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Lighting Design for Open-Plan Offices

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Good office lighting is a key element in assuring worker satisfaction and performance. This Update provides guidance on lighting design for open-plan offices based on current best practice and the results of research conducted by NRC's Institute for Research in Construction.

This Update expands on Update No. 60, which summarized the findings of the Cost-effective Open-Plan Environments (COPE) project. IRC's partners in COPE were: Public Works and Government Services Canada, the Building Technology Transfer Forum, USG Corporation, Ontario Realty Corporation, British Columbia Buildings Corporation, Steelcase Incorporated, and Natural Resources Canada. For more information on COPE, see http://irc.nrc-cnrc.gc.ca/ie/cope. Three related Updates address workstation design, acoustics, and ventilation and air quality.

The traditional focus of office lighting design has been to ensure the visibility of paper-based tasks carried out on desktops (horizontal desk surfaces). However, there are many other issues involved in good lighting design for the modern office, where most work is performed on computer screens (vertical, self-luminous surfaces).

These issues have been addressed by the Illuminating Engineering Society of North America (IESNA) in its recent Lighting Design Guide. The Guide is included in both the IESNA Handbook[1] and its recommended practice for office lighting.[2] NRC's Institute for Research in Construction has conducted several projects specifically addressing lighting for partitioned, open-plan offices (cubicles) that supplement or modify the information provided by the IESNA. From this research, IRC has developed recommendations for enhancing lighting quality in open-plan offices, as reported in this Update.

Definitions

Illuminance is the amount of light falling on a surface, and is measured in lux.

Luminance is the amount of light emitted by a surface, and is measured in candelas per square metre (cd/m^2). It is a function of the light falling on a surface (its illuminance) and the surface's reflective properties.

Illuminance Selection

Until the advent of the IESNA Lighting Design Guide, horizontal illuminance on the desk surface was the primary numerical design criterion for office lighting. With the shift in office work from paper to computer, the recommended horizontal illuminance level has been reduced. The IESNA recommends 300 lux if computer use is intensive and 500 lux if it is intermittent. By comparison, in studies in an office set-up where occupants used dimmers to select their preferred lighting conditions, IRC found that average chosen illuminances on the desk surface were in the range of 400-500 lux,[3] even for those who are intensive computer users.

Workstation design can have a large effect on office lighting. For a given lighting system, small workstations, high panels, and dark-coloured panels all reduce the illumination reaching the desktop.[4] Figure 1 shows that increasing the panel height from 1.65 to 2.60 m (42″ to 66″) can decrease illuminance on the desktop by about 20%. The effect varies according to the type of ambient lighting (luminaire) used. Luminaires with a parabolic louvre direct light straight down to the desktop and are therefore affected least by panels. Indirect or direct/indirect luminaires rely on reflections from the ceiling and other surfaces for light to reach the desktop and are therefore affected most by panels. Luminaires with prismatic lenses are somewhere in between. Reducing the reflectance of workstations from 50% to 20%, or decreasing workstation size from

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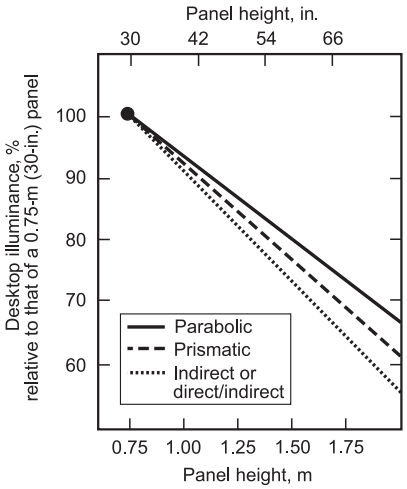

Figure 1. Effect of panel height on desktop illuminance. Results shown are for a workstation 3.05 m by 3.05 m (10 ft by 10 ft) with surface reflectances of 50%.

A description of luminaire types is available at: http://irc.nrc-cnrc.gc.ca/ie/cope/04-1-Lighting_Principles.html#Types

3.05 by 3.05 m (10 by 10 ft.) to 2.4 by 2.4 m (8 by 8 ft.) can further decrease illuminance by about 10%.

An office worker's field of view usually includes vertical surfaces behind the computer screen, such as panels and walls. The IESNA recommends 50 lux for vertical surface illuminance. However, IRC research suggests that workers prefer higher levels, averaging around 200-300 lux on surfaces of mid-reflectance.[5]

Individual Lighting Control

The average illuminances presented above do not take into account the wide range of individual preferences for lighting conditions.[3] In one experiment in an open-plan office set-up, 94 participants were given dimming control over separate direct and indirect luminaires, and switching control over an under-shelf task light. The lighting conditions chosen yielded desktop illuminances ranging from below 100 up to 800 lux (Figure 2).

Failure to meet workers' lighting needs can adversely affect their satisfaction and mood.[5] It is best to provide some form of individual control over lighting—ideally, dimming control over the lighting associated with each workstation. The benefits of individual control are not limited to satisfaction improvement—it can also deliver lighting energy savings of 10 to 30%.[5]

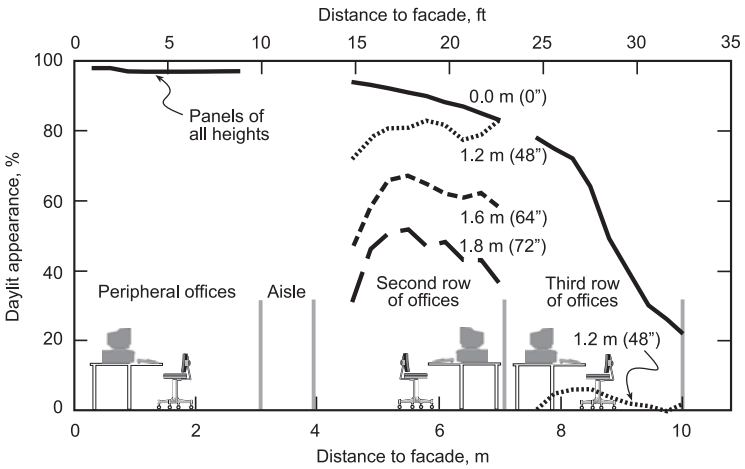

Figure 3. The effect of panel height on daylight availability for workstations. "Daylit appearance" is the percentage of working hours with appreciable daylight (≥150 lux). In this example, workstations are 3.05 by 3.05 m (10 by 10 ft), reflectances are 50% and the perimeter is a curtain wall with windows from desktop level to ceiling.

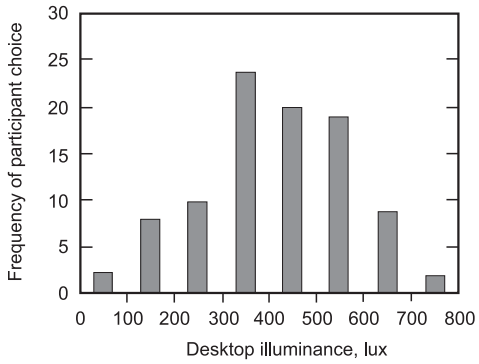

Figure 2. Desktop illuminance levels chosen by participants in a mock-up office

Illuminance from Daylight

With good design, some or all of the prescribed illuminance can be provided by daylight, providing several benefits. First, energy can be saved by dimming or switching off lights during periods when daylight is available: with appropriate control systems, lighting energy savings in the range of 25-60%[4] near the building perimeter are achievable. Second, occupant satisfaction increases: this is due to a combination of the qualities of daylight as a light source and the view to the outside provided by windows. Third, there is evidence that daylight is associated with health benefits. For proper functioning of circadian rhythms and associated hormone production, the body needs light at a relatively high level at certain times of the day and with an appropriate spectrum. Although the exact level, time and spectrum are subjects of ongoing research, daylight seems to match the requirements quite well.[6]

Thus the challenge is to design open-plan office spaces to optimize access to daylight. Low panels, light-coloured panels, and high ceilings all increase the penetration of daylight to workstations distant from a window.[4] Figure 3 shows the effect of panel height on daylight availability for workstations, as one moves away from the window.

Luminance

Another important element of office lighting is luminance. It is luminance, not illuminance, that causes the sensation of brightness. In general, people prefer bright spaces, provided glare is limited. The luminance of major surfaces in an office[3] should be at least 30 cd/m^2. Office design

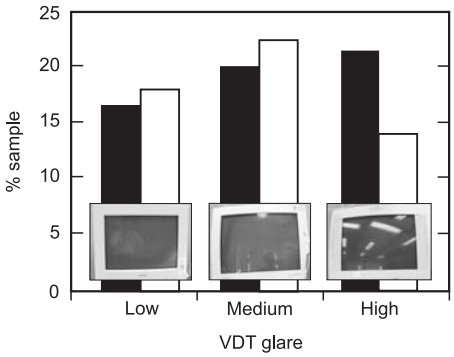

Figure 4. The percentage of office workers in the COPE field study that were either highly satisfied (white) or highly dissatisfied (black) with their lighting, as a function of glare on the computer screen

choices that increase illuminance for a given lighting system (large workstations, low panels, and light-coloured panels) also increase luminance.[4] In particular, dark-coloured surfaces should be limited to small areas in offices. Light-coloured surfaces are required to achieve both the recommended luminance and illuminance values.

Glare

Glare is too much luminance in the wrong place, and makes for uncomfortable working conditions and reduces occupant satisfaction.[4,7] Glare can come from a bright light source that shines directly into the eyes, or from light reflected on a shiny surface such as a computer screen or magazine. Bright light sources directly overhead can also cause discomfort. Figure 4 shows the percentage of office workers in the COPE field study that were either highly satisfied or highly dissatisfied with their lighting, as a function of glare on the computer screen.

Glare should be eliminated at its source by selecting luminaires that do not emit light at angles likely to create glare directly or through reflection, particularly on computer screens. Glare from sunlight can be eliminated by using good-quality, easily adjusted window shades. Residual glare on computer screens can be further reduced by locating them so they do not face glare sources. Computer screens should also have anti-reflection coatings; flat LCD screens are less susceptible to reflected glare than traditional (CRT) screens. For computer tasks themselves, the use of dark text on a light background reduces the severity of reflected glare.

Uniformity

While people do not generally like dark spaces or spaces with excessive brightness and glare, they do prefer some variation in luminance across a room. The IESNA recommends that, across a person's field of view, the ratio of maximum luminance to minimum luminance should not exceed 10:1. IRC research suggests that ratios up to 20:1 might be acceptable,[3] provided there is a good reason for this—for example, highlighting an area or objects of visual interest. In the vicinity of the occupant's primary task, lower ratios are preferred. The IESNA recommends that the luminance ratio between a task and the immediately adjacent surroundings should not exceed 3:1 (or vice versa); IRC research suggests lower ratios.[3,5] When participants chose office lighting levels using dimmers, their choices resulted in an average desktop to background luminance ratio of 1.5 – 2 : 1, and an average computer screen to background luminance ratio of 0.8 – 1.2 : 1.

Office design choices that reduce illuminance (small workstations, high separating panels, and dark-coloured panels) also reduce uniformity.[4] Note that higher luminance ratios than those described above are often acceptable in daylit situations.

Flicker

A common problem with fluorescent lighting is flicker, which is associated with increased incidence of headaches and eyestrain, and reduced task performance.[7] Fluorescent lamps require components called ballasts to convert electricity into a form necessary for lamp ignition and operation. There are two basic types of ballast: magnetic (older technology) and electronic (newer). It is magnetic ballasts that cause flicker. They cause light from fluorescent lamps to fluctuate at twice the frequency of AC electricity supply, or 120 Hz. Some people may detect this oscillation directly; for others who do not perceive the flickering visually, there is evidence that the neurological system does pick it up, which may cause problems.

Electronic ballasts eliminate flicker by operating at a much higher frequency that renders light output oscillations undetectable. This type of ballast is more expensive than the magnetic type, but reduces lighting energy consumption by around 15%.

Maintenance

No matter how well designed, a lighting system requires good maintenance. For example, the output of a luminaire can decrease by around 10% because of reflector and lens surface degradation and dirt accumulation. These losses can be offset with regular cleaning. Lamp output declines with time, also resulting in lower energy efficiency. Consider replacing groups of very old lamps; group relamping is also cheaper than spot relamping, on a per-lamp basis.

Malfunctioning or burnt-out lamps should be replaced as soon as possible, and identical luminaires in a given area should use identical lamps to avoid distracting differences in colour or luminance. Also ensure that the lamp and ballast have been designed to work together, as incompatible combinations reduce light output and energy efficiency.

If the office space is reconfigured, the luminous environment could be substantially affected. Changes to the lighting design to accommodate these effects should always be considered as part of the office reconfiguration.

Interrelationships and Trade-Offs

Some office design choices that contribute to good lighting may have a negative effect on other aspects of the indoor environment. For example, as mentioned, lower panels improve daylight penetration, the view to windows, and electric light distribution. They also improve satisfaction with ventilation, but, on the negative side, they increase noise transmission and reduce privacy.

While proximity to a window increases satisfaction with lighting, and may promote energy savings and health benefits, it can also expose people to greater temperature extremes. Therefore, features to alleviate thermal discomfort may be required.

Summary of Recommendations

Information in best practice guides and the results of recent IRC research indicate that individual control over light levels is the ideal in terms of achieving worker satisfaction. Where this is not possible, the following quantitative guidelines should be followed for illumination and luminance:

- Illuminance on desk working surfaces: 400 – 500 lux
- Luminance on major surfaces: > 30 cd/m^2
- Luminance ratios:
  - 1.5 – 2 : 1 between the desktop and background
  - 0.8 – 1.2 : 1 between the computer screen and background
  - up to 20:1 across in the broader field of view, provided the luminance variations match the features of the space

Following the guidelines below will further improve worker satisfaction with office lighting:

- Use light-coloured (50% reflectance for walls, 80% for ceilings), non-shiny surface finishes
- Design for daylight, and provide as many people as possible with a window view
- Eliminate glare through appropriate choice of lamps, luminaires, luminaire layout and workstation design
- Eliminate flicker by using electronic ballasts
- Design and implement a maintenance plan
- Ensure that lighting choices have a minimal negative effect on other aspects of the office environment, and that choices in other aspects of office design have minimal negative effect on the luminous environment.

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