Table 5A 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

Source: Swierczyna et al. (2008, 2009).

Hospital and Laboratory Equipment

Hospital and laboratory equipment items are major sources of sensible and latent heat gains in conditioned spaces. Care is needed in evaluating the probability and duration of simultaneous usage when many components are concentrated in one area, such as a laboratory, an operating room, etc. Commonly, heat gain from equipment in a laboratory ranges from 15 to 70 Btu/h·ft^2 or, in laboratories with outdoor exposure, as much as four times the heat gain from all other sources combined.

Medical Equipment. It is more difficult to provide generalized heat gain recommendations for medical equipment than for general office equipment because medical equipment is much more varied in type and in application. Some heat gain testing has been done, but the equipment included represents only a small sample of the type of equipment that may be encountered.

Data presented for medical equipment in Table 6 are relevant for portable and bench-top equipment. Medical equipment is very specific and can vary greatly from application to application. The data are presented to provide guidance in only the most general sense. For large equipment, such as MRI, heat gain must be obtained from the manufacturer.

Laboratory Equipment. Equipment in laboratories is similar to medical equipment in that it varies significantly from space to space. Chapter 14 of the 2007 *ASHRAE Handbook—HVAC Applications* discusses heat gain from equipment, which may range from 5 to 25 W/ft^2 in highly automated laboratories. Table 7 lists some values for laboratory equipment, but, with medical equipment, it is for general guidance only. Wilkins and Cook (1999) also examined laboratory equipment heat gains.

Office Equipment

Computers, printers, copiers, etc., can generate very significant heat gains, sometimes greater than all other gains combined. ASHRAE research project RP-822 developed a method to measure the actual heat gain from equipment in buildings and the radiant/convective percentages (Hosni et al. 1998; Jones et al. 1998). This methodology was then incorporated into ASHRAE research project RP-1055 and applied to a wide range of equipment (Hosni et al. 1999) as a follow-up to independent research by Wilkins and McGaffin (1994) and Wilkins et al. (1991). Komor (1997) found similar results. Analysis of measured data showed that results for office equipment could be generalized, but results from laboratory and hospital equipment proved too diverse. The following general guidelines for office equipment are a result of these studies.

Nameplate Versus Measured Energy Use. Nameplate data rarely reflect the actual power consumption of office equipment. Actual power consumption is assumed to equal total (radiant plus convective) heat gain, but its ratio to the nameplate value varies widely. ASHRAE research project RP-1055 (Hosni et al. 1999) found that, for general office equipment with nameplate power consumption of less than 1000 W, the actual ratio of total heat gain to nameplate ranged from 25% to 50%, but when all tested equipment is considered, the range is broader. Generally, if the nameplate value is the only information known and no actual heat gain data are available for similar equipment, it is conservative to use 50% of nameplate as heat gain and more nearly correct if 25% of nameplate is used. Much better results can be obtained, however, by considering heat gain to be predictable based on the type of equipment. However, if the device has a mainly resistive internal electric load (e.g.,

Table 5B 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

Source: Swierczyna et al. (2008, 2009).

a space heater), the nameplate rating may be a good estimate of its peak energy dissipation.

Computers. Based on tests by Hosni et al. (1999) and Wilkins and McGaffin (1994), nameplate values on computers should be ignored when performing cooling load calculations. Table 8 presents typical heat gain values for computers with varying degrees of safety factor.

Monitors. Based on monitors tested by Hosni et al. (1999), heat gain for cathode ray tube (CRT) monitors correlates approximately with screen size as

$$q_{mon} = 5S - 20 \quad (7)$$

where

q_{mon} = sensible heat gain from monitor, W
S = nominal screen size, in.

Table 8 shows typical values.

Flat-panel monitors have replaced CRT monitors in many workplaces. Power consumption, and thus heat gain, for flat-panel displays are significantly lower than for CRTs. Consult manufacturers' literature for average power consumption data for use in heat gain calculations.

Laser Printers. Hosni et al. (1999) found that power consumption, and therefore the heat gain, of laser printers depended largely on the level of throughput for which the printer was designed. Smaller printers tend to be used more intermittently, and larger printers may run continuously for longer periods.

Table 9 presents data on laser printers.These data can be applied by taking the value for continuous operation and then applying an appropriate diversity factor. This would likely be most appropriate for larger open office areas. Another approach, which may be appropriate for a single room or small area, is to take the value that most closely matches the expected operation of the printer with no diversity.

Copiers. Hosni et al. (1999) also tested five photocopy machines, including desktop and office (freestanding high-volume copiers) models. Larger machines used in production environments were not addressed. Table 9 summarizes the results. Desktop copiers rarely operate continuously, but office copiers frequently operate continuously for periods of an hour or more. Large, high-volume photocopiers often include provisions for exhausting air outdoors; if so equipped, the direct-to-space or system makeup air heat gain needs to be included in the load calculation. Also, when the air is dry, humidifiers are often operated near copiers to limit static electricity; if this occurs during cooling mode, their load on HVAC systems should be considered.

Miscellaneous Office Equipment. Table 10 presents data on miscellaneous office equipment such as vending machines and mailing equipment.

Diversity. The ratio of measured peak electrical load at equipment panels to the sum of the maximum electrical load of each individual item of equipment is the usage diversity. A small, one- or two-person office containing equipment listed in Tables 8 to 10 usually contributes heat gain to the space at the sum of the appropriate listed values. Progressively larger areas with many equipment items always experience some degree of usage diversity resulting from whatever percentage of such equipment is not in operation at any given time.

Wilkins and McGaffin (1994) measured diversity in 23 areas within five different buildings totaling over 275,000 ft^2. Diversity was found to range between 37 and 78%, with the average (normalized based on area) being 46%. Figure 4 illustrates the relationship between nameplate, sum of peaks, a-nd actual electrical load with diversity accounted for, based on the average of the total area tested. Data on actual diversity can be used as a guide, but diversity varies

Table 5C Recommended Rates of Radiant Heat Gain from Hooded Gas 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: 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

Source: Swierczyna et al. (2008, 2009).

Table 5D 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

Source: Swierczyna et al. (2008, 2009).

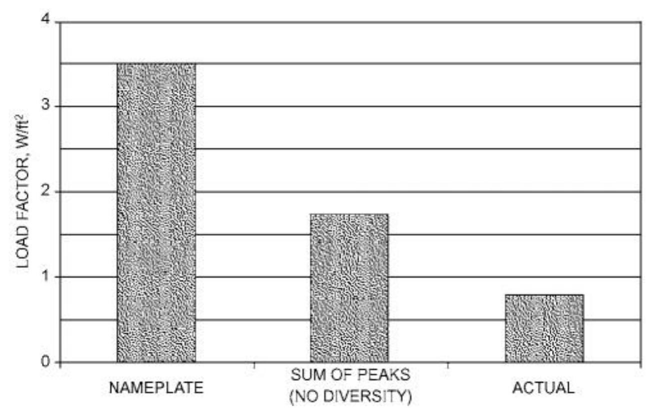

Fig. 4 Office Equipment Load Factor Comparison
(Wilkins and McGaffin 1994)

significantly with occupancy. The proper diversity factor for an office of mail-order catalog telephone operators is different from that for an office of sales representatives who travel regularly.

ASHRAE research project RP-1093 derived diversity profiles for use in energy calculations (Abushakra et al. 2004; Claridge et al. 2004). Those profiles were derived from available measured data sets for a variety of office buildings, and indicated a range of peak weekday diversity factors for lighting ranging from 70 to 85% and for receptacles (appliance load) between 42 and 89%.

Heat Gain per Unit Area. Wilkins and Hosni (2000) and Wilkins and McGaffin (1994) summarized research on a heat gain per unit area basis. Diversity testing showed that the actual heat gain per unit area, or load factor, ranged from 0.44 to 1.08 W/ft^2, with an average (normalized based on area) of 0.81 W/ft^2. Spaces tested were fully occupied and highly automated, comprising 21 unique areas in five buildings, with a computer and monitor at every workstation. Table 11 presents a range of load factors with a subjective description of the type of space to which they would apply. Table 12 presents more specific data that can be used to better quantify the amount of equipment in a space and expected load factor. The medium load density is likely to be appropriate for most standard office spaces. Medium/heavy or heavy load densities may be encountered but can

Table 5E 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. *Source*: Swierczyna et al. (2008, 2009).

Table 6 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

Source: Hosni et al. (1999).

be considered extremely conservative estimates even for densely populated and highly automated spaces.

Radiant Convective Split. ASHRAE research project RP-1482 (Hosni and Beck 2008) is examining the radiant/convective split for common office equipment; the most important differentiating feature is whether the equipment had a cooling fan. Footnotes in Tables 8 and 9 summarizes those results.

INFILTRATION AND MOISTURE MIGRATION HEAT GAINS

Two other load components contribute to space cooling load directly without time delay from building mass: (1) infiltration, and (2) moisture migration through the building envelope.

INFILTRATION

Principles of estimating infiltration in buildings, with emphasis on the heating season, are discussed in Chapter 16. When economically feasible, somewhat more outdoor air should be introduced to a building than the total of that exhausted, to create a slight overall positive pressure in the building relative to the outdoors. Under these conditions, air usually exfiltrates, rather than infiltrates, through the building envelope and thus effectively eliminates infiltration sensible and latent heat gains. However, there is concern, especially in some climates, that water may condense within the building envelope; actively managing space air pressures to reduce this condensation problem, as well as infiltration, may be needed.

When positive air pressure is assumed, most designers do not include infiltration in cooling load calculations for commercial buildings. However, including some infiltration for spaces such entry areas or loading docks may be appropriate, especially when those spaces are on the windward side of buildings. But the downward stack effect, as occurs when indoor air is denser than the outdoor,

Table 7 Recommended Heat Gain from Typical Laboratory Equipment

Equipment	Nameplate, W	Peak, W	Average, W
Analytical balance	7	7	7
Centrifuge	138	89	87
	288	136	132
	5500	1176	730
Electrochemical analyzer	50	45	44
	100	85	84
Flame photometer	180	107	105
Fluorescent microscope	150	144	143
	200	205	178
Function generator	58	29	29
Incubator	515	461	451
	600	479	264
	3125	1335	1222
Orbital shaker	100	16	16
Oscilloscope	72	38	38
	345	99	97
Rotary evaporator	75	74	73
	94	29	28
Spectronics	36	31	31
Spectrophotometer	575	106	104
	200	122	121
	N/A	127	125
Spectro fluorometer	340	405	395
Thermocycler	1840	965	641
	N/A	233	198
Tissue culture	475	132	46
	2346	1178	1146

Source: Hosni et al. (1999).

Table 8 Recommended Heat Gain from Typical Computer Equipment

Equipment	Description	Nameplate Power Consumption, W	Average Power Consumption, W
Desktop computer[a]	Manufacturer A (model A); 2.8 GHz processor, 1 GB RAM	480	73
	Manufacturer A (model B); 2.6 GHz processor, 2 GB RAM	480	49
	Manufacturer B (model A); 3.0 GHz processor, 2 GB RAM	690	77
	Manufacturer B (model B); 3.0 GHz processor, 2 GB RAM	690	48
	Manufacturer A (model C); 2.3 GHz processor, 3 GB RAM	1200	97
Laptop computer[b]	Manufacturer 1; 2.0 GHz processor, 2 GB RAM, 17 in. screen	130	36
	Manufacturer 1; 1.8 GHz processor, 1 GB RAM, 17 in. screen	90	23
	Manufacturer 1; 2.0 GHz processor, 2 GB RAM, 14 in. screen	90	31
	Manufacturer 2; 2.13 GHz processor, 1 GB RAM, 14 in. screen, tablet PC	90	29
	Manufacturer 2; 366 MHz processor, 130 MB RAM, 14 in. screen)	70	22
	Manufacturer 3; 900 MHz processor, 256 MB RAM (10.5 in. screen)	50	12
Flat-panel monitor[c]	Manufacturer X (model A); 30 in. screen	383	90
	Manufacturer X (model B); 22 in. screen	360	36
	Manufacturer Y (model A), 19 in. screen	288	28
	Manufacturer Y (model B), 17 in. screen	240	27
	Manufacturer Z (model A), 17 in. screen	240	29
	Manufacturer Z (model C), 15 in. screen	240	19

Source: Hosni and Beck (2008).

[a]Power consumption for newer desktop computers in operational mode varies from 50 to 100 W, but a conservative value of about 65 W may be used. Power consumption in sleep mode is negligible. Because of cooling fan, approximately 90% of load is by convection and 10% is by radiation. Actual power consumption is about 10 to 15% of nameplate value.

[b]Power consumption of laptop computers is relatively small: depending on processor speed and screen size, it varies from about 15 to 40 W. Thus, differentiating between radiative and convective parts of the cooling load is unnecessary and the entire load may be classified as convective. Otherwise, a 75/25% split between convective and radiative components may be used. Actual power consumption for laptops is about 25% of nameplate values.

[c]Flat-panel monitors have replaced cathode ray tube (CRT) monitors in many workplaces, providing better resolution and being much lighter. Power consumption depends on size and resolution, and ranges from about 20 W (for 15 in. size) to 90 W (for 30 in.). The most common sizes in workplaces are 19 and 22 in., for which an average 30 W power consumption value may be used. Use 60/40% split between convective and radiative components. In idle mode, monitors have negligible power consumption. Nameplate values should not be used.

Table 9 Recommended Heat Gain from Typical Laser Printers and Copiers

Equipment	Description	Nameplate Power Consumption, W	Average Power Consumption, W
Laser printer, typical desktop, small-office type[a]	Printing speed up to 10 pages per minute	430	137
	Printing speed up to 35 pages per minute	890	74
	Printing speed up to 19 pages per minute	508	88
	Printing speed up to 17 pages per minute	508	98
	Printing speed up to 19 pages per minute	635	110
	Printing speed up to 24 page per minute	1344	130
Multifunction (copy, print, scan)[b]	Small, desktop type	600	30
		40	15
	Medium, desktop type	700	135
Scanner[b]	Small, desktop type	19	16
Copy machine[c]	Large, multiuser, office type	1750	800 (idle 260 W)
		1440	550 (idle 135 W)
		1850	1060 (idle 305 W)
Fax machine	Medium	936	90
	Small	40	20
Plotter	Manufacturer A	400	250
	Manufacturer B	456	140

Source: Hosni and Beck (2008).

[a]Various laser printers commercially available and commonly used in personal offices were tested for power consumption in print mode, which varied from 75 to 140 W, depending on model, print capacity, and speed. Average power consumption of 110 W may be used. Split between convection and radiation is approximately 70/30%.

[b]Small multifunction (copy, scan, print) systems use about 15 to 30 W; medium-sized ones use about 135 W. Power consumption in idle mode is negligible. Nameplate values do not represent actual power consumption and should not be used. Small, single-sheet scanners consume less than 20 W and do not contribute significantly to building cooling load.

[c]Power consumption for large copy machines in large offices and copy centers ranges from about 550 to 1100 W in copy mode. Consumption in idle mode varies from about 130 to 300 W. Count idle-mode power consumption as mostly convective in cooling load calculations.

might eliminate infiltration to these entries on lower floors of tall buildings; infiltration may occur on the upper floors during cooling conditions if makeup air is not sufficient.

Infiltration also depends on wind direction and magnitude, temperature differences, construction type and quality, and occupant use of exterior doors and operable windows. As such, it is impossible to accurately predict infiltration rates. Designers usually predict overall rates of infiltration using the number of **air changes per hour (ach)**. A common guideline for climates and buildings typical of at least the central United States is to estimate the achs for winter

Table 10 Recommended Heat Gain from Miscellaneous Office Equipment

Equipment	Maximum Input Rating, W	Recommended Rate of Heat Gain, W
Mail-processing equipment		
Folding machine	125	80
Inserting machine, 3600 to 6800 pieces/h	600 to 3300	390 to 2150
Labeling machine, 1500 to 30,000 pieces/h	600 to 6600	390 to 4300
Postage meter	230	150
Vending machines		
Cigarette	72	72
Cold food/beverage	1150 to 1920	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	4800	2470
Coffee maker, 10 cups	1500	1050 W sens., 1540 Btu/h latent
Microfiche reader	85	85
Microfilm reader	520	520
Microfilm reader/printer	1150	1150
Microwave oven, 1 ft^3	600	400
Paper shredder	250 to 3000	200 to 2420
Water cooler, 32 qt/h	700	350

Table 11 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 Hosni (2000).

heating conditions, and then use half that value for the cooling load calculations.

Standard Air Volumes

Because the specific volume of air varies appreciably, calculations are more accurate when made on the basis of air mass instead of volume. However, volumetric flow rates are often required for selecting coils, fans, ducts, etc.; basing volumes on measurement at standard conditions may be used for accurate results. One standard value is 0.075 lb_{da}/ft^3 (13.33 ft^3/lb). This density corresponds to about 60°F at saturation and 69°F dry air (at 14.696 psia). Because

Table 12 Cooling Load Estimates for Various Office Load Densities

Load Density*	Number	Each, W	Total, W	Diversity	Load, W
Light					
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					493
Recommended equipment load factor = 0.5 W/ft^2					
Medium					
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/ft^2					
Medium/Heavy					
Computers	10	65	650	1	650
Monitors	10	70	700	1	700
Laser printer—small office	1	320	320	0.5	160
Fax machine	1	30	30	0.5	15
Total Area Load					1525
Recommended equipment load factor = 1.5 W/ft^2					
Heavy					
Computers	12	75	900	1	900
Monitors	12	80	960	1	960
Laser printer-small office	1	320	320	0.5	160
Fax machine	1	30	30	0.5	15
Total Area Load					2035
Recommended equipment load factor = 2.0 W/ft^2					

Source: Wilkins and Hosni (2000).
*See Table 11 for descriptions of load densities.

air usually passes through the equipment at a density close to standard for locations below about 1000 ft, the accuracy desired normally requires no correction. When airflow is to be measured at a particular condition or point, such as at a coil entrance or exit, the corresponding specific volume can be read from the sea-level psychrometric chart. For higher elevations, the mass flow rates of air must be adjusted and higher-elevation psychrometric charts or algorithms must be used.

Heat Gain Calculations Using Standard Air Values

Air-conditioning design often requires the following information:

1. Total heat

Total heat gain q_t corresponding to the change of a given standard flow rate Q_s through an enthalpy difference Δh is

$$q_t = 60 \times 0.075 Q_s \Delta h = 4.5 Q_s \Delta h \quad (8)$$

where 60 = min/h, 0.075 = lb_{da}/ft^3.

This total heat equation can also be expressed as

$$q_t = C_t Q_s \Delta h$$

where C_t = 4.5 is the air total heat factor, in Btu/h·cfm per Btu/lb enthalpy h.

2. Sensible heat

Sensible heat gain q_s corresponding to the change of dry-bulb temperature Δt for given airflow (standard conditions) Q_s is