

Heat Gain From Office Equipment

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ASHRAE Technical Committee 4.1, Load Calculation Methods, has completed two recent research projects and the results will be of interest to engineers who perform cooling load calculations. ASHRAE Research Project RP-822 focused on development of a method by which the actual heat gain and radiant and convective split from equipment in buildings could be measured [Hosni et al., 1996]. This methodology then was incorporated into a second research project, RP-1055, where the technique was applied to a wide range of equipment [Hosni et al., 1999]. A research team at Kansas State University, led by M.H. Hosni, completed both of these research projects. This research was followed up independent research by Wilkins and McGaffin, 1994.

The independent research by Wilkins and McGaffin produced significant data on the overall building load as measured at panels serving distinct areas within a building. Data was also collected on the measured power consumption of individual items of office equipment. The TC 4.1 research as executed by Hosni et al., expanded on this by obtaining data in a more controlled and formal manner.

Hosni's work for TC 4.1 also included measurement of the radiant and convective split of the heat gain from the equipment. Documentation relative to radiant and convective split is relevant when using advanced load methods.

Research Project RP-1055 obtained heat gain measurements from office, laboratory, and hospital equipment. The final effort of this research was to take the collected data and identify patterns or gen-

eralizations that could be widely used for common applications. It was discovered that results for general office equipment could be generalized, but results from laboratory and hospital equipment proved too diverse.

Here we will present generalized guidelines based on the results of all previously mentioned research for office equipment. The reader is encouraged to consult the project's final report and the technical paper (Hosni et al., 1999) for detailed discussions of results for laboratory and hospital equipment.

Nameplate vs. Measured

It is now well documented that nameplate data overstates the actual power consumption of office equipment. Power consumption of this type of equipment is assumed to be equal to the total (radiant plus convective) heat gain. Many engineers would find it convenient if a standard number or ratio could be applied to all nameplate data to obtain a useful esti-

mation of the actual heat gain. All research completed to date, however, suggests that this is not possible.

In Hosni et al., 1999 work as part of RP-1055, they found that for general office equipment with nameplate power consumption of less than 1,000 W, that the actual total heat gain to nameplate ratio ranged from 25% to 50%. When all tested equipment was considered, the range was broader. The conclusion was that if the nameplate was the only information known and no actual heat gain data were available for similar equipment, then it would be conservative to use 50% of nameplate and most accurate if 25% of nameplate were used. Wilkins and McGaffin also found a wide range in this ratio.

Use of this type of blanket ratio could introduce a large degree of error into calculations. Nameplate data for similar equipment varied widely but the actual measured heat gain data was consistent. Applying a generalized ratio could introduce an error of 100% or more. Much better results can be obtained by considering the heat gain as being predictable based on the type of equipment, not based on nameplate data.

Results by Equipment Type

The data collected in RP-1055 for all

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equipment tested was sorted and reviewed in an attempt to identify trends or generalizations that could be presented for use by practicing engineers. It was discovered that clear patterns could be established for office equipment but that laboratory and hospital equipment was too diverse to be generalized. Office equipment was grouped into categories such as computers, monitors, printers, facsimile machines, and copiers. Results for the measured heat gain of equipment within a given group were then analyzed to establish patterns.

Computers

Hosni et al. tested a total of eight computers of Pentium or 486 grade. Four were tested together with a monitor and four were tested alone. The measured maximum ranged from 52 W to 70 W. The nameplate power ranged from 165 W to 759 W. The heat gain from computers tested with monitors was determined by subtracting a typical value for a monitor from the total of the two. Wilkins and McGaffin reported data on 12 computers of 486 grade and older. The average heat gain for the 12 was 56 W and the average nameplate was 391 W. The average heat gain for all 20 computers tested was 55.6 W.

The heat gain from computers showed little reduction when idle versus operational. The exception was computers equipped with the Energy Star energy-saver feature. This feature will place a computer in a “sleep” mode if it remains idle for a preset period of time. Hosni et al., 1999 found that the heat gain reduced to a typical value of 18 W when in sleep mode. This sleep mode on an individual piece of equipment likely will not affect the peak-cooling load but it could affect the diversity factor and maximum heat gain of larger areas within a building.

Two conclusions can be drawn from these data. The first is that nameplate data on computers should be ignored when performing cooling load calculations. The second is that a typical value for heat gain from a computer can be established and applied in cooling load calculations to obtain practical results. Engineers typically want to be conservative in cooling load calculations. *Table 1* allows engineers to choose heat gain values for computers with varying degrees of safety factor.

Monitors

The magnitude of the nameplate power consumption for all monitors tested by Hosni et al. ranged from 168 W to 565 W.

	Continuous (watts)	Energy Saver (watts)
Average Value	55	20
Conservative Value	65	25
Highly Conservative Value	75	30
Based on 386, 486, and Pentium grade.		

Table 1: Typical heat gain from computers.

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Monitor Size	Continuous (watts)	Energy Saver (watts)
Small Monitor (13 in. to 15 in.)	55	0
Medium Monitor (16 in. to 18 in.)	70	0
Large Monitor (19 in. to 20 in.)	80	0
Typical values for monitors displaying Windows.		

Table 2: Typical heat gain from monitors.

Device Size	Continuous (watts)	1 page per min. (watts)	Idle (watts)
Small Desktop	130	75	10
Desktop	215	100	35
Small Office	320	160	70
Large Office	550	275	125

Table 3: Typical heat gain from laser printers.

The measured maximum total heat gain of all monitors tested ranged from 53 W to 86 W. The monitors tested ranged from 14 in. to 20 in. (36 cm to 51 cm). Hosni et al., 1999 found that the measured total heat gain correlated closely with monitor size. Hosni et al., 1999 developed the following relationship to estimate the heat gain from monitors as a function of monitor size:

$$\text{Heat Gain} = 5 \times S - 20$$

Where S is the monitor size in inches and heat gain is in units of watts. For example, a 15 in. (38 cm) monitor would have a heat gain of 55 W.

Wilkins and McGaffin did not sort their data by monitor size. They presented data on 10 monitors (13 in. to 19 in. [33 cm to 48 cm]) and found that the average value for the heat gain was 60 W. Their testing was done in 1992 when DOS still was used and the Windows operating system was being introduced. They discovered that monitors displaying Windows consumed more power than monitors displaying DOS. *Table 2* is a quick reference for engineers who may prefer a table to an equation. The energy-saver mode for monitors reduces the power consumption and heat gain to zero. *Table 2* is derived from research by both Hosni and Wilkins.

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. *Table 3* presents data on four general categories of laser printers. Hosni et al., 1999 opined that smaller printers are used more intermittently and that the larger printers may run continuously for longer periods of time.

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Device	Continuous (watts)	1 page per min. (watts)	Idle (watts)
Desktop Copier	400	85	20
Office Copier	1100	400	300

Table 4: Typical heat gain from copiers.

Device	Continuous (watts)	Idle (watts)
Facsimile Machine	30	15
Image Scanner	25	15
Dot Matrix Printer	50	25

Table 5: Typical heat gain from miscellaneous equipment.

These data can be applied in at least two ways. The most obvious is to take the value for continuous operation and then apply an appropriate diversity factor. Diversity factors are discussed further later. This likely would 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 presented data on a total of five copy machines. Copy machines were considered to be of two types, desktop and office. Office-type copiers represented freestanding office grade copiers. Larger machines used in production environments were not addressed. *Table 4* represents a summary of the results. Hosni et al., 1999 observed that it would be unlikely that desktop copiers would be operated continuously but that office copiers were of the type that often are operated continuously for periods of an hour or more.

Freestanding office-type copy machines often are installed in rooms outside the primary occupied area of an office. These copy rooms generally can tolerate a short-term increase in temperature caused by a period of continuous copier operation. Engineers must consider each application and determine the appropriate mode of operation.

Miscellaneous Equipment

Table 5 lists a few other types of equipment that may be encountered. Values for facsimile machines and image scanners are based on data from Hosni et al., 1999. The values presented for dot matrix printers are compiled from data presented by Hosni et al., 1999 and by Wilkins and McGaffin, 1994.

Diversity

The actual peak heat gain for all equipment in a common area of a building is less than the sum of the peak for each because of usage diversity. It is important to have a clear understanding of what diversity is, if the data presented here is to be applied accurately. Diversity, as discussed here, is not related to the

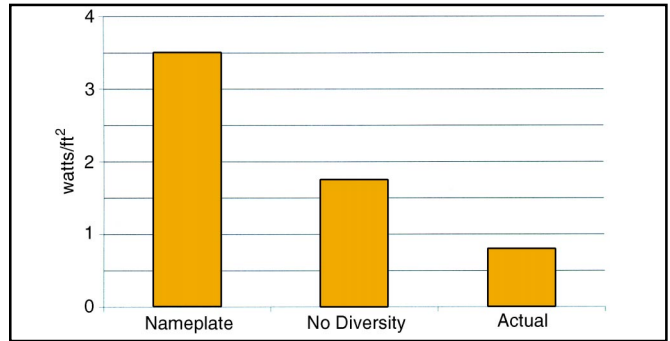


Figure 1: Load factor comparison.

discrepancy between nameplate data and the measured heat gain. Diversity enters into the equation when some equipment is idle or turned off and is not contributing its maximum heat or power to the overall cooling load of a given space or system within a building.

Wilkins and McGaffin were able to measure diversity with a combination of measurements at dedicated equipment power panels and detailed inventories of equipment in the areas served by the panels. Their work encompassed 23 areas within five different buildings totaling more than 275,000 ft² (25 550 m²). The first step was a survey to account for every piece of equipment in the space and to measure the power consumption of each. The peak power consumption (assumed to be equal to peak total heat gain) of all equipment was summed to provide a value for the maximum possible total heat gain of the equipment in the area.

Continuous measurements were taken for a period of one workweek at the equipment panels serving the area. Care was taken during the survey to assure that only receptacles wired to the equipment panels were powering equipment. The peak power consumption recorded at the equipment panel represented the actual peak total heat gain of all equipment in the space. The ratio of the measured peak at the equipment panels and the sum of the maximum of each individual item of equipment is the usage diversity.

Diversity was found to range between 37% and 78% with the average (normalized based on area) being 46%. *Figure 1* illustrates the relationship between nameplate, the sum of the peaks, and the actual with diversity accounted for. *Figure 1* is taken from Wilkins and McGaffin and is based on the average of the total area tested. Data on actual diversity can be used as a guide but diversity will vary significantly for spaces with different occupants. The proper diversity factor for an office of mail order catalog telephone operators will be different from that of an office of sales representatives who travel regularly.

Heat Gain per Unit Area

Wilkins and McGaffin found in the areas that they tested that the actual heat gain per unit area ranged from 0.44 W/ft² to 1.05 W/ft² with an average (normalized based on area) of 0.81 W/ft². These data were compiled based on 275,000 ft² (25 550 m²) of office space in five buildings. These spaces were fully occupied and highly automated with a computer and monitor at every workstation. *Table 6* presents a range of load factors

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Type of Space	Load Factor	Description
Light Load	0.5	Assumes 167 ft ² /workstation with computer and monitor at each, plus printer and facsimile. Computer, monitor, and facsimile diversity 0.67, printer diversity 0.33.
Medium Load	1	Assumes 125 ft ² /workstation with computer and monitor at each, plus printer and facsimile. Computer, monitor, and facsimile diversity 0.75, printer diversity 0.50.
Medium/Heavy Load	1.5	Assumes 100 ft ² /workstation with computer and monitor at each, plus printer and facsimile. Computer and monitor diversity 0.75, printer and facsimile diversity 0.50.
Heavy Load	2	Assumes 83 ft ² /workstation with computer and monitor at each, plus printer and facsimile. Computer and monitor diversity 1.0, printer and facsimile diversity 0.50.

Table 6: Typical equipment load factors.

with a subjective description of the type of space to which they would apply.

Wilkins and McGaffin performed tests in 275,000 ft² (25 550 m²) of highly automated spaces, comprising 21 unique areas in five different buildings. The maximum load factor they reported was 1.08 W/ft². This corresponds to a medium load density space based on the subjective classifications presented in *Table 6*. It is likely that the medium load density will 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. Other research supports this, including work

Device	Fan	Radiant	Convective
Computer	Yes	10% to 15%	85% to 90%
Monitor	No	35% to 40%	60% to 65%
Comp. + Monitor	—	20% to 30%	70% to 80%
Laser Printer	Yes	10% to 20%	80% to 90%
Copier	Yes	20% to 25%	75% to 80%
Facsimile	No	30% to 35%	65% to 70%

Table 7: Radiant-convective split.

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by Komor in 1997. Komor performed a consolidation of data obtained from several sources and in all cases, his findings were consistent with *Table 6*.

Radiant Convective Split

Office equipment produces both radiant and convective heat gains. Convective heat gain is converted instantly to cooling load while radiant heat gain is

absorbed first by the building mass and then converted to cooling load over time. This distinction can impact the time and the magnitude of the peak cooling load. Hosni et al., 1998 developed a method to measure radiant heat gain from equipment using a net radiometer mounted on an articulating arm.

Hosni et al., 1999 found that the radiant-convective split for equipment was

fairly uniform. The most important differentiating feature was whether or not the equipment had a cooling fan. *Table 7* is a summary of Hosni et al., 1999 results.

Future Trends

The data that we have presented here is based on contemporary equipment. The relevance of these data in the future is certainly a legitimate question. The Lawrence Berkley National Laboratory sponsored research in 1995 and reported that equipment energy intensity will decrease until 2002 and then begin to increase slowly through 2010. To date, this prediction has proven accurate. It is likely that the data presented here will be relevant for several more years.

Conclusions

Heat gain from equipment is an important contributor to the overall heat gain of a space. The information presented in this article should be a useful tool to engineers performing cooling loads or energy analyses. We also hope that equipment manufacturers understand the importance of nameplate values for cooling load calculations and take appropriate steps to provide more realistic power consumption information.

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