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**Daylighting Design: A Balancing Act**

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## Daylighting Design: A Balancing Act

Daylighting design has matured into a comprehensive controllable building system that brings and regulates daylight within the building.

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Although lighting is the number one source of energy consumption in any commercial building or school—accounting for between 35-65 percent of overall energy use—electric light typically is wasted by being at 100 percent output all day, even when there is available sunlight to offset the need for full output. This is especially uneconomical during peak hours, when electricity demand and corresponding demand charges are high.

Yet, there is available natural light all around us. By bringing more natural daylight deep into the building, you are able to reduce the need for electric light output and, therefore, save energy and reduce operating costs.

Daylighting design not only takes advantage of available natural light by bringing it into the building, but also by managing the proportionate levels of electric light output and regulating heat and glare through the use of window treatments to maximize the efficiency, functionality and comfort of the environment.

As more advanced building management systems (BMS) continue to emerge, integrating control of HVAC, electrical, fire, energy and security for more effective operations, daylighting design provides the opportunity for even greater efficiency.



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### Pleasing, Productive, Positive

The motivation to integrate daylighting design does not rest solely on financial reward. Rather, daylighting design is a means to creating a healthy and productive workforce, as well as sustainable buildings that meet codes and guidelines.

Dozens of studies have confirmed that classrooms are more effective learning environments with greater amounts of daylight. Likewise, several studies have reported statistically significant improvements in employee productivity in office environments, cash register sales in retail stores and overall improved health and

### In Brief

An overview of daylighting systems and their design factors.

### Related Products:

Building Management Systems;  
Electric Lighting Control Systems;  
Controllable Window Shades or Blinds; Dimmable Digital Ballasts.

morale of occupants as a direct result of natural daylight in commercial spaces.

Recent architectural trends, such as large window-to-wall ratios, light shelves above lower (view) windows and more skylights in low rise commercial buildings, enhance daylight penetration. In fact, California mandates the use of skylights and daylighting control systems in single story commercial buildings with a ceiling height greater than 15 feet in the 2005 edition of Title 24, the State's energy code.

### Integrated Efficiency Systems

In the past five years or so, daylighting has evolved from the practice of bringing more natural light into the building interior to a more comprehensive and integrated system for balancing building-wide efficiency.

The immediate effect of bringing more daylight into the building is that shading

of the windows in some form or other is required; otherwise, the interior of the building can become too hot and the radiant heat and glare from the sun will become uncomfortable.

For that reason, daylighting design has matured into a comprehensive controllable building system that brings and regulates daylight within the building. True integration occurs when an electric lighting control system is integrated with controllable window systems—such as controllable window shades or blinds—to provide glare control benefits, reduce the cooling load and protect interior surfaces from UV and near UV wavelengths.

Integrated daylighting control systems consist of controllable lighting fixtures (such as fluorescent dimming systems), motorized window covers, photo sensors that measure the available daylight and a lighting controller that executes the control of electric light levels and position of window covers.

These systems may also be integrated with a building management system. This integration provides the owner a single point of control for all of the major building functions, delivering a better ability to control energy use in the building and a single point of contact for a technology contractor. In short, an integrated building provides better value to its owner.

## Designing for Daylighting

The response of buildings to daylighting systems depends on the architectural features of the building, the design of the interior of the building, exterior obstructions, weather conditions and other such factors.

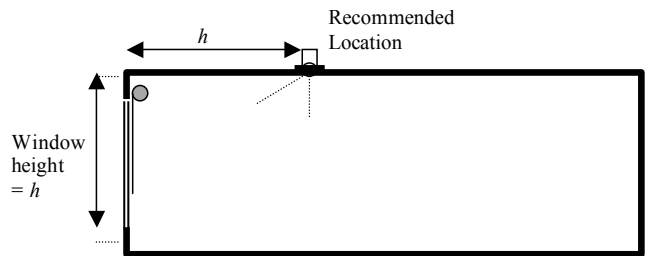
In addition, it is advisable to treat different building exposures differently. The northern exposure frequently provides the best source of daylight because all the light is diffused and relatively free from glare. The southern exposure, on the other hand, may need overhead shielding from the midday high sun angles; while east and west windows present a greater risk for direct sun glare (which can be managed with motorized window coverings).

It is important to understand the impact these variable factors can have on the success of the system in the early stages of designing for daylighting. By strategically planning around these factors you can create the most optimal system.

## Locating the Photocell

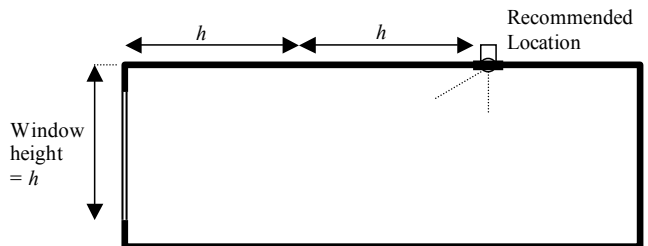
The goal of the control system is to keep the incident illuminance, or the lighting level measured by a light meter, approximately constant on a target surface—whether that surface is a work plane, an object or art, or something else. The sensor location is somewhat critical because it needs to be exposed to incident daylight that correlates with the illumination to be controlled, and the signal strength needs to be reasonable.

Other than direct sun light, which in most cases we want to eliminate from the task surface anyway, the other source of daylight is the *reflected* (and relatively diffused) sunlight from the sky and from clouds. In daylighting applications, the challenge is to orient the sensor in such a way that it measures this reflected daylight in proportion to how it varies on the task surface.



**Figure 1: Sensor Placement with Window Shades**

When window shades are used, the sensor is located so that it has a direct view of the window being controlled. In a side lighted room with the sensor mounted in the ceiling, a good location is about one window height into the room from the window. The same sensor location provides a good signal for controlling the electric lighting.



**Figure 2: Sensor Placement without Window Shades**

When window shades are not in use, it is preferable to locate the sensor further into the room, because in these cases there is a lot of daylight near the window. Locating the sensor about two window heights into the room works well in this case.

Typically, the sensor is located on the ceiling—in a working environment this is usually above the desk. Photo sensors should not be pointed directly towards a light source (whether sun or electric light sources). It is also important that the sensor not look towards the exterior to eliminate the influence of specular reflected light (bright glare as a result of reflections from vehicles, parking areas, or snow).

As a general rule, when window shades are used in a side lighted room, the sensor should be mounted on the ceiling as illustrated in *Figure 1*.

When window shades are not used, it is preferable to locate the sensor on the ceiling as shown in *Figure 2*.

## Controlling the Light

The choice of the electric light control method plays a significant role as far as overall success is concerned. A *set point* control method (also called *integral reset*) aims to keep the photo sensor signal constant during the operation of the system—somewhat like a thermostat. On the other hand, a *proportional* control method allows the signal to vary during the operation. The former is suitable for non-critical applications, such as exterior lighting, lobbies and atria. The latter is used in critical applications where maintaining light level to within a predetermined range is important.

It was discovered early on that the set point control method does not work well for critical lighting control applications. The

location of the sensor requires light from the light fixtures to reflect from a low reflectance surface before reaching the sensor—which means that the sensor's ability to measure changes in the electric light output is diminished relative to changes in daylight and, therefore, the system tends to overcompensate by keeping the electric lights fully on or fully dimmed most of the time.

It is much better to use a proportional control method because the sensor measures only, or predominantly, the daylight contribution in the space and electric light output is determined in proportion to this measurement: the higher the daylight level, the lower the electric light output. Practice has shown this method to work very well in a variety of applications.

Finally, when the control system incorporates both window shades and electric lights, the illumination is allowed to vary within a preset band without moving the shades. When the illumination moves outside this band, the shades are moved to bring it back in the center of the band. This operation ensures that the shades do not move continuously or too frequently, which would be distracting and bothersome to the occupants.

## Delivering a Functioning System

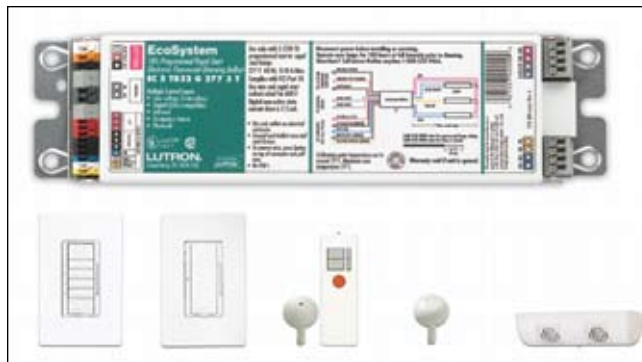
While daylighting systems require commissioning after installation, the commissioning process has been simplified in the last several years, and manufacturers have trained technicians to perform this job in a high-quality fashion.

The initial installation of a daylighting control system involves a calibration procedure. It is important to 'tell' the system when the target illumination level meets its goal, and this defines the contribution of electric light required at a particular daylight level, as measured by the photo sensor. In addition, a night time set point is needed, which defines the electric light contribution when no daylight is present.

In addition to calibrating the electric light output, when window shades are used, the commissioning agent needs to define the upper bounds for acceptable window luminance. This will determine how often the shades move as well as how bright the window will appear.

Many commercial building and education facility projects now are using fluorescent lighting control systems with dimmable digital ballasts that incorporate daylighting. The recently introduced digital ballast technology offers unique benefits for a daylighting control system. Daylighting control zones may be different from occupant control zones, and several zones with different light output requirements may be controlled using the signal from a single sensor. The result is superior performance and a high level of flexibility.

Automatic systems that switch off or dim the lights in response to daylight are highly effective in office environ-



Multiple input digital addressable dimming ballasts (top) facilitate any combination of sensors and wallstations to provide daylighting, automated energy management and manual control of light levels. Bottom Row (left to right): scene control wall station, one-button wall station, infrared receiver and remote, photocell sensor and occupant sensor.

ments. And with the addition of window coverings that are controlled by occupants or an automatic system, energy savings could reach an astonishing 70 percent.<sup>1</sup>

## Manual Override Control

As with any control system, it is very important to give occupants some level of user control. This can range from individual controls for every occupant to a centrally located manual control that operates the shades and lights independently. In any case, the addition of individual controls has been shown in many studies to have a positive effect on satisfaction and motivation, and thereby on performance.

There are a number of factors that impact the success of a daylighting system, which need to be considered early on in the project. But integrated systems are a technological and economic reality because of the tremendous environmental, cost and productivity benefits they provide. With less complicated installation and commissioning of daylighting systems and more advanced lighting controls and building management systems available, commercial building designs continue to embrace the natural daylight that is all around us. ▀

<sup>1</sup>Reinhart, C.F. (2002) Effect of interior design on the daylight availability in open plan offices. National Research Council of Canada, Internal Report NRCC-45374, NRC: Ottawa.

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