

# FIELD TEST

## DELTA

Demonstration and Evaluation of Lighting Technologies and Applications

### T5 FLUORESCENT HIGH-BAY LUMINAIRES AND WIRELESS LIGHTING CONTROLS



## Project Profile

DELTA field-tested T5 fluorescent luminaires and wireless motion-sensing lighting controls in a distribution center warehouse in Albany, N.Y. The demonstration in this high-bay environment was designed to test the performance and energy efficiency of a retrofit T5 fluorescent lighting system compared to the existing metal halide lighting system.

## Field Test Objectives

DELTA tested a retrofit T5 fluorescent lighting system with wireless controls in a warehouse to:

- Compare illuminances and energy usage to the previous metal halide (MH) lighting
- Gather worker feedback
- Verify operation of the system components

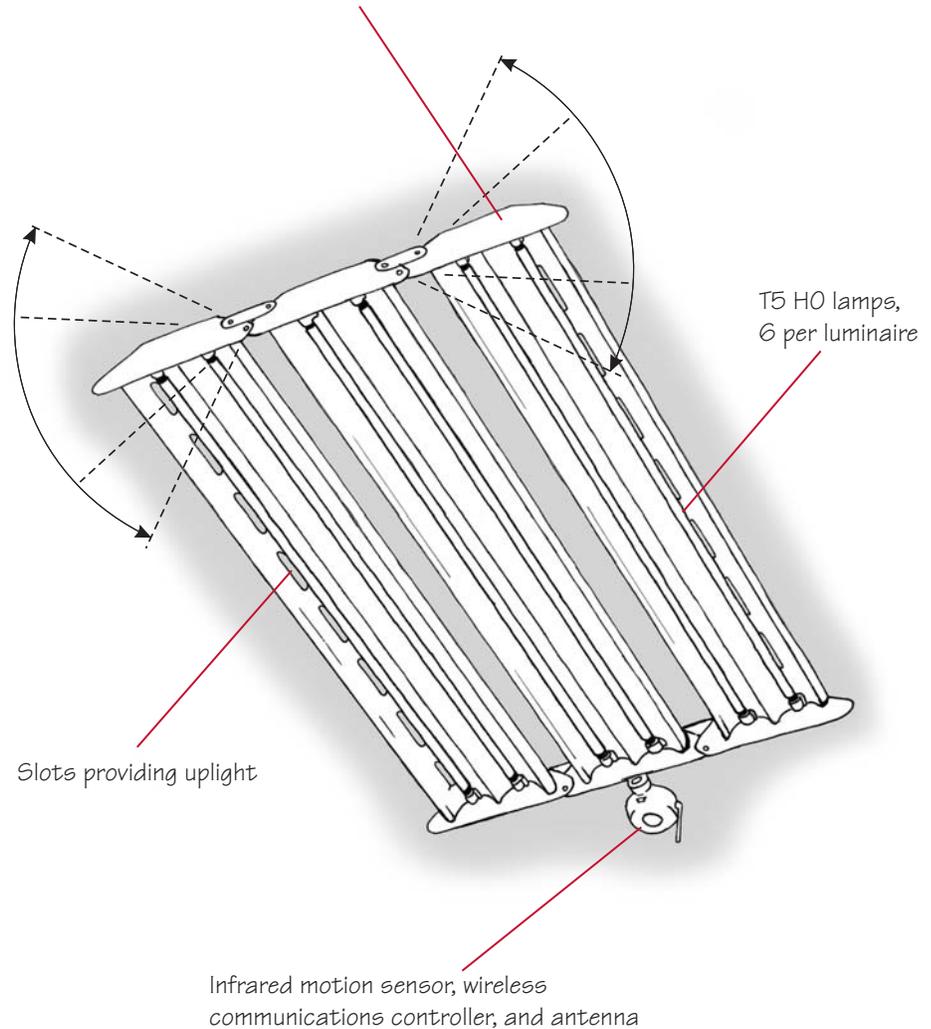
## Overview of the Lighting System

The AWL (Adjustable Warehouse Light) luminaire was developed by Lamar Lighting of Farmingdale, N.Y. The housing of the AWL holds six T5 high-output (HO) fluorescent lamps and allows the two outer segments to be adjusted to up to 45° above or below the horizontal in five fixed positions. New product features added for this demonstration included uplight slots and a wireless controls system developed by Watt Stopper/Legrand.

Uplight slots were added to the design of the AWL to minimize glare by decreasing the contrast between the luminaire and the background. Uplight slots are located on the two outermost edges of the luminaire.

Another new feature of the AWL is the controls system, which was added for this field test. Each luminaire has an infrared motion sensor and wireless communication system that allows luminaires to respond to occupancy either independently or in groups. Under the grouped scenario, when one luminaire senses movement, it communicates wirelessly with the rest of the network; those luminaires programmed to be in the same group will switch from “sleep” to “wake” mode. Grouping can give the appearance that the entire aisle is turning on upon entry. When the control mode is set to independent operation,

Hinged luminaire segments with adjustable aiming ( $\pm 45^\circ$ ,  $\pm 22.5^\circ$ , and flat); overall luminaire size 32" x 46" (0.8m x 1.2 m)



### Features of the Adjustable Warehouse Light (AWL)

the lights change from “sleep” mode to “wake” mode successively as a person proceeds down the aisle.

Each motion sensor controls three relays, one for each of the three ballasts in the luminaire. Ballasts are tandem-wired so that the lamps can be controlled in a bilaterally symmetrical pattern.

The wireless control system uses a 900 MHz communication protocol (*Topdog*<sup>®</sup>) to form a “broadcast network”; program settings reside in each luminaire’s controller, so a central controller is not required for the system to operate. Control settings for this prototype system are programmed using a laptop computer with a wireless transceiver device. In addition to establishing groups, the computer can be used to adjust motion sensor delay times and sensitivity settings without having to physically access the luminaires in the ceiling.

The same type of transceiver can also be installed in a standalone panel to allow a facility manager to change the programmed lighting settings. In addition to sleep and wake modes, this panel can coordinate photosensor signals, load shed commands, and emergency overrides. (These features were not evaluated in this study.)

## Field Test

### Test Site

The Trans World Entertainment Distribution Center in Albany, N.Y., was the site of the field test. The distribution center receives and ships DVDs, CDs, and related entertainment merchandise to retail stores. The new lighting system was installed in a 20,750 ft<sup>2</sup> (1928 m<sup>2</sup>) portion of the warehouse housing tall racks of merchandise awaiting distribution to retail stores.

### Warehouse Operation Patterns

The distribution center has two main types of warehouse storage requiring two different forklift vehicles, a “man-up truck” and a “reach truck” for retrieval.

The man-up truck raises the worker above the floor to retrieve small, individual boxes of media. Workers operating a man-up truck must have sufficient illumination to read the addresses on the rack, as well as the labels on the boxes. They must retrieve each required box, adhere a bar-code label, and stack the box on a pallet. These workers must sometimes step off their man-up trucks and climb deep into storage racks to locate and retrieve a specific box. Operating a man-up truck requires several minutes in one location and often takes place at heights exceeding 20 feet.

Some aisles store pallets of merchandise that are handled in bulk. These are accessed using a “reach truck” that keeps the operator at ground level. Reach truck operators must drive the vehicle to the correct location, raise the vehicle’s forks to precisely the correct height, lift and extract the entire pallet, lower the pallet to the ground, then drive the pallet to another part of the warehouse.



### Field Test Site Characteristics

Area (with new lighting) .....	20,750 ft <sup>2</sup> (1928 m <sup>2</sup> )
Ceiling height.....	33 ft (10 m)
Luminaire mounting height.....	30 ft (9 m)
Luminaire spacing .....	25–35 ft (7.6–10.7 m)
Storage rack height.....	23 ft (7 m)
Typical aisle width .....	9.5 ft (2.9 m)
Aisle length:	
Nine storage aisles.....	98–143 ft (29.9–43.6 m)
Two cross-aisles.....	122 ft (37.2 m)
Reflectances:	
Ceiling, 11%; floor, 12%; wall, 45%; rack, 20%	

### Lighting System Characteristics

#### Existing Lighting

High-bay-type metal halide (MH) with “spread” distribution	
Luminaire.....	Lithonia TE-400M-E17-277 with clear, flat glass bottom
Lamp .....	400 W clear BT-37 metal halide lamp
Power .....	458 W (including ballast losses) per luminaire
Approximately 8 years old; 44 luminaires installed	

#### Retrofit Lighting

“AWL” luminaire operating six, 54 W, T5 high output (HO) fluorescent lamps	
Luminaire .....	Lamar AWL-654Z5UU
Lamp .....	GE F54W-T5-841-ECO
Designated light levels .....	Full output (351 W)
	2/3 output (234 W)
	1/3 output (117 W)
Motion sensor .....	Watt Stopper/Legrand prototype
45 luminaires installed <sup>1</sup>	

#### Lighting Power Density

Existing Lighting .....	0.97 W/ft <sup>2</sup>
Retrofit Lighting.....	0.76 W/ft <sup>2</sup> (maximum)

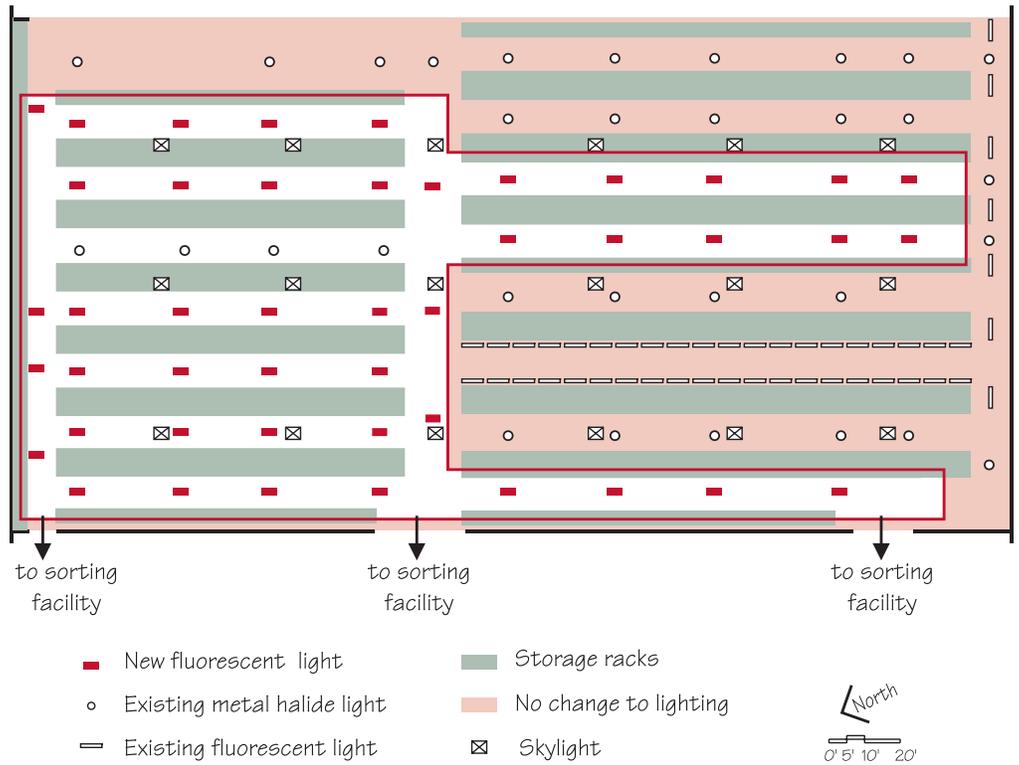
<sup>1</sup> During the retrofit installation, one luminaire was added because one location had a junction box to provide power, but never had the previous luminaire type installed.



“Reach trucks” (left) are used to move large pallets of boxes. This task keeps the driver on the ground, looking upward to aim the vehicle’s forks to the correct location. “Man-up truck” operators (right) must identify and collect small boxes. This sometimes requires stepping off the vehicle to climb onto racks at all heights.

## Lighting System Installation

Existing MH luminaires were replaced with AWL luminaires in the locations shown in the lighting plan. Illuminance calculations showed that the flat configuration of the AWL produced the highest illuminance in the aisles, so the adjustable segments were set to the flat configuration. The motion sensors on the AWL luminaires were set to switch to sleep mode after five minutes of sensing no movement.



**Storage rack area lighting plan**



**Before and after — A warehouse aisle with its original metal halide lighting is shown on the left; the revised lighting scheme using the AWL fluorescent system at full output is pictured on the right. Illuminances for both conditions are shown on page 5.**

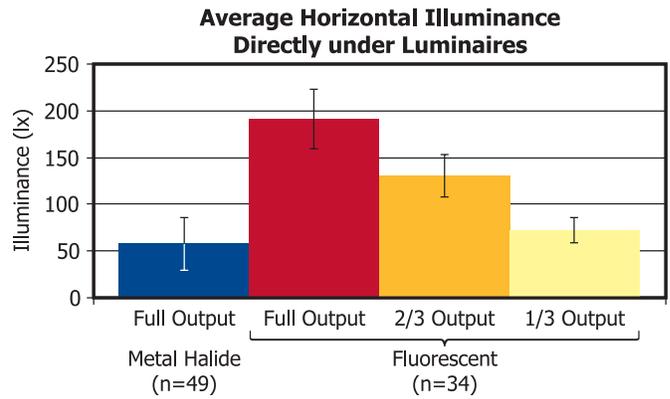
# Photometric Measurements

The DELTA team measured horizontal illuminance on the floor beneath the luminaires both before and after the retrofit. Vertical illuminances were measured beneath one typical luminaire and halfway between two luminaires at each of the five shelf levels. Vertical measurements were collected in the same locations both before and after the retrofit. Skylights were blocked during photometric measurements and during worker surveys to focus on the impact of electric lighting alone.

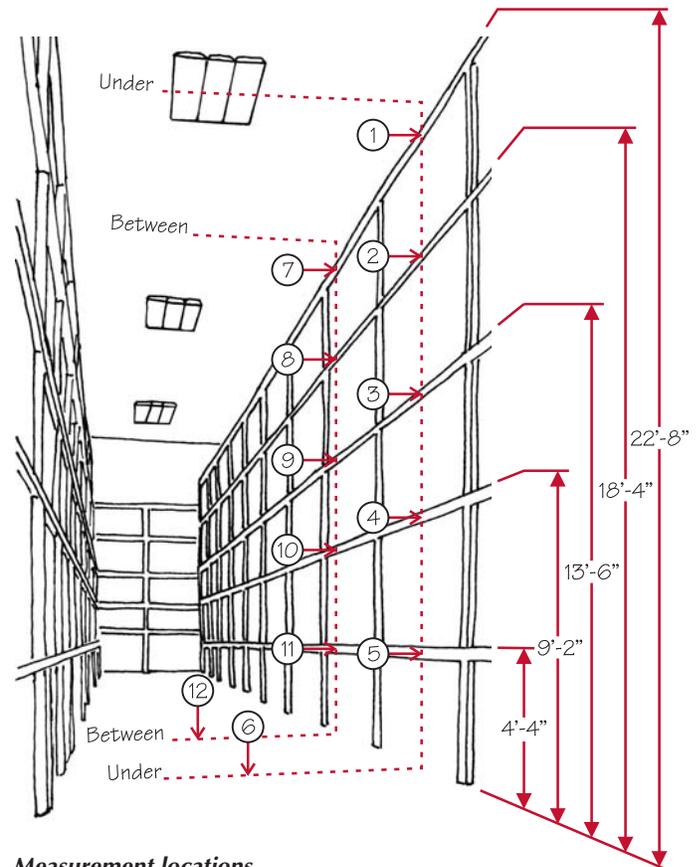
As shown in the figure at upper right and the table below, the illuminance provided by the AWL system at 1/3 light output was nearly the same as the light output of the previous metal halide system.<sup>2</sup>

It should be noted that the metal halide (MH) lamps at this warehouse were relamped upon failure, not group-relamped. Many of the lamps have continued to operate far beyond rated life, and thus have suffered from severe lumen depreciation. Also, despite being lensed, the existing MH luminaires showed evidence of dust and insect ingress. As a result of these light loss factors, the overall light output of the previous system was severely diminished. Although it required 458 W per luminaire, the previous system's light output was nearly the same as that of the new fluorescent system at 1/3 output (113 W). If the existing system were cleaned and relamped, it is expected that its light output would initially match or even exceed that of the new fluorescent AWL system at full output. Over time, however, the fluorescent system would overtake the cleaned, relamped MH system because T5HO fluorescent lamps experience less lumen depreciation over their life than standard metal halide. It should also be noted that the AWL luminaires are unlensed, which may cause greater luminaire dirt depreciation over time than if they were covered.

<sup>2</sup> At this light output, some areas had lower illuminance than recommended by IESNA for some types of warehouse storage. Recommended practice, according to the *IESNA Lighting Handbook, Ninth Edition*, is 50 lux for inactive storage, 100 lux for active storage of large items, and 300 lux for active storage of small items.



Photometric measurement results, before and after retrofit, for the field test area (error bars indicate standard deviation).



Measurement locations

## Detailed photometric measurements

	Under luminaire					Between luminaires				
	Meas. location	MH before	Fluorescent			Meas. location	MH before	Fluorescent		
			Full output	2/3 output	1/3 output			Full output	2/3 output	1/3 output
Vertical Illuminance (lux)	1	345	450	297	160	7	29	99	63	31
	2	102	220	135	72	8	55	95	64	35
	3	55	121	67	40	9	34	90	59	37
	4	28	86	47	25	10	23	88	58	27
	5	22	60	39	21	11	20	60	40	21
Horizontal Illuminance (lux)	6	67	181	115	61	12	57	186	120	62
Lamp luminance (cd/m <sup>2</sup> )			20,000-21,000				80,000-180,000*	10,000-19,000*		
Background luminance (cd/m <sup>2</sup> )			10-30				10-80*	10-30*		

\*As observed 5-15 ft (1.5-4.6 m) from directly below luminaire



## Worker Surveys

The DELTA team investigated worker impressions about lighting quality and acceptability of the motion-sensor system.

### Surveys – Lighting Quality

Workers answered survey questions about the amount and quality of light, both before and after the retrofit. After the lighting system was changed, three fluorescent light levels were evaluated (1/3, 2/3, and full output), and each was compared to one aisle still having the existing MH lighting. Workers were split into three groups, with one group answering survey questions each day to counterbalance the order in which groups observed the three light levels. Workers spent two hours working under one lighting condition in all eleven aisles with the fluorescent lighting, then completed the survey. The DELTA team then changed the lighting to the next condition, and workers repeated the same task, completing surveys for all three light levels within one day.

When compared to the existing MH system, workers greatly preferred the higher light levels that the AWL lighting system provided.<sup>3</sup> The exception was when there was no difference in light levels (1/3 fluorescent output and existing MH output). Workers indicated that the existing MH lighting system did not provide enough light. They indicated that none of the conditions constituted “too much light.”

Workers indicated that the AWL was not too bright to look at directly. Even at full light output, workers indicated that the AWL was not too bright when looking upward from the ground to see pallets, nor when working on racks above the ground level.

*“When I look at the [AWL] lights in this aisle and then at my paperwork, I do not see ‘bars’ on my sheets... [However with the existing MH lighting,] I have to wait for the spots to clear.”*

*“The other lights [existing MH lighting] hurt my eyes.”*

At AWL’s 2/3 and full outputs, workers indicated that they had enough light to climb into the racks and to read labels. At 1/3 output and with the existing MH lighting, worker ratings on these questions were more neutral or negative. (The DELTA team observed some instances in which workers used personal task lights when the lights were in the 1/3 output condition.) Under all lighting conditions, workers tended to agree that they had enough light to drive a forklift safely, though less so with the lower light levels.

*“I needed to use truck [task] light today [at 1/3 output].”*

*“I know some people bring flashlights to be able to see into racks when they have to climb around in there.”*

Workers rated the AWL system as more comfortable when the light output was higher (2/3 output and full output) compared to 1/3 fluorescent output and the existing MH lighting’s full output. Opinions about the appearances of people and colors were mixed. Workers indicated that the lower light levels made shadows noticeable, a sentiment that was lessened as illuminances increased. For the most part, workers were not concerned about reflections from shiny objects under any of the lighting conditions.

Overall, the workers preferred the new lighting, particularly at the highest (full) light output. Opinions about the existing MH lighting tended to worsen after the AWL installation. It stands to reason that the AWL system caused the remaining aisle with the existing MH lighting to appear darker when compared to the various fluorescent lighting modes. However, even when the illuminance levels were about the same (1/3 fluorescent output and output from existing MH system), impressions about the existing lighting system remained less favorable than before the AWL installation (though only statistically significant [ $p < 0.05$ ] in one case).

*“It’s like night and day! I can’t believe how dark it used to be!”*

*“That was really bright! It’s great!”*

The AWL “has much better lighting all-around. The aisle is brighter [than existing MH lighting], but the light is not too powerful.”

At 1/3 output “both aisles are relatively the same... [The] difference is negligible.”

*“Right now [1/3 output] it’s a little too dim in here. Sometimes with [full output] it’s too bright, but with 2/3 on it looks good to me.”*

### Surveys – Motion Sensors

Workers also gave their feedback about the motion sensors used in this field test.<sup>3</sup> DELTA evaluated four lighting control modes: two grouping modes and two wake modes. The grouping modes were programmed to operate the luminaires either independently or grouped by aisle. Lights changed to a wake mode of either 2/3 or full light output when occupied. All four lighting control modes used 1/3 light output as the sleep mode when aisles were unoccupied. The presentation order of these control modes was counterbalanced.

Workers were allowed a half day to observe each of the four lighting control modes over the course of their normal operations. During the second half of the day, the lighting was fixed at 1/3 output. At the end of the workers’ day, they answered four survey questions comparing their impressions about the system’s performance during the first part of their day to the second part of their day. Workers were not informed of what aspect, if any, was changed about the lighting. On one day, the lighting did not change at all. During the second week, this presentation order was reversed and randomized.

<sup>3</sup> Detailed statistical results available from LRC.

Workers were asked whether they agreed or disagreed with four statements concerning: 1) perception of safety upon entering aisles, 2) approval of the lighting, 3) perception of brightness, and 4) awareness of switching.

Analysis of the survey data shows that the motion sensors did not make a strong impression on these workers. There was no clear preference for either grouped or individually switched operation. It should be noted that the workers did not experience the “waking” of the lighting system every time they entered an aisle. Aisles often remained in wake mode despite being unoccupied because aisles were visited more frequently than the timer delay setting (5 minutes).<sup>4</sup>

Overall, being able to work under higher light levels was more conspicuous and valuable to these workers than the changing between sleep and wake modes upon entry into the aisles or grouping.

*“I like when you go in there and they light up, then when you leave, they go dark.”*

*“When lights came on [full output], the entire aisle was much brighter and visibility much better.”*

*“I really didn’t notice much difference in the lighting—I’m not that observant.”*

*“I don’t really notice [motion sensing]; I’m kind of on autopilot.”*

*“I’m not there when they switch on and off.”*

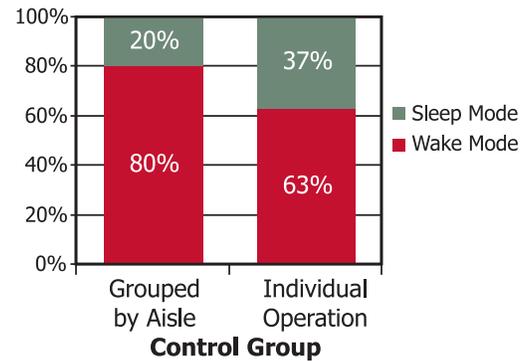
<sup>4</sup> Shorter delay times will impact energy savings by increasing the amount of time in sleep mode.



## Energy Savings, Annual Cost Savings, and Environmental Implications

The use of a sleep mode creates energy savings because the wattage decreases when the light output reduces to 1/3. If the sleep mode were programmed to turn the lights entirely off (rather than 1/3 output), energy savings would be even higher. DELTA projected energy savings by sampling sleep and wake activity on individual luminaires using battery-powered light loggers. The total amount of time in sleep and wake modes was divided by the the total time that light loggers were used in these locations (approximately 3700 hours in individual modes, and 1050 hours in grouped modes).

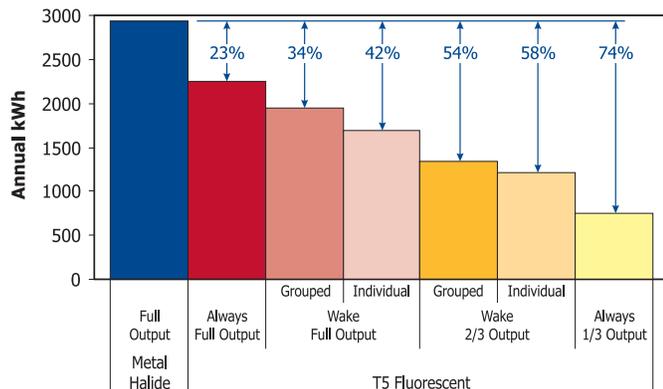
This monitoring technique revealed that motion sensors provide substantial energy savings. Lights were in sleep mode for 20% of the hours of operation when grouped by aisle. When operated individually, sleep mode increased to 37% of operating hours.



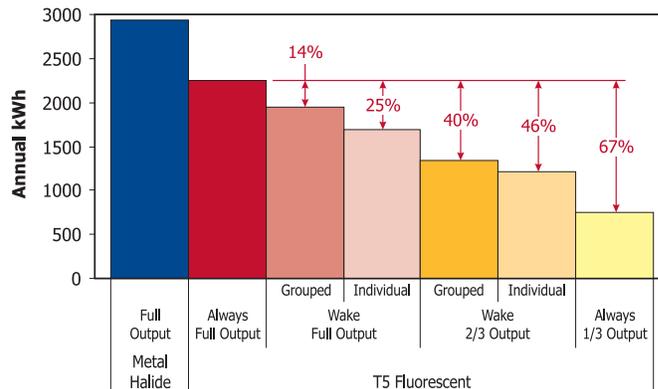
**Percentage of time in sleep mode vs. wake mode for aisle-grouped luminaire control and individual luminaire control**

At this warehouse, some aisles are busy, with little or no time in sleep mode. Additionally, aisle occupancy patterns change from one day to the next, depending on what merchandise was being shipped. The data comprising the figure above include samples from all aisles with fluorescent lighting over the course of three months (February through April 2008.) At busier times for this warehouse, such as end-of-the-year holidays, energy savings from motion sensors will be lower.

These percentages were used to project annual energy savings. Since the AWL system is capable of three light levels (1/3, 2/3, and full) and two types of motion sensor control (individual or grouped), energy savings were evaluated for several combinations of light level and control mode. Sleep and wake percentages were multiplied by wattages for each light level (1/3=117 W, 2/3=234 W, full=351 W), which were then multiplied by the hours of operation per year (approximately 6400 hours). Annual energy use for one AWL luminaire in each of the fluorescent control modes was compared to the baseline of the existing metal halide luminaire type.



**Projected annual energy use (one luminaire) and percentage savings with T5 lighting modes vs. metal halide**



**Projected annual energy use (one luminaire) and percentage savings compared to T5 full output with no motion sensors**

The AWL system can save energy. The upper left figure shows that the AWL system at full output can save 23% over the energy used by the existing MH lighting system. Use of motion sensors can save 34-74% depending on which sleep and wake control modes are used, and depending on grouped vs. individual operation. The upper right figure shows incremental savings from motion sensors alone, compared to unswitched fluorescent at full output. (This information would be useful if a similar facility had fluorescent lighting already and was considering the use of motion sensors.) These translate to annual energy cost savings and lower power plant emissions, shown in the tables at right and below.<sup>5</sup>

**Annual energy cost savings for each AWL**

	Annual savings per AWL*
Annual savings, MH to T5 upgrade	\$65
Additional annual savings due to motion sensors:	
Wake full output, grouped	\$29
Wake full output, individual	\$53
Wake 2/3 output, grouped	\$86
Wake 2/3 output, individual	\$98
Additional annual savings, fixed 1/3 output (i.e., no increased light levels)	\$142

\* Savings based on \$0.095/kWh energy cost.

<sup>5</sup> Calculated using U.S. EPA "Power Profiler," accessed at [www.epa.gov/cleanenergy/energy-and-you/how-clean.html](http://www.epa.gov/cleanenergy/energy-and-you/how-clean.html)

**Reduced power plant pollution from annual use of each AWL**

	Compared to Metal Halide			Compared to Fluorescent w/o Motion Sensors		
	SO <sub>2</sub>	NO <sub>x</sub>	CO <sub>2</sub>	SO <sub>2</sub>	NO <sub>x</sub>	CO <sub>2</sub>
	lbs (kg)	lbs (kg)	lbs (kg)	lbs (kg)	lbs (kg)	lbs (kg)
Fluorescent (no control)	2.7 (1.2)	0.7 (0.3)	533 (242)	—	—	—
Grouped, wake full output	3.9 (1.8)	0.9 (0.4)	771 (350)	1.2 (0.6)	0.3 (0.1)	238 (108)
Individual, wake full output	5.0 (2.2)	1.2 (0.5)	967 (439)	2.2 (1.0)	0.5 (0.2)	434 (197)
Grouped, wake 2/3	6.3 (2.9)	1.5 (0.7)	1235 (560)	3.6 (1.6)	0.9 (0.4)	702 (318)
Individual, wake 2/3	6.8 (3.1)	1.6 (0.7)	1333 (605)	4.1 (1.9)	1.0 (0.4)	800 (363)
Constant 1/3	8.7 (3.9)	2.1 (0.9)	1699 (771)	6.0 (2.7)	1.4 (0.6)	1166 (529)

Sulphur dioxide (SO<sub>2</sub>) is associated with visible pollution (haze) and acid rain. SO<sub>2</sub> is also a direct lung irritant. Nitrogen oxides (NO<sub>x</sub>) are a primary cause of ozone production (a main component in smog) and acid rain. Carbon dioxide (CO<sub>2</sub>) is a possible contributor to future climate change, such as global warming.

# Hardware and Maintenance Observations

## Alignment

Unlike circular luminaires (such as MH), rectangular luminaires may be difficult to align perfectly when hung from a single mounting point. Nevertheless, leveling of the AWL luminaires appeared successful.

## Size Conflicts with Warehouse Operations

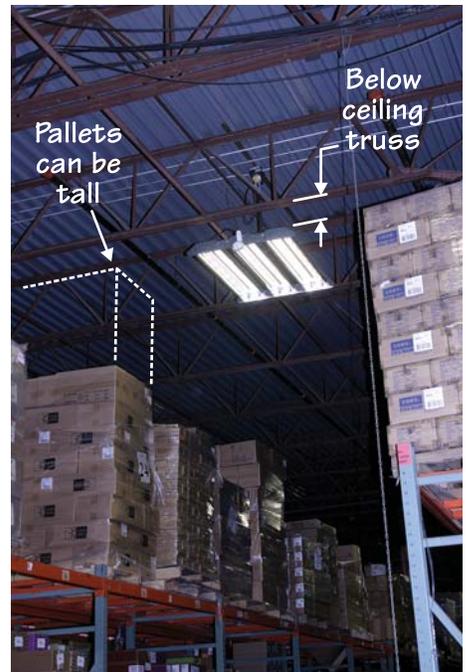
Because of the AWL's large size, it must be mounted below the roof truss structure. Therefore, in some instances, tall pallets of boxes may be difficult to move without physically contacting the luminaires. Evidence of this conflict appeared in the form of misaligned sensors, rotated luminaires, and apologetic feedback from workers.

occurred within the first year of operation. These failures may have been caused by ballast failure, relay failure, or wiring problems. Relamping did not correct these problems. New ballasts solved a few of these failures, though not all.

Lamp failures were not common within the first year of operation. Luminaires in the aisles turned on and off several times a day. However, there is less concern with premature lamp failure from frequent switching because the ballasts operating the lamps are programmed-start.

## Lighting Control Operation

The controls system successfully operated the AWL luminaires both individually and in groups. The DELTA team verified that when operating in the individual control setting, luminaires remained in sleep mode in parts of the aisle not being used, as intended.



*Slight misalignment because of shape and mounting method of AWL is shown in photo on left. Evidence of misalignment from accidental collision by normal warehouse activity is shown on right.*

*Large luminaires hanging below ceiling trusses sometimes interfered with movement of tall pallets.*

The luminaire stem length (24 in) was chosen from standard stem lengths to ensure clearance from the roof structure. A rigid stem was necessary to ensure leveling of the luminaires and sensors when hung from a single mounting point. Alternate mounting techniques could have mitigated alignment problems.

## Some Failures

Although not widespread, there were a few instances in which pairs of lamps did not operate (8 out of 135 pairs). Some failures occurred immediately upon installation; others

## Wireless Communication

Generally speaking, the wireless system was successful in controlling the luminaires from any location in the test area of the warehouse. When the DELTA team changed the lighting modes, there were some instances of unsuccessful communication. These were usually corrected by repeating the command. In some cases, these were corrected by moving to a different broadcast location. For day-to-day use of the wireless controls (e.g., grouped aisles turning to wake mode upon occupancy), the DELTA team did not observe any instances where the luminaires did not communicate to each other.



## Sensor Responsiveness

Warehouse activity in the aisles took place from the ground level up to the ceiling. Some motion sensors did not respond quickly to moving traffic on the floor. Throughout the warehouse, this aspect was tested by walking down a “sleeping” aisle in order to trigger operation in individual luminaires. Some luminaires did not turn on until experimenters walked anywhere from 5 ft to 15 ft (1.5 to 4.6 m) beyond the sensor location. Part of this delay was not because of functionality or the sensors’ sensitivity setting, but instead because of the programmed-start ballasts used to operate the T5 lamps. (Programmed-start ballasts require at least a half-second and commonly exceed a full second to start the lamp; these ballasts require 1.2 seconds for starting.) Some warehouse personnel informally commented that they noticed the delay.

## Sensor Coverage and False-offs

When the system was initially installed, the DELTA team observed a few instances of false-offs, in which the lights reduced to sleep mode when the aisle was still occupied. This usually happened when warehouse workers spent long periods of time in the upper levels of the racks. It is possible that the coverage pattern of the infrared sensors did not fully match the tall, narrow volume of occupied space. It is also possible that false-offs occurred because human movement was obstructed from the sensor’s view (such as by tall pallets of merchandise, the large forklift itself, or when climbing into racks). To minimize the disruption of possible false-offs, the system was programmed so that the luminaires never switched to lower than 1/3 light output in sleep mode. Even at 1/3 output, workers still had sufficient light to perform their tasks, since it corresponded to the amount of light they had with the previous lighting system.<sup>6</sup> (See photometric measurements on page 5.) Even at the 1/3 sleep mode, a false-off was nonetheless noticeable to workers. The DELTA team observed the distraction experienced by a worker who was quietly performing data entry at a central computer. Her movements did not trigger an occupancy signal because they were small finger movements and were far from the sensor.

## Sensitivity

In response to false-offs and sensor delays, Watt Stopper personnel increased the controls’ sensitivity to occupancy. This adjustment was performed using the laptop-enabled wireless controls software, without having to physically access each sensor. The problem with increased sensitivity, however, was that the coverage area extended beyond the range of the aisle and into the perpendicular travel aisles. As a result, the sensors mounted closest to the travel aisles were masked to minimize false-ons from cross-traffic. Masking tape concealed half of the sensor’s cone-shaped range of sensitivity. After adjusting the sensitivity and overseeing the masking, DELTA observed only rare instances of false-ons and false-offs.

## False-ons

The masking of the sensors was successful in limiting false-ons from cross-traffic. However, DELTA observed a few other instances of false-ons in which lights were in wake mode, but it was not possible for occupancy in the aisle itself to have triggered the operation. This is not problematic for warehouse operations but does constitute missed energy savings. It is not clear what caused these occasional false-ons. The sensor may have had a “view” to traffic in a neighboring aisle through gaps in the racks.

## Maintenance Comments

A warehouse electrician was in charge of attaching the wireless controllers to the AWLs, installing them in the warehouse, reinstalling the controllers, and investigating failed lamps or ballasts. This electrician commented that he liked the quick-disconnect feature on the programmed-start T5 ballasts.

Comments from maintenance personnel about lighting quality and motion sensor behavior echoed those of the other workers. One maintenance worker commented that he liked the fact that when the power to the warehouse is interrupted, the fluorescent system restrikes instantly. This enables him to determine quickly whether the backup generator is working successfully or if the generator requires attention.

*“BIG difference... it’s like coming out of a cave! It’s definitely an improvement.”*

<sup>6</sup> Recommended practice according to IESNA’s *Lighting Handbook, 9th Edition*: 50 lx for inactive storage, 100 lx for active storage of large items, 300 lux for active storage of small items.

# Findings

## *Photometric and Energy Performance*

- New, clean T5HO AWL luminaires provided three times the light output of the existing MH high-bay luminaires at this facility, while simultaneously requiring 23% fewer watts (saving \$65 per year for each luminaire<sup>7</sup>).
- Even with frequent occupancy throughout the day, these storage aisles showed substantial energy savings from the use of both T5 fluorescent and motion sensors. Energy savings was achieved without annoying workers.
- Individually controlled luminaires were in sleep mode more often than grouped luminaires, thus increasing energy savings.

## *Worker Feedback*

- Workers preferred the AWL to the existing metal halide system in many respects, particularly when illuminances were higher.
- T5HO fluorescent was not considered to be glaring at this site, even when workers looked directly at the bare lamps of the luminaire.
- Workers were not bothered by motion sensor activity as long as the lights did not turn off while they were working in the space.
- Workers did not show a distinguishable preference for grouped vs. individual control of luminaires by motion sensors.

## *Operation*

- The large size of the AWL required it to be mounted below structural trusses, which sometimes interfered with warehouse operations.
- The wireless control system allowed motion sensors to operate luminaires either in groups or individually. The wireless system operated successfully for day-to-day operations.
- Programmed-start ballasts used with T5 lamps increased the amount of time necessary to turn on the lights. This delay was more noticeable with independent motion sensor operation than with grouped operation. Though workers at this facility did not express widespread concern about sensor delay, this may be important at other facilities.

## *Current Product Status*

- The AWL is available commercially.
- The wireless controls system is available in other Watt Stopper/Legrand products.

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<sup>7</sup> Savings based on \$0.095/kWh. Refer to table on p. 8 for more information about savings due to motion sensors.

**Field Test DELTA**

Issue 3

**T5 Fluorescent High-Bay Luminaires and Wireless Lighting Controls**

December 2008

Field Test DELTA evaluates new energy-efficient lighting products to independently verify field performance claims and to suggest improvements. A primary goal of the Field Test DELTA program is to facilitate rapid market acceptance of innovative energy-efficient technologies.

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