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

DELTA Portfolio

Lighting Case Studies ▲ *Volume 2, Issue 5, Revised*

Staples Distribution Center
Killingly, CT

Type:
Warehouse / Distribution Center

Site Sponsors:
The Connecticut Light and Power Company, an operating company of Northeast Utilities

Project Profile

The Staples Distribution Center in Killingly, Connecticut, is a 312,000 square foot (28,650 square meter) storage and shipping facility that supplies over 200 office product retail stores throughout the northeastern United States. Merchandise arrives from manufacturers in bulk quantities in Receiving, then is moved by forklift either to Bulk Storage, to be shipped directly to stores, or to storage aisles. When required, the pallets of merchandise are moved from the storage aisles into the peripheral stacks of two different multilevel sorting towers, where more than 100 employees separate the material into smaller quantities. An elevated conveyor belt system then moves the merchandise to Shipping, where it is bundled into pallets again and shipped to the individual stores. The facility operates 20 hours a day Monday through Friday, and 12 hours on Saturday (closed Sunday). There are approximately 270 employees working the day shift and 80 working the evening shift.

During the planning stages for this facility, both conventional metal halide and fluorescent lighting systems were designed. Staples had previously used metal halide luminaires in tall-ceiling warehouse applications, but opted to test luminaires using T8 fluorescent lamps as an energy-effective alternative. T8 fluorescent lamps were selected for their energy efficiency, long lamp life, easy switching, high lumen maintenance, and even light distribution characteristics. Staples' facility design team calculated that the higher initial cost of this unorthodox solution would be offset by substantial energy savings. In addition, the electric utility provided a rebate as part of its new-construction energy-incentive program.

Occupancy sensors are used in the narrow storage aisles to switch off 80% of the lighting when the aisle is not in use. The maximum lighting power density for the facility is 0.66 W/ft^2 (7.1 W/m^2) including some localized task lighting, but the occupancy sensors reduce the effective lighting power density for the whole facility to 0.62 W/ft^2(6.7 W/m^2). Overall, the fluorescent lighting system results in significant lighting energy savings compared to Staples' conventional metal halide system designed to the same illuminance criteria. Employee response to the lighting has been positive, with most responding that the lighting is more even and more comfortable than in other warehouses in which they had worked.

It should be noted, however, that a metal halide lighting system is still a viable solution for lighting a warehouse when improved lamps and ballasts are used (see the blue-screened sidebar on page 3).

Lighting Objectives

All spaces

- Reduce life-cycle cost. Use products that reduce the maintained cost of lighting compared to Staples' conventional lighting systems.
- Meet average illuminance criteria using energy-efficient products. Reduce lighting power density below that used in Staples' other distribution centers.
- Minimize flicker. Use high-frequency electronic ballasts.
- Keep light levels high over time. Use lamps with high lumen maintenance.
- Create pleasant work environment. Design spaces that appear bright and inviting for employees.
- Reduce glare. Use lower-brightness luminaires than are used in Staples' conventional metal halide design.
- Minimize shadows. Use luminaires which produce soft shadows from racks, stacks of boxes, and equipment.
- Qualify for utility-sponsored incentives for energy efficiency.

Warehouse aisles

- Reduce energy use in unoccupied aisles. Use occupancy sensors to switch lighting according to use.
- Reduce restrike time. Use fluorescent lamps so that lighting can be switched off and back on without a restrike time delay.
- Provide effective light distribution. Provide uniform vertical illuminances on shelving to help forklift operators read location labels.
- Provide uniformity. Provide lighting overlap from multiple lamps on the shelving, so that even when a lamp burns out, work can continue until relamping is performed.

▲ *Lighting and Control Features*

- ▲ Energy efficiency. Primary light sources are T8 fluorescent lamps powered by instant-start electronic ballasts used in high-efficiency luminaires.
- ▲ Enhanced lamps. Compared to standard T8 lamps, the enhanced T8 lamps used on the project have a 20% longer lamp life (24,000 hours) and higher color rendering capabilities. An alumina coating inside the glass tube improves lumen maintenance from 0.90 (at 40% lamp life) to 0.95.
- ▲ Luminaires with uplight. Uplight brightens the light-finished ceiling, reducing the contrast of the luminaire compared to the surrounding ceiling.
- ▲ Uniform lighting. The linear fluorescent systems provide excellent vertical and horizontal illuminance uniformity in long, narrow storage aisles.
- ▲ Occupancy sensors. In narrow storage aisles, occupancy sensors switch off 80% of lighting when the aisle is not in use.

Fluorescent lighting, as demonstrated in this case study, is one alternative to the conventional metal halide lighting system that had originally been intended for use in this warehouse.

Staples' conventional lighting system used magnetically ballasted, 400-W clear, universal-burn metal halide lamps in luminaires that were all switched on at the start of the workday and off at the end of the day. In narrow warehouse aisles, luminaires were mounted at the bottom of the ceiling trusses, centered in the aisle, 32' (9.6 m) on center. Glass refractors produced a long, narrow aisle-lighter distribution. More open areas employed high-bay industrial luminaires.

The energy efficiency of this metal halide system could be improved by using pulse-start metal halide lamps with linear reactor ballasts, controlled with a bilevel dimming system triggered by occupancy sensors. In addition, using lower wattage lamps in luminaires spaced closer together would improve illuminance uniformity and reduce glare. Such changes would increase the cost of this metal halide system, so the energy savings would have to be evaluated with respect to the increased life-cycle cost.

Techniques

Project Specifications

The principal light sources used in the Staples facility are F32T8 4' (1200 mm) extra-long-life, rapid-start lamps with a color rendering index (CRI) of 84 and a correlated color temperature (CCT) of 3500 K. Lamps are operated with instant-start, reduced harmonics, high power factor electronic ballasts. The adjustable loading dock lights use 120-W BR40/FL lamps.

A Industrial luminaire, 8' long (2440 mm) with apertured reflector producing 20% uplight. White-painted linear parabolic reflector. Two fluorescent lamps in cross section. Mounted on structural trusses at ceiling plane above aisles. Four-lamp ballast.
Lamps: (4) F32T8XL/835

B Industrial luminaire, 12' (3660 mm) long, with white-painted apertured reflector producing 16% uplight. Three fluorescent lamps in cross section, mounted on structural trusses at ceiling plane above Bulk Storage, Shipping, and Receiving areas. Three-lamp ballasts.
Lamps: (9) F32T8XL/835

C Striplight, 8' (2440 mm) long, with one fluorescent lamp in cross section. Surface mounted below elevated conveyor belt in Shipping and at each of the lower levels of the Break Pack and Full Case Towers. Two-lamp ballast.
Lamps: (2) F32T8XL/835

D Striplight with one fluorescent lamp in cross section, 4' (1220 mm) long. Surface-mounted in center archways between narrow storage aisles. One-lamp ballast. Lamp: F32T8XL/835

E Industrial luminaire similar to type A with two fluorescent lamps in cross section, 8' (2440 mm) long, with white reflector and 8% uplight. Suspended above Maintenance and Battery Recharging area. Four-lamp ballast.
Lamps: (4) F32T8XL/835

F Industrial luminaire, 8' (2440 mm) long, with one fluorescent lamp in cross section. Apertured reflector and 8% uplight. Suspended above top floors of Break Pack and Full Case Towers. Two-lamp ballast.
Lamps: (2) F32T8XL/835

G Industrial luminaire, 8' (2440 mm) long, with three fluorescent lamps in cross section, similar to type B. Surface-mounted in administrative areas of Break Pack Tower. Three-lamp ballasts.
Lamps: (6) F32T8XL/835

H Extendible-arm dock light with swivel-adjustable head for directing light into trucks. Mounted to wall adjacent to loading bays, 6' (1830 mm) above the floor.
Lamp: (1) 120-W BR40/FL

Wattage

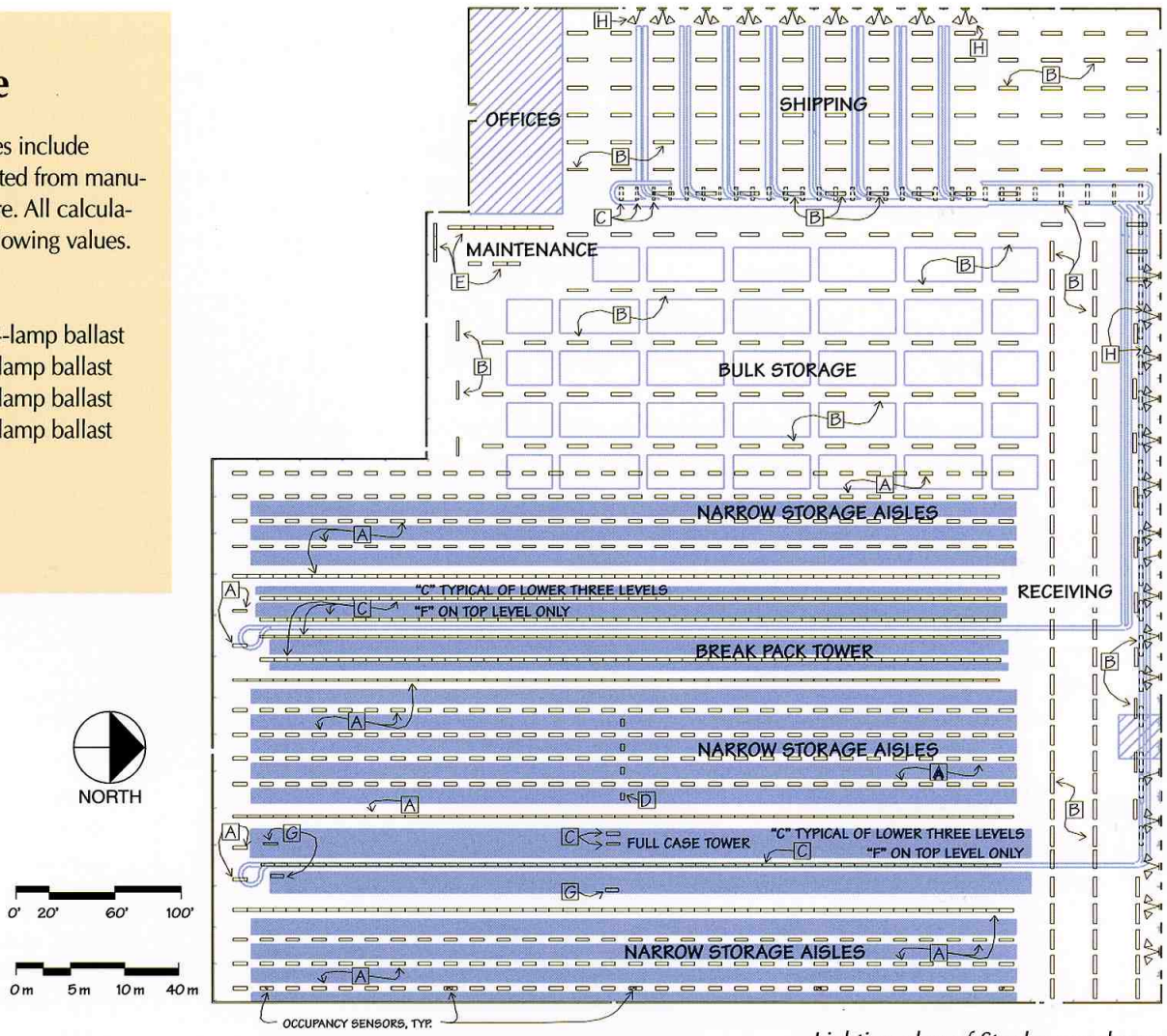
Input wattages for luminaires include ballast watts and are estimated from manufacturers' published literature. All calculations were based on the following values.

T8 fluorescent lamps

F32T8 (4'): 113 W per 4-lamp ballast
F32T8 (4'): 87 W per 3-lamp ballast
F32T8 (4'): 58 W per 2-lamp ballast
F32T8 (4'): 35 W per 1-lamp ballast

Incandescent lamps

120BR40 / FL: 120 W



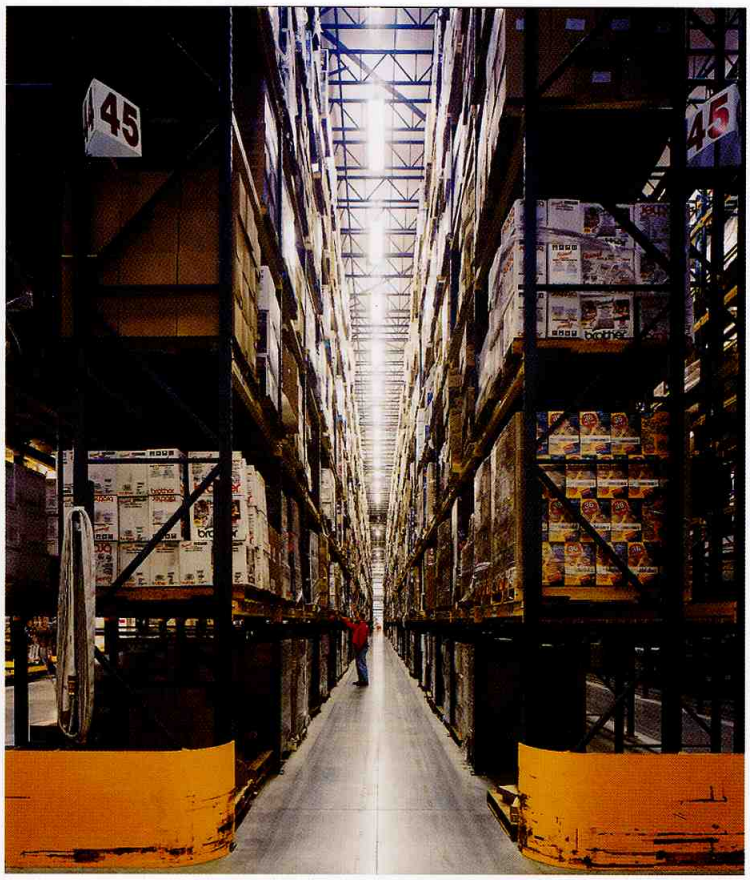
Lighting plan of Staples warehouse

Details

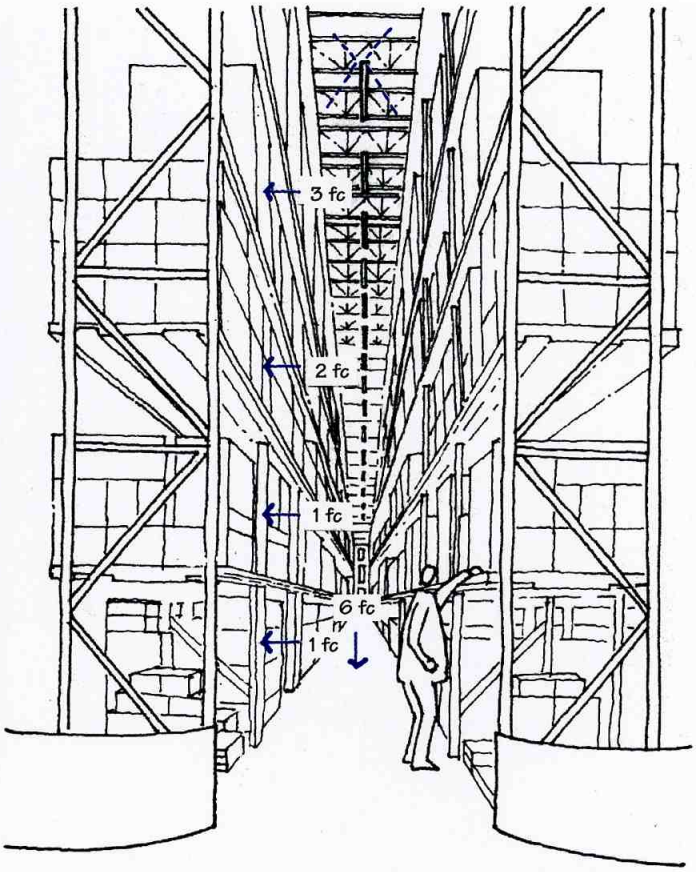
Warehouse spaces are most often lighted with metal halide or other types of high-intensity discharge (HID) luminaires because it is believed that an HID point-source lamp can provide better optical control and higher light output to compensate for high mounting locations. Although this is true, there are also disadvantages to HID lighting: high-brightness luminaires, flicker, sharp shadows cast by obstructions and the worker's own body, and a long restrike time (except for pulse-start metal halide lamps). When a lamp burns out, a large area is darkened, making prompt relamping imperative. The use of fluorescent lighting in this Staples facility was an experiment to test whether linear fluorescent lighting could eliminate these problems and provide the necessary illumination for task performance at lower energy use and lower life-cycle costs.

Narrow Storage Aisles

The rack warehouse space has a sloped roof, and the ceiling height varies from 44' to 52' (13 m to 16 m). Bulk merchandise is received on pallets and is stored in 35' (11 m) tall racks. The aisles between these racks are 6.5' (2 m) wide and 460' (140 m) long. An automatic guidance system helps forklift operators move their machines to the correct floor location so that driving is not a



Narrow storage aisle



Perspective of the narrow storage aisle

critical visual task within the narrow aisle itself. Operators visually spot the rack location labels when storing or retrieving pallets and read packaging to verify the products.

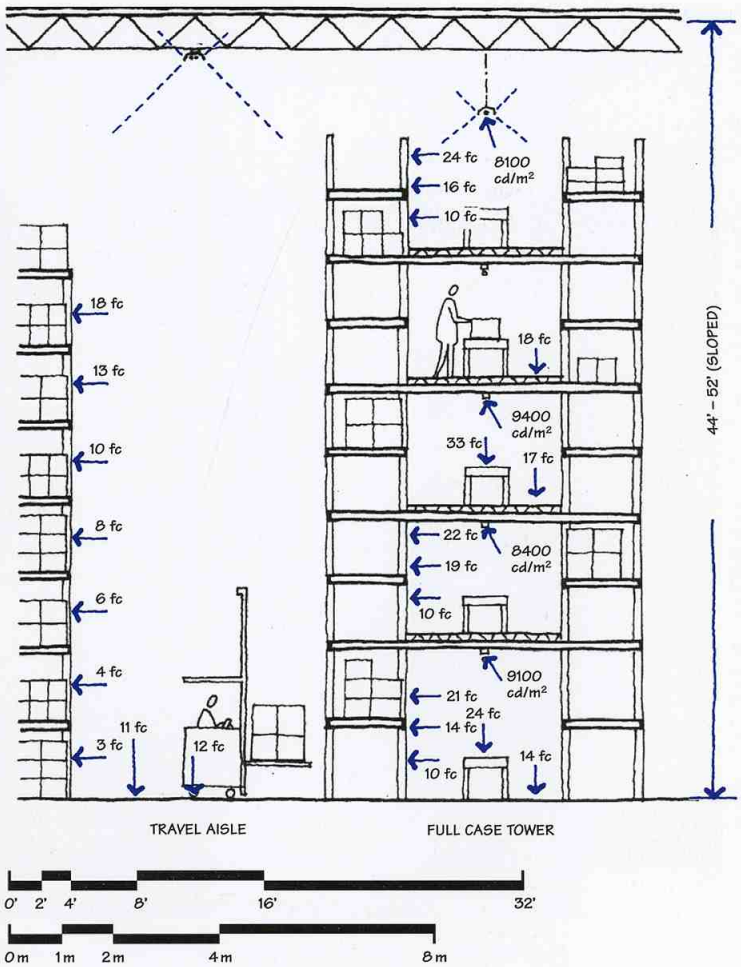
The 8' (2440 mm) long fluorescent luminaires (type A) are mounted on the bottom of the ceiling trusses, an average of 46' (14 m) above the floor. They are centered above the aisle, spaced 16' (4.8 m) on center. The luminaires are designed to produce a narrow downlight distribution (perpendicular to the length of the lamps), with 20% of the light going upward to light the ceiling. The narrow downward light provides a uniform distribution of light on the vertical face of the racks. Vertical illuminances on the racks are within an 11-to-1 maximum-to-minimum ratio, ranging from 12 footcandles (fc) [130 lux (lx)] at the top rack to 1.1 fc (12 lx) on the lowest rack. (This is very uniform compared to the 50-to-1 ratio produced by the 400-W metal halide lighting in other Staples facilities where luminaires are spaced 32' on center to provide comparable average illuminances.) Floor illuminances are very consistent, ranging from 5 to 6 fc (55 to 67 lx) along the aisle.

The uplight reduces luminaire glare by reducing the brightness difference between the bare T8 lamps and the surrounding ceiling. The luminance ratio between the T8 luminaire and the adjacent ceiling is about 32 to 1 (1600 cd/m² to 50 cd/m²).

Every fifth luminaire is continuously on during operating hours to provide a safe but low level of light for observation, and luminaires between these units are on a different circuit controlled by a ceiling-mounted passive infrared (PIR) occupancy sensor. When the aisle is in use, these lamps switch on, but six minutes after the sensor detects no movement, the lamps switch off to save energy (see *Economic Analysis* for actual savings). A Lighting Research Center (LRC) study on frequently switched lamps showed that instant-start electronic ballasts are not necessarily harder on standard T8 lamps than rapid-start electronic ballasts. However, care should be taken to ensure lamp/ballast compatibility for a frequent switching application. If this information is unavailable from manufacturers, the LRC recommends specifying a programmed-start ballast.

Details

Travel / storage aisle



Cross section through travel aisle and Full Case Tower

Travel/Storage Aisles

Four aisles in the facility are designated for two-way forklift travel. There is rack storage on both sides, although one side feeds boxes into either the Full Case or Break Pack towers where merchandise is unpacked into smaller units. Travel aisles are 16' (4.8 m) wide, wider than narrow storage aisles. Visual tasks include navigating forklifts and locating correct destination slots.

Light levels are higher in these aisles than in the narrow storage aisles, since they are almost always in use and forklift traffic is heavier. Type A luminaires run in a continuous line down the aisle and are not controlled by occupancy sensors. Uniformity of illuminance on the vertical stacks is excellent, ranging from 3 to 18 fc (36 to 190 lx). Floor illuminances range from 11 to 12 fc (110 to 130 lx). Ceiling luminances are similar to those measured in the narrow aisles.

Full Case Tower

Full Case Tower

The Full Case Tower is 39' (12 m) wide, 41' (12 m) tall, and 450' (140 m) long, with five levels full of workers retrieving larger boxes of merchandise (e.g., a single printer, a case of binders, a paper-shredder) to fill merchandise orders. Visual tasks include reading printed orders, locating these larger stock items on shelves, and loading items onto the conveyor belt.

On the four lower floors of the Full Case Tower, a continuous line of T8 fluorescent striplights (type C) is mounted to the overhead steel structure, centered between the shelving bins and the conveyor belts. On the top floor of the tower, there is no immediate ceiling to reflect light downward, so one-lamp T8 fluorescent industrial luminaires with 8% uplight (type F) are suspended from the structural trusses above (type F).

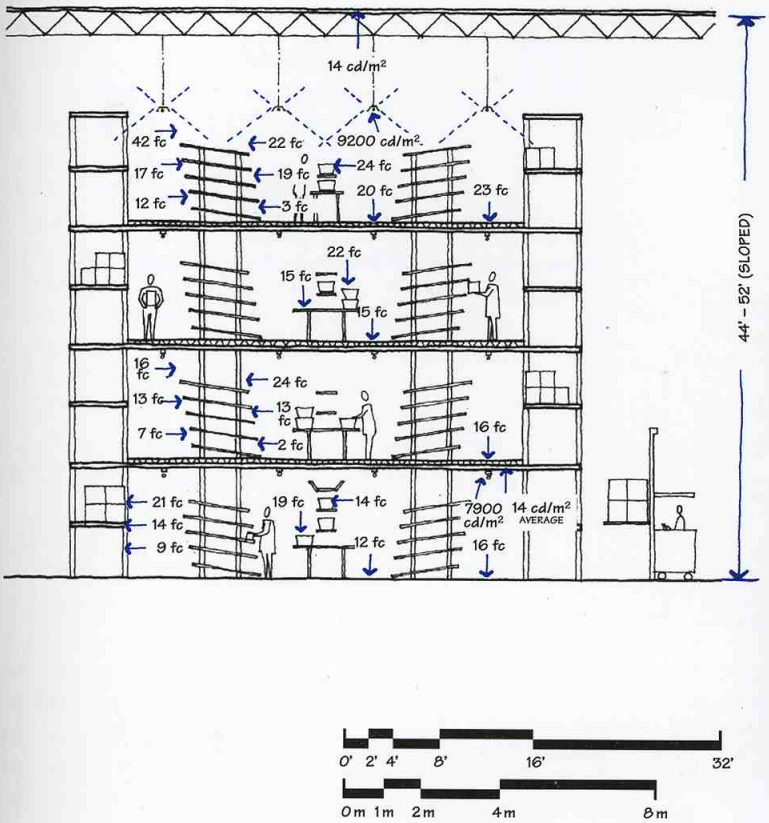
> ***"It's the best lighting I've seen in a warehouse."***
>
> ***–Equipment Supervisor***

On all levels of the Full Case Tower, horizontal illuminances on the conveyor range from 24 to 33 fc (260 to 360 lx). Vertical illuminances on the face of the boxes range from 10 to 24 fc (100 to 260 lx). Ceiling luminances vary from 7 to 19 cd/m², with bare lamp luminances ranging from 8100 to 9400 cd/m².

Break Pack Tower

The Break Pack Tower is 51' (15 m) wide, 40' (12 m) tall, and 450' (140 m) long, with four levels full of workers selecting small pieces of merchandise (e.g., a roll of tape, a box of pens, a box of diskettes) to fill specific merchandise orders. Visual tasks in the central aisles include reading printed orders, locating specific stock items within larger boxes, filling reusable bins with order items, and loading completed order bins onto the conveyor belt system. Visual tasks on the peripheral aisles include identifying boxes and moving them into the feeding end of the sloped racks.

In the central aisles of the Break Pack Tower, a continuous line of T8 fluorescent striplights (type C) is centered between the shelving units and the conveyor belts, as well as



Cross section through Break Pack Tower

Break Pack Tower

Details

centered on the peripheral aisles between the exterior and interior shelving units (type C). The top floor uses reflectored industrial luminaires (type F) in the same locations.

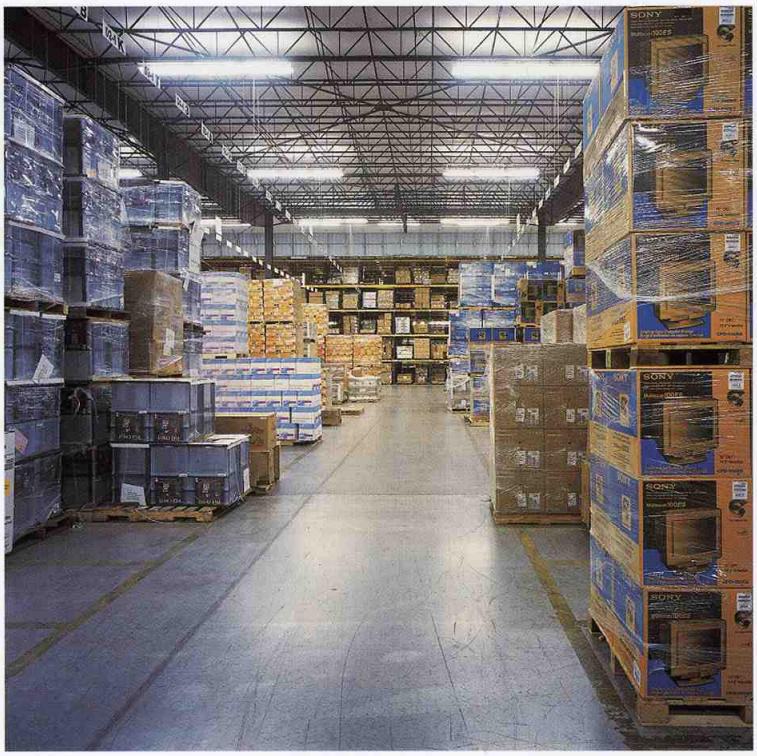
> ***"People in my department complain about everything, but not lighting."***
> ***–Shipping Supervisor***

In the central spaces of the three lower levels, horizontal illuminances on the conveyor belt range from 15 to 30 fc (160 to 330 lx), depending on the number of red order bins stacked in the area. Vertical illuminances range from 2 to 24 fc (25 to 260 lx). Values are similar in the peripheral aisles of the Break Pack Tower. Some employees commented that it was difficult to see inside the bins because of shadows cast by the front edge of the bin (see *Staff Response*). On the top floor of the Break Pack Tower, all illuminances are slightly higher than on lower floors, possibly because there is less stacked merchandise stored in this space. Floor illuminances range from 20 to 23 fc (210 to 240 lx) while vertical illuminances range from 3 to 22 fc (32 to 237 lx) in the central aisles and 12 to 42 fc (130 to 450 lx) in the peripheral aisles.

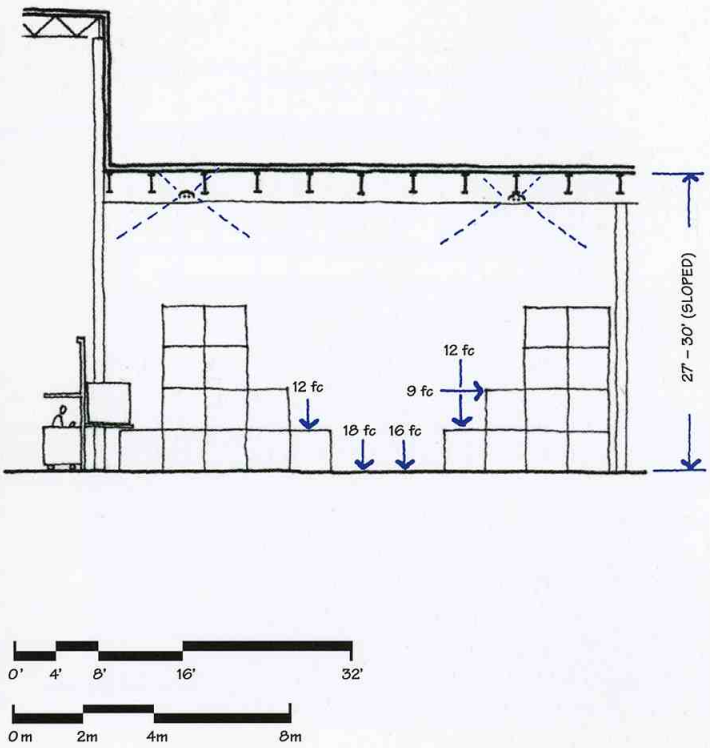
Bulk Storage

Pallets of bulk merchandise are moved from the delivery trucks in the Receiving area to Bulk Storage while they await direct shipment to retail stores. This is open floor space with a ceiling sloping from 30' to 27' (9.1 to 8.1 m). Painted lines on the concrete floor designate temporary storage areas and circulation aisles. Twelve-foot (3.6 m) long F32T8 fluorescent industrial luminaires with uplight (type B) are spaced on a 26' x 32' (7.9 m x 9.7 m) grid to provide general lighting. The light levels vary according to the amount and height of the stacked merchandise and the color of the boxes. The main visual task in Bulk Storage is forklift navigation.

Shadows from stacked merchandise are a common problem in bulk storage spaces. The fluorescent luminaires mitigate this problem in two ways. The lamps are linear, and the light is diffused evenly along the length of the 12' luminaire, so any shadows cast have extremely soft edges. Also, the luminaires direct 16% of their light upward. This uplight bounces off a light-colored ceiling, resulting in a low level of diffuse ambient light on the workplane. Uplight



Bulk Storage



Cross section through Bulk Storage

and light-colored ceilings also help minimize glare by reducing the brightness difference between the luminaire and the surrounding ceiling (see *Lessons Learned*). The Staples facility ceiling is 59% reflective, and its exposed trusswork is painted a dark color. White-painted ceilings and trusswork of 70 or 80% reflectance would be even more effective.

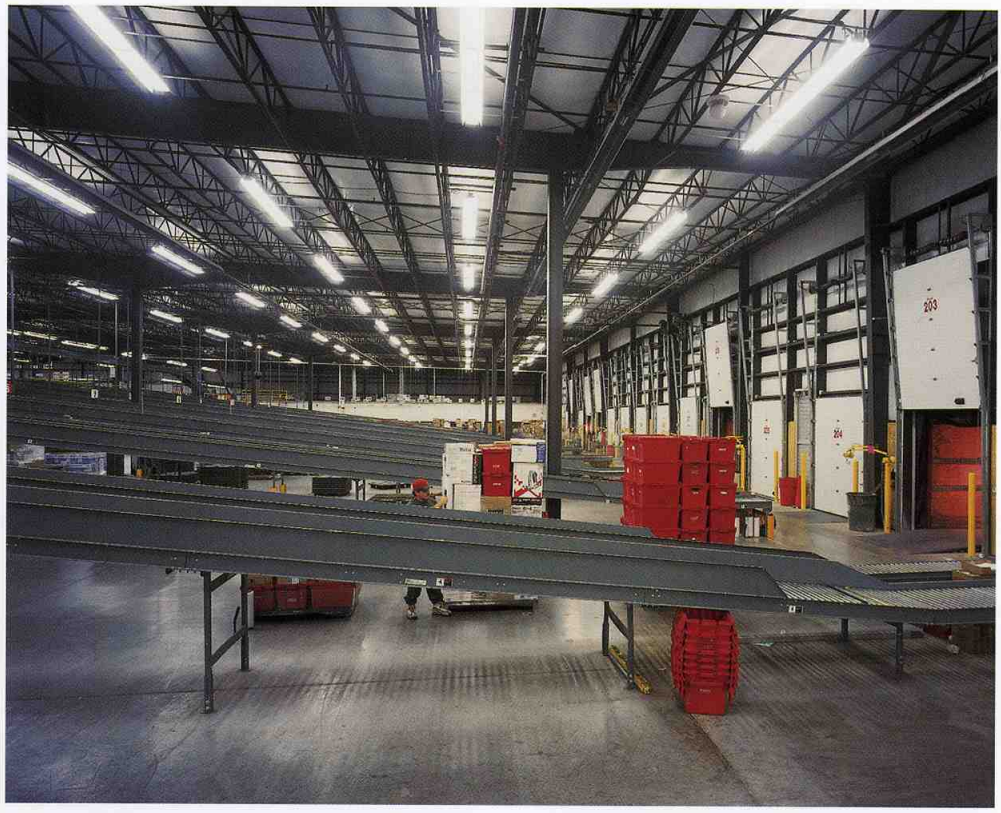
Horizontal illuminances range from 12 to 18 fc (130 to 200 lx) in sparsely stocked areas. At 4' (1.2 m) above the floor, DELTA measured a vertical illuminance of 9 fc (99 lx).

Shipping

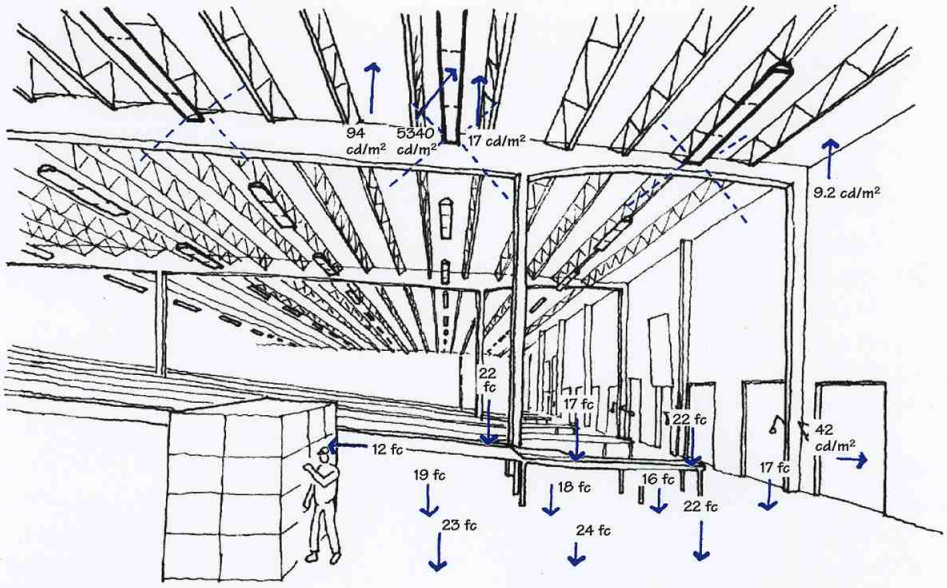
In Shipping the ceiling slopes from 32' to 30' (9.7 to 9.1 m). Employees retrieve boxes and order bins from conveyor ramps, load them onto pallets, shrink-wrap the pallets, then use a forklift to move them onto trucks. Visual tasks include reading labels, filling out paperwork, and operating forklifts.

Twelve-foot (3.6 m) long fluorescent industrial luminaires (type B) with uplight are mounted to ceiling trusses on 26' x 17' centers (7.9 m x 5.2 m) to provide ambient lighting with minimal shadows. Floor illuminances are very even, ranging from 17 fc (190 lx) near the loading doors to 24 fc (260 lx) in the center of the space. Horizontal illuminances on the conveyor ramps range from 17 to 24 fc (180 to 260 lx). Where the elevated conveyor structure blocks light from the ceiling luminaires, a row of 8' (2.4 m) fluorescent striplights (type C) is mounted under the structure on 10' (3.0 m) centers to supplement illuminances.

Swivel-head dock lights (type H) with incandescent BR lamps are wall mounted at each loading bay to aim light into truck cavities. The extendible arm projects light into the truck, illuminating the area where the forklift is headed. However, the forklift itself obstructs the light from the dock light, casting a shadow on the area that the driver needs to see. When the driver turns to face into the dock light, the glare is uncomfortable and reduces visibility.



Shipping



Perspective of Shipping

Project Evaluation

Energy Impact

DELTA calculated lighting power densities for both the warehouse and the office areas of the facility. The total connected lighting power density (LPD) in the evaluated industrial spaces is 0.66 W/ft² (7.1 W/m²). Occupancy sensors installed in the storage aisles reduce the in-use LPD to 0.62 W/ft² (6.7 W/m²). The occupancy sensors in these narrow storage aisles are responsible for switching off 80% of the lighting for 36 hours per week (32% of the time the building is occupied).

These LPDs compare very favorably with the LPDs of two other possible lighting conditions. The original metal halide design for this facility would have created an LPD of 0.86 W/ft². If the LPD of the facility were specified using the ASHRAE/IES 90.1 System Performance Method for warehouses of these heights, the maximum LPD allowance would have been 1.8 W/ft² (see sidebar, *Building Areas and Lighting Power Densities*).

Building Areas and Lighting Power Densities (LPD)

	Total Area (ft²)	Total Connected LPD (W/ft²)	In-use LPD (W/ft²)	ASHRAE/IES* Allowed LPD (W/ft²) (system performance)	CONV.† LPD (W/ft²)
Shipping	45,641	0.63	0.63	1.8	0.58
Bulk Storage	53,625	0.35	0.35	1.8	0.46
Aisle (w/ Sensors)	83,237	0.45	0.31	1.8	0.90
Break Pack Tower	29,311	1.54	1.54	1.8	1.54 ¶
Full Case Tower	18,769	0.98	0.98	1.8	0.98 ¶
Travel Aisles	34,698	0.76	0.76	1.8	1.52
Receiving	41,078	0.63	0.63	1.8	0.87
Office	6,474	0.87	0.87	1.8 ‡	0.87 ¶
	312,832	0.66	0.62	1.8	0.86

• ASHRAE = American Society of Heating, Refrigerating and Air-Conditioning Engineers; IES = Illuminating Engineering Society of North America.
† CONV. = Conventional lighting design, primarily using metal halide luminaires, with fluorescent luminaires in Towers and Offices.
‡ Determined using prescriptive method.
¶ Lighting in these (non-high bay) spaces use fluorescent, not metal halide lamps; LPDs are the same as in the "In-Use" condition.

1 W/ft² = 10.76 W/m²

Occupancy Sensors

The narrow storage aisles are used intermittently, and not for long periods of time, making these spaces ideal for the use of occupancy sensors. The aisles were equipped with passive infrared (PIR) occupancy sensors that require an unobstructed line of sight to moving occupants. These sensors detect the movement of heat sources (e.g., forklifts and workers), and have optional long-range lenses that can accommodate tall spaces such as these.

Some workers complained that the lights do not turn on soon enough when entering some of these aisles, or that the lights turn off when movement is not sustained. The sensitivity and aiming of the occupancy sensors require adjustment in some aisles (see *Lessons Learned*).

Environmental and Economic Analysis

By using energy-saving electronic ballasts and T8 lamps as a building standard, and reducing lighting use with occupancy sensors, this warehouse achieved significant energy savings and reduced costs relative to the original metal halide design. DELTA compared the annual energy cost based on observed day and night use with two hypothetical models. The first model is based on the energy use of the project as if it had been built with the metal halide system at an LPD of 0.86 W/ft². The second model is based on an ASHRAE/IES 90.1 model with an LPD of 1.8 W/ft². To perform the comparisons, DELTA made the following assumptions:

- 68% of lights on in the narrow storage aisles for 112 hours per week (20 hours/day weekdays, 12 hours/Saturday, closed Sunday)
- 100% of lights on in the rest of the facility for 112 hours per week

The fluorescent system as installed will provide substantial economic and energy savings compared to Staples' conventional lighting systems and systems operating at maximum ASHRAE/IES LPDs. Occupancy sensors save additional electricity and money. The figures below are calculated assuming a demand charge of $9.50 per kW, a standard industrial energy rate in this geographic area of 6.8¢ per kWh during peak hours and 5.3¢ per kWh

Economic and Environmental Analysis (Including Occupancy Sensor Operation)

	Difference Compared to Conventional Design		Difference Compared to ASHRAE/IES Allowed LPD	
Annual energy savings, lighting (kWh)	430,000 kWh		2,100,000 kWh	
Annual lighting energy savings	$39,800		$190,000	
Annual heating* cost increase	($7,400)		N/A	
Annualized relamping† savings	$400		N/A	
Total annual cost savings	$32,800		N/A	
Material / installation cost increase	($69,800)		N/A	
Simple payback period	2.1 years		N/A	
	Tons	Metric Tons	Tons	Metric Tons
Annual CO_2 reduction	356	323	1,800	1,600
Annual SO_2 reduction	2.1	1.9	10.0	9.4
Annual NO_x reduction	0.56	0.51	2.8	2.5

* A lower lighting LPD will increase heating system demand in winter. Air conditioning is not used in the facility, so no air conditioning savings were calculated.
† Assume group relamping at 80% of lamp life. Savings includes cost of lamps, labor, and disposal.

off-peak, and additional annual service charges and taxes.

According to the region's power utility, Northeast Utilities, reduced energy from this facility will result in lower power plant emissions of CO_2, SO_2, and NO_x compounds (see table below). By reducing these emissions into the atmosphere, there is a smaller contribution to problems such as global warming, acid rain, and smog.

The initial cost of this fluorescent lighting installation was approximately $70,000 more than if the conventional metal halide design had been used. Northeast Utilities compensated Staples for much of the difference, with a "conservation investment" of approximately $61,000.

Staff Response

The DELTA team received surveys from 108 employees describing their experiences with the lighting. DELTA specifically asked about visual comfort, task visibility, reactions to controls, comparison to lighting in previous warehouses, and any changes to the lighting the employees would suggest (see sidebar, *Lighting Survey*).

The survey did not specifically ask the employees to answer questions based on their immediate work areas alone, so DELTA assumes that much of the response was based on the facility as a whole. However, there was some variation according to where the individual worked. Shipping and Receiving areas are unobstructed, and attention is focused downward, well away from the luminaires; responses from these areas are especially positive. The Break Pack and Full Case Towers have smaller-scale spaces, lighted with bare striplights without shielding or reflectors. Employees in these spaces work in close proximity to the luminaires and regularly retrieve items from within deep storage racks. Some employees here complain of both glare and shadows. Forklift drivers spend most of their time moving in and out of the narrow storage aisles with the occupancy sensors. This group reported the most complaints about the lights turning on and off. These seem to be minor complaints, as the overall ratings for the building are still high.

In order to gauge whether employees found the lighting in the Killingly Distribution Center to be better or worse than other Staples facilities using conventional metal halide lighting, employees in the Staples' Hagerstown, Maryland, facility were asked to complete an identical survey form. The Hagerstown Distribution Center, built in 1997, is almost identical in size, layout, finishes, racks, equipment, use, and lighting criteria. It uses pendant-mounted metal halide aisle-lighters in aisles, metal halide high-bay industrial downlights in Shipping, Receiving, and Bulk Storage areas; and the same fluorescent lighting in offices, Break Pack, and Full Case Tower areas as was specified for both facilities.

The team also interviewed the maintenance manager, facility manager, and representatives from the various areas of the Killingly facility. These individuals generally liked the lighting, especially when compared to previous warehouse facilities in which they had worked.

The maintenance manager finds the lighting of the facility to be greatly improved, both in quality and quantity, over his previous workplace. He did express concern that the number of fluorescent lamps to change at the end of lamp life is quite large, and accessing them is difficult for his staff.

Maintenance and Product Performance

The overall response to product performance was positive. Managers are very pleased that the energy-efficient lighting design has kept

LIGHTING SURVEY
Percentages of People Who Agree:

	Total		Shipping & Receiving Employees		Forklift Drivers		Break Pack& Full Case Employees	
	Killingly (n=108)	Hagerstown (n=178)	Killingly (n=29)	Hagerstown (n=65)	Killingly (n=21)	Hagerstown (n=58)	Killingly (n=49)	Hagerstown (n=45)
1. Overall, the lighting is good.	89%	44%	93%	45%	80%	38%	94%	51%
2. Overall, it is easy to see what I need to see.	87%	49%	90%	49%	80%	41%	92%	56%
3. Overall, the lighting is comfortable.	81%	53%	86%	51%	85%	45%	80%	64%
4. The lighting is too bright.	7%	9%	3%	11%	20%	10%	6%	7%
5. The lighting is too dim.	16%	55%	3%	57%	20%	66%	18%	42%
6. The lighting is not where I need it to be.	15%	53%	0%	54%	20%	60%	18%	47%
7. The lighting causes deep shadows.	20%	43%	3%	43%	10%	52%	35%	36%
8. Reflections of the light fixtures hinder my work.	20%	28%	3%	29%	20%	28%	29%	31%
9. The lighting is glaring.	23%	22%	7%	20%	15%	24%	37%	29%
10. The lighting makes colors look odd.	9%	18%	0%	31%	10%	28%	14%	20%
11. The lighting turning on and off is disturbing.	23%	n/a	14%	n/a	35%	n/a	20%	n/a
12. How does the lighting of this distribution center compare to other facilities? Better	52%	18%						
About Same	37%	46%						
Worse	11%	36%						

energy use to a minimum. Very few ballast failures have occurred. Extra-long-life lamps were specified to minimize the frequency of relamping. With the exception of the BR40 lamps used in the dock lights (type H), only one type of lamp has to be stocked for the entire facility.

There have been a greater-than-expected number of lamp failures in two of the nine narrow storage aisles, probably because of electrical supply and wiring problems. DELTA measured the electrical characteristics in one aisle and found the voltage to be 306 V (on a 277 V system). The other aisle with problems had an intermittent short-circuit. Either of these conditions could cause premature lamp failures.

Occupancy sensors did not work as expected in one aisle. DELTA noticed that a user had to walk 15′ to 20′ into the aisle before the sensor switched on the lights. DELTA recommends readjusting the aiming of the sensor (see *Lessons Learned*).

Lessons Learned

- **Fluorescent luminaires can be used to light tall warehouse aisles.** A linear fluorescent source can provide more uniform vertical illuminances and reduced shadows on shelving in warehouse aisles when compared to some metal halide lighting systems. Because of their lower lumen output compared to metal halide lamps, fluorescent luminaires must be spaced more closely than metal halide luminaires, but this practice minimizes dark areas when a single lamp burns out.

- **Fluorescent lighting can provide a cost-effective solution in a warehouse environment.** Although first costs were greater when compared to Staples' conventional metal halide system, this fluorescent lighting system provided substantial energy savings, with a simple payback period of 2.1 years.

- **Occupancy sensors save energy by turning off the lights when warehouse aisles are unoccupied.** When specifying occupancy sensors, the type of sensor and the coverage pattern should be carefully matched to each area. Factors to consider include height of space, traffic patterns, and time delay. An occupancy sensor should be located and aimed so that it will detect all occupants within the intended coverage area.

- **Occupancy sensors will often need sensitivity and time delay adjustment after initial installation.** Sensors may require aiming or adjustment more than once to fine tune their operation for a specific situation.

- **Uplight on ceilings improves warehouse lighting.** Uplight on a light-colored ceiling serves several important functions: it makes the luminaires appear less glaring because it reduces the contrast between the luminaire and its background, increases vertical illuminance on storage shelves, and provides a psychological lift because the space appears brighter.

- **Shadows are a problem in sorting tower shelving areas where bins are used.** The front edges of the bins can cast shadows, making it difficult to see inside the bins. Lighter-colored flooring, racks, and conveyors would increase reflected light into shelves, reducing shadows.

DELTA MEMBERS
Consolidated Edison Company of New York, Inc.
New York State Energy Research and Development Authority
Northeast Utilities System
Lighting Research Center

DELTA STEERING COMMITTEE
Patricia Glasow, Roger Knott, Mitchell Kohn, Peter Morante, Peter Jacobson, Marsha Walton

DELTA Portfolio Lighting Case Studies
Volume 2, Issue 5, Revised
Staples Distribution Center
Killingly, CT
Staples Site Sponsor:
The Connecticut Light and Power Company, an operating company of Northeast Utilities

December 1999

Program Directors: Naomi Miller, Sandra Vasconez
Reviewers: Russell Leslie, Mark Rea
Project Coordinator: Peter Boyce
Publication Manager: Judith Block
Research Associate: Jennifer Brons
Evaluation Team: Peter Boyce, Naomi Miller Dalia Kairiukstiene, Jennifer Brons
Technical Assistance: Eve Quellman, Javier Ten, Kami Wilwol, Ge Zhang

CREDITS
Staples Corporation: Director of Facilities: Robert Valair; V.P. Facilities Management and Purchasing: Mark Buckley; Director of Maintenance: Larry Utz; Facility Managers: Allan La Flamme, Matt Grossi
Northeast Utilities System:
DELTA Project Contact: Paul Musulin
CL&P Project Representative: Steve Kelly
Architect: Carter Burgess Corporation
Engineers: Carter Burgess Corporation
Energy Consultant: Carolyn Banks, Energy Logic, Inc.
Lighting Design: Carter Burgess Corporation, Lighting Research Center
Electrical Contractor: Commercial Electrical Contractors, Inc.
Luminaire Manufacturers: Types A-G, Metalux; **Type H**, Hubbell
Ballasts: MagneTek B432I277RH and B332I277RH
Occupancy Sensor: The Watt Stopper

DELTA Portfolio Graphic Design and Production: JSG Communications, Inc.
Photographer: Robert Benson

Rensselaer

For publications ordering information contact:
Lighting Research Center, Rensselaer Polytechnic Institute, Troy, New York 12180-3590 • FAX (518) 276-2999
Phone: (518) 276-8716 • e-mail: lrc@rpi.edu • World Wide Web: www.lrc.rpi.edu

ISSN 1075-3966 Printed on recycled paper