50.

Source: Wilkins and McGaffin (1994).

Cooling Load Estimates for Various Office Load Densities

	Number	Each, W	Total, W	Diversity	Load, W
Light Load Density[a]					
Computers	6	55	330	0.67	220
Monitors	6	55	330	0.67	220
Laser printer—small desk top	1	130	130	0.33	43
Fax machine	1	15	15	0.67	10
Total Area Load					494
Recommended equipment load factor = 0.5 W/ft²					
Medium Load Density[a]					
Computers	8	65	520	0.75	390
Monitors	8	70	560	0.75	420
Laser printer—desk	1	215	215	0.5	108
Fax machine	1	15	15	0.75	11
Total Area Load					929
Recommended equipment load factor = 1.0 W/ft²					
Medium/Heavy Load Density[a]					
Computers	10	65	650	1	650
Monitors	10	70	700	1	700
Laser printer—small office	1	320	320	0.5	160
Facsimile machine	1	30	30	0.5	15
Total Area Load					1525
Recommended equipment load factor = 1.5 W/ft²					
Heavy Load Density[a]					
Computers	12	75	900	1	900
Monitors	12	80	960	1	960
Laser printer-small office	1	320	320	0.5	160
Facsimile machine	1	30	30	0.5	15
Total Area Load					2035
Recommended equipment load factor = 2.0 W/ft²					

Source: Wilkins and McGaffin (1994).

Refrigerating Effect Produced by Open Refrigerated Display Fixtures

	Btu/h·ft of Fixture*		
Type of Display Fixture	**Latent Heat**	**Sensible Heat**	**Total Refrigerating Effect**
Low temperature			
Frozen Food			
Single Deck	38	207	245
Single Deck, Double Island	70	400	470
2 Deck	144	576	720
3 Deck	322	1288	1610
4 or 5 Deck	400	1600	2000
Ice Cream			
Single Deck	64	366	430
Single Deck, Double Island	70	400	470
Standard Temperature			
Meats			
Single Deck	52	298	350
Multideck	219	876	1095
Dairy			
Multideck	196	784	980
Produce			
Single Deck	36	204	240
Multideck	192	768	960

*These figures are general magnitudes for fixtures adjusted for average desired product temperatures and apply to store ambients in front of the display cases of 72°F to 74°F with 50% to 55% rh. Raising the dry bulb only 3°F to 5°F and the humidity 5% to 10% can increase heat removal 25% or more. Equally lower temperatures and humidities as in winter, have an equally marked effect on lowering heat removal from the space.

VENTILATION

ASHRAE Standard 62.2-2007, Ventilation and Acceptable Air Quality in Low-Rise Residential Buildings

Low-rise residential ventilation for single and multiple family structures of three stories or fewer above grade, including manufactured and modular houses.

Whole-house mechanical ventilation systems are required for each dwelling unit:

$$cfm = 0.01\ (ft^2\ floor\ area) + 7.5\ (number\ of\ bedrooms + 1).$$

Exceptions: (a) building is in zone 3B or 3C of the IECC 2007 climate zone map, (b) building has no mechanical cooling and is in zone 1 or 2 of the climate zone map (see p. 184), or (c) building is thermally conditioned for human occupancy for less than 876 hours per year and if the authority having jurisdiction determines that window ventilation is sufficient.

Alternate means may be used to provide the required ventilation rate when approved by a licensed design professional. In hot humid climates whole-house net mechanical exhaust shall not exceed 7.5 cfm per 100 ft^2. In severe cold climates net supply systems shall not exceed 7.5 cm per 100 ft^2. (Climates are defined on p. 184.)

Local mechanical exhaust:

Intermittent Local Ventilation Exhaust Airflow Rates

Application	Airflow	Notes
Kitchen	100 cfm	Vented range hood (including appliance-range hood combinations) required if exhaust fan flow rate is less than 5 kitchen air changes per hour.
Bathroom	50 cfm	

Continuous Local Ventilation Exhaust Airflow Rates

Application	Airflow	Notes
Kitchen	5 air changes per hour	Based on kitchen volume
Bathroom	20 cfm	

Ventilation openings: not less than 4% of floor, nor less than 5 ft^2 for habitable rooms; and not less than 4% of floor space, nor less than 1.5 ft^2 for toilets and utility rooms.

Supply ductwork for thermal conditioners except evaporative coolers, shall have a MERV 6 filter or better in accordance with ASHRAE Standard 52.2.

Airflows all refer to delivered airflow as tested, or the fans' rating at 0.25 in. sp. with duct sizing meet the prescriptive sizing of the table below.

Prescriptive Duct Sizing

Duct Type	Flex Duct				Smooth Duct			
Fan Rating CFM @ 0.25 in. wg	50	80	100	125	50	80	100	125
Diameter in.	Maximum Length ft. (m)							
3	X	X	X	X	5	X	X	X
4	70	3	X	X	105	35	5	X
5	NL	70	35	20	NL	135	85	55
6	NL	NL	125	95	NL	NL	NL	145
7 and above	NL	NL	NL	NL	NL	NL	NL	NL

This table assumes no elbows. Deduct 15 feet of allowable duct length for each elbow.
NL = no limit on duct length of this size.
X = not allowed, any length of duct of this size with assumed turns and fitting will exceed the rated pressure drop.

ASHRAE Standard 62.1-2007 (Occupancies except for low-rise residential)

Use of natural ventilation systems is permitted in lieu of or in conjunction with mechanical ventilation. Naturally ventilated spaces shall be permanently open to and within 25 ft of operable wall or roof openings to the outdoors; free openable area at least 4% of net occupiable floor area. If interior spaces are ventilated through adjoining rooms, free area between rooms shall be permanently unobstructed and at least 8% of the area of the interior room, nor less than 25 ft^2. Occupants must have ready access to the openings.

All airstream surfaces shall be designed to resist mold growth and resist erosion. Ductwork construction shall meet SMACNA standards. Fuel-burning appliances shall have sufficient air for combustion and adequate removal of combustion products, which shall be vented directly outdoors. Filters or air cleaners with minimum MERV 6 by ASHRAE Standard 52.2 shall be provided upstream of all cooling coils or other devices with wetted surfaces through which air is supplied to occupied space. Relative humidity should be below 65% when system performance is analyzed with outdoor at the design dew point and mean coincident dry bulb. Drain pans slope minimum 1/8 in. per ft to outlet at lowest point, and drain line shall have p-trap or other seal when drain pan is at negative static pressure relative to the outlet. Drain pan shall extend from leading edge of the coil to a distance of half the vertical dimension of the coil.

Discharge from non-combustion equipment that captures contaminants generated by the equipment shall be discharged directly outdoors.

Investigate outdoor air quality. Survey and document local outdoor air quality, with description of noticeable air problems and conditions regarding its acceptability. If unacceptable, treat it. Cleaning for ozone is required only if in a high-ozone area and if the minimum design outdoor airflow is 1.5 air changes or more.

Outdoor air intakes shall be located so the shortest distance from intake to any specific contaminant source shall equal or exceed Table 5.1.

Design intakes to manage rain and snow entrainment and include bird screens.

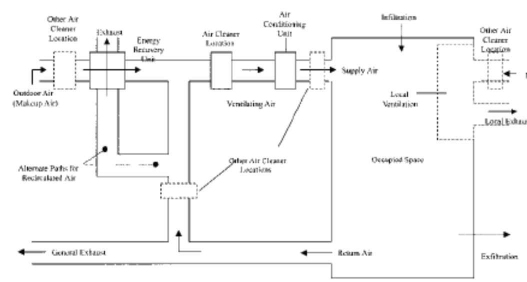


TABLE 5-1 Air Intake Minimum Separation Distance

Object	Minimum Distance, ft (m)
Significantly contaminated exhaust (Note 1)	15 (5)
Noxious or dangerous exhaust (Notes 2 and 3)	30 (10)
Vents, chimneys, and flues from combustion appliances and equipment (Note 4)	15 (5)
Garage entry, automobile loading area, or drive-in queue (Note 5)	15 (5)
Truck loading area or dock, bus parking/idling area (Note 5)	25 (7.5)
Driveway, street, or parking place (Note 5)	5 (1.5)
Thoroughfare with high traffic volume	25 (7.5)
Roof, landscaped grade, or other surface directly below intake (Notes 6 and 7)	1 (0.30)
Garbage storage/pick-up area, dumpsters	15 (5)
Cooling tower intake or basin	15 (5)
Cooling tower exhaust	25 (7.5)

Note 1: Significantly contaminated exhaust is exhaust air with significant contaminant concentration, significant sensory-irritation intensity, or offensive odor.
Note 2: Laboratory fume hood exhaust air outlets shall be in compliance with NFPA 45-1991[3] and ANSI/AIHA Z9.5-1992.[4]
Note 3: Noxious or dangerous exhaust is exhaust air with highly objectionable fumes or gases and/or exhaust air with potentially dangerous particles, bioaerosols, or gases at concentrations high enough to be considered harmful. Information on separation criteria for industrial environments can be found in the ACGIH Industrial Ventilation Manual[5] and in the *ASHRAE Handbook—HVAC Applications*.[6]
Note 4: Shorter separation distances are permitted when determined in accordance with (a) Chapter 7 of ANSI Z223.1/NFPA 54-2002[7] for fuel gas burning appliances and equipment; (b) Chapter 6 of NFPA 31-2001[8] for oil burning appliances and equipment, or (c) Chapter 7 of NFPA 211-2003[9] for other combustion appliances and equipment.
Note 5: Distance measured to closest place that vehicle exhaust is likely to be located.
Note 6: No minimum separation distance applies to surfaces that are sloped more than 45 degrees from horizontal or that are less than 1 in. (3 cm) wide.
Note 7: Where snow accumulation is expected, distance listed shall be increased by the expected average snow depth.

Air classification in Table 5.2:

- Class 1—Low contaminant concentration, inoffensive odor and sensory irritation, suitable for recirculation or transfer to any space.
- Class 2—Moderate contaminants, odor and sensory irritation; can be recirculated or transferred to any space with class 2 or class 3 air used for similar purpose and with similar pollutant source, and air not harmful or objectionable but is inappropriate for transfer or recirculation to spaces used for different purpose.
- Class 3—Significant contaminants, odor, and sensory irritation; can be recirculated or transferred only within same space.
- Class 4—Highly objectionable with fumes, gases, or potentially dangerous contaminants at harmful concentration. Not suitable for any recirculation or transfer.

TABLE 5-2 Airstreams

Description	Air Class
Diazo printing equipment discharge	4
Commercial kitchen grease hoods	4
Commercial kitchen hoods other than grease	3
Laboratory hoods	4
Residential kitchen vented hoods	3

Either the ventilation rate procedure or the IAQ procedure shall be used to design ventilation systems. The IAQ procedure is based on analysis of contaminant sources, concentrations, and targets, and perceived acceptability targets. Use design techniques that can be reliably demonstrated to result in indoor contaminant concentrations equal to or lower than achieved by the ventilation rate procedure.

Ventilation Rate Procedure

Zone: Space or spaces with similar occupant category (Table 6-1), occupant density, zone air distribution effectiveness (Table 6-2), and primary airflow per unit area.

1. **Breathing Zone OA flow**, $V_{bz} = R_p P_z + R_a \Delta_z$
   when Δ_z = zone floor area, ft^2; P_z = zone maximum occupancy; R_p = outdoor air required per person (Table 6-1); R_a = outdoor air required per unit area (Table 6-1)
2. **Zone Air Distribution Effectiveness**, E_z (Table 6-2)
3. **Single Zone or 100% OA** Systems, OA intake flow, $V_{ot} = \Sigma_{oz}$ from all zones
4. **Multiple Zone Recirculating** Systems
   a. Zone primary (OA plus recirculating) airflow fraction, $Z_p = V_{oz}/V_{pz}$
   where V_{pz} = airflow from air handler (OA + recirc.); for VAV systems V_{pz} is minimum expected.
   b. System ventilation efficiency, E_v (Table 3) (or alternative method in an appendix of the standard)
   c. System uncorrected OA intake, $V_{ou} = D\Sigma_{allzones} R_p P_z + \Sigma_{allzones} R_a \Delta_z$
   where occupant diversity $D = P_s/\Sigma_{allzones} P_z$
   where P_s = system population
   d. System OA intake $V_{ot} = V_{ou}/E_v$

(Standard 62.1, Appendix A contains an alternate procedure, which may require less outdoor air.) Provide exhaust ventilation in accordance with Table 6-4, any combination of outdoor air, recirculated air, and transfer air.

5. **Variable Load Conditions.** System design shall be capable of providing required ventilation rates in the breathing zone whenever the zones of the system are occupied under all load conditions.
6. **Short Term Conditions.** If peak occupancy is of short duration and/or ventilation may be varied or interrupted for a short period, design may be based on average conditions over a time period, $T = 3\ v/V_{bz}$ (T in minutes, v volume of zone, ft^3, V_{bz} ft^3/min calculated using design population P_z.

TABLE 6-1 MINIMUM VENTILATION RATES IN BREATHING ZONE
(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

Occupancy Category	People Outdoor Air Rate, R_p		Area Outdoor Air Rate, R_a		Notes	Default Values: Occupant Density (see Note 4)	Default Values: Combined Outdoor Air Rate (see Note 5)		Air Class
	cfm/person	L/s·person	cfm/ft²	L/s·m²		#/1000 ft² or #/100 m²	cfm/person	L/s·person	

GENERAL NOTES FOR TABLE 6-1

1 **Related requirements:** The rates in this table are based on all other applicable requirements of this standard being met.
2 **Smoking:** This table applies to no-smoking areas. Rates for smoking-permitted spaces must be determined using other methods. See Section 6.2.9 for ventilation requirements in smoking areas.
3 **Air density:** Volumetric airflow rates are based on an air density of 0.075 lb_{da}/ft^3 (1.2 kg_{da}/m^3), which corresponds to dry air at a barometric pressure of 1 atm (101.3 kPa) and an air temperature of 70°F (21°C). Rates may be adjusted for actual density but such adjustment is not required for compliance with this standard.
4 **Default occupant density:** The default occupant density shall be used when actual occupant density is not known.
5 **Default combined outdoor air rate (per person):** This rate is based on the default occupant density.
6 **Unlisted occupancies:** If the occupancy category for a proposed space or zone is not listed, the requirements for the listed occupancy category that is most similar in terms of occupant density, activities and building construction shall be used.
7 **Health-care facilities:** Rates shall be determined in accordance with Appendix E.

ITEM-SPECIFIC NOTES FOR TABLE 6-1

A For high school and college libraries, use values shown for Public Assembly Spaces—Libraries.
B Rate may not be sufficient when stored materials include those having potentially harmful emissions.
C Rate does not allow for humidity control. Additional ventilation or dehumidification may be required to remove moisture.
D Rate does not include special exhaust for stage effects, e.g., dry ice vapors, smoke.
E When combustion equipment is intended to be used on the playing surface, additional dilution ventilation and/or source control shall be provided.
F Default occupancy for dwelling units shall be two persons for studio and one-bedroom units, with one additional person for each additional bedroom.
G Air from one residential dwelling shall not be recirculated or transferred to any other space outside of that dwelling.

Correctional Facilities									
Cell	5	2.5	0.12	0.6		25	10	4.9	2
Dayroom	5	2.5	0.06	0.3		30	7	3.5	1
Guard stations	5	2.5	0.06	0.3		15	9	4.5	1
Booking/waiting	7.5	3.8	0.06	0.3		50	9	4.4	2
Educational Facilities									
Daycare (through age 4)	10	5	0.18	0.9		25	17	8.6	2
Daycare sickroom	10	5	0.18	0.9		25	17	8.6	3
Classrooms (ages 5–8)	10	5	0.12	0.6		25	15	7.4	1
Classrooms (age 9 plus)	10	5	0.12	0.6		35	13	6.7	1
Lecture classroom	7.5	3.8	0.06	0.3		65	8	4.3	1
Lecture hall (fixed seats)	7.5	3.8	0.06	0.3		150	8	4.0	1
Art classroom	10	5	0.18	0.9		20	19	9.5	2
Science laboratories	10	5	0.18	0.9		25	17	8.6	2
University/college laboratories	10	5	0.18	0.9		25	17	8.6	2
Wood/metal shop	10	5	0.18	0.9		20	19	9.5	2
Computer lab	10	5	0.12	0.6		25	15	7.4	1
Media center	10	5	0.12	0.6	A	25	15	7.4	1
Music/theater/dance	10	5	0.06	0.3		35	12	5.9	1
Multi-use assembly	7.5	3.8	0.06	0.3		100	8	4.1	1
Food and Beverage Service									
Restaurant dining rooms	7.5	3.8	0.18	0.9		70	10	5.1	2
Cafeteria/fast-food dining	7.5	3.8	0.18	0.9		100	9	4.7	2
Bars, cocktail lounges	7.5	3.8	0.18	0.9		100	9	4.7	2
General									
Break rooms	5	2.5	0.06	0.3		25	10	5.1	1
Coffee stations	5	2.5	0.06	0.3		20	11	5.5	1
Conference/meeting	5	2.5	0.06	0.3		50	6	3.1	1
Corridors	–	–	0.06	0.3		–			1
Storage rooms	–	–	0.12	0.6	B	–			1
Hotels, Motels, Resorts, Dormitories									
Bedroom/living room	5	2.5	0.06	0.3		10	11	5.5	1

TABLE 6-1 MINIMUM VENTILATION RATES IN BREATHING ZONE *(Continued)*
(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

Barracks sleeping areas	5	2.5	0.06	0.3		20	8	4.0	1
Laundry rooms, central	5	2.5	0.12	0.6		10	17	8.5	2
Laundry rooms within dwelling units	5	2.5	0.12	0.6		10	17	8.5	1
Lobbies/prefunction	7.5	3.8	0.06	0.3		30	10	4.8	1
Multipurpose assembly	5	2.5	0.06	0.3		120	6	2.8	1
Office Buildings									
Office space	5	2.5	0.06	0.3		5	17	8.5	1
Reception areas	5	2.5	0.06	0.3		30	7	3.5	1
Telephone/data entry	5	2.5	0.06	0.3		60	6	3.0	1
Main entry lobbies	5	2.5	0.06	0.3		10	11	5.5	1
Miscellaneous Spaces									
Bank vaults/safe deposit	5	2.5	0.06	0.3		5	17	8.5	2
Computer (not printing)	5	2.5	0.06	0.3		4	20	10.0	1
Electrical equipment rooms	–	–	0.06	0.3	B	–			1
Elevator machine rooms	–	–	0.12	0.6	B	–			1
Pharmacy (prep. area)	5	2.5	0.18	0.9		10	23	11.5	2
Photo studios	5	2.5	0.12	0.6		10	17	8.5	1
Shipping/receiving	–	–	0.12	0.6	B	–			1
Telephone closets	–	–	0.00	0.0		–			1
Transportation waiting	7.5	3.8	0.06	0.3		100	8	4.1	1
Warehouses	–	–	0.06	0.3	B	–			2
Public Assembly Spaces									
Auditorium seating area	5	2.5	0.06	0.3		150	5	2.7	1
Places of religious worship	5	2.5	0.06	0.3		120	6	2.8	1
Courtrooms	5	2.5	0.06	0.3		70	6	2.9	1
Legislative chambers	5	2.5	0.06	0.3		50	6	3.1	1
Libraries	5	2.5	0.12	0.6		10	17	8.5	1
Lobbies	5	2.5	0.06	0.3		150	5	2.7	1
Museums (children's)	7.5	3.8	0.12	0.6		40	11	5.3	1
Museums/galleries	7.5	3.8	0.06	0.3		40	9	4.6	1
Residential									
Dwelling unit	5	2.5	0.06	0.3	F,G	F			1
Common corridors	–	–	0.06	0.3					1
Retail									
Sales (except as below)	7.5	3.8	0.12	0.6		15	16	7.8	2
Mall common areas	7.5	3.8	0.06	0.3		40	9	4.6	1
Barbershop	7.5	3.8	0.06	0.3		25	10	5.0	2
Beauty and nail salons	20	10	0.12	0.6		25	25	12.4	2
Pet shops (animal areas)	7.5	3.8	0.18	0.9		10	26	12.8	2
Supermarket	7.5	3.8	0.06	0.3		8	15	7.6	1
Coin-operated laundries	7.5	3.8	0.06	0.3		20	11	5.3	2
Sports and Entertainment									
Sports arena (play area)	–	–	0.30	1.5	E	–			1
Gym, stadium (play area)	–	–	0.30	1.5		30			2
Spectator areas	7.5	3.8	0.06	0.3		150	8	4.0	1
Swimming (pool & deck)	–	–	0.48	2.4	C	–			2
Disco/dance floors	20	10	0.06	0.3		100	21	10.3	1
Health club/aerobics room	20	10	0.06	0.3		40	22	10.8	2
Health club/weight rooms	20	10	0.06	0.3		10	26	13.0	2
Bowling alley (seating)	10	5	0.12	0.6		40	13	6.5	1
Gambling casinos	7.5	3.8	0.18	0.9		120	9	4.6	1
Game arcades	7.5	3.8	0.18	0.9		20	17	8.3	1
Stages, studios	10	5	0.06	0.3	D	70	11	5.4	1

Ventilation Rate Procedure to Standard 62.1

(There is also an Indoor Air Quality Procedure, which is performance-based.)

Definitions

A_z	=	zone floor area, ft^2
P_z	=	zone population
R_p	=	outdoor airflow rate per person, cfm, from Table 6-1
R_a	=	outdoor airflow rate per unit area, cfm, from Table 6-1
V_{bz}	=	breathing zone airflow, $V_{bz} = R_p - P_z + R_a \cdot A_z$
E_z	=	zone air distribution effectiveness, Table 6-2
V_{oz}	=	outdoor airflow required for zone, $V_{oz} = V_{bz} / E_z$
V_{ot}	=	outdoor intake airflow
		For single-zone system, $V_{ot} = V_{oz}$
		For 100% outdoor system (one air handler), $V_{ot} = \Sigma_{all\ zones}\ V_{oz}$
Z_p	=	zone primary air fraction, from Table 6-3, $Z_p = V_{oz} / V_{pz}$
		where Vpz = zone primary air zone
E_v	=	system ventilation efficiency, from Table 6-3
V_{ou}	=	Uncorrected outdoor intake airflow, $V_{ou} = D\Sigma_{all\ zones}\ (R_p \cdot P_z) + \Sigma_{all\ zones}\ (R_a \cdot P_z)$
V_{ot}	=	design outdoor intake, $V_{ot} = V_{ou} / E_v$

Exhaust airflow shall be provided in accordance with Table 6-4.

Strict separation of spaces containing environmental tobacco smoke (ETS) from ETS-free areas is required. ETS-free areas must be at a positive pressure with respect to adjacent or connected ETS areas.

TABLE 6-2 Zone Air Distribution Effectiveness

Air Distribution Configuration	E_z
Ceiling supply of cool air.	1.0
Ceiling supply of warm air and floor return.	1.0
Ceiling supply of warm air 15°F (8°C) or more above space temperature and ceiling return.	0.8
Ceiling supply of warm air less than 15°F (8°C) above space temperature and ceiling return provided that the 150 fpm (0.8 m/s) supply air jet reaches to within 4.5 ft (1.4 m) of floor level. *Note:* For lower velocity supply air, E_z = 0.8.	1.0
Floor supply of cool air and ceiling return provided that the 150 fpm (0.8 m/s) supply jet reaches 4.5 ft (1.4 m) or more above the floor. *Note:* Most underfloor air distribution systems comply with this proviso.	1.0
Floor supply of cool air and ceiling return, provided low-velocity displacement ventilation achieves unidirectional flow and thermal stratification.	1.2
Floor supply of warm air and floor return.	1.0
Floor supply of warm air and ceiling return.	0.7
Makeup supply drawn in on the opposite side of the room from the exhaust and/or return.	0.8
Makeup supply drawn in near to the exhaust and/or return location.	0.5

1. "Cool air" is air cooler than space temperature.
2. "Warm air" is air warmer than space temperature.
3. "Ceiling" includes any point above the *breathing zone.*
4. "Floor" includes any point below the *breathing zone.*
5. As an alternative to using the above values, E_z may be regarded as equal to air change effectiveness determined in accordance with ANSI/ASHRAE Standard 129[16] for all air distribution configurations except unidirectional flow.

TABLE 6-3 System Ventilation Efficiency

Max (Z_p)	E_v
≤0.15	1.0
≤0.25	0.9
≤0.35	0.8
≤0.45	0.7
≤0.55	0.6
>0.55	Use Appendix A

1. "Max Z_p" refers to the largest value of Z_p, calculated using Equation 6-5, among all the zones served by the system.
2. For values of Z_p between 0.15 and 0.55, one may determine the corresponding value of E_v by interpolating the values in the table.
3. The values of E_v in this table are based on a 0.15 average outdoor air fraction for the system (i.e., the ratio of the *uncorrected outdoor air intake* V_{ou} to the total *zone primary airflow* for all the zones served by the air handler). For systems with higher values of the average outdoor air fraction, this table may result in unrealistically low values of E_v and the use of Appendix A may yield more practical results.

TABLE 6-4 Minimum Exhaust Rates

Occupancy Category	Exhaust Rate, cfm/unit	Exhaust Rate, cfm/ft²	Notes	Exhaust Rate, L/s·unit	Exhaust Rate, L/s·m²	Air Class
Arenas	–	0.50	B	–	–	1
Art classrooms	–	0.70		–	3.5	2
Auto repair rooms	–	1.50	A	–	7.5	2
Barber shops	–	0.50		–	2.5	2
Beauty and nail salons	–	0.60		–	3.0	2
Cells with toilet	–	1.00		–	5.0	2
Copy, printing rooms	–	0.50		–	2.5	2
Darkrooms	–	1.00		–	5.0	2
Educational science laboratories	–	1.00		–	5.0	2
Janitor closets, trash rooms, recycling	–	1.00		–	5.0	3
Kitchenettes	–	0.30		–	1.5	2
Kitchens—commercial	–	0.70		–	3.5	2
Locker/dressing rooms	–	0.25		–	1.25	2
Locker rooms	–	0.50		–	2.5	2
Paint spray booths	–	–	F	–	–	4
Parking garages	–	0.75	C	–	3.7	2
Pet shops (animal areas)	–	0.90		–	4.5	2
Refrigerating machinery rooms	–	–	F	–	–	3
Residential kitchens	50/100	–	G	25/50	–	2
Soiled laundry storage rooms	–	1.00	F	–	5.0	3
Storage rooms, chemical	–	1.50	F	–	7.5	4
Toilets—private	25/50	–	E	12.5/25	–	2
Toilets—public	50/70	–	D	25/35	–	2
Woodwork shop/classrooms	–	0.50		–	2.5	2

A Stands where engines are run shall have exhaust systems that directly connect to the engine exhaust and prevent escape of fumes.
B When combustion equipment is intended to be used on the playing surface additional dilution ventilation and/or source control shall be provided.
C Exhaust not required if two or more sides comprise walls that are at least 50% open to the outside.
D Rate is per water closet and/or urinal. Provide the higher rate where periods of heavy use are expected to occur, e.g., toilets in theatres, schools, and sports facilities. The lower rate may be used otherwise.
E Rate is for a toilet room intended to be occupied by one person at a time. For continuous system operation during normal hours of use, the lower rate may be used. Otherwise use the higher rate.
F See other applicable standards for exhaust rate.
G For continuous system operation, the lower rate may be used. Otherwise use the higher rate.

Multiple-Zone Systems

(From Appendix A of Standard 62.1-2004)

This is an alternative procedure for calculating the *system ventilation efficiency* (E_v) that must be used when Table 6-3 values are not used. In this alternative procedure, E_v is equal to the lowest calculated value of the *zone ventilation efficiency* E_{vz} (see Equation A-3 below). Figure A-1 contains a ventilation system schematic depicting most of the quantities used in this appendix.

The *zone ventilation efficiency* E_{vz}, i.e., the efficiency with which a system distributes outdoor air from the intake to an individual *breathing zone*, shall be calculated using Equation G-1 or G-2.

Single Supply Systems $$E_{vz} = 1 + X_s - Z_d \quad \text{(A-1)}$$

Equation A-1 (or A-2) shall be used for "single supply" systems, where all the ventilation air is a mixture of outdoor air and recirculated air from a single location, e.g., Reheat, Single-Duct VAV, Single-Fan Dual-Duct, and Multizone.

General Case $$E_{vz} = (F_a + X_s{*}F_b - Z_d{*}F_c)/F_a \quad \text{(A-2)}$$

Equation A-2 shall be used for systems that provide all or part of their ventilation by recirculating air from other zones without directly mixing it with outdoor air, e.g., dual-fan dual-duct, fan-powered mixing box, and transfer fans for conference rooms.

The system ventilation efficiency shall be calculated using Equation G-3.

$$E_v = minimum\ (E_{vz}) \quad \text{(A-3)}$$

Definitions

A_z **Zone Floor Area:** the net occupiable floor area of the *zone* m², (ft²).

D **Occupant Diversity:** the ratio of the *system population* to the sum of the *zone populations*: $D = P_s/\Sigma P_z$.

E_z **Zone Air Distribution Effectiveness** (E_z): a measure of how effectively the zone air distribution uses its supply air to maintain acceptable air quality in the *breathing zone*. E_z is determined from Table 6.2.

E_v **System Ventilation Efficiency:** the efficiency with which the system distributes air from the outdoor air intake to the breathing zone in the ventilation-critical zone, which requires the largest fraction of outdoor air in the primary airstream. E_v is determined from Table 6-3.

P_s **System Population**: the maximum simultaneous number of occupants in the area served by the system. Where population fluctuates, it may be averaged as described in Section 6.2.5.2. **Note**: Occupant load for egress often determines system population.

P_z **Zone Population:** the largest number of people expected to occupy the zone during typical usage. If P_z is not known, it is determined from the default occupant densities listed in Table 6-1. Where population fluctuates, it may be averaged as described in Section 6.2.5.2.

R_p **People Outdoor Air Rate**: the outdoor airflow rate per person to be provided in the breathing zone to dilute contaminants that are emitted at a rate that is related more to population than to floor area. The value of R_p for a zone is determined from Table 6.1.

V_{bz} **Breathing Zone Outdoor Airflow:** the outdoor airflow required in the breathing zone of an occupiable space, $V_{bz} = R_pP_z + R_aA_z$.

V_{oz} **Zone Outdoor Airflow:** the design outdoor airflow required in the zone, i.e., $V_{oz} = V_{bz}/E_z$.

V_{ot} **Outdoor Air Intake Flow**: the design outdoor airflow required at the ventilation system outdoor air intake.

V_{ou} **Uncorrected Outdoor Air Intake**: The outdoor air intake flow required if the system ventilation efficiency E_v were 1.0. $V_{ou} = D{*}\Sigma R_p{*}P_z + \Sigma R_a{*}A_z$.

V_{pz} **Zone Primary Airflow:** The primary airflow supplied to the *zone* from the air-handling unit at which the outdoor air intake is located, L/s (cfm). It includes outdoor intake air and recirculated air from that air-handling unit but does not include air transferred or air recirculated to the zone by other means.

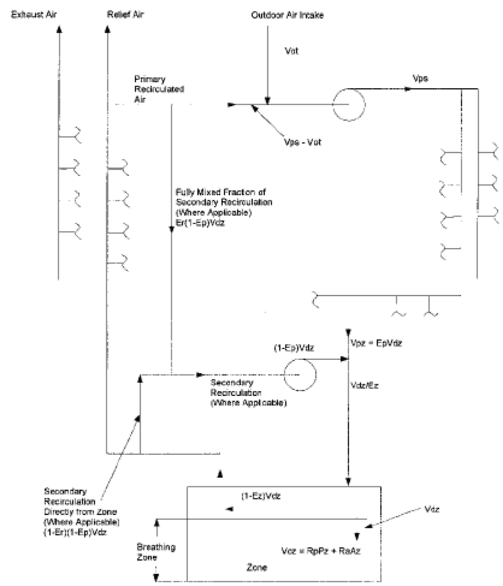


Figure A-1 Ventilation System Schematic

Table E-1 Outdoor Air Requirements for Ventilation of Health Care Facilities (Hospitals, Nursing and Convalescent Homes)

Application	Estimated Maximum** Occupancy P/1000 ft² or 100 m²	Outdoor Air Requirements cfm/person	cfm/ft²	Comments
Patient rooms Medical procedure Operating rooms Recovery and ICU	10 20 20 20	25 15 30 15		Special requirements or codes and pressure relationships may determine minimum ventilation rates and filter efficiency. Procedures generating contaminants may require higher rates.
Autopsy rooms	20		0.50	Air shall not be recirculated into other spaces.
Physical therapy	20	15		

* Table E-1 prescribes supply rates of acceptable outdoor air required for acceptable indoor air quality. These values have been chosen to dilute human bioeffluents and other contaminants with an adequate margin of safety and to account for health variations among people and varied activity levels.
** Net occupiable space.

Operation and Maintenance

Provide an O&M manual together with final system design drawings, updated and maintained on site.

Table 8-1 Minimum Maintenance Activity and Frequency

Item	Activity Code	Minimum Frequency[a]
Filters and air cleaning devices	A	According to O & M Manual
Outdoor air dampers and actuators	B	Every three months or in accordance with O & M Manual
Humidifiers	C	Every three months of use or in accordance with O & M Manual
Dehumidification coils	D	Regularly when it is likely that dehumidification occurs but no less than once per year or as specified in the O & M Manual
Drain pans and other adjacent surfaces subject to wetting	D	Once per year during cooling season or as specified in the O & M Manual
Outdoor air intake louvers, bird screens, mist eliminators, and adjacent areas	E	Every six months or as specified in the O & M Manual
Sensors used for dynamic minimum outdoor air control	F	Every six months or periodically in accordance with O & M Manual
Air-handling systems except for units under 2000 cfm (1000 L/s)	G	Once every five years
Cooling towers	H	In accordance with O & M Manual or treatment system provider
Floor drains located in plenums or rooms that serve as air plenums	I	Periodically according to O & M Manual
Equipment/component accessibility	J	
Visible microbial contamination	K	
Water intrusion or accumulation	K	

ACTIVITY CODE:
A Maintain according to O & M Manual.
B Visually inspect or remotely monitor for proper function.
C Clean and maintain to limit fouling and microbial growth.
D Visually inspect for cleanliness and microbial growth and clean when fouling is observed.
E Visually inspect for cleanliness and integrity and clean when necessary.
F Verify accuracy and recalibrate or replace as necessary.
G Measure minimum quantity of outdoor air. If measured minimum air flow rates are less than 90% of the minimum outdoor air rate in the O & M Manual, they shall be adjusted or modified to bring them above 90% or shall be evaluated to determine if the measured rates are in conformance with this standard.
H Treat to limit the growth of microbiological contaminants.
I Maintain to prevent transport of contaminants from the floor drain to the plenum.
J Keep clear the space provided for routine maintenance and inspection around ventilation equipment.
K Investigate and rectify.

[a] Minimum frequencies may be increased or decreased if indicated in the O&M manual.