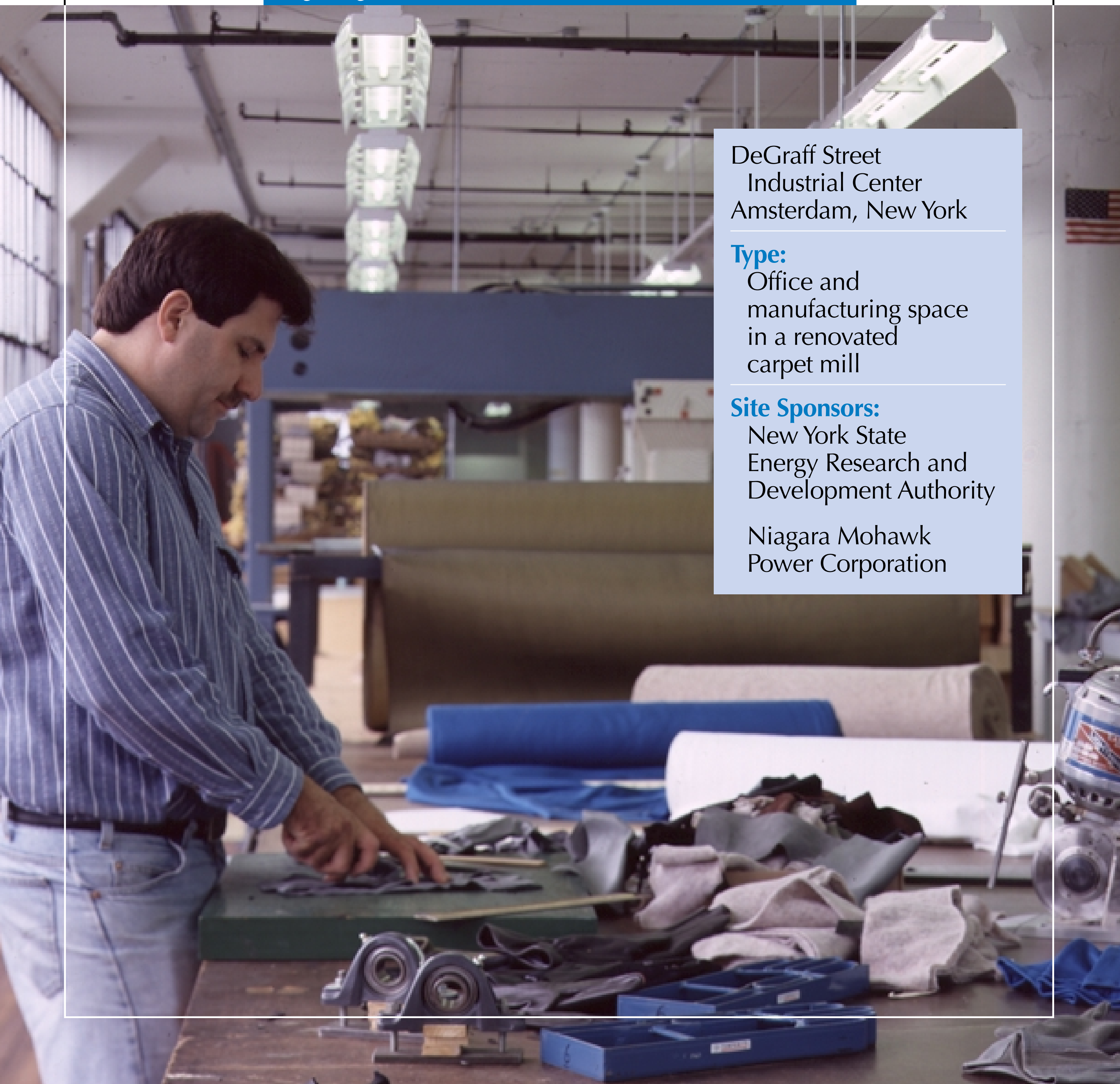
Demonstration and Evaluation of Lighting Technologies and Applications • Lighting Research Center

DELTA Portfolio

Lighting Case Studies ▲ *Volume 1, Issue 4*

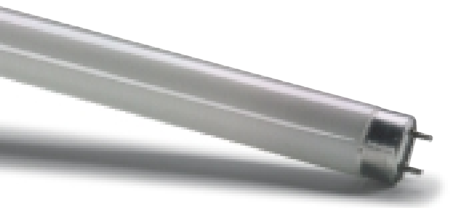


DeGraff Street
Industrial Center
Amsterdam, New York

Type:
Office and manufacturing space in a renovated carpet mill

Site Sponsors:
New York State Energy Research and Development Authority

Niagara Mohawk Power Corporation



Project Profile

Amsterdam, New York, was once the center for carpet manufacturing in the United States. Most of this industry has moved elsewhere, but the carpet mill buildings remain. The city has been challenged to find other uses for these long, narrow buildings with expanses of translucent windows.

The six-story building at 16 DeGraff Street in Amsterdam underwent renovation. The sixth floor has been remodeled into offices for several small companies as well as the Montgomery County Economic Development Corporation (MCEDC). The second floor now houses US Products, a manufacturer of high-quality gloves.

The lighting in these spaces was designed to retain the industrial character of the carpet mills, and to take advantage of the plentiful daylight. Large columns with flared capitals, ducts, and pipes were purposely left exposed, and the original wire-glass translucent windows left intact. Energy-efficient T8 fluorescent lamps and electronic ballasts are used in the principal luminaires on both floors. Galvanized steel stovepipe was incorporated into light valances in the offices as a decorative element. Photosensors and an energy management system (EMS) were installed to reduce energy consumption in the glove factory.

● *Lighting Objectives for the Office Floor*

- Retain the character of the carpet mill by using luminaires with an industrial appearance.
- Use daylight to save energy by providing users two-level manual switching of electric lighting and manually adjustable vertical blinds.
- Reduce lighting energy and qualify for utility-sponsored rebates.
- Create work spaces with good task visibility and visual comfort for employees.
- Minimize initial cost of the lighting installation.

● *Lighting Objectives for the Glove Factory*

- Meet the owner's minimum requirements for 65-75 footcandles (fc) (700-800 lux [lx]) of horizontal workplane illuminance throughout the floor for sewing, cutting, and inspection tasks.
- Optimize daylight energy savings from large existing windows by installing photosensors to switch off half the electric lighting in windowed bays when sufficient daylight is present.
- Use energy-efficient lighting products to reduce connected load and qualify for utility-sponsored rebates.
- Automatically turn lights off after work hours.
- Minimize lamp flicker and avoid casting sharp shadows on work tables. Shadows and stroboscopic effects can be hazardous when working with some industrial machinery.
- Minimize uncomfortable glare from electric lighting for employees.
- Minimize initial cost of the lighting installation.

▲ *Lighting and Control Features*

- ▲ Energy-efficient lamps and ballasts.
- ▲ Vertical blinds in the office space to control window glare.
- ▲ Two-level switching in the office space.
- ▲ EMS with photosensor input in the glove factory to reduce electric lighting near windows when a preset level of daylight is reached. The EMS also sweeps lights off at the end of the work shift.

Techniques

Project Specifications

The principal light sources used in the second-floor glove factory are T8 4′ (1220 mm) rapid-start lamps with a color rendering index (CRI) of 75 and a correlated color temperature (CCT) of 3500 K. In the offices on the sixth floor, 4100 K lamps were installed. Wall sconces use 13-W CFQ lamps, 80 CRI, 2700 K.

Conference room pendants use 50-W PAR30/FL halogen lamps. F32T8 lamps are operated on instant-start, reduced-harmonics electronic ballasts for energy efficiency and reduced flicker. Normal power factor (NPF) magnetic ballasts are used to drive the small compact fluorescent lamps because high power factor (HPF) ballasts are too large to fit in the wall sconces.

The plans below and on the next page show the sixth-floor offices and the second-floor glove factory.

Sixth Floor Offices

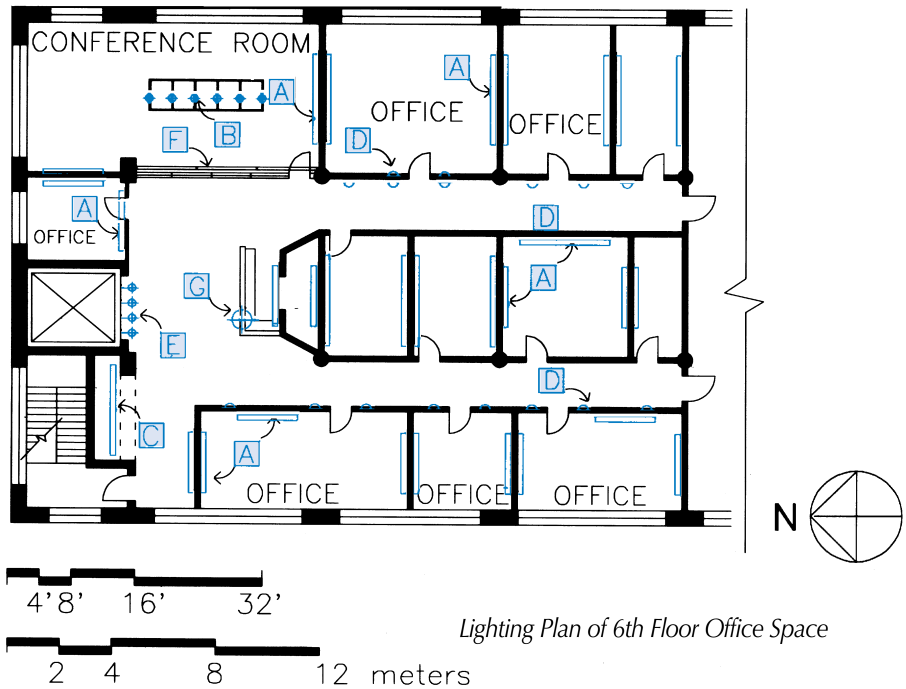
A Striplight with two fluorescent lamps in cross section, 8′ (2440 mm) and 12′ (3660 mm) long, with job-built metal fascia to shield view of lamps. Two-level switching with tandem-wired two-lamp and three-lamp instant-start electronic ballasts.
Lamps: F32T8/RE741 (see note 1).

B Custom configuration of metal brackets supporting seven decorative incandescent pendants with galvanized steel shades. Configuration mounted above conference table.
Lamps: 50PAR30/FL/Halogen, one per pendant.

C Striplight with two fluorescent lamps in cross section, 4′ (3660 mm) long, mounted to the back side of a concrete beam to wash the walls of an artwork alcove. Two-lamp electronic ballasts.
Lamp: F32T8/RE741 (see note 1).

D Wall sconce with two compact fluorescent lamps, 12″ tall (305 mm) x 7″ (180 mm) wide x 4.5″ (115 mm) projection, centered 74″ (1880 mm) above floor so that top of sconce aligns with top of door opening. Sconce has curved galvanized steel fascia with perforations. NPF magnetic ballasts.
Lamps: F13CFQ/RE827 (see note 2).

E Wall-mounted “vaportight” luminaire with screwbase socket, ruby glass globe, wire guard, and one compact fluorescent lamp. Cast aluminum housing and guard construction. Lamp: CFQ20W/GX32d/27 with modular screwbase magnetic ballast (see note 2).



Lighting Plan of 6th Floor Office Space

F Striplight with two fluorescent lamps in cross section, 8′ (2440 mm) long, mounted at base of header above conference room doors with job-built metal fascia to shield view of lamps. Two-level switching with tandem-wired three-lamp instant-start electronic ballasts. Lamps: F32T8/RE741 (see note 3).

G Portable incandescent table lamp with translucent shade located on reception desk for supplemental lighting.
Lamp: 50/200/250 A-21. (Luminaire temporarily supplied by owner. When future budgets permit, table lamp will match appearance of sconces and utilize screwbase compact fluorescent lamps.)

(Note 1: These lamps were specified at 3500 K but installed with 4100 K lamps.)

(Note 2: These lamps were specified at 3500 K but installed with 2700 K lamps.)

(Note 3: These lamps were specified at 3500 K but installed with 4100 K lamps, and metal fascia had not yet been installed.)

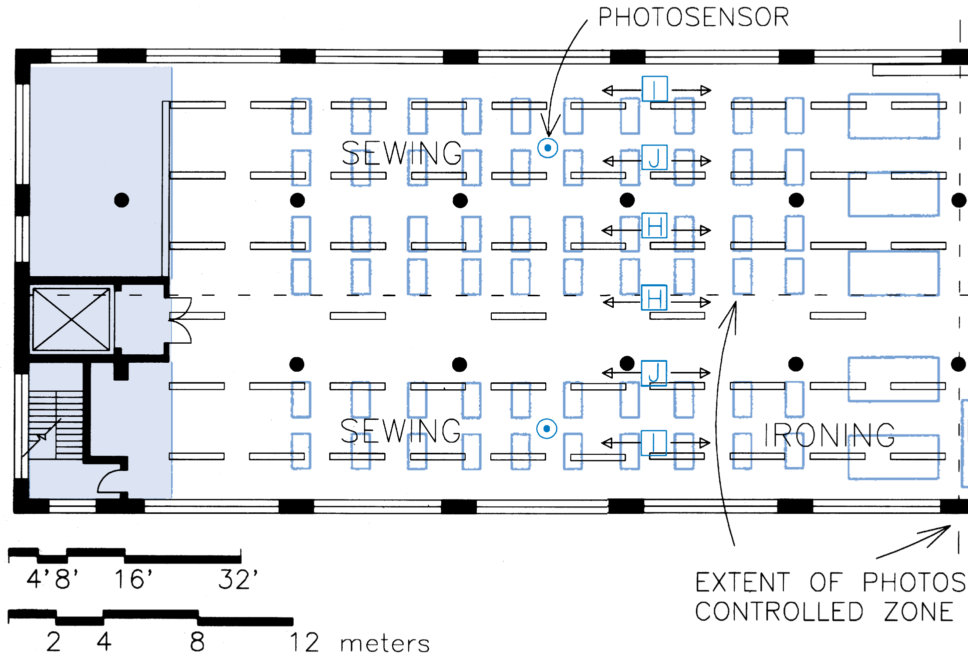
Techniques

Second Floor Glove Factory

H Stem-mounted six-lamp fluorescent industrials, 8′ (2440 mm) long, with white-painted apertured reflectors providing 20% uplight. 3′ (915 mm) overall suspension length. Three 4′ (1220 mm) lamps in cross section. Lamps are tandem-wired with outer lamps driven by one 4-lamp electronic ballast, inner lamps driven by one 2-lamp electronic ballast. Lamps: F32T8/RE735.

I Same as type H except that outer rows of lamps are switched by photosensor.

J Same as type H except that inner row of lamps is switched by photosensor.



Wattage for Lighting in Office and Factory Areas

Input wattages for luminaires include ballast watts and are estimated from manufacturers' published literature. All calculations were based on the following values:

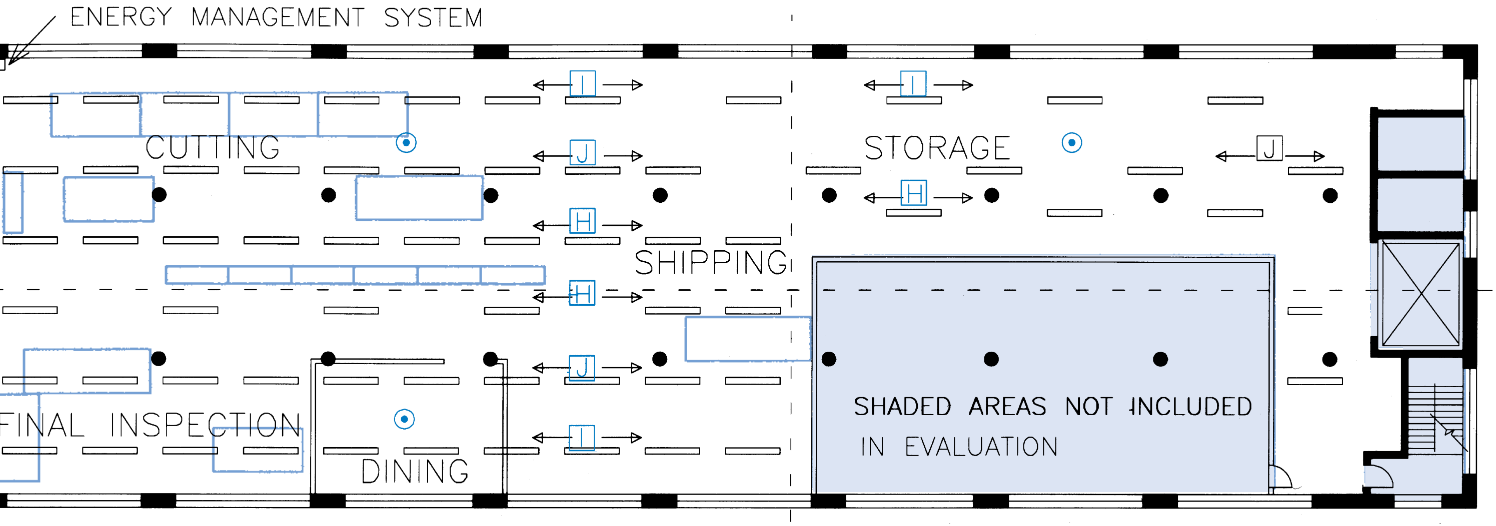
T8 fluorescent lamps (electronic ballast)
F32T8 (4′): 114 W per 4-lamp ballast
F32T8 (4′): 90 W per 3-lamp ballast
F32T8 (4′): 62 W per 2-lamp ballast (Types A, C, F)*
F32T8 (4′): 58 W per 2-lamp ballast (Types H, I, J)*

Compact fluorescent lamps (magnetic ballast)
F13CFQ: 17 W per lamp
CFQ20W/GX32d/27 with modular screw-base magnetic ballast: 22 W per lamp

Incandescent lamps
50PAR30/FL/Halogen: 50 W
50/200/250 A-21: 200 W at most commonly used setting

Wattage differences due to different ballast manufacturers.

DeGraff Street Industrial Center front facade



Lighting Plan of 2nd Floor Glove Factory

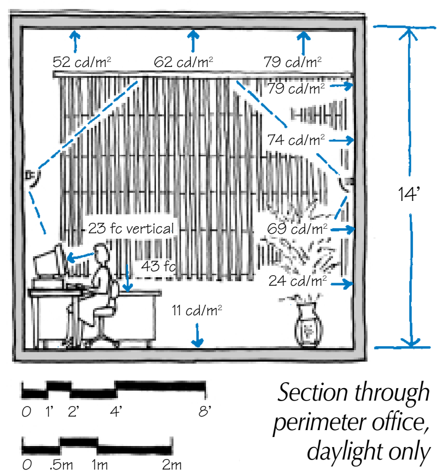
Details

Sixth floor offices

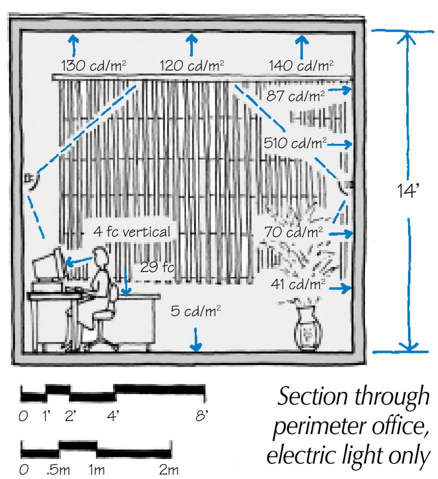
Perimeter Office Each perimeter office has a large window on the outside wall. Fluorescent valance luminaires (type A), either 8′ or 12′ (2.4 m or 3.6 m) long, are wall-mounted at 7′6″ (2.3 m) above the floor and direct the light both upward and downward, relying on the white walls for reflection. The curved metal stovepipe fascia effectively blocks the view of the lamps, but would redirect light more efficiently if the interior of the stovepipe were painted white.

During the day, most of the light in the exterior offices comes from daylight entering through the large windows. In the offices, lamps in the valance luminaires are tandem-wired for two-level switching. This allows occupants to supplement daylight with half of the maximum energy from the lamps. In a typical 14′ x 19′ (4.3 m x 5.8 m) east-facing exterior office, the DELTA team measured 47 fc (510 lx) on the desktop from daylight alone, at 3:30 p.m. on an overcast autumn day. The electric lighting at full level added 29 fc (310 lx) to the desktop,

Perimeter office with window



Section through perimeter office, daylight only



Section through perimeter office, electric light only

Details

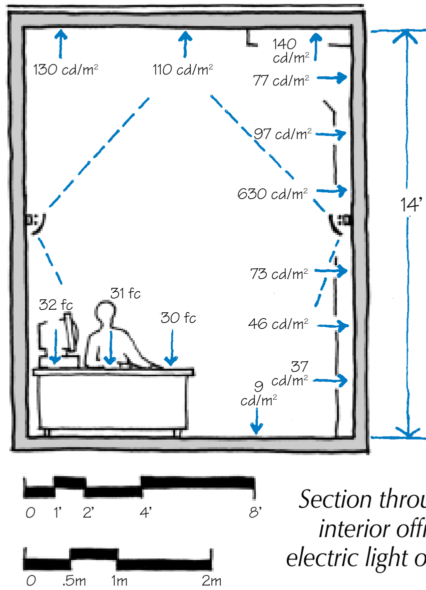
Perimeter Office (continued)

for a total of 76 fc (820 lx). Vertical illuminance on the computer screen surface measured 27 fc (290 lx) with daylight alone and 40 fc (430 lx) with both daylight and electric lighting. Employees reported that the reflections on the computer screen from the electric lighting were not distracting, probably because the brightness from the luminaire was spread over the whole wall and did not create any sharp-edged patch of brightness to be imaged in the screen.

Employees use full-length vertical blinds at the windows to adjust the amount and the angle of the daylight entering their offices and redirect sunlight to avoid distracting reflections on their computer screens. During most of the year, daylight alone is sufficient for their visual tasks. Only during heavy cloud cover or with the darkness of late winter afternoons do employees use electric light.

Interior office DELTA evaluated a medium-size interior office with no windows. It was not occupied continuously during the workday, but the electric lighting remained on until the employee left work. Two 8′ (2.4 m) fluorescent valance luminaires (type A) were mounted on the side walls of the 12′ x 16′ (3.7 m x 4.9 m) office. Illuminances from the electric lighting ranged from 32 to 36 fc (340 to 390 lx) on the desktop. Vertical illuminance on the computer screen measured 22 fc (240 lx). The employee reported no problem with screen reflections from the valances or lighted walls.

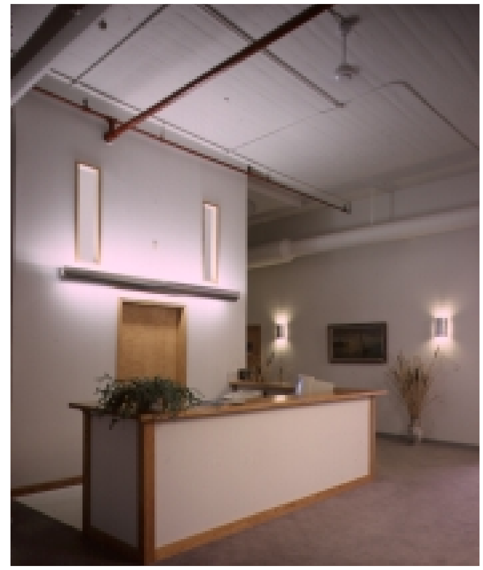
Corridor and reception area A series of curved metal wall sconces (type D) are spaced approximately 8′ (2.4 m) on



Section through interior office, electric light only

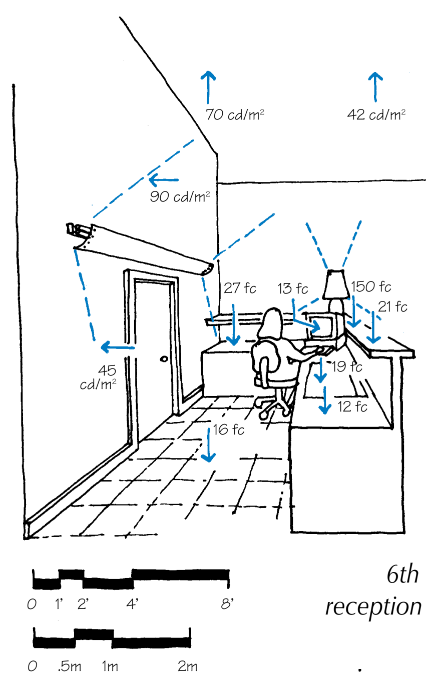
center along one side of the corridors in the sixth-floor offices. Each sconce's galvanized metal fascia shields the 13-W compact fluorescent lamps from view and redirects light onto the wall behind it. Daylight usually pours into the corridors from the open doors of the exterior offices. The combination provides 5 to 16 fc (55 to 173 lx) along the length of the east corridor floor on an overcast autumn afternoon. The sconces contribute 1 to 6 fc (15 to 60 lx) of this illuminance. The sconces put highlights on the corridor walls, provide ambient light in the corridors, and serve as points of visual interest. Even though the floor illuminance from the sconces is low, light reflected from the walls helps to make the corridors appear bright.

The reception area, located across from the elevator, indirectly receives some daylight from windows on both sides of the building. Electric light also spills into this area through the windows and door leading to the copy room behind the reception desk. On an overcast fall day, the reception area received 12 to 27 fc (130 to 295 lx) on the



6th floor reception area

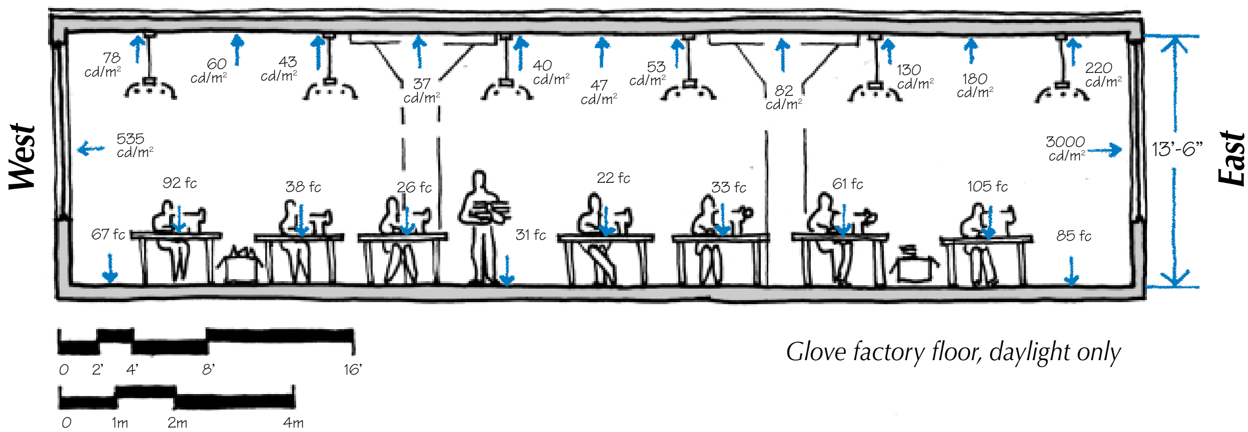
desk surface, with little variation over the course of the day. Computer screen illuminance was 14 fc (150 lx) during the day, and employees reported no perceived glare. A portable incandescent table lamp is used for additional task lighting (not shown in photo).



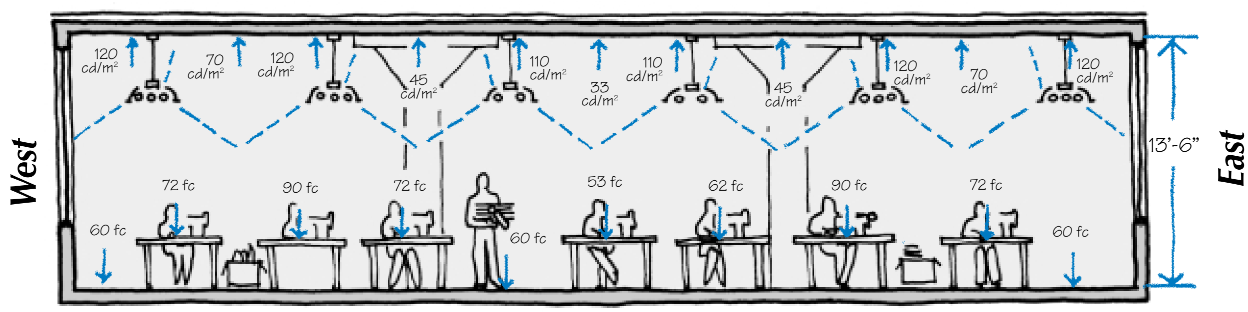
6th floor reception area

Second floor glove factory work areas

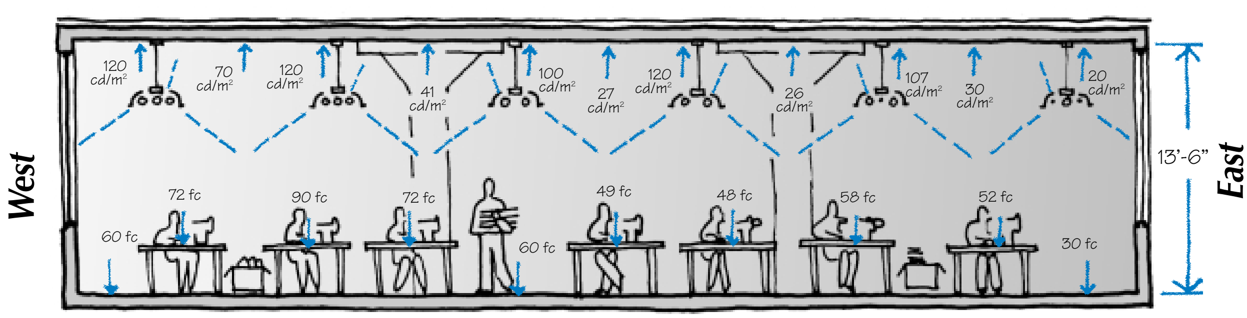
The glove factory extends the length of the building. Employees perform many visually demanding tasks here. Glove-making involves many steps, including cutting, sewing, ironing, and stamping for shipment. In order to keep quality high, the glove is frequently inspected during production and after finishing. Lighting is critical at these inspection points to spot imperfections, particularly when the gloves are made of dark-colored material. These inspections include low-contrast tasks such as counting stitches and matching leather colors and textures.



Glove factory floor, daylight only



Glove factory floor, full-level electric light only



Glove factory floor, with electric light contribution when photosensors have switched off lamps near east windows

Because specific task areas and visual demands were unknown at the time of design, the lighting for the glove factory was laid out in a regular grid over the entire floor. Eight-foot fluorescent industrial luminaires (type H) with apertured reflectors direct most of the light downward. Twenty percent of the light is directed onto the white-painted ceiling, contributing ambient light that helps wash out shadows on tasks, reduces the contrast of the luminaires against the ceiling, and makes the space look brighter and more pleasant. Luminaires are mounted at 10′ (3.1 m) above the floor, high enough to be out of the way of moving equipment.

Abundant daylight is available from windows at almost all times of the year, especially in the outer bays of the building. The fluorescent luminaires (types H, I, J) have three lamps in cross section. They are designed so that the outboard lamps in the row of luminaires nearest the windows (type I) and the inboard lamps of the second row of luminaires from the window (type J) are powered by a single circuit and can be switched off when daylight is available. Photosensors are mounted to the ceiling in these outer bays to switch off half of the lamps automatically when daylight reaches a preset

Details

2nd floor glove factory

Glove Factory *(continued)*

level. The photosensors provide input to the EMS, which does the switching through low-voltage relays.

With all overhead luminaires on, measured illuminances on the work surfaces near the east windows at 10 a.m. ranged from 150 to 190 fc (1600 to 2000 lx). When the photosensors have switched one circuit of lamps off, these levels are reduced to 120 to 160 fc (1300 to 1700 lx).

Sewing station

At nearly every workstation, workers have inexpensive 60-W incandescent task lights to increase illuminances on small sewing or inspection tasks. DELTA observed that most employees (more than 80%) use the task lights for the entire day; a smaller number use them part of the day. Depending on the position of the task light, it contributed 90 to 460 fc (970 to 4950 lx) to the needle of the sewing machine.

An EMS automatically shuts off lights after work hours, on weekends, and on holidays. See "Controls" on p. 9.

Large translucent windows, approximately 10′ high x 23′ long (3.0 x 7.0 m), run the length of the factory floor. The tall windows allow light to penetrate deeply into the space. Their close spacing results in a very uniform daylight contribution along the length of the building. The translucent glass (54% transmission) diffuses the light, reducing the extreme glare of direct sun. It also helps distribute light onto the ceiling. However, these windows are still annoying sources of glare when the sun angle is low. Employees have installed make-shift black plastic shades on some windows to block this extreme brightness in the winter.

Ironing station

Project Evaluation

Energy Impact

The lighting power densities (LPDs) in the offices and in the glove factory include task lights. They easily comply with applicable energy conservation standards. In the offices, efficient lighting equipment, such as electronic ballasts and T8 lamps, keeps the total connected load low. The large industrial windows provide so much daylight that few electric lights in exterior offices are ever switched on. These features reduce the LPD during business hours to only 0.31 W/ft^2.

Building Areas and Lighting Power Densities

Space	Total area (ft^2)	Total connected LPD	ASHRAE Allowed LPD (system performance method)	NY State Conservation Construction Code	In-use LPD during business hours
Offices	5,100	1.17	2.3	2.4	0.31
Glove Factory	18,600	1.09	2.5	2.7	0.80

For watts per square meter, multiply LPD by 10.76.

"The dual switching works great. I very seldom have to use both circuits because of all the daylight."
–Wayne Hazard, MCEDC Director

"I've experienced glare on computer screens before, but not in this installation."
–Rob Sitterley, MCEDC employee

The original lighting plan in the glove factory space was a regular grid of luminaires designed to provide a consistent illuminance throughout the space. This layout would have produced an LPD of 1.4 W/ ft^2. Once the machinery was installed, the factory owners saw that they could reduce or eliminate lighting in areas where visual tasks are less demanding. They removed 22 of the luminaires originally installed in storage areas and the center circulation aisle. In the remaining aisle, luminaires were delamped by one-third. The LPD for the total connected load was therefore lowered to 1.09 W/ft^2. Because daylight alone is sufficient for the storage area operations, the owners have switched off all storage area lights in the lighting breaker panel. Based on a sampling of actual conditions, DELTA calculated that the savings due to these changes and the photosensor switching of lights bring the actual LPD during the workday down to 0.80 W/ft^2.

Controls

Energy Management System

An EMS on the glove factory floor controls all lighting circuits. It integrates the lighting panel and uses low-voltage control and up to 48 switched inputs to control circuit breakers. It acts as a programmable time clock and switches lights off at preset hours, blinking the lights as a warning five minutes before the lights are swept off. Manual override switches located at entries enable workers to switch lights on as they enter in the morning (6:30 to 7:00 a.m.). Lights are automatically switched off for the half-hour lunch break, then switched back on at the end of the break. Lights are swept off 15 minutes after the end of the shift, then again every two hours until midnight. This ensures that no lights will be left on throughout the night.

The EMS also receives input from one photosensor in each of five control zones. When the ceiling-mounted photosensor detects a preset level of daylight that corresponds to approximately 80 fc (860 lx) on a table 10′ (3.0 m) from the window, it signals the EMS to shut off half the lamps in the two rows of luminaires closest to the windows. When the photosensor senses diminishing daylight plus half the electric light, which was intended to correspond to 65 fc (700 lx) on the work table, it signals the EMS to re-energize those lamps. The photosensors are designed with a 10-minute time delay and a "dead band zone" to ensure that fluctuating daylight conditions do not produce a distracting switching of lights.

This EMS is a low-cost and extremely flexible control system. Unfortunately, the system does not save significant amounts of lighting energy in this specific application for three reasons. First, it is effective at sweeping off lights after employees go home, but the staff is already conscientious about switching off lights, so the sweeps are seldom necessary. Second, the photosensors were difficult to calibrate and did not work as intended. Once set, they did not switch at the preset levels. (See "Maintenance and Product Performance" on p. 11 for more details.) Third, employees perceive the daylighting control system as an impediment to sewing, cutting, and inspecting tasks because it reduces the overhead light. Employees prefer the highest possible glare-free illuminances on their tasks, even when ambient illuminances exceed 100 fc (1100 lx). As a result, the employees have learned to override the daylighting controls using an elaborate procedure of resetting circuit breakers and pushing override switches.

Project Evaluation

Control of Daylight

On the sixth floor, bright windows cause glare. The DELTA team logged several complaints from occupants of exterior offices. A fabric vertical blind system with 3″ (76 mm) slats and manual controls has been installed in most of the windowed rooms, and occupants in these offices reported that they avoid the window glare by adjusting the blind angle several times during the day. All offices are equipped with two-level manual switching that allows all, half, or none of the lamps in the valance luminaires to be switched on. Office occupants can set the electric light level according to their task needs and the level of available daylight.

Environmental and Economic Analyses

The lighting and controls design features provide energy savings at the DeGraff Street Industrial Center. DELTA compared the annual lighting energy cost to a hypothetical model. The comparison was based on a one-day observation of lighting used on the two floors. The "conventional" model is based on an allowed LPD calculated with ASHRAE/IES 90.1 1989 System Performance (Room-by-Room) Method. The allowed LPD is 2.3 W/ft^2 on the office floor, and 2.5 W/ft^2 on the glove manufacturing floor. The model uses the following assumptions:

- Standard construction with typical-sized windows
- 100% of lights on in the offices during the 9-hour workday
- 25% of lights on in the office area for an additional 3 hours/day for fewer staff working early or late
- 100% of lights on in the glove factory during the 9-hour workday, 5 days/week; and during a 4-hour workday, 50 Saturdays/year.

Based on the total connected load, the annual energy savings for the glove factory is 64,163 kWh ($5,390 at 8.4 cents per kWh) less than the energy cost for the conventional design. In the offices, the annual savings is 14,450 kWh ($1,214 at 8.4 cents per kWh). Switching off lights in the storage area and photosensors on the glove factory floor saves 13,407 kWh ($1,126 at 8.4 cents per kWh). Abundant daylight on the office floor saves an additional 10,590 kWh per year ($889 at 8.4 cents per kWh). Because neither floor is air-conditioned, no cooling load savings were considered.

The initial cost of the lighting on the glove factory floor was $46,000, or $2.48/$ft^2$. This included $5,000 for the EMS as well as wiring, the lighting panel, and installation. Lighting equipment and installation on the sixth-floor offices initially cost about $19,000, or $3.73/$ft^2$. Using conventional lamps and magnetic ballasts, an installed conventional office lighting system would cost $3.30 to 3.50/$ft^2$ (6 to 11% less) for similarly sized office spaces. The building developer received electric utility rebates from Niagara Mohawk Power Corporation for using energy-efficient lighting products amounting to $3,000 for the glove factory floor and $1,800 for the office floor. This helped to offset some of the higher costs. Even without the rebates, and assuming the cost of a conventional system at the low end of the estimated range, the simple payback on the sixth-floor offices is less than two years.

According to estimates of the United States Environmental Protection Agency (EPA), reduced energy from the two floors of this building (when compared to a building at the ASHRAE LPD of 2.3 and 2.5 W/ft) will result in lower power plant emissions of 77.1 fewer tons (70 metric tons) of CO_2, 1315 fewer pounds (596 kg) of SO_2, and 567 fewer pounds (257 kg) of NO_x compounds. By reducing these emissions into the atmosphere, there is a smaller contribution to problems such as global warming, acid rain, and smog.

Employee Response

The DELTA team surveyed employees working in both the sixth-floor offices and in the second-floor glove factory for their opinions on the electric lighting, daylighting, and effectiveness of the lighting controls. The survey enabled DELTA to find out which lighting features were successful in terms of task visibility, visual comfort, appearance, and ease of use.

On the sixth floor, five of the seven employee work areas are offices with large translucent exterior windows (10′ x 23′ [3.1 m x 7.1 m]). Occupants reported to DELTA that they seldom switch on the electric lighting except when there is very heavy cloud cover or on late winter afternoons. Even in these darker conditions, they frequently switch on only half of the lamps in the luminaires.

> ***"We make gloves for the government, and there are no mistakes allowed in government work. They come to check on our work once a week and we haven't had a rejection. Together with the task lighting, we have enough lighting to see the little seams you need to see."***
>
> ***–Carmen Gatta***
> ***Floor supervisor, US Products***

The office workers were very satisfied with the lighting; all seven rated the lighting as comfortable. All rated the lighting better in this installation than in similar workplaces in other buildings. All expressed sensitivity to the problem of reflected glare on their VDT screens, but did not find the electric lighting disturbing. The employee in the interior office without a window reported that he is sensitive to lamp color and was pleased with the color of fluorescent light installed on the office floor. Some employees worked for several months without the valance fascias installed over the wall-mounted striplights,

LIGHTING SURVEY—Glove Factory Floor—Percentage of People Who Agree:	
1. Glaring sunlight makes it difficult to see their work.	30%
2. Sunlight is sometimes uncomfortable because of glare.	33%
3. It is noticeable when lights go on and off during the day.	67%
4. It is bothersome when lights go on and off during the day.	13%
5. It is preferable to work under daylight alone.	11%
6. It is preferable to work under daylight and electric light.	67%
7. It makes no difference working under daylight alone or daylight and electric light.	22%
8. The lighting is comfortable.	89%
9. The lighting makes it easier to see their work.	86%

and complained about their difficulty with screen reflections during that time. The few office workers who had windowed offices without vertical blinds complained about screen glare from the windows, but all those with vertical blinds were able to control the daylight to their satisfaction.

On the second floor, the 27 glove factory workers surveyed were also very satisfied with the electric lighting in the factory. Eighty-nine percent of the factory employees responded that the electric lighting was comfortable. All but one respondent said the lighting made it easy to see the work. Two-thirds of the workers reported that they prefer to work under a combination of daylight and electric light, while 11% claimed to prefer daylight alone. Nearly all explained that they needed both to provide sufficient light to see the glove stitches, especially when both thread and material are dark in color.

However, 30% of those who responded to the DELTA survey reported that the sunlight often caused uncomfortable glare. Thirty percent reported that the glare made it difficult to see their work. DELTA found no relationship between the location of the workstations and complaints about window glare, in spite of the fact that other buildings in the factory complex blocked the afternoon sunlight on the west side of the building.

Of those who reported discomfort or difficulty in working due to glare, more than half reported that the morning was the worst time, probably because the east side windows capture the low-angle sun during typical work hours. Fifty percent of the people surveyed who reported difficulty in working due to glare also reported that summer was the worst season.

Maintenance and Product Performance

Lamps, ballasts, and luminaires perform reliably in this project. Automatic photosensor control of lighting is an important design feature of the controls system in the glove factory, but its performance was disappointing. It is intended to switch lights on and off when certain preset light levels are detected by the ceiling-mounted sensor. The sensor is pointed straight down and has a 45-degree cone of view. To set a desired illuminance level on the work surface with this type of sensor, the designer must know the relationship between the work surface illuminance and sensed ceiling illuminance, but this relationship may vary according to the angle of daylight and the materials covering the desk and floor areas below the sensor. The programming instructions for the sensor suggest waiting until the daylight conditions and the work plane illuminance reach the desired minimum or maximum level, then turning a set-point screw on the photosensor controller to "capture" that value. This procedure had to be performed for both the high and low setpoints on the device for five different zones of the floor. In practice, the procedure was clumsy, imprecise, and time-consuming. In addition, the designer had no way to test the setpoints without returning on another day and waiting for daylight conditions to trigger lights to trip on or off.

Although the designer and manufacturer's representative made two trips to adjust the setpoints of the photosensors, the DELTA team found that lamps were tripping on and off at much higher illuminances than intended. The "dead band" was 112 to 177 fc (1,200 to 1,900 lx) on the workplane, rather than the intended 65 to 80 fc (700 to 860 lx) range.

Lessons Learned

- **Tall windows can be an energy asset.** They bring light deep into perimeter spaces, making the workplace look bright and spacious. In private office spaces, plentiful daylight means lights are seldom switched on, saving lighting energy.
- **Direct and reflected glare problems from windows are inevitable.** Window glare will occur at some time of day, at some time during the year. Designers must plan for glare control through overhangs, blinds, shades, awnings, or other devices.
- **For optimal energy savings and visual task performance, the lighting plan should be coordinated with the equipment layout.** Knowing where equipment is located and tasks are performed allows the lighting to be "tuned" to provide high light levels where needed and lower levels for circulation and storage areas. This tuning may involve eliminating or delamping luminaires, and saves energy.

Lessons Learned *(continued)*

- **Two-level switching under individual control allows comfortable VDT-viewing light levels and energy savings.**
- **An EMS may not always be cost-effective.** The glove factory is a small facility with tightly scheduled work hours. Because of the large open space, it is easy to see which lights are on. The employees take responsibility for switching lights off at the end of the day. The timed functions of the EMS are saving little compared to the savings due to careful employees.
- **The settings of photosensors and control devices should be quick and easy to adjust.** The photosensors in the glove factory required a cumbersome setpoint adjustment procedure, and necessitated waiting for appropriate daylight conditions. A better photosensor would have numerical calibration for high- and low-end settings rather than an uncalibrated set screw, as well as a more reliable procedure for relating photosensor readings to work plane illuminance. In this application, photosensors would operate more consistently with a sensor having a narrow viewing range, aimed at a solid-color wall or ceiling surface. Angle of daylight and work station layout would then be less likely to affect light readings in the zone.
- **An EMS is only useful if management is trained in its programming and use. Employees may override its function if they don't understand and like the way it is programmed.** Solutions include hands-on training in the EMS for owners or managers so that they do not feel intimidated about programming changes; better communication between management and employees so that they feel they are participating in the effort to save energy; and agreement between management and staff about appropriate light levels. Another option is using a daylight dimming system that reduces light output without switching lamps off. Dimming would call less attention to the energy-saving effort of the EMS, making it more acceptable psychologically.

This publication is dedicated to James Barron of NYSERDA, a personal friend and colleague, whose commitment to energy efficiency and to the Lighting Research Center were driving factors behind the DELTA program.

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