Dangers and Pitfalls of Installing LED Retrofit Lamps in Hazardous Locations

Increasingly, industrial facility operators with hazardous rated areas are converting from their fluorescent and high intensity discharge (HID) legacy lighting to modern solid state or Light Emitting Diode (LED) technology. The capital investment in retrofitting a hazardous location facility to LED technology can be significant. However, when the change to LED is implemented effectively, it offers a compelling return on investment (ROI) in terms of energy savings, reduced long term maintenance and improved facility safety. This paper examines one key decision in making the conversion to LED technology; the decision of using replacement Integral LED Luminaires or modifying existing legacy fixtures with LED Retrofit Kits. Performance, reliability and safety concerns will be explored, specifically comparing Integral LED Luminaires to the use of retrofit lamps in hazardous locations.

Integral LED Luminaire vs LED Retrofit Kit

An Integral LED Luminaire replaces an existing installed legacy light fixture and is engineered around the unique needs of LED technology. Delivered ready to install, it is a fully contained LED luminaire assembly including the external environmental enclosure (housing and globe assembly), electrical connectors and wiring, internal LED power supply (driver), and LED light emitters typically soldered to a circuit board (LED array).

Integrated LED Luminaires

LED Retrofit Kit

In contrast, an LED Retrofit Kit modifies an existing installed legacy light fixture from typically fluorescent or HID technology to LED technology, without replacing the legacy light fixture's enclosure. In this case the legacy lamp is replaced with an LED light subassembly or "LED lamp" that directly screws into the legacy lamp socket. The LED lamp includes the LED power supply and LED array(s). Some degree of wiring reconfiguration may be needed for the electrical supply to the socket within the legacy fixture to accommodate the electrical requirements of the LED lamp.

LED Retrofit Safety Standards

In 2010, UL added a standard (UL1598C) to allow for retrofitting older technology light fixtures with LED. CSA C22.2 No. 250.1 is the Canadian equivalent standard to

UL 1598C. These standards prohibit LED retrofitting in hazardous locations, unless the retrofit kit has been tested for compliance for use in a specific luminaire per UL844 (Standard for Luminaires for Use in Hazardous (Classified Locations) or CSA C22.2 No. 137 (Electric Luminaires for Use in Hazardous Locations). Hazardous locations are defined as areas where fire or explosion hazards may exist due to flammable gases, liquids and vapors, combustible dust or ignitable fibers and flyings.

Our earlier whitepaper LED Retrofit Kits in Hazardous Locations addressed the requirements for utilizing retrofit kits in hazardous locations, as well as how to look up a retrofit kit's certification limitations. At the time of its release, there were very few retrofit lamps certified for use in a hazardous location.

For the purpose of this paper, Emerson's engineering team evaluated 5 units of a 24W LED lamp. The lamp is advertised as a 150W HID equivalent, listed with a certification for Class I Division 2 suitability for use in several hazardous location HID luminaires. The 24W LED lamps were installed in the Appleton™ Mercmaster™ HID luminaires and the appropriate modifications were made to the luminaire per the lamp manufacturer's instructions. Temperature, photometric, and electrical surge data was collected. This paper addresses problems with these lamps that may be similar with other LED retrofit lamps on the market today.

In this brief, we will look in depth at:

- Retrofit lamp lumen output claims and how they relate to luminaire performance
- The effects of "active cooling and dynamic temperature control" on light output
- Illumination standards and code concerns that may result from use of a retrofit lamp
- Reliability factors influencing product lifespan
- Risks and certification impacts associated with fixture modifications

What are the current code requirements?

To be approved for use in a hazardous location, a retrofit kit must be tested for compliance to hazardous location luminaire standards (UL 844 "Standard for Luminaires for Use in Hazardous Locations" or CSA C22.2 No. 137 "Electric Luminaires for Use in Hazardous Locations") and certified for use with a specific fixture manufacturer and model. Included in this certification will be established hazardous location temperature classification codes (T-Codes), which are critical to verifying product suitability for a particular hazardous location environment. In addition, for a Class I, Division 2 rating the retrofit kit components must be determined to be non-arcing and non-sparking. These retrofit kits will include new labels, updating the certification of the retrofitted luminaire, including the lamp manufacturer's name and certification file number, electrical parameters, new hazardous classification, and new maximum ambient temperature. This new label must be applied to the retrofitted luminaire.

Does the "LED Retrofit Lamp" meet the UL requirements?

The lamp used in our evaluation is cULus listed for Class I Division 2 suitability for three manufacturers' HID fixtures. However, it is important to note that the original HID fixtures that this lamp is certified to retrofit were also certified for Class II (dust) environments. Unless the LED lamp carries with it a retrofit certification that extends to Class II (and the tested sample did not), luminaires retrofitted will not be certified for Class II suitability. As of the date this study was written, no LED retrofit lamp was certified for Class I Division 1 or Class II environments.

Determining LED Equivalencies for HID Luminaires

In retrofit applications, the appropriate lumen output of a new LED luminaire is often a source of confusion. HID and LED luminaires have several key technological differences that result in lower lumen output needs for a replacement LED luminaire than its HID counterpart.

Emerson has developed a guideline for LED lumen equivalencies for HID retrofits, found in Table I. Utilizing these guidelines helps to ensure that illumination will adequately cover the demands of the original HID lighting application. Another "rule of thumb" practice is to use 1/3 of the HID wattage as the targeted LED wattage.

Both lumen and power guidelines are estimates, and the best way to analyze a retrofit solution is with a lighting

HID Equivalent	LED Lumen Range	Power Consumption (Watts)
70 Watt	2000 – 3000	23
100 Watt	3000 – 4000	33
150 Watt	4000 – 5000	50
175 Watt	5500 – 7000	58
250 Watt	8000 – 10000	83
350 Watt	10000 – 12000	116
400 Watt	12000 – 14000	133
600 Watt	16000 – 18000	200
750 Watt	18000 – 20000	250
1000 Watt	24000 – 26000	333
1250 Watt	29000 - 31000	417
1500 Watt	37000 - 39000	500

Table 1 HID Equivalency Estimates

simulation indicating illuminance that can be compared to required levels. Differences in optical designs and fixture efficacy will have a significant impact on the lumen output and power consumption needed for a suitable retrofit. A well-designed optic with newer, high efficacy LEDs will reduce the amount of light and energy required.

Relative and Absolute Photometry

Photometric measurements for luminaires with traditional sources (lamp type luminaires such as high- pressure sodium or mercury vapor) were commonly relative. Relative photometry is based on providing the light output measurement of a lamp in isolation as well as the lamp as part of a luminaire system. The optical efficiency of the luminaire is calculated as the quotient of the luminaire output and the lamp output:

Optical Efficiency =
Luminaire Luminous Flux/ Lamp Luminous Flux

By doing this, optical losses from reflectors, refractors, globes, etc. are identified, and consequently, the effects of increasing or decreasing lamp wattage can be easily predicted. For example, the lamp output of a typical 150W high pressure sodium lamp is approximately 15,800 lumens. After optical losses, the total lumen output of an Appleton Mercmaster III with a standard glass globe is reported at 13,611 lumens. Adding a reflector reduces the total lumen output further to 11,630. This equates to optical efficiencies of 86% and 74%, respectively.

The Illuminating Engineering Society (IES) testing standards for LED lighting today require that manufacturers of LED luminaires provide photometric data based on absolute, as opposed to relative photometry. Absolute photometry provides the lumen output of a specific luminaire as measured by a goniophotometer. Since the entire luminaire system is considered every time, optical efficiency is 100%. In the case of a retrofit lamp, it is important to recognize that the advertised light output is that of the lamp, not the retrofit luminaire, and optical losses must be taken into consideration.

Fixture Lumens Measured 39% below Advertised Lamp Output

The retrofit lamp tested for this study has a published rated lumen output of 3425 lumens. This is claimed by the manufacturer to be enough to convert HID luminaires rated up to 150 watts to energy efficient LED technology. As previously explained, this stated lumen output is the luminous flux of the lamp alone. Note that all existing HID hazardous location luminaires require the use of a globe or refractor over the lamp.

The lumen output considered for comparison in any lighting study needs to be one that includes this globe and all other optical losses inherent in a HID luminaire. (By comparison, Emerson's LED lumen output specifications are absolute goniophotometer measurements, provided at the luminaire level with a globe installed.)

To test the photometric performance of the LED retrofit lamp, Emerson installed the lamp in a HID luminaire with a glass globe, per the lamp manufacturer's instructions.①

Each of the five LED retrofit lamps were tested in the same way, with resultant measured lumen outputs of 2133 lumens, 2125 lumens, 2068 lumens, 2080 lumens, and 2076 lumens. The mean lumen output of 2096 lumens equates to a luminous efficiency of 61% and is 39% below the lumen output of the LED lamp alone provided in the manufacturer's literature. This lumen difference between the lamp and the luminaire output is expected and significant.

In comparison, Integral LED Luminaires on the market offer lumen outputs ranging from 3,000 – 5,500 lumens for 70W to 150W equivalencies under the same testing conditions. This is up to 2 ½ times more light than the tested LED retrofit lamp solution, which the manufacturer claims as an equivalent for 150W HID fixtures. Table 2 provides the LM79 goniophotometer test data for the LED retrofitted luminaires and several Integral LED alternatives.

Model	Luminous Flux (Lumens)	Power Consumption (Watts)
Retrofit Luminaire #1 with Globe	2133	23.46
Retrofit Luminaire #2 with Globe	2125	23.48
Retrofit Luminaire #3 with Globe	2068	23.37
Retrofit Luminaire #4 with Globe	2080	22.89
Retrofit Luminaire #5 with Globe	2076	22.78
MLLED2CD5BU 70W Equivalent with Diffused Globe	3150	26.7
MLLED3CD5BU 100W Equivalent with Diffused Globe	4259	36.5
MLLED4CD5BU 150W Equivalent with Diffused Globe	5199	47
VMV3L2AUNV1S891 70-100W Equivalent with Diffused Globe	3004	25.6
VMV5L2AUNV1S891, 100-150W Equivalent with Diffused Globe	4908	39.7

Table 2 Light Output, Power Consumption, and Efficacy Comparison of Various Retrofit Alternatives

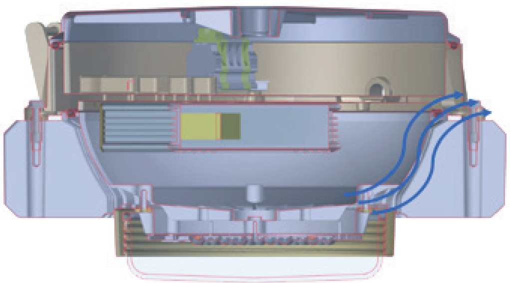


Figure 1, Heat removal illustration for an integral LED luminaire

What is "Advanced" Cooling and Dynamic Temperature Control?

Any light producing device produces heat. Solid state lighting designs employ the use of metal heat sinks to conduct heat away from sensitive components such as LEDs and power supplies. Special attention to creating efficient thermal designs results in luminaires that will operate reliably for the life of the luminaire, even in elevated ambient environments. Figure 1 illustrates the flow of heat away from the LED array board in the Appleton Mercmaster Low Profile LED luminaire.

Traditional HID luminaires were not designed with LED use in mind, and therefore do not employ the same heat-sink methodologies. In order to make up for this lack of heat sinking, retrofit lamp solutions must utilize alternative methods to prevent LEDs from overheating. One such method is known as dynamic temperature control, or alternatively can be described as, active cooling or thermal foldback. This design approach implements a feedback loop to monitor the heat in the lamp, and reduce the current supplied by the driver in an attempt to prevent premature failure. The result of this procedure is reduced light output in elevated ambient temperature environments. For this reason, active cooling poses concerns with regards to safe illumination levels and is not allowed in many refineries.

Tests Indicate Significant Light Output Reduction above 77°F

In order to test the effects of dynamic temperature control, the Emerson team monitored luminaire power consumption and light output under controlled elevated ambient temperatures in the retrofitted fixtures with the LED lamp installed. Changes in lumen output can be directly calculated based on observed cut-backs in current (and power consumption). Following stabilization (at 25°C), the ambient air temperature was increased, monitoring three samples simultaneously. The results are provided in Table 3.

As expected, the use of thermal fold-back in the lamp's "dynamic cooling system" resulted in a steady reduction in power consumption as the ambient temperature was elevated. Assuming light output at stabilization temperature of 25°C (77°F) as our baseline, the results

Test Chamber Ambient (°C/°F)	Light Output (%)	Luminaire #1 (Volts)	Luminaire #1 (Amps)	Luminaire #1 (Watts)	Luminaire #1 Globe Temp. (°C)	Luminaire #2 (Volts)	Luminaire #2 (Amps)	Luminaire #2 (Watts)	Luminaire #2 Globe Temp. (°C)	Luminaire #3 (Volts)	Luminaire #3 (Amps)	Luminaire #3 (Watts)	Luminaire #3 Globe Temp. (°C)
18.1 / 64.6	109.9	120.0	0.2045	24.05	18.1	120.0	0.2111	24.71	18.1	120.0	0.2084	24.56	18.1
19.2 / 66.6	108.6	120.0	0.2010	23.72	19.6	120.0	0.2097	24.58	19.5	120.0	0.2067	24.42	19.5
19.7 / 67.5	106.8	120.0	0.1993	23.54	21.1	120.0	0.2068	24.29	21.2	120.0	0.2039	24.13	20.9
20.1 / 68.2	105.7	120.0	0.1981	23.40	23.1	120.0	0.2052	24.12	23.6	120.0	0.2025	23.97	23.3
21.1 / 70.0	104.7	120.0	0.1963	23.19	28.4	120.0	0.2027	23.84	29.9	120.0	0.2002	23.71	29.0
23 / 73.4	101.7	120.0	0.1939	22.93	34.8	120.0	0.2003	23.59	36.7	120.0	0.1982	23.40	36.2
23.7 / 74.7	101.3	120.0	0.1939	22.87	36.4	120.0	0.1998	23.55	38.2	120.0	0.1980	23.46	37.8
25.4 / 77.7	100.0	120.0	0.1921	22.68	39.6	120.0	0.1989	23.44	41.3	120.0	0.1972	23.37	41.2
27.6 / 81.7	98.7	120.0	0.1902	22.49	42.8	120.0	0.1979	23.32	44.4	120.0	0.1964	23.28	44.5
29.5 / 85.1	97.8	120.0	0.1901	22.49	45.4	120.0	0.1977	23.31	47.1	120.0	0.1958	23.22	47.5
37.3 / 99.1	90.7	120.0	0.1775	20.99	53.7	120.0	0.1795	21.14	55.0	120.0	0.1772	21.00	55.7
41.3 / 106.3	85.5	120.0	0.1652	19.53	56.5	120.0	0.1670	19.67	57.8	120.0	0.1649	19.53	58.5
45.3 / 113.5	80.2	120.0	0.1528	18.06	59.3	120.0	0.1544	18.19	60.5	120.0	0.1525	18.06	61.2
50.4 / 122.7	70.0	120.0	0.1407	16.62	63.3	120.0	0.1437	16.92	64.3	120.0	0.1398	16.54	64.7
55.2 / 131.3	62.6	120.0	0.1253	14.78	67.4	120.0	0.1295	15.23	68.1	120.0	0.1242	14.67	68.6
Note: sum of light from 3 luminaires measured simultaneously.													

Table 3 Ambient vs Light Output Test for Retrofit HID Luminaire with Glass Globe

Ambient Temperature (°C/°F)	Expected Retrofit Luminaire Output (lumens)
25 / 77	2096
30/ 86	2050
37 / 99	1901
41 / 106	1792
45 / 113	1681
50 / 122	1467
55 / 131	1312

Table 4 Ambient Temperature vs Expected Retrofit Luminaire Output

indicated a slight reduction in light output from 25° to 30°C (77° to 86°F) of less than 3%. However, at 40°C the lamp output had decreased by 15% and by 55°C (104°F) the lamp output was a mere 62.6% of its 25°C (77°F) value. Applying this to our baseline 2096 lumen output (previously established) for the retrofit luminaire we would expect the lumen outputs shown in Table 4.

The results of this experiment indicate that at 30°C (86°F), the LED luminaire modified with the retrofit lamp will provide a light output less than 60% of its advertised 3425 lumens. At 41°C (106°F) the provided light output approaches 50%. Why is this significant? Because a typical summer day on the street in Houston, Texas can easily surpass 90°F, let alone inside an operating petrochemical or chemical processing plant. The average summer temperature in Saudi Arabia is 45°C (113°F), but temperatures of up to 54°C (129°F) are not unusual. At 55°C (131°F), the LED retrofit solution performs slightly better than some industrial flashlights.

Utilization of Fans to Aid in Solving Thermal Challenges

Some LED retrofit lamps, such as the one tested, may rely on a simple fan that is required to run non-stop to keep the lamp cool. But such cooling implementation comes with various disadvantages.

Unfortunately, dirty industrial environments can compromise fan operation, and most facility managers and electricians recognize fans for what they are: yet another potential failure point in a system.

To simulate a dirt clogged fan, the Emerson engineering team applied tape to the vents to restrict air flow. The retrofit luminaire light output dropped to an average of 1617 lumens with the tape applied at a 23.9°C ambient temperature.

Integral LED Luminaires from major manufacturers do not employ fans, and use of active thermal foldbacks can be mitigated with effective thermal design.

Omni Directional Lamps Provide Inefficient Distribution of Light

Luminaires that employ lamps, such as incandescent and high intensity discharge, produce an omni- directional spread of light. Some of the light is applied where needed, but a portion of the light is wasted. One consequence of this light distribution is that more lumens are needed to reach the desired levels of illumination on the work surface.

This can be seen in the polar candela distribution and zonal lumen summary for a 150W HPS Mercmaster III luminaire, shown in Figure 2 and Table 5 ② As indicated in the zonal lumen summary, 38.6% of the light output is lost

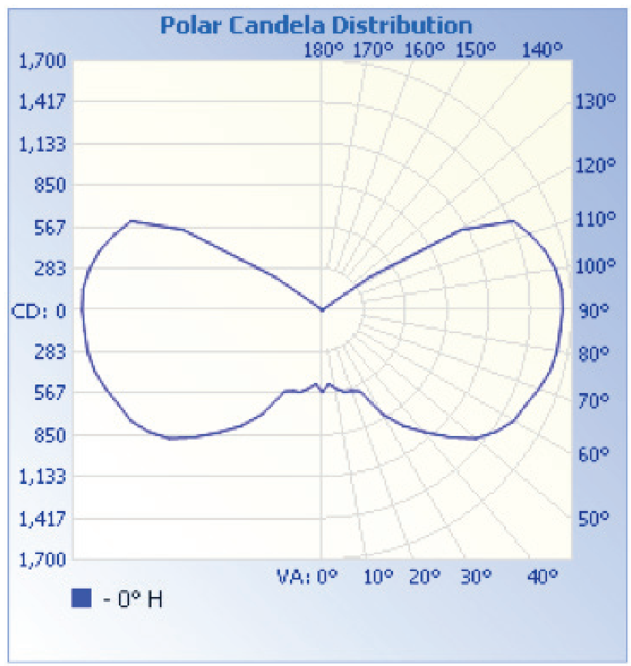


Figure 2 Polar Candela of Appleton 150W HPS

Zonal Lumen Summary			
Zone	**Lumens**	**% Lamp**	**% Luminaire**
0-30	520.5	3.3%	3.6%
0-40	1,125.3	7.1%	8.3%
0-60	3,367.9	21.3%	24.7%
60-90	4,994.9	31.6%	36.7%
70-100	5,251.4	33.2%	38.6%
90-120	4,799.0	30.4%	35.2%
0-90	8,362.8	52.9%	61.4%
90-180	5,252.2	33.2%	38.6%
0-180	13,615.0	66.2%	100.0%

Table 5 Zonal Lumen Summary of Appleton 150W HPS

to up-light, with only 24.7% of the total light output landing within the 0-60° beam. Furthermore, nearly 37% of the light output of this luminaire falls between 60 and 90°; the primary area where glare is produced.

LED retrofit lamps, commonly called "corn cob lights," produce an omni-directional spread, similar to traditional lamps. As shown in Figure 3 and Table 6, the distribution of the light is similar, although the total luminous flux (light output) is significantly less. This results in an unfocused, 360° distribution, losing over 35% of the light produced above the 90° horizontal plane.

Like the HID solution, 30% of the light output is directed in the 60-90° zonal range, increasing the incidence of discomfort glare. At 25°C (77°F) only 1,614 lumens are directed downward, with a mere 823 lumens in the 60° beam angle.

The Appleton 150W equivalent LED luminaire solution, as shown in Figure 4 and Table 7, is specifically designed to optimize the distribution of light, delivering 4,081 lumens of downlight (83.5% of the total luminous flux) with over 3,300 lumens landing within the 0-60° beam. That's roughly equivalent to the 150W HID solution (3,367 lumens in the 60° beam) and four times as much light than that delivered with the LED lamp retrofit solution (823 lumens).

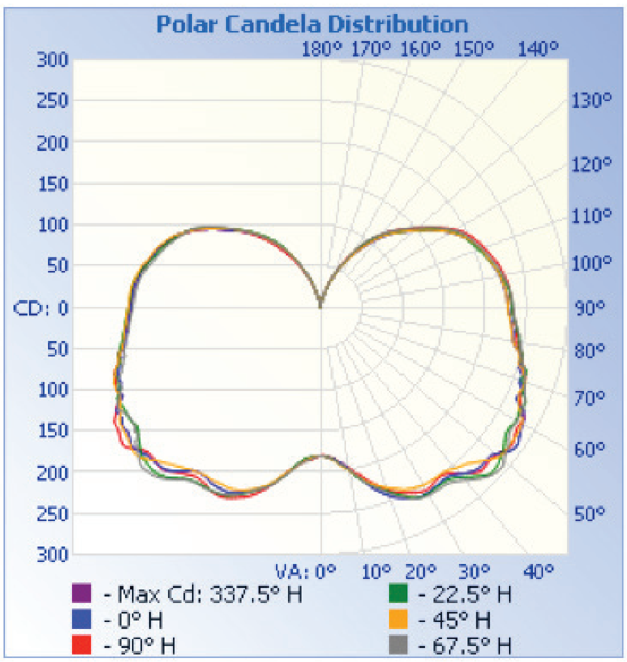


Figure 3 Polar Candela with LED Retrofit Lamp

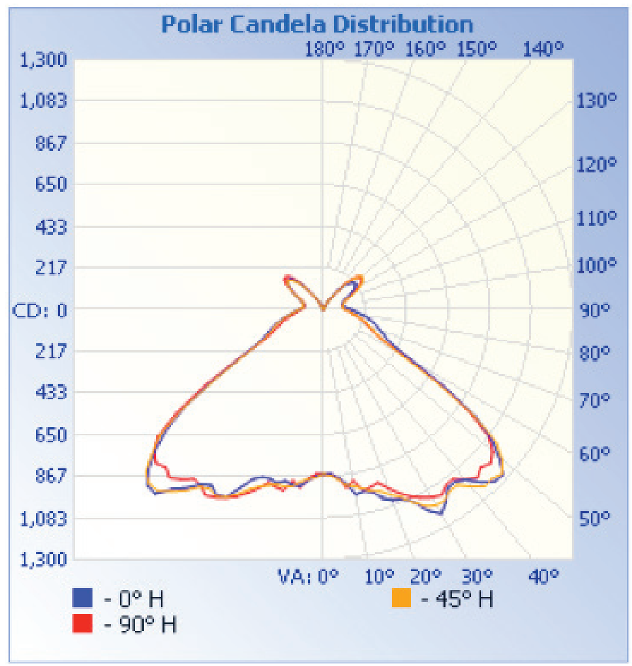


Figure 4 Polar Candela of Appleton MLLED4CJ5BU

Zonal Lumen Summary		
Zone	Lumens	% Luminaire
0-30	195.9	7.5%
0-40	357.4	13.6%
0-60	823.0	31.3%
60-90	790.8	30.1%
70-100	772.4	29.4%
90-120	671.6	25.6%
0-90	1,613.8	61.5%
90-180	1,012.1	38.5%
0-180	2,626.0	100.0%

Table 6 Zonal Lumens LED Retrofit Lamp

Zonal Lumen Summary		
Zone	Lumens	% Luminaire
0-30	858.1	17.6%
0-40	1,584.0	32.4%
0-60	3,331.1	68.2%
60-90	750.1	15.4%
70-100	529.0	10.8%
90-120	372.5	7.6%
0-90	4,081.2	63.5%
90-180	805.3	16.5%
0-180	4,886.5	100.0%

Table 7 Zonal Lumen Summary Appleton MLLED4CJ5BU

	0-30 Lumens	0-60 Lumens	0-90 Lumens	90-180 Lumens	0-30 %	0-60 %	0-90 %	90-180 %
150W Equivalent LED Retrofit Lamp	195.9	823	1613.8	1012.1	7.5	31.3	61.5	38.5
Appleton Mercmaster 150W LED Equivalent	858.1	3331.1	4081.2	805.3	17.6	68.2	83.5	16.5
Appleton Mercmaster 150W HPS	520.6	3367.9	8362.8	5252.2	3.8	24.7	61.4	38.6

Table 8 Comparison of Zonal Data

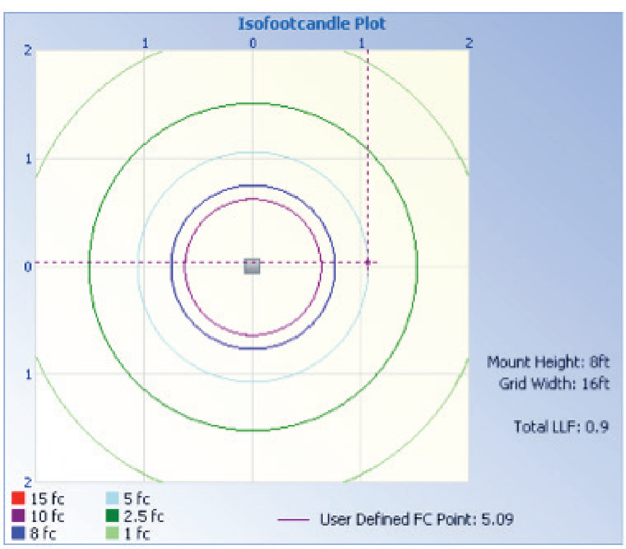
Table 8 provides a summary comparison of the photometric properties of the LED equivalent retrofit lamp, the Appleton Mercmaster LED 150W equivalent luminaire, and the original 150W High Pressure Sodium luminaire. Although the light distribution of the 150W HPS and the retrofitted luminaire are similar (comparing the lumen percentages by zone), the illumination from the LED lamp solution falls far short of equivalent of equivalent illumination, especially where it is needed most, in the 0-60° zone.

Light Output Fails to Meet IES and API RP540 Standards

One of the biggest challenges in lighting industrial areas is achieving balanced illumination. With uniform brightness, a space is optically larger, safer and more productive. When light is poorly distributed, dark areas result that limit vision and can lead to eye fatigue and lowered productivity. In hazardous locations, where the smallest mistake can escalate into a disaster, poor distribution of light can be far more dangerous.

The purpose of lighting standards is to provide guidance on minimum illumination levels necessary to ensure safe work environments. For example, the standards for lighting in the IES Handbook and in API RP540 (American Petroleum Institute Recommended Practice for Electrical Installations) recommend five foot-candles (FC) of average maintained illumination in standard walkway passages. To meet this requirement, the plants have historically hung 70-100W task fixtures 15 feet apart and between 7 to 10 feet high on a typical 3 feet wide catwalk. Areas where process work is occurring, or measurements taken, will typically require higher levels of illumination.

As shown in Figure 5, a traditional Appleton Mercmaster III 70W HPS luminaire, with a dome reflector to direct the light, is able to provide a 16 foot diameter 5 foot-candle circle of illuminance to the walkway, just meeting the typical requirements. Unfortunately, dome reflectors are often broken and thrown away over time. As shown in the plot to the right, without the dome reflector, a typical 70W HPS luminaire is only able to deliver 3 foot-candles to the ground at a distance of 8 feet from directly under the fixture.



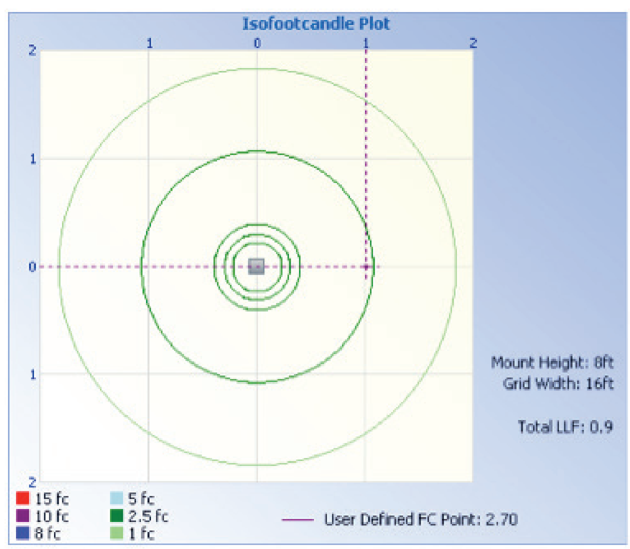


Figure 5 Plot of Appleton 70W Mercmaster III 70W HPS Luminaire with(left) and without (right) dome reflector

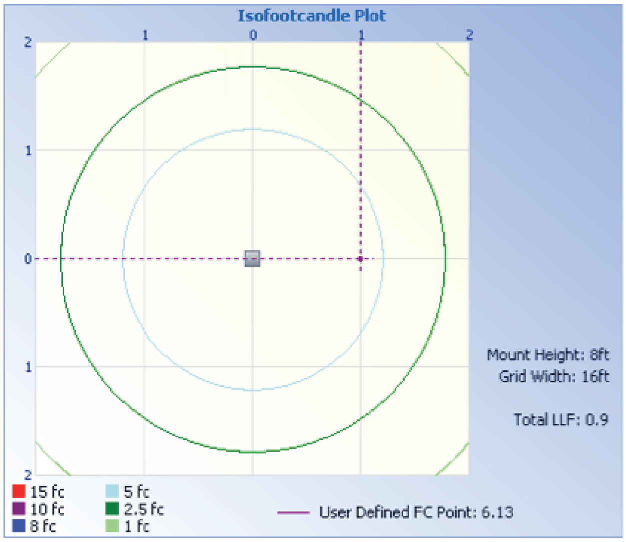


Figure 6 Plot with Appleton 150W HPS

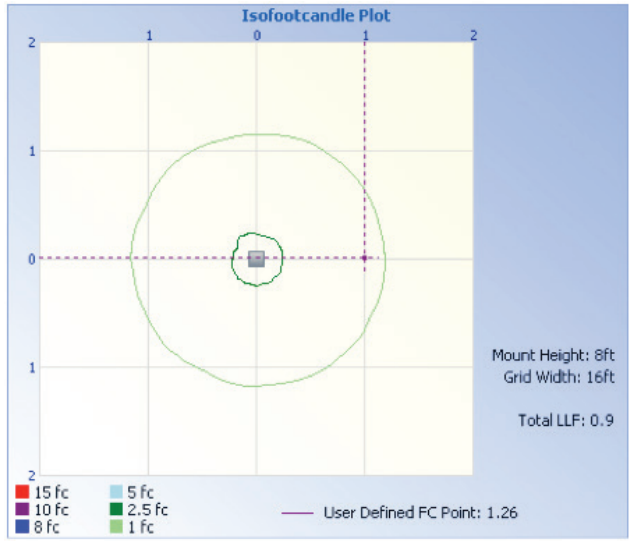


Figure 7 Plot with L ED Retrofit Lamp

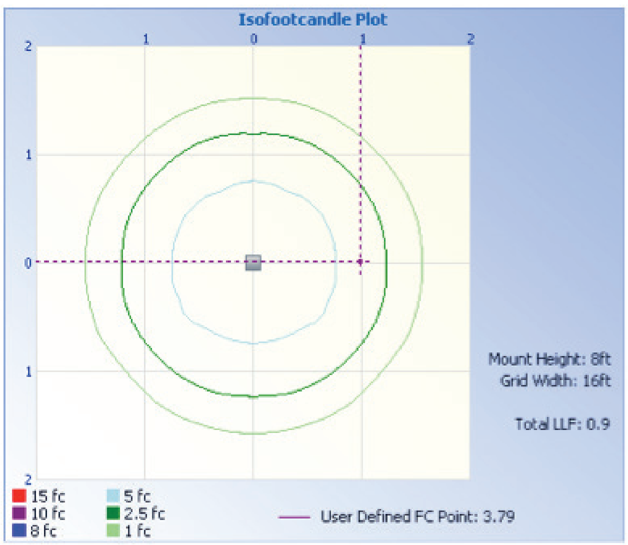


Figure 8 Plot of Appleton MLLED2CJ5BU (70W equiv)

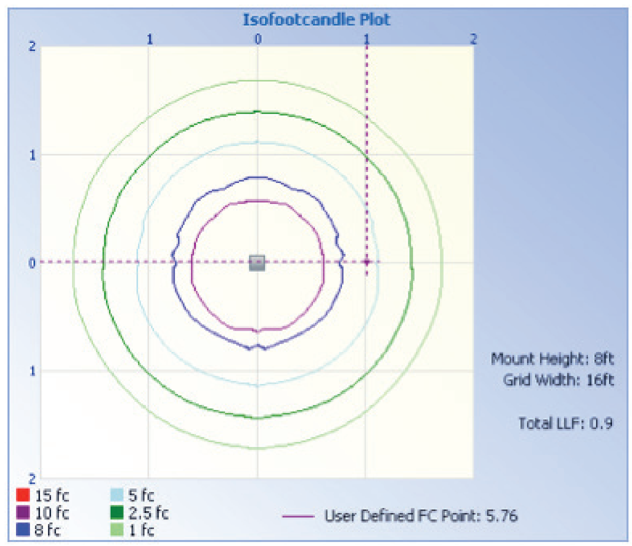


Figure 9 Plot of Appleton MLLED4CJ5BU (150W equiv)

Since the LED retrofit lamp claims to be suitable for the replacement of 150W Appleton luminaires, a similar plot is provided in Figure 6, using the photometric files from a 150W HPS Appleton Mercmaster luminaire at a mounting height of 8 feet.

As shown in the simulated plot, the 150W HPS luminaire (without a reflector) would deliver an approximately 20 foot diameter circle with illuminance levels of 5 foot-candles or above. Comparatively, the resultant illuminance with the retrofit lamp is shown in Figure 7. This solution produces a maximum of 2.5 foot-candles of light directly under the luminaire. While this illuminance is 50% below the requirement, the performance eight feet out is significantly worse; delivering a mere 1.26 foot-candles of light.

Alternatively, the Appleton 70W and 150W LED equivalent solutions are shown in Figures 8 and 9 respectively.

The 70W equivalent luminaire delivers an approximate 12 foot diameter, 5 foot-candles circle of light, and the 150W equivalent luminaire an approximate 18 foot diameter of 5 foot-candles level illumination, matching the 150W HPS luminaire.

Ground Illuminance at 8 Foot Mounting Height	Illuminance under fixture	Illuminance 4 feet from Center	Illuminance 8 feet from Center
70W HPS with Reflector	15 FC	12 FC	6 FC
150W HPS without Reflector	8 FC	7 FC	6 FC
Appleton 70W LED Equivalent (no reflector)	7 FC	7 FC	4 FC
Appleton 150W LED Equivalent (no reflector)	12 FC	11 FC	6 FC
150W Equivalent LED Retrofit Lamp	3 FC	3 FC	1 FC

Table 9 Illuminance Comparison

Outdoor walkway, approximately 3 feet wide, with fixtures hung 8 feet high and 15 feet apart.

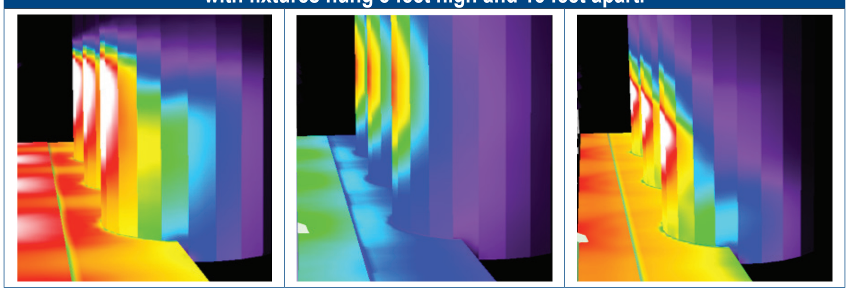


Figure 10 Luminaires Left to Right: 70W HPS, 24W LED Retrofit, 24W Mercmaster LED Low Profile with Prismatic Refractor

Outdoor walkway, approximately 3 feet wide, with fixtures hung 8 feet high and 15 feet apart.

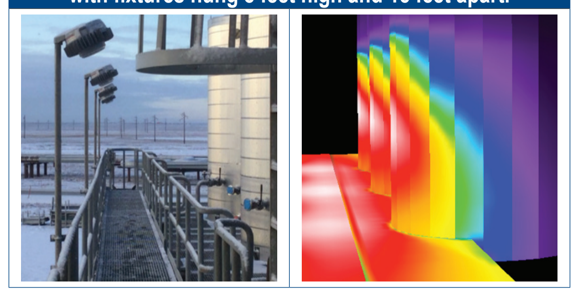
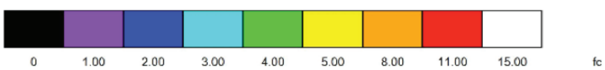


Figure 11 Walkway Application with Type I, 30W Mercmaster Generation 3 LED Luminaires



Luminaire Used	Minimum Illuminance (FC)	Maximum Illuminance (FC)	Average Illuminance (FC)	Uniformity Min/Max (FC)
70W HPS with Dome Reflector	8.9	14.0	11.0	0.7
Retrofit with 24W LED Lamp	3.0	3.7	3.3	0.8
Mercmaster LED Low Profile 24W Luminaire with Refractor	8.0	9.5	8.6	0.9
Mercmaster Gen 3 LED 30W with Type I Optics	12.0	14.0	13.0	0.9

Table 10 Comparison of Illuminance Results for Walkway Application

The comparison of the Isofootcandle plots is shown in Table 9.

In order to determine how well the LED lamp retrofit solution would perform against the standards identified above, Emerson used DIALux®, a popular lighting software package, to simulate commonly found applications ③.

The first simulation is an outdoor walkway, approximately 3 feet wide, with fixtures hung 8 feet high and 15 feet apart. The simulation results are illustrated in the false color renderings shown in Figure 10 and summarized in Table 10. The 70W HPS Mercmaster luminaire with a dome reflector exceeds the required illuminance target, with a minimum illuminance of 8.9 foot-candles. The 24W Mercmaster LED Low profile (70W equivalent Integral LED Luminaire) similarly provides a minimum of 8.0 foot-candles of light to the walkway, with improved uniformity, and a reduction in hot spots. The 24W LED retrofit lamp solution fails to meet the target, providing a minimum illuminance on the walkway of only 3 foot-candles. At 25°C, this solution falls 40% short of the required illuminance. This illuminance will fall by another 20%, at the rated 45°C (113°F) to 2.4 foot-candles, based on the testing presented earlier in this paper.

Another option available with an integral LED design is to incorporate secondary optics to direct the light where specifically needed. Emerson offers Type I optics that are designed to meet the needs of walkway lighting. As shown in Figure 11, the 30W, Mercmaster Generation 3 LED provides a minimum of 12 foot-candles of illumination for this application with a min/max uniformity of 0.9.

Underneath a pipe-rack, with fixtures hung 12 feet high and 15 feet apart.

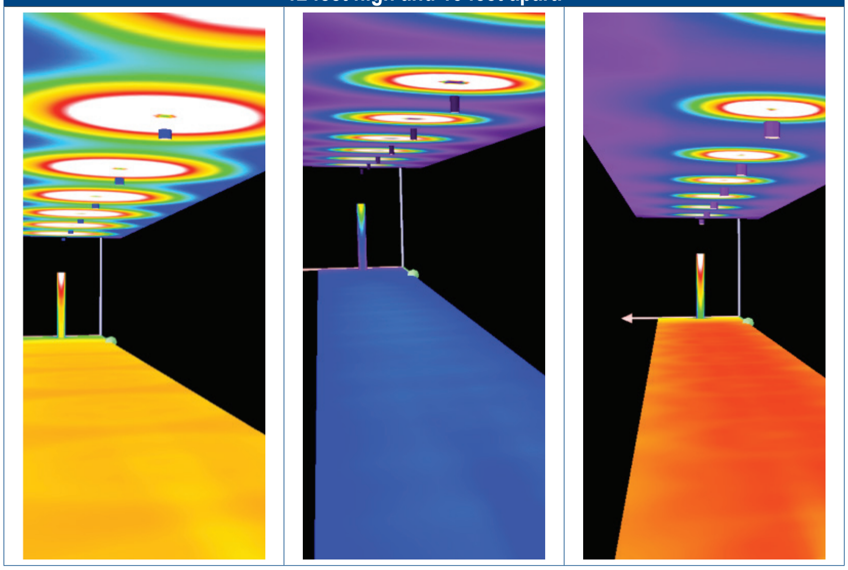
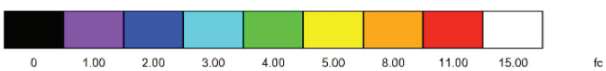


Figure 12 Pipe-rack Application Comparing (left to right) 150W HPS, LED Retrofit Lamp, and 48W (150W equivalent) Mercmaster LED Low Profile Luminaires



Underneath a pipe-rack, with fixtures hung 12 feet high and 15 feet apart.

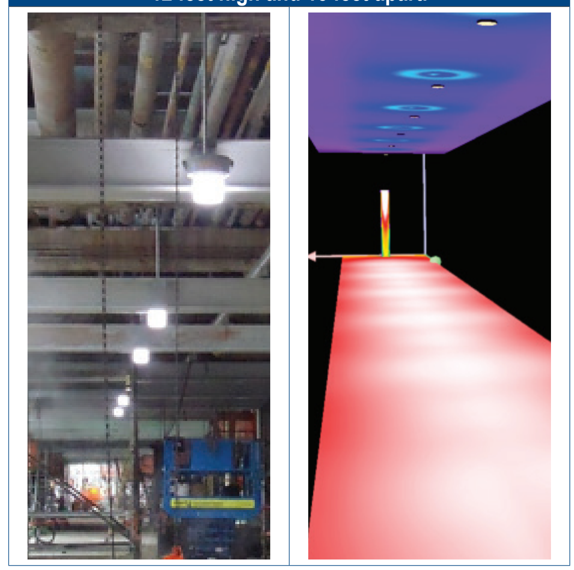


Figure 13 Pipe-rack Application with a 48W (150W equivalent) Mercmaster LED Low Profile Luminaire with Refractor Replaced with Diffused Polycarbonate Globe

Luminaire Used	Minimum Illuminance (FC)	Maximum Illuminance (FC)	Average Illuminance (FC)	Uniformity Min/Max (FC)
150W HPS	7.0	7.8	7.4	0.9
Retrofit with 24W LED Lamp	2.2	2.4	2.3	0.9
Mercmaster LED Low Profile 48W Luminaire with Prismatic Refractor	9.0	9.9	9.5	0.9
Mercmaster LED Low Profile 48W Luminaire with Diffused Globe	13.0	15.0	14.0	0.9

Table 11 Comparison of Illuminance Results for Pipe-rack Application

The second typical application that we simulated was underneath a pipe-rack, with luminaires mounted 12 feet high and 15 feet apart, shown in Figure 12. Again, the targeted illumination per IES guidelines and API RP540 is 5 foot-candles.

The original 150W HPS luminaire installation delivered a minimum illuminance of 7.0 foot-candles. Comparatively, the LED retrofit lamp and 150W Equivalent (48W) Mercmaster LED Low profile with a prismatic refractor deliver minimum illuminance of 2.2 and 9.0 foot- candles, respectively. The LED lamp retrofit solution simply does not have enough light output to deliver the required illumination in this 150W HPS application. In this application some up-light is desired in order to illuminate overhead obstructions.

For applications requiring more illumination on the ground, a diffused globe can be used in place of the prismatic refractor, reducing the up-light and delivering nearly 50% more downward light. This simulation is shown in Figure 13 (results are summarized in Table 11).

LED Life, Beyond L70

In a recent study of industrial LED users conducted by Emerson and *Electrical Construction & Maintenance* magazine, 46% of the respondents expressed past experience with LED product failures. The LED retrofit lamp under evaluation advertises rated life of 50,000 hours based on a reported L70 per IES-TM21 (compared to a lamp life span of 24,000 hours for high pressure sodium). Although we have not tested the LED retrofit lamp for 50,000 hours, we note certain concerns about this claim.

IES-TM21 is intended to provide a method for estimating LED lumen depreciation over time for a given temperature in a controlled environment, in order to provide an L70 (the number of hours to reach 70% of initial LED light output). TM21 accounts for LED lumen depreciation ONLY and does not consider luminaire design or driver component selection, which can greatly impact luminaire life. Is LED lumen depreciation an accurate portrayal of reliability when the number one cause of light failure comes from the LED driver and not the LEDs? In fact, L70 alone is not an accurate indication of luminaire life, or in this case, LED lamp life.

In the industry study, 26% of the failures experienced were attributed to heat. The LED retrofit lamp manufacturer makes no reference to ambient temperature with regards to their rated life claims. Is the manufacturer's 50,000 hour claim based on a fixture ambient of 25°C, 45°C, or some other temperature? Unlike integral LED luminaire products that are designed with custom heat sinks, engineered to optimize thermal performance and pull heat away from sensitive electronic components, a socket-based LED lamp product has limited ability to shed heat away from the LEDs.

Some might believe that the internal fan in the retrofit lamp does an adequate job of "actively cooling the lamp" to extend life. Consider however, the dirt and grime present in a typical industrial facility. Any build-up of dirt on the fan vents will compromise the operation of the fan, and a failure of this device will quickly result in elevated internal temperatures and premature lamp failure.

LED Retrofit Lamp Solution Lacks Adequate Surge Protection

In the same industry study, another 14% of the failures end users experienced were caused by electrical surges. Electrical surges and transients are common in industrial environments. In addition to indirect lightning strikes, electrical equipment such as blowers, welding machines, HID luminaires, pumps, and compressors, can induce transients in the AC power lines, damaging LED lighting systems, which are susceptible to both differential and common mode transients. In response to solid state design failures, the IEEE developed recommendations for testing LED luminaires for reliability against these electrical disturbances. The IEEE recommendations were then adopted by ANSI, the DOE, and NEMA as standard practice for outdoor luminaires.

ANSI C136.2-2018 was updated in 2018 and revised test procedures for evaluating outdoor luminaires classified for operation up to 600V. According to Kevin Fitzmaurice, Principal, Lighting & Smart Services, Georgia Power and Chair of ANSI Committee for Outdoor Lighting (C136), "C136.2 contains minimum performance requirements and test procedures for evaluating luminaire and control devices under test (DUTs) for dielectric withstand and electrical transient immunity."

This ANSI standard divides outdoor luminaires into risk categories: typical, enhanced, and extreme with requirements of 6kV/3kA, 10kV/5kA, and 20kV/10kA respectively. The standard also requires that a luminaire withstand 40 strikes at the specified level and details the testing methodology.

Due to size constraints in retrofit lamps, surge protection is often lacking. The tested 24W LED retrofit lamp specified 10kA surge protection in their literature (no voltage specified). The Emerson engineering team tested 2 lamps per the ANSI C136.2-2018 procedure for typical risk (6kV/3kA) with both lamps failing; lamp 1 at 3.5kV and lamp 2 at 3kV. Manufactures offering hazardous location Integral LED Luminaires for retrofit applications are able to provide 6kV surge protection for typical risk, with some models offering enhanced protection.

Read the Fine Print

It is interesting to note that although the manufacturer advertises a 5-year warranty on their brochure, the fine print in their terms and conditions clarifies that this warranty applies to operation less than 12 hours per day, with warranty reduced to 3 years for more than 12 hours a day of operation. Comparatively, many hazardous location LED luminaire manufactures provide a warranty that covers a minimum of 5 years of operation, regardless of the number of hours used per day.

Gaskets are Key to Retaining Hazardous Seals

In a hazardous location, it is important to consider the ballast body housing condition; particularly as it relates to the gaskets. Enclosed and gasketed luminaires depend on the integrity of the silicon gaskets to insure safety in a hazardous environment. Retrofitting the body of the luminaire with an integral LED design guarantees new gaskets with tested seals.

Transfer of Liability

One final issue that should be considered is that use of a retrofit lamp in a HID luminaire requires internal rewiring to bypass the magnetic ballast and connect the socket directly to the AC voltage line. Unlike the newest LED T8 retrofit lamp design, the HID retrofit lamps are not plug and play. Wire nuts are provided to rewire the fixture for the new lamp, and a stick-on label for the fixture advises the user that the fixture has been modified and transfers the UL file from the luminaire to the lamp manufacturer.

Ultimately, failure to properly disconnect the ballast and rewire the luminaire could result in lamp failure, injury, electrical malfunction, or other hazards. Because of these concerns, LED luminaire manufactures warn customers against modifying HID luminaires to install third party lamps. For consumers who have modified a HID lighting fixture that is involved in an electrical shock, fire, or other safety related incident, they should contact the manufacturer or installer of the LED retrofit lamp, not the HID lighting fixture manufacturer.

Emerson's Takeaway

Pressured by tight budgets, a plant manager tasked with modernization of the lighting within their facility's hazardous locations may be tempted to install low-cost LED Retrofit Kits, rather than Integral LED Luminaire assemblies. On the surface the appeal of this new alternative is straightforward. Along with being inexpensive, LED Retrofit Kits are marketed as being safe, simple-to-install, and rugged, along with being just as capable of producing energy-efficient bright lighting as the higher-priced LED luminaires traditionally installed in hazardous areas. Published specifications seem to affirm the claims.

However, like most things that seem too good to be true, LED Retrofit Kits often do not live up to their hype. Outlined here are the results of lab-based performance testing comparing LED Retrofit Kits to Integral LED Luminaires. Findings clearly illustrate that the two are not equal — whether the basis of comparison is current code standards, lighting quality, lumen output, surge protection, overall reliability or total cost of ownership. In each of these performance categories, the integral LED assembly proved to be superior.

In the interest of safety, Emerson does not approve or authorize installation of LED conversion or retrofit products to its legacy lighting fixtures, as they were not designed, qualified, or agency certified for use with LED lighting technology, nor does Emerson assume responsibility or liability for any such modified Appleton or O-Z/Gedney light fixtures. Due to safety concerns, Emerson has issued a bulletin, warning their customers against modifying their HID luminaires to install third party lamps. Furthermore, Emerson advises that customers that have modified an Appleton or O-Z/Gedney lighting fixture that is involved in any type of electrical or safety related incident should contact the manufacturer or installer of the LED retrofit lamp for resolution. The bulletin can be found on our website.

For the safest, most efficient lighting it is critically important to educate yourself to ensure the best LED lighting decisions for your facility. Learn more at www.masteringLED.com.

NOTES ON TEST METHODOLOGY

① *Photometric tests were performed in an NVLAP (National Voluntary Laboratory Accreditation Program) approved laboratory per LM79 procedures. The IES files were generated on a goniophotometer using absolute photometry, measuring the total light output of the fixture with the lamp (and globe) installed. The ambient temperature in the laboratory was controlled at 25°C and the luminaire was allowed to stabilize per the defined IES test procedure. This is the same procedure used when we test Emerson integral LED luminaire designs.*

② *All photometric plots have been prepared with Photometric Pro™ lighting software, using a constant light loss factor of 0.9.*

③ *For the retrofit lamp solution, we used the IES file provided on the lamp manufacturer's website. For Emerson's solution, we used NVLAP approved IES files, created per IES LM79 procedures. Identical simulated environments were created comparing Appleton MercmasterIII fixtures with high pressure sodium lamps to retrofitted luminaires with the 24W LED lamp as well as to an Appleton integrated LED design solution.*

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