Lighting Coordination

OBJECTIVE

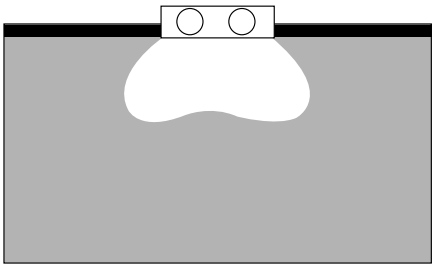
Design the lighting system to best integrate with daylight and provide controls for high-performance, comfortable, and energy-efficient lighting.

- The cost-effectiveness of daylighting depends on lighting energy savings.
- Effective controls help capture maximum savings from daylighting.
- Lighting design must include daylight from the beginning.

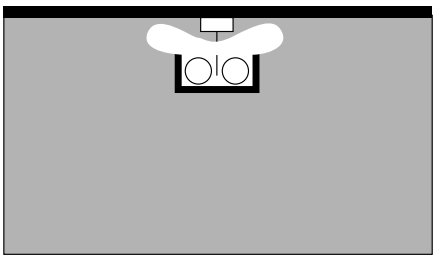
KEY IDEAS

Use a Lighting Strategy that Integrates with Daylight

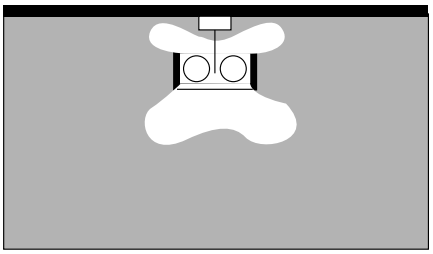
- **Make daylight integration part of lighting design from the beginning.** Lighting strategy, fixture selection, and method of control are all affected by the goal of daylight integration. For buildings primarily occupied during the day (schools, retail) that do not have tasks requiring higher illumination at night, design the electric lighting to augment daylight.
- **Choose a task/ambient strategy for easy integration with daylighting.** Daylighting can provide required ambient lighting for most operating hours. Provide user-controllable task lights to assure that task illumination requirements are met at all locations when supplemental lighting is necessary. Users near windows will often use daylight as their primary task source. In general, design ambient illumination levels to be significantly less than task levels (but not less than 1/3 of task levels).
- **Use direct/indirect lighting to avoid glare and match daylight distribution.** Direct/indirect lighting keeps the brightest light sources out of view, and is a good pair with daylight spatial distribution. These systems require a clean, high reflectance ceiling and adequate ceiling height. Don't use pendant-style direct/indirect fixtures if ceiling height is less than 9' (2.9 m). For best light distribution, pendants should be hung at least 1'-6" (0.46 m) from the ceiling. A direct/indirect system will generally be more efficient at providing task illuminance than an indirect system.



Direct lighting, typical candlepower distribution from ceiling-mounted luminaire



Indirect lighting, typical candlepower distribution from suspended luminaire



Direct/Indirect lighting, typical candlepower distribution from suspended luminaire

- **Balance the light in a deep room.** In daylighted spaces greater than 15 ft (4.6 m) in depth, provide vertical illumination on back wall (using ceiling fixtures within two feet of wall or with wallwashers) with a cool color temperature greater than 4000°K to balance luminance differences between the front and back and prevent a gloomy feeling. Use walls or partitions with high-reflectance, light-colored surfaces.
- **Organize fixture layout to match daylighting distribution.** To ensure adequate illumination, group fixtures by areas of similar daylight availability (e.g., in rows parallel to window wall). Arrange lighting circuits in zones parallel to window wall for daylighting even if controls are not specified, to allow the possibility for controls to be added as retrofit. Recircuiting is generally difficult and costly in a retrofit project. However, retrofits for daylighting control are possible even with non-optimal circuiting, due to newer dimming and ballast control technology.

Choose the Right Hardware

- **Use 32-Watt T8 tri-phosphor fluorescent lamps and dimming ballasts.** Fluorescent lighting is the source of choice for both dimming and switching applications, because it can be efficiently dimmed over a wide range without changes in color and can be turned on and off virtually instantaneously. Most dimming fluorescent ballasts dim to 10-20% light output (@ 30% power), but "architectural" dimmers dim to 1% (these dimmers come at a cost premium).
- **Try to match the cool color temperature of daylight.** For best color temperature pairing with daylight, specify fluorescent lamps with a minimum color temperature of 4100°K.
- **Avoid high-intensity discharge lamps.** Most HID sources (metal halide, high pressure sodium and mercury vapor) are not appropriate for dimming applications because they suffer color shifts as they dim and have a more limited dimming range. (They can be used with appropriate switching in high bay spaces such as warehouses.)
- **Avoid lamps that do not dim well.** Don't specify 34-watt T12 lamps if planning to use dimming controls, because they do not dim reliably.
- **Choose energy-efficient hardware.** No matter what the lighting strategy, always choose the most cost-effective lighting technologies and the most effective controls available within the design budget.

Maximize Visual Comfort

- **Follow recommended practice guidelines regarding glare from downlights.** To minimize direct glare, electric lighting should generally have a minimum Visual Comfort Probability (VCP) of 80% for computer-based tasks and 70% for other office tasks. Note that VCP is not defined for indirect lighting or any fixture with an upward component. VCP is defined as the percentage of people who find the lighting free of discomfort glare.
- **Keep ambient lighting low for computer screens.** If computers are present, ambient lighting should not exceed 30 fc (300 lux). But make sure that user-controlled task lighting is available for hard copy tasks. A rule of thumb for spaces with video display terminals (VDTs): provide as little light as possible on computer screens, 15-30 fc (150-300 lux) for surround lighting, and 50 fc (500 lux) on adjacent hard copy tasks. See IES RP-1 Guidelines and other IES literature (see TOOLS & RESOURCES) for assistance.
- **Keep lamp reflectance out of computer screens.** Limit the potential for reflected glare from ceiling lights in computer screens. If ceiling downlights are used, limit high angle brightness to no more than 850 candelas per square meter at 55 degrees altitude (preferably) and at 65 degrees (definitely). When installing computers, verify that the placement of the computer does not result in reflected images of ceiling fixtures in screen. If reflections are evident, adjust position or locations of screen or apply anti-reflection filters to computer screen face.
- **Watch ceiling brightness with computers.** Indirect or direct/indirect lighting is good for VDT users, but observe some rules about the ceiling brightness. Ceiling luminance for VDT tasks ideally has a ratio across the ceiling of less than 4 to 1. Ceiling and wall surface luminances should be less than 850 candelas per square meter at any angle, as averaged over a 2 by 2-foot (0.6m by 0.6m) area. In open plan areas, VDT workspaces benefit from lower, uniform lighting.
- **Avoid brightness glare from exposed lamps in the field of view.** Obstruct direct views of sources to avoid glare. Direct/indirect lighting is one method. Careful space planning is another.
- **Use lighting strategies to balance window glare if anticipated.** Keep luminance of interior environment high to balance window brightness if there are no architectural modifiers such as deep reveals, shading devices or elements to filter daylight. (See GLAZING SELECTION and SHADING STRATEGY to control window glare.) A slight wall or ceiling wash towards the back of the space (farthest area from window) is generally effective. A small increase in energy use for this purpose is acceptable.

- **Lighting quality comes before energy efficiency.** Don't reduce occupant comfort or satisfaction for higher energy savings. An occupant's productivity is far more expensive than the energy she uses.

Coordination

- **Flag potential conflicts early,** such as furniture or colors that will interfere with light distribution, poor location or access for electrical rooms, and crowded ceiling plenums. Pick bright surround colors. Keep ceilings and walls as bright as possible.
- **Balance window glare with well-placed lighting.** Slightly raise the luminance of walls and ceiling regions away from the windows, to soften the contrast between the two. As noted above, this is especially important in deeper spaces.
- **Include calibration and maintenance plans in the construction documents.** Develop a set of recommended procedures and schedules for control system calibration, other lighting system commissioning, operation, maintenance and replacement, and format in a clear and easy-to-use package. Make this documentation part of the lighting construction documents. Provide documentation that can be passed along to the ultimate occupants of the space so that they can understand how to best use the lighting systems and controls.

INTEGRATION ISSUES

ARCHITECTURE

Location of the windows directly influences lighting control strategies and placement of photocell sensors. Coordinate with lighting design.

Quality of the perimeter spaces depends on blending and balance between daylight (a strongly directional light from the side providing high illumination and cool color) and the very different nature of electric lighting.

INTERIOR

Interior surfaces, and especially the ceiling, must be light colored.

Coordinate workstations with window placement and fixture locations, especially for glare-sensitive workspaces (e.g., computers). Align view direction of VDT parallel to the window wall.

Locations of partitions and other tall furniture should not interfere with penetration of daylight. This may require re-orienting partitions or using translucent panels rather than opaque.

HVAC

Lighting designer should supply a reasonable estimation of lighting power reduction due to daylight controls for the purpose of cooling load calculations. Expect the perimeter zones to have less than peak electric lighting loads at peak cooling periods (e.g., summer noon).

Locations of lighting fixtures and supply/return registers should be coordinated so as not to disrupt air flow.

LIGHTING

Incorporating a daylighting strategy does not have a negative effect on lighting design. In fact, lighting quality is typically higher in a carefully daylighted space.

COST-EFFECTIVENESS

Direct/indirect systems using pendant fixtures are typically a 50% cost premium over direct lighting fixtures. However, cost-effectiveness of a lighting system may ultimately depend on occupant satisfaction and owner avoidance of future retrofits.

Many efficient lighting technologies have short paybacks and often qualify for utility rebates or incentives, due to the very large percentage of building energy use consumed by lighting. Costs of some newer technologies (e.g., dimmable electronic ballasts) are falling rapidly with time. Be sure to use current cost estimates in your analysis.

OCCUPANT COMFORT

A lighting system is not successful if occupants cannot comfortably perform their tasks.

Task illuminance under direct lighting is highly sensitive to the task location with respect to fixture and partition locations. Because lighting is fixed in place often long before furniture and partitions are installed, and because furnishing may be relocated in the future, direct lighting systems have a higher chance of leading to occupant dissatisfaction versus indirect systems.

! PROVISOS

- Relying on calculations or past experience alone may not yield satisfactory results in the final product because of the complex, dynamic qualities of daylight. It is strongly recommended that the architect and lighting designer work together with an outdoor physical scale model to assess the nature of the anticipated daylighted space. Confirm intuition with your observations of window glare, daylight quality, and distribution.
- Designing for a maximum of 1.5 watts per square foot for installed lighting is an easily achievable target. With efficient equipment and sensitive design, high quality lighting can be achieved at 1.0 watt per square foot or even lower.
- Do not use pendant-style fixtures with ceilings less than 9 ft (2.74 m).
- Simple changes in a building, like wall redecoration or furniture relocation, can have a strong influence on complicated lighting systems. If such changes are anticipated, a more flexible approach to lighting is recommended.

TOOLS & RESOURCES

- **Design Professionals** Use a lighting specialist whenever daylighting controls are planned. Lighting designers (as opposed to electrical engineers) are recommended in general for a higher quality end result. Cost for added service is recouped in improved performance and occupant satisfaction, and gives the best chance at gaining energy savings.
- **Books** There are many titles available on general lighting design, but little to assist high performance lighting design with daylight controls. The IES may be the best source for literature.

  Advanced Lighting Guidelines: 1993, from the U.S. Department of Energy, is a thorough and informative guide to all aspects of various lighting technologies.
- **IES** The Illuminating Engineering Society is a resource for literature, standards, codes, guidelines and a monthly journal covering lighting, daylighting and visual comfort. These materials provide useful and up-to-date technical information. Local chapters also may offer classes or other resources. For publications, call (212) 248-5000, ext. 112.
- **EPRI** The Electric Power Research Institute has a collection of fact sheets, brochures, guidelines and software available. Call EPRI Lighting Information Office (800) 525-8555.
- **California Energy Commission** The CEC administers California Energy Code (Title 24) and offers good literature and design guidelines to assist with compliance, along with the code documents. Contact the CEC at (916) 654-4287 to request a publications list.
- **LBNL Lighting Systems Research Group** is a good source of information on all aspects of energy-efficient lighting practices. For a publications list, contact Pat Ross at (510) 486-6845, or visit the Group's website at http://eande.lbl.gov/BTP.
- **Lighting Research Center**, at Rensselaer Polytechnic Institute, is source of general information about lighting products and practice. Contact them at (518) 276-8716 or http://www.lrc.rpi.edu.
- **Utility Company** Many utilities offer workshops, design assistance, publications, and sometimes incentives for energy-efficient lighting equipment. Inquire at your local utility about new construction or retrofit programs.
- **International Association for Energy-efficient Lighting** The IAEEL issues a useful quarterly newsletter free of charge. Write to IAEEL, c/o NUTEK, S-11786, Stockholm, Sweden and request placement on the newsletter mailing list.
- **Calculation Methods** Well-established methods exist for calculating light levels with a proposed design. The best source for reference material on this topic is the IES (see above (i.e., the IESNA magazine *Lighting Design + Application*, Software Survey, September 1996)). Many lighting designers use daylighting software such as Lumen Micro and LightScope (available from Lighting Technologies, Inc., 303-449-1822), Luxicon (available from Cooper Lighting, 708-806-3553), LightCAD and BEEM (available from EPRI, 612-938-6014), and Adeline and Radiance (available from LBNL, 510-486-4757) in place of tedious hand calculations. A package that is capable of addressing daylight and electric light integration is recommended. For a list of lighting design software with daylight capabilities, request a "Daylighting Design Tool Survey" from the Windows and Daylighting Group at the Lawrence Berkeley Laboratory (510) 486-5605.
- **Scale Models** A physical model, built accurately with materials that match intended finish reflectances and viewed outdoors, is a good tool to assess window glare, daylight distribution, and quality of the daylighted environment. This is a quick and easy study activity useful for the architect and the lighting designer to perform together. See ENVELOPE AND ROOM DECISIONS for more information.

- **Full Scale Mock-ups** This is the only method for truly viewing the intended lighting scheme before construction. This can be costly and time-consuming unless the local utility or lighting manufacturer offers assistance, but is easily justified, at least for large projects.

☑ CHECKLIST

1. Review fenestration design and intended space plan for initial assessment of daylighting and glare concerns.
2. Estimate daylight levels through calculations, computer modeling or physical model photometry.
3. Select lighting strategy and type of control, depending on above two decisions.
4. Lay out the lighting system, coordinating with window placement and daylighting control zones. Be sure to produce an installed lighting power density lower than the energy code maximum.
5. Estimate electric lighting illuminance levels. Determine daylight and electric lighting distribution throughout each lighting zone and ensure that dimming zones maintain the required levels and distribution.
6. Select the most efficient technologies available within project budget that meet design objectives. Check with utility about lighting programs.
7. Calculate expected electric lighting savings due to daylight controls, for use in a cost/benefit analysis (see Section 11, COST/BENEFIT ANALYSIS). Provide expected lighting power reduction at peak times to mechanical engineer for cooling load calculations.
8. Review glare issues with architect. If window design or selection of window coverings is not anticipated to be adequate, compensate for window glare by balancing interior luminance distribution with the lighting design.
9. Flag potential conflicts with interior design, plenum elements, etc.
10. Include performance specifications, control system documentation, calibration instructions, other commissioning recommendations and maintenance plan with the lighting design documents.

If you have...

no time

1. Design a lighting system at a maximum of 1.5 watts per square foot, with supplemental task lighting if necessary, fixtures grouped with windows and by daylighting zone, and special attention to glare in computer workspaces.
2. Estimate daylight levels before final system design and selection of control strategy.
3. Check for utility rebates before final design and specification.
4. Include previously described documentation with the construction documents.

a little time

In addition to above:

1. Include a lighting specialist on the design team.
2. Review glare concerns with the architect and take appropriate measures.

more time

In addition to above:

1. Consider a direct/indirect lighting strategy while exploring other alternatives.
2. Use lighting software and/or physical model photometry to estimate daylight levels and nature of the daylighted space.
3. Consider a full-scale mock-up of a typical workspace.