fan-cooled (TEFC) motors are slightly more efficient. For speeds lower or higher than those listed, efficiencies may be 1 to 3% lower or higher, depending on the manufacturer. Should actual voltages at motors be appreciably higher or lower than rated nameplate voltage, efficiencies in either case will be lower. If electric motor load is an appreciable portion of cooling load, the motor efficiency should be obtained from the manufacturer. Also, depending on design, the maximum efficiency might occur anywhere between 75 to 110% of full load; if underloaded or overloaded, the efficiency could vary from the manufacturer's listing.

Overloading or Underloading

Heat output of a motor is generally proportional to the motor load, within the 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, can be accurately established, and the reduced load efficiency data can be obtained from the motor manufacturer.

Radiation and Convection

Unless the manufacturer's technical literature indicates otherwise, the heat gain normally should be equally divided between radiant and convective components for the subsequent cooling load calculations.

APPLIANCES

In a cooling load estimate, heat gain from all appliances—electrical, gas, or steam—should be taken into account. Because of the variety of appliances, applications, schedules, use, and installations, estimates can be very subjective. Often, the only information available about heat gain from equipment is that on its nameplate.

Cooking Appliances

These appliances include common heat-producing cooking equipment found in conditioned commercial kitchens. Marn (1962) concluded that appliance surfaces contributed most of the heat to commercial kitchens and that when appliances were installed under an effective hood, the cooling load was independent of the fuel or energy used for similar equipment performing the same operations.

Gordon et al. (1994) and Smith et al. (1995) found that gas appliances may exhibit slightly higher heat gains than their electric counterparts under wall-canopy hoods operated at typical ventilation rates. This is due to the fact that the heat contained in the combustion products exhausted from a gas appliance may increase the temperatures of the appliance and surrounding surfaces, as well as the hood above the appliance, more than the heat produced by its electric counterpart. These higher temperature surfaces radiate heat to the kitchen, adding moderately to the radiant gain directly associated with the appliance cooking surface.

Marn (1962) confirmed that where the appliances are installed under an effective hood, only radiant gain adds to the cooling load; convected and latent heat from the cooking process and combustion products are exhausted and do not enter the kitchen. Gordon et al. (1994) and Smith et al. (1995) substantiated these findings.

Sensible Heat Gain for Hooded Cooking Appliances. To establish a heat gain value, nameplate energy input ratings may be used with appropriate usage and radiation factors. Where specific rating data are not available (nameplate missing, equipment not yet purchased, etc.) or as an alternative approach, recommended heat gains listed in Table 5 for a wide variety of commonly encountered equipment items may be used. In estimating the appliance load, probabilities of simultaneous use and operation for different appliances located in the same space must be considered.

The radiant heat gain from hooded cooking equipment can range from 15 to 45% of the actual appliance energy consumption (Talbert et al. 1973, Gordon et al. 1994, Smith et al. 1995). This ratio of heat gain to appliance energy consumption may be expressed as a radiation factor. It is a function of both appliance type and fuel source. The radiation factor F_R is applied to the average rate of appliance energy consumption, determined by applying usage factor F_U to the nameplate or rated energy input. Marn (1962) found that radiant heat temperature rise can be substantially reduced by shielding the fronts of cooking appliances. Although this approach may not always be practical in a commercial kitchen, radiant gains can also be reduced by adding side panels or partial enclosures that are integrated with the exhaust hood.

Heat Gain from Meals. For each meal served, the heat transferred to the dining space is approximately 15 W, of which 75% is sensible and 25% is latent.

Heat Gain for Electric and Steam Appliances. The average rate of appliance energy consumption can be estimated from the nameplate or rated energy input q_{input} by applying a duty cycle or usage factor F_U. Thus, the sensible heat gain $q_{sensible}$ for generic types of electric, steam, and gas appliances installed under a hood can be estimated using one of the following equations:

$$q_{sensible} = q_{input} F_U F_R \qquad (10)$$

or

$$q_{sensible} = q_{input} F_L \qquad (11)$$

where F_L is defined as the ratio of sensible heat gain to the manufacturer's rated energy input.

Table 4 lists usage factors, radiation factors, and load factors based on appliance energy consumption rate for typical electrical, steam, and gas appliances under standby or idle conditions.

Unhooded Equipment. For all cooking appliances not installed under an exhaust hood or directly vent-connected and located in the conditioned area, the heat gain may be estimated as 50% ($F_U = 0.50$)

Table 4A   Hooded Electric Appliance Usage Factors, Radiation Factors, and Load Factors

Appliance	Usage Factor F_U	Radiation Factor F_R	Load Factor $F_L = F_U F_R$ Elec/Steam
Griddle	0.16	0.45	0.07
Fryer	0.06	0.43	0.03
Convection oven	0.42	0.17	0.07
Charbroiler	0.83	0.29	0.24
Open-top range without oven	0.34	0.46	0.16
Hot-top range without oven	0.79	0.47	0.37
with oven	0.59	0.48	0.28
Steam cooker	0.13	0.30	0.04

Sources: Alereza and Breen (1984), Fisher (1998).

Table 4B   Hooded Gas Appliance Usage Factors, Radiation Factors, and Load Factors

Appliance	Usage Factor F_U	Radiation Factor F_R	Load Factor $F_L = F_U F_R$ Gas
Griddle	0.25	0.25	0.06
Fryer	0.07	0.35	0.02
Convection oven	0.42	0.20	0.08
Charbroiler	0.62	0.18	0.11
Open-top range without oven	0.34	0.17	0.06

Sources: Alereza and Breen (1984), Fisher (1998).

or the rated hourly input, regardless of the type of energy or fuel used. On average, 34% of the heat may be assumed to be latent and the remaining 66% sensible. Note that cooking appliances ventilated by "ductless" hoods should be treated as unhooded appliances from the perspective of estimating heat gain. In other words, all energy consumed by the appliance and all moisture produced by the cooking process is introduced to the kitchen as a sensible or latent cooling load.

Recommended Heat Gain Values. As an alternative procedure, Table 5 lists recommended rates of heat gain from typical commercial cooking appliances. The data in the "with hood" columns assume installation under a properly designed exhaust hood connected to a mechanical fan exhaust system.

Hospital and Laboratory Equipment

Hospital and laboratory equipment items are major sources of heat gain in conditioned spaces. Care must be taken 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 50 to 220 W/m^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 and can be presented, but the equipment included represents only a small sample of the type of equipment that may be encountered.

The 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, engineers must obtain heat gain from the manufacturer.

Laboratory Equipment. Equipment in laboratories is similar to medical equipment in that it will vary significantly from space to space. Chapter 13 of the 1999 *ASHRAE Handbook—Applications* discusses heat gain from equipment, stating that it may range from 50 to 270 W/m^2 in highly automated laboratories. Table 7 lists some values for laboratory equipment, but, as is the case for medical equipment, it is for general guidance only. Wilkins and Cook (1999) also examined laboratory equipment heat gains.

Office Equipment

Computers, printers, copiers, calculators, checkwriters, posting machines, etc., can generate 9 to 13 W/m^2 for general offices or 18 to 22 W/m^2 for purchasing and accounting departments. ASHRAE *Research Project* 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* 1055 and applied to a wide range of equipment (Hosni et al. 1999) as a follow-up to independent research by Wilkins et al. (1991) and Wilkins and McGaffin (1994). 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 of such equipment is assumed equal to the total (radiant plus convective) heat gain, but the ratio of such energy to the nameplate value varies widely. ASHRAE *Research Project* 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 would be conservative to use 50% of nameplate as heat gain and more nearly correct if 25% of nameplate were used. Much better results can be obtained, however, by considering the heat gain as being predictable based on the type of equipment.

Office equipment is grouped into categories such as computers, monitors, printers, facsimile machines, and copiers, with heat gain results within each group analyzed to establish patterns.

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 correlates approximately with screen size as

$$q_{mon} = 0.2S - 20 \qquad (12)$$

where

q_{mon} = heat gain from monitor, W
S = nominal screen size, mm

Wilkins and McGaffin (1994) tested ten monitors (330 to 480 mm), finding the average heat gain value to be 60 W. This testing was done in 1992 when DOS was prevalent and the Windows™ operating system was just being introduced. Monitors displaying Windows consumed more power than those displaying DOS. Table 8 tabulates typical values.

Laser Printers. Hosni et al. (1999) found that the power consumed by laser printers, and therefore the heat gain, depended largely on the level of throughput for which the printer was designed. It was observed that smaller printers are used more intermittently and that 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 could be to take the value that most closely matches the expected operation of the printer with no diversity. This may be appropriate when considering a single room or small area.

Copiers. Hosni et al. (1999) also tested five copy machines considered to be of two types, desktop and office (freestanding high-volume copiers). Larger machines used in production environments were not addressed. Table 9 summarizes of the results. It was observed that desktop copiers rarely operated continuously but that office copiers frequently operated continuously for periods of an hour or more.

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

Diversity. The ratio of the measured peak electrical load at the 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 through 10 can be expected to contribute heat gain to the space at the sum of the appropriate listed values. Progressively larger areas with many equipment items will 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 25 600 m^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, the sum of the peaks, and the actual electrical load with diversity accounted for, based on the average of the total

Table 5 Recommended Rates of Heat Gain From Typical Commercial Cooking Appliances

Appliance	Size	Energy Rate, W		Recommended Rate of Heat Gain,[a] W			
				Without Hood			With Hood
		Rated	Standby	Sensible	Latent	Total	Sensible
Electric, No Hood Required							
Barbeque (pit), per kilogram of food capacity	36 to 136 kg	88	—	57	31	88	27
Barbeque (pressurized) per kilogram of food capacity	20 kg	210	—	71	35	106	33
Blender, per litre of capacity	1.0 to 3.8 L	480	—	310	160	470	150
Braising pan, per litre of capacity	102 to 133 L	110	—	55	29	84	40
Cabinet (large hot holding)	0.46 to 0.49 m³	2080	—	180	100	280	85
Cabinet (large hot serving)	1.06 to 1.15 m³	2000	—	180	90	270	82
Cabinet (large proofing)	0.45 to 0.48 m³	2030	—	180	90	270	82
Cabinet (small hot holding)	0.09 to 0.18 m³	900	—	80	40	120	37
Cabinet (very hot holding)	0.49 m³	6150	—	550	280	830	250
Can opener		170	—	170	—	170	0
Coffee brewer	12 cup/2 brnrs	1660	—	1100	560	1660	530
Coffee heater, per boiling burner	1 to 2 brnrs	670	—	440	230	670	210
Coffee heater, per warming burner	1 to 2 brnrs	100	—	66	34	100	32
Coffee/hot water boiling urn, per litre of capacity	11 L	120	—	79	41	120	38
Coffee brewing urn (large), per litre of capacity	22 to 38 L	660	—	440	220	660	210
Coffee brewing urn (small), per litre of capacity	10 L	420	—	280	140	420	130
Cutter (large)	460 mm bowl	750	—	750	—	750	0
Cutter (small)	360 mm bowl	370	—	370	—	370	0
Cutter and mixer (large)	28 to 45 L	3730	—	3730	—	3730	0
Dishwasher (hood type, chemical sanitizing), per 100 dishes/h	950 to 2000 dishes/h	380	—	50	110	160	50
Dishwasher (hood type, water sanitizing), per 100 dishes/h	950 to 2000 dishes/h	380	—	56	123	179	56
Dishwasher (conveyor type, chemical sanitizing), per 100 dishes/h	5000 to 9000 dishes/h	340	—	41	97	138	44
Dishwasher (conveyor type, water sanitizing), per 100 dishes/h	5000 to 9000 dishes/h	340	—	44	108	152	50
Display case (refrigerated), per cubic metre of interior	0.17 to 1.9 m³	1590	—	640	0	640	0
Dough roller (large)	2 rollers	1610	—	1610	—	1610	0
Dough roller (small)	1 roller	460	—	460	—	460	0
Egg cooker	12 eggs	1800	—	850	570	1420	460
Food processor	2.3 L	520	—	520	—	520	0
Food warmer (infrared bulb), per lamp	1 to 6 bulbs	250	—	250	—	250	250
Food warmer (shelf type), per square metre of surface	0.28 to 0.84 m³	2930	—	2330	600	2930	820
Food warmer (infrared tube), per metre of length	1.0 to 2.1 m	950	—	950	—	950	950
Food warmer (well type), per cubic metre of well	20 to 70 L	37400	—	12400	6360	18760	6000
Freezer (large)	2.07 m³	1340	—	540	—	540	0
Freezer (small)	0.51 m³	810	—	320	—	320	0
Griddle/grill (large), per square metre of cooking surface	0.43 to 1.1 m²	29000	—	1940	1080	3020	1080
Griddle/grill (small), per square metre of cooking surface	0.20 to 0.42 m²	26200	—	1720	970	2690	940
Hot dog broiler	48 to 56 hot dogs	1160	—	100	50	150	48
Hot plate (double burner, high speed)		4900	—	2290	1590	3880	1830
Hot plate (double burner stockpot)		4000	—	1870	1300	3170	1490
Hot plate (single burner, high speed)		2800	—	1310	910	2220	1040
Hot water urn (large), per litre of capacity	53 L	130	—	50	16	66	21
Hot water urn (small), per litre of capacity	7.6 L	230	—	87	30	117	37
Ice maker (large)	100 kg/day	1090	—	2730	—	2730	0
Ice maker (small)	50 kg/day	750	—	1880	—	1880	0
Microwave oven (heavy duty, commercial)	20 L	2630	—	2630	—	2630	0
Microwave oven (residential type)	30 L	600 to 1400	—	600 to 1400	—	600 to 1400	0
Mixer (large), per litre of capacity	77 L	29	—	29	—	29	0
Mixer (small), per litre of capacity	11 to 72 L	15	—	15	—	15	0
Press cooker (hamburger)	300 patties/h	2200	—	1450	750	2200	700
Refrigerator (large), per cubic metre of interior space	0.71 to 2.1 m³	780	—	310	—	310	0
Refrigerator (small) per cubic metre of interior space	0.17 to 0.71 m³	1730	—	690	—	690	0
Rotisserie	300 hamburgers/h	3200	—	2110	1090	3200	1020
Serving cart (hot), per cubic metre of well	50 to 90 L	21200	—	7060	3530	10590	3390
Serving drawer (large)	252 to 336 dinner rolls	1100	—	140	10	150	45
Serving drawer (small)	84 to 168 dinner rolls	800	—	100	10	110	33
Skillet (tilting), per litre of capacity	45 to 125 L	180	—	90	50	140	66
Slicer, per square metre of slicing carriage	0.06 to 0.09 m²	2150	—	2150	—	2150	680
Soup cooker, per litre of well	7 to 11 L	130	—	45	24	69	21
Steam cooker, per cubic metre of compartment	30 to 60 L	214000	—	17000	10900	27900	8120
Steam kettle (large), per litre of capacity	76 to 300 L	95	—	7	5	12	4
Steam kettle (small), per litre of capacity	23 to 45 L	260	—	21	14	35	10
Syrup warmer, per litre of capacity	11 L	87	—	29	16	45	14

Table 5 Recommended Rates of Heat Gain From Typical Commercial Cooking Appliances (*Concluded*)

| Appliance | Size | Energy Rate, W | | Recommended Rate of Heat Gain,[a] W | | | |
| | | | | Without Hood | | | With Hood |
		Rated	Standby	Sensible	Latent	Total	Sensible
Toaster (bun toasts on one side only)	1400 buns/h	1500	—	800	710	1510	480
Toaster (large conveyor)	720 slices/h	3200	—	850	750	1600	510
Toaster (small conveyor)	360 slices/h	2100	—	560	490	1050	340
Toaster (large pop-up)	10 slice	5300	—	2810	2490	5300	1700
Toaster (small pop-up)	4 slice	2470	—	1310	1160	2470	790
Waffle iron	0.05 m^2	1640	—	700	940	1640	520
Electric, Exhaust Hood Required							
Broiler (conveyor infrared), per square metre of cooking area	0.19 to 9.5 m^2	60800	—	—	—	—	12100
Broiler (single deck infrared), per square metre of broiling area	0.24 to 0.91 m^2	34200	—	—	—	—	6780
Charbroiler, per linear metre of cooking surface	0.6 to 2.4 m	10600	8900	—	—	—	2700
Fryer (deep fat)	15 to 23 kg oil	14000	850	—	—	—	350
Fryer (pressurized), per kilogram of fat capacity	6 to 15 kg	1010	—	—	—	—	38
Griddle, per linear metre of cooking surface	0.6 to 2.4 m	18800	3000	—	—	—	1350
Oven (full-szie convection)		12000	5000	—	—	—	850
Oven (large deck baking with 15.2 m^3 decks), per cubic metre of oven spacer	0.43 to 1.3 m^3	17300	—	—	—	—	710
Oven (roasting), per cubic metre of oven space	0.22 to 0.66 m^3	28300	—	—	—	—	1170
Oven (small convection), per cubic metre of oven space	0.04 to 0.15 m^3	107000	—	—	—	—	1520
Oven (small deck baking with 7.7 m^3 decks), per cubic metre of oven space	0.22 to 0.66 m^3	28700	—	—	—	—	1170
Open range (top), per 2 element section	2 to 10 elements	4100	1350	—	—	—	620
Range (hot top/fry top), per square metre of cooking surface	0.36 to 0.74 m^2	22900	—	—	—	—	8500
Range (oven section), per cubic metre of oven space	0.12 to 0.32 m^3	40600	—	—	—	—	1660
Gas, No Hood Required							
Broiler, per square metre of broiling area	0.25	46600	190[b]	16800	9030	25830	3840
Cheese melter, per square metre of cooking surface	0.23 to 0.47	32500	190[b]	11600	3400	15000	2680
Dishwasher (hood type, chemical sanitizing), per 100 dishes/h	950 to 2000 dishes/h	510	190[b]	150	59	209	67
Dishwasher (hood type, water sanitizing), per 100 dishes/h	950 to 2000 dishes/h	510	190[b]	170	64	234	73
Dishwasher (conveyor type, chemical sanitizing), per 100 dishes/h	5000 to 9000 dishes/h	400	190[b]	97	21	118	38
Dishwasher (conveyor type, water sanitizing), per 100 dishes/h	5000 to 9000 dishes/h	400	190[b]	110	23	133	41
Griddle/grill (large), per square metre of cooking surface	0.43 to 1.1 m^2	53600	1040	3600	1930	5530	1450
Griddle/grill (small), per square metre of cooking surface	0.23 to 0.42 m^2	45400	1040	3050	1610	4660	1260
Hot plate	2 burners	5630	390[b]	3430	1020	4450	1000
Oven (pizza), per square metre of hearth	0.59 to 1.2 m^2	14900	190[b]	1970	690	2660	270
Gas, Exhaust Hood Required							
Braising pan, per litre of capacity	102 to 133 L	3050	190[b]	—	—	—	750
Broiler, per square metre of broiling area	0.34 to 0.36 m^3	68900	1660	—	—	—	5690
Broiler (large conveyor, infrared), per square metre of cooking area/minute	0.19 to 9.5 m^2	162000	6270	—	—	—	16900
Broiler (standard infrared), per square metre of broiling area	0.22 to 0.87 m^2	61300	1660	—	—	—	5040
Charbroiler (large), per linear metre of cooking area	0.6 to 2.4 m	34600	21000	—	—	—	3650
Fryer (deep fat)	15 to 23 kg	23500	1640	—	—	—	560
Oven (bake deck), per cubic metre of oven space	0.15 to 0.46 m^3	79400	190[b]	—	—	—	1450
Griddle, per linear metre of cooling surface	0.6 to 2.4 m	24000	6060	—	—	—	1540
Oven (full-size convection)		20500	8600	—	—	—	1670
Oven (pizza), per square metre of oven hearth	0.86 to 2.4 m^2	22800	190[b]	—	—	—	410
Oven (roasting), per cubic metre of oven space	0.26 to 0.79 m^3	44500	190[b]	—	—	—	800
Oven (twin bake deck), per cubic metre of oven space	0.31 to 0.61 m^3	45400	190[b]	—	—	—	810
Range (burners), per 2 burner section	2 to 10 burners	9840	390	—	—	—	1930
Range (hot top or fry top), per square metre of cooking surface	0.26 to 0.74 m^3	37200	1040	—	—	—	10700
Range (large stock pot)	3 burners	29300	580	—	—	—	5740
Range (small stock pot)	2 burners	11700	390	—	—	—	2290
Range top, open burner (per 2 element section)	2 to 6 elements	11700	4000	—	—	—	640
Steam							
Compartment steamer, per kilogram of food capacity/h	21 to 204 kg	180	—	14	9	23	7
Dishwasher (hood type, chemical sanitizing), per 100 dishes/h	950 to 2000 dishes/h	920	—	260	110	370	120
Dishwasher (hood type, water sanitizing), per 100 dishes/h	950 to 2000 dishes/h	920	—	290	120	410	130
Dishwasher (conveyor, chemical sanitizing), per 100 dishes/h	5000 to 9000 dishes/h	350	—	41	97	138	44
Dishwasher (conveyor, water sanitizing), per 100 dishes/h	5000 to 9000 dishes/h	350	—	44	108	152	50
Steam kettle, per litre of capacity	12 to 30 L	160	—	12	8	20	6

Sources: Alereza and Breen (1984), Fisher (1998).

[a]In some cases, heat gain data are given per unit of capacity. In those cases, the heat gain is calculated by: q = (recommended heat gain per unit of capacity) × (capacity)

[b]Standby input rating is given for entire appliance regardless of size.

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
X-ray system	1725	534	480
X-ray system	2070		18

Source: Hosni et al. (1999)

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

Source: Hosni et al. (1999)

area tested. Data on actual diversity can be used as a guide, but diversity varies 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.

Heat Gain per Unit Area. Wilkins (1998) and Wilkins and Hosni (2000) summarized recent research on a heat gain per unit area basis. The diversity testing showed that the actual heat gain per unit area, or load factor, ranged from 4.7 to 11.6 W/m^2, with an average (normalized based on area) of 8.7 W/m^2. Spaces tested

Table 8   Recommended Heat Gain from Typical Computer Equipment

	Continuous, W	Energy Saver Mode, W
Computers[a]		
Average value	55	20
Conservative value	65	25
Highly conservative value	75	30
Monitors[b]		
Small monitor (330 to 380 mm)	55	0
Medium monitor (400 to 460 mm)	70	0
Large monitor (480 to 510 mm)	80	0

Sources: Hosni et al. (1999), Wilkins and McGaffin (1994).
[a]Based on 386, 486, and Pentium grade.
[b]Typical values for monitors displaying Windows environment.

Table 9   Recommended Heat Gain from Typical Laser Printers and Copiers

|	Continuous, W	1 page per min., W	Idle, W
Laser Printers			
Small desktop	130	75	10
Desktop	215	100	35
Small office	320	160	70
Large office	550	275	125
Copiers			
Desktop copier	400	85	20
Office copier	1,100	400	300

Source: Hosni et al. (1999).

Table 10   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 3300	390 to 2150
Labeling machine, 1,500 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	1725	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 sens., 450 latent
Microfiche reader	85	85
Microfilm reader	520	520
Microfilm reader/printer	1150	1150
Microwave oven, 28 L	600	400
Paper shredder	250 to 3000	200 to 2420
Water cooler, 30 L/h	700	350

Table 11 Recommended Load Factors for Various Types of Offices

Load Density of Office	Load Factor, W/m²	Description
Light	5.4	Assumes 15.5 m²/workstation (6.5 workstations per 100 m²) with computer and monitor at each plus printer and fax. Computer, monitor, and fax diversity 0.67, printer diversity 0.33.
Medium	10.8	Assumes 11.6 m²/workstation (8.5 workstations per 100 m²) with computer and monitor at each plus printer and fax. Computer, monitor, and fax diversity 0.75, printer diversity 0.50.
Medium/ Heavy	16.1	Assumes 9.3 m²/workstation (11 workstations per 100 m²) with computer and monitor at each plus printer and fax. Computer and monitor diversity 0.75, printer and fax diversity 0.50.
Heavy	21.5	Assumes 7.8 m²/workstation (13 workstations per 100 m²) 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).
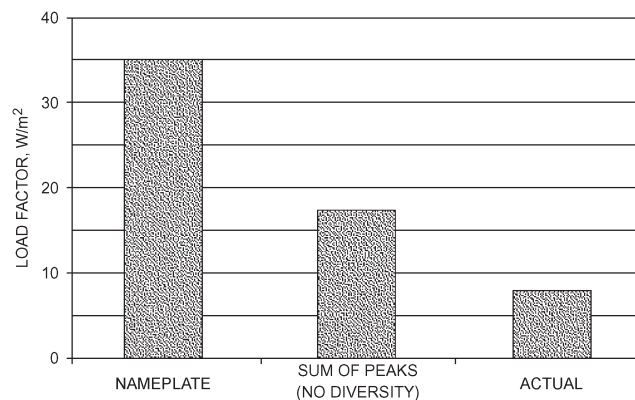
Fig. 4 Office Equipment Load Factor Comparison
(Wilkins and McGaffin 1994)

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

Radiant Convective Split. Hosni et al. (1999) found that the radiant-convective split for equipment was fairly uniform, the most important differentiating feature being whether or not the equipment had a cooling fan. Table 13 is a summary of those results.

HEAT GAIN THROUGH FENESTRATION AREAS

The primary weather-related variable influencing the cooling load for a building is solar radiation. The effect of solar radiation is more pronounced and immediate in its impact on exposed nonopaque surfaces. The calculation of solar heat gain and conductive heat transfer through various glazing materials and associated mounting frames, with or without interior and/or exterior shading devices, is discussed in Chapter 30. This chapter covers the

Table 12 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 = 5.4 W/m²					
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 = 10.8 W/m²					
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 = 16.1 W/m²					
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 = 21.5 W/m²					

Source: Wilkins and McGaffin (1994).
[a] See Table 11 for descriptions of load densities.

Table 13 Summary of Radiant-Convective Split for Office Equipment

Device	Fan	Radiant	Convective
Computer	Yes	10 to 15%	85 to 90%
Monitor	No	35 to 40%	60 to 65%
Computer and monitor	–	20 to 30%	70 to 80%
Laser printer	Yes	10 to 20%	80 to 90%
Copier	Yes	20 to 25%	75 to 80%
Fax machine	No	30 to 35%	65 to 70%

Source: Hosni et al. (1999).

application of such data to the overall heat gain evaluation and the conversion of the calculated heat gain into a composite cooling load for the conditioned space. Table 14 includes some useful solar equations.

Fenestration Direct Solar, Diffuse Solar, and Conductive Heat Gains

For fenestration heat gain, use the following equations: