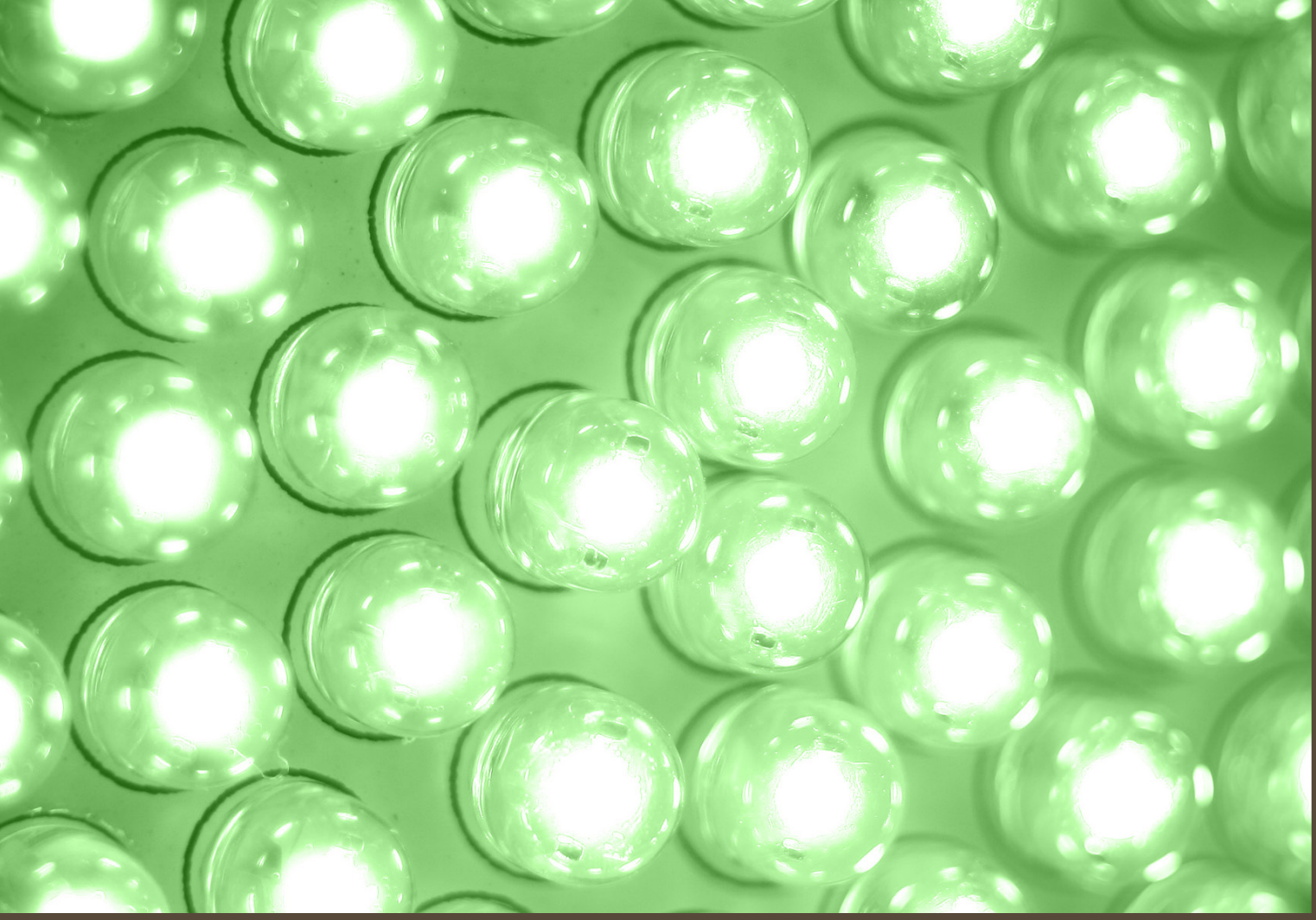


Emergency Lighting: Performance Expectations, Retrofit Implications and LEDs

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All commercial, industrial, public and multi-unit residential buildings are required to maintain lighting to sufficiently illuminate internal and external means of egress so that a building can be quickly and safely evacuated when necessary. The means of egress includes all of the pathways between building occupants and a building's exit doors, including hallways and stairwells, continuing outside to the public way. During periods when normal electrical power is available, lighting is referred to as illumination of the means of egress. When normal electrical power is not available, lighting is referred to as emergency lighting.



An emergency lighting system consists of many different components and requires periodic testing and inspection to determine that it is in good operating order. The emergency lighting system is just one component of a facility's overall life safety system, which also includes the means of egress, fire suppression and smoke detection systems, and doorways. A code authority, typically a fire marshal or building inspector, must approve every aspect of the life safety system prior to building occupancy, and has the authority to cite a facility or shut it down if periodic inspections determine that components of the life safety system are not properly maintained.

Over time, various components of an emergency lighting system will wear out and need to be maintained or replaced. As lamp technology has evolved from incandescent to fluorescent, and more recently to lighting based on light emitting diode (LED) technology, the potential energy savings have motivated many facilities to accelerate the replacement of older luminaires. However, because an emergency lighting system plays a key role in the safety of building occupants, changes to any component must be carefully evaluated to determine that the system itself is not compromised. This is especially true in the context of retrofitting fluorescent luminaires with LED lighting.

This UL white paper provides an overview of issues and implications relating to the use of LED lighting technology in emergency lighting systems. The white paper begins with a review of the essential components of an emergency lighting system and discusses the performance requirements applicable to emergency lighting systems in public buildings as well as the specifications of UL 924, the Standard for Safety of Emergency Lighting and Power Equipment. The paper then addresses the specific technical challenges of retrofitting existing fluorescent lighting fixtures to

accommodate the use of LED tubes and available options. The white paper concludes with considerations for architects, builders, building owners and building operators on the current and future use of LEDs in emergency lighting systems.

Components of an Emergency Lighting System

The key parts of an emergency lighting system are an emergency power source (either a fuel-powered generator, central battery station or individual battery packs), a transfer switch to bring the emergency power source on line when normal power is lost and luminaires. Exit signs and path markers are often considered part of an emergency lighting system, but these devices only provide directional information to occupants seeking to evacuate a facility and are not emergency lighting system components.

An emergency power source has a defined capacity to operate a specific number and type of emergency luminaires for a specified minimum time. U.S. fire codes require that an emergency lighting system operate for at least 90 minutes. In larger facilities, one or more generators may provide emergency power for applications other than lighting, such as communications, ventilation, security, and even critical industrial processes

Smaller facilities that don't require a generator will often use luminaires with individual battery packs. Sometimes referred to as inverter/charger packs, these battery packs are connected between the utility source and a luminaire and are maintained in a continual state of charge by the power that is normally available. When power is lost, an internal relay switch allows the battery to energize the luminaire. Battery packs can be included as a factory-installed component of a luminaire or they can be added to an installed luminaire. In the case of fluorescent lamps, field conversions of normal luminaires to emergency luminaires are routine because of available industry standards that allow manufacturers to design battery packs that are compatible with lamps of a certain size and type, regardless of lamp manufacturer.

As an alternative to using an installed luminaire to provide both normal and emergency lighting, special luminaires known as unit equipment can be strategically installed along paths of egress. Such equipment typically has one or two integral lights that can illuminate an area, and a dedicated internal battery that powers its operation when normal power is lost.

Emergency Lighting Performance Requirements

Loss of power in a commercial setting can result in a variety of undesirable consequences. In a retail setting, the ability to process routine transactions is impaired and electronic and video security systems can be compromised. In industrial settings, manufacturing processes as well as safety systems may become inoperable. In high-rise business or residential buildings, elevators, ventilation and communication systems may be shut down.

Further, in every instance, the loss of normal power could be a symptom of a more serious problem, such as a fire in or around a building's main electrical service area. Because the cause and status of an incident may not be immediately known, a general rule is to evacuate the building. People need light in order to navigate, and an emergency lighting system is designed, installed and maintained specifically to assist in such an event.

The evacuation of larger buildings requires proportionately more time than smaller structures. The National Fire Protection Association (NFPA) has estimated that 30 minutes is typically the maximum amount of time required to evacuate all but the tallest buildings. Based on the NFPA's estimate, relevant building and fire codes require that emergency lighting systems operate for a minimum of 90 minutes. This three times safety factor is intended to account for obstacles and other difficulties that may be encountered during an evacuation, to provide some illumination for first responders navigating a building, and to offer a buffer in cases of nonperforming equipment. Some special environments, such as hospital operating rooms, may require emergency lighting operating time that extends beyond 90 minutes.

The Life Safety Code, NFPA 101, specifies the minimum amount of illumination to be provided by an emergency lighting system. At the beginning of a power outage, the minimum requirement is an average illumination of 1 foot-candle (equivalent to 10 lux), measured along the walking surface of the path of egress, with illumination of not less than 0.1 foot-candle at any point. Because emergency lighting power often depends

on batteries that gradually lose output strength, the required illumination along the egress path can decrease to 60% of the initial requirement, i.e., to an average of 0.6 foot-candles, after 90 minutes has passed.

In most facilities these requirements will typically mandate the use of multiple luminaires that are appropriately spaced and which offer broad light distribution characteristics to achieve the minimum required illumination levels.

UL 924 Emergency Lighting Performance Requirements

UL 924 details a comprehensive program for evaluating the construction and performance of emergency luminaires. It includes the requirements necessary to safeguard against the risk of electric shock by limiting access to conductive parts that operate at dangerous voltages. The standard also identifies both prevention and containment criteria to safeguard against the risk of fire. These are the core principles found in most UL product safety standards.

UL 924 also requires that emergency lighting equipment perform as expected under extreme conditions. It requires equipment to withstand building power surges without damage or loss of operational capability. As noted previously, the Standard also requires equipment to provide a minimum level of output illumination and light distribution. For equipment with batteries, the Standard requires emergency lighting equipment to operate for 90 minutes under full load and under the most severe anticipated environmental conditions such as extreme temperatures and lower than expected battery charging voltages.

First published in 1958, the requirements of UL 924 apply to all luminaire technologies, including incandescent, fluorescent, high-intensity discharge and LED. As new technologies have been introduced over time, the Standard has been modified to reflect the unique performance characteristics of each technology. This approach makes UL 924 a technology-neutral Standard that offers a consistent, reliable and effective safety assessment regardless of technology. LEDs used in lighting applications merely represent the most recent in a line of technological developments that have resulted in changes to requirements.

LED Arrays and Drivers

LEDs are semiconductor assemblies that emit visible light when a small forward voltage is applied. To be an effective source of illumination, individual LEDs are often grouped in close proximity to one another and powered by a single source of electrical current. LEDs grouped in this manner are referred to as an array, and their source of current is called a driver.

In recent years, significant progress has been made to enhance the performance of LED luminaires. However, industry performance standards addressing the interface between drivers and arrays do not yet exist. To optimize a luminaire's photometric performance, the driver and array must be fully compatible so that the driver can adjust current to stabilize the array's heat dissipation, thereby allowing for the correct luminous output over the life of the luminaire. But the protocols used to facilitate communication between driver and array are usually proprietary to a particular design.

Zhaga is the industry consortium for the standardization for LED light engines (the combination of an LED driver and array). The consortium is currently working to establish common mechanical, thermal and electrical interface parameters to promote greater interchangeability between products from different manufacturers. However, an effective driver-array communication protocol is not currently part of the Zhaga program effort.

LED Tubes and Fluorescent Luminaire Retrofits

The first significant group of LED lighting products to enter the market was self-ballasted lamps. These products were intended to directly compete with self-ballasted, compact fluorescent lamps (CFLs) that were originally designed to directly compete with incandescent lamps. CFLs have achieved significant market penetration in the residential lighting sector due to the energy savings they produce. CFLs are now reliable and are available at a price that makes them an attractive alternative to incandescent lamps. LED versions of these products are still more expensive, but can be expected to be more price-competitive in the future as production volumes increase and improvements in design and manufacturing provide more consistent and reliable long-term performance.

It is the use of LEDs in the commercial lighting sector that represents the most attractive opportunity today, especially as a replacement for fluorescent lighting tubes widely used in office and retail environments. Modern

fluorescent lighting using high-frequency electronic ballasts is energy efficient and long-lasting and offers acceptable color quality in these environments. However, technical advancements in LED technology will soon lead to tube lighting that surpasses the useful lifetime performance of fluorescent tubes without the environmental concerns associated with the mercury used in fluorescent lamps.

Requirements for LED tubes are being addressed in a new Supplement A to UL 1993, the Standard for Safety of Self-Ballasted Lamps. These LED tubes are physically designed to fit into the same luminaires currently using fluorescent lamps and equipped with the same pin-type lampholder interface. However, achieving a compatible electrical interface is not as easy as achieving a compatible fit. A fluorescent luminaire includes a ballast, whose electrical output is specifically designed to operate a specific type of fluorescent lamp. The input requirements for a fluorescent lamp include a starting voltage that can range from 100 to 1000 V, which then drops to nearly zero once the lamp arc is established.

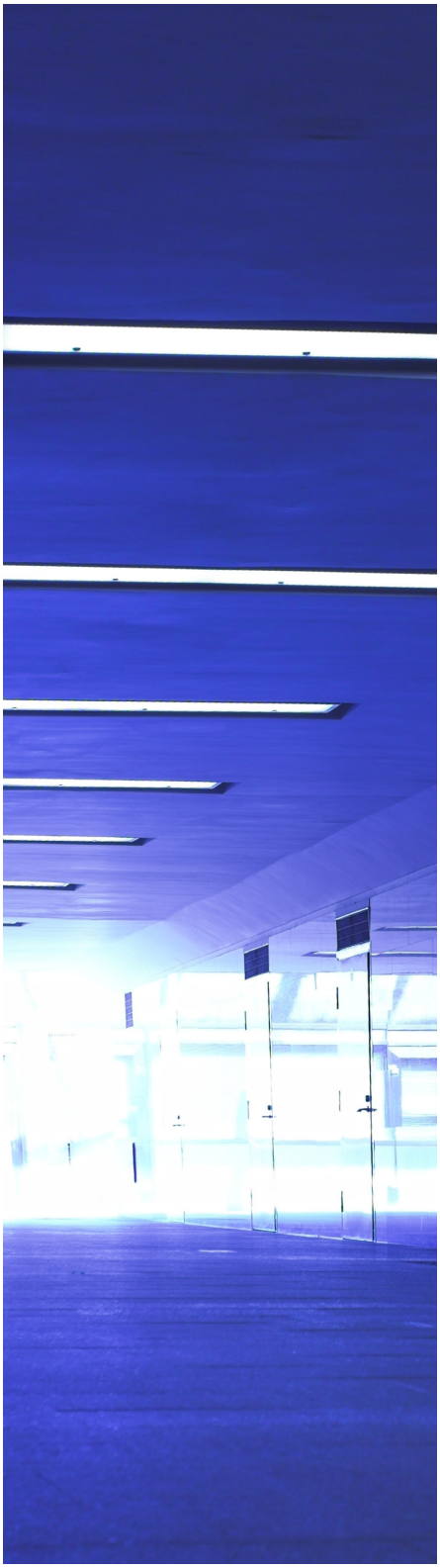
Most LED drivers, by contrast, are designed for a constant line voltage input of 120 – 277 V, while LED arrays are typically designed for a direct current input range from 12 – 150 V, depending on the number of LEDs connected in series. Therefore, in retrofitting most LED tube lamps, the ballast in the luminaire must be bypassed. When the LED driver circuitry is integral to the tube, the branch circuit wires that previously served as input to the ballast are then connected directly to the lampholder. In situations where a separate driver is provided, the branch circuit wires are connected to the LED driver input and the driver output is connected to the lampholder. In these cases the remaining fluorescent ballast can be discarded or left in place.

An exception to this general design approach is a universal LED tube lamp that incorporates input conversion circuitry that can handle a wide range of input signals. These universal tubes make it possible to directly replace a fluorescent lamp with an LED tube lamp without rewiring the luminaire.

There are additional considerations in retrofitting a fluorescent luminaire with an LED tube. These include the different types of lampholders (for pre-heat, rapid-start or instant-start lamps), and whether the LED tube is intended to be powered from both ends or through two pins connected to a single lampholder. Markings must also be applied to the retrofitted luminaire, so that service personnel are advised that the luminaire is no longer suitable for use with a fluorescent lamp. The full set of requirements for LED retrofits can be found in UL 1598C, Outline of Investigation for LED Retrofit Luminaire Conversion Kits.

LED Emergency Luminaires and Retrofits

LED luminaires equipped with emergency battery packs can be evaluated according to the specifications of UL 924 to determine compliance with its minimum illumination and operating requirements. However, unlike fluorescent inverter-charger packs that can be wired



into previously installed fluorescent luminaires, the lack of standards for an LED driver and array interface restricts the addition of an LED emergency battery pack to a previously installed LED luminaire. To adequately demonstrate that a suitably configured emergency LED driver and LED array combination meet the illumination and operating requirements, they need to be tested together. UL certifies emergency LED drivers for this purpose and requires that certified drivers specify the LED luminaires with which they can be used.

LED tube retrofits intended to be used for emergency lighting also pose some additional challenges. In addition to a lamp, lampholders and ballast, a fluorescent luminaire also includes a housing and lens, or diffuser. The diffuser serves as part of the optical assembly so light emitted from the fluorescent lamp is efficiently directed and distributed. However, because LEDs only emit light in a single direction, most LED tubes place the LED array facing the floor to maximize the usable light. This placement fails to take full advantage of the optical design of the fixture housing.

In many cases, LED tubes combined with fluorescent luminaire fixtures will provide a very different photometric pattern than that achieved with fluorescent lamps. If fluorescent luminaires serve as part of the facility's emergency lighting system and currently provide the required illumination over the egress paths, retrofitting the luminaires with LED tubes may reduce illumination below required levels.

Emergency Lighting System Maintenance

Both NFPA 101 and the International Fire Code require all facilities to perform periodic inspection and maintenance of any emergency lighting system. All certified emergency luminaires that include batteries are equipped with a momentary contact test switch. This switch is used by maintenance personnel to test a battery's functionality in the event of a loss of power, a test which should be performed monthly.

In addition, each facility should also simulate a full duration, i.e., 90 minute, power interruption at least once per year to test whether batteries have sufficient capacity to maintain required emergency lighting. During this test, illumination levels should be checked along the required means of egress through the entire facility to validate that the minimum required levels are being achieved.

All equipment, no matter how well-designed, eventually requires maintenance and/or replacement. This is especially true for batteries, whose chemistry gradually decays to the point where they are unable to provide sufficient power to operate a luminaire. It is also true for the light source, especially when the light source is an LED array. Other light sources, including incandescent and fluorescent lamps, have a lumen output vs. lifetime curve that is relatively flat until the light fails completely. LEDs, on the other hand, emit gradually lower amounts of light as they age. This aging characteristic makes it difficult for maintenance personnel to determine whether an emergency luminaire can still meet its performance requirements without conducting a power outage simulation and directly measuring the LEDs illumination using a light meter.

Current industry practice considers an LED to have reached its end-of-life when its output declines to 70% of its initial level. But if an emergency lighting system provides an average of 1.1 foot-candles of illumination along the means of egress when initially approved, a mere 10% reduction in light output is required for the system to fall below the minimum code requirements. Therefore, the expected end-of-life of an individual LED and the point where an emergency luminaire may require maintenance or replacement are not always the same.

Nonetheless, LED technology has come a long way in the last 10 years and quality LED luminaires can be expected to produce the majority of their original light output for many years. With LED luminaires now poised to capture an increasing share of the commercial market, the next decade will no doubt offer interesting new challenges for maintaining code-compliant emergency lighting systems.

Considerations for Architects, Builders, Building Owners and Operators

There are a few important issues for those considering the possible inclusion of LED luminaires in their emergency lighting systems. If LED luminaires are part of new construction, an architect responsible for the photometric layout of the emergency lighting system should fully account for the light output and distribution patterns of the LED luminaires. Future concern is then limited to whether compatible parts will be available for ongoing maintenance and component replacement. Given the pace of change within the LED industry and the expected lifetime of current product lines, second and third generation LED products may not be backward compatible with current offerings. However, the energy savings and reduced maintenance expenses realized in the interim should help to offset this longer-term concern.

In remodeling projects both the LED luminaire selection and luminaire layout should account for how lumen output and distribution pattern of LEDs differ from existing fluorescent or incandescent luminaires. Additional fixtures may be needed to properly illuminate the egress path, potentially offsetting some of the anticipated energy savings. In the case of a retrofit program that leaves fixtures in place and only replaces the electronic components, care is required to maintain both minimum and average egress path illumination levels. Uncertainty regarding the availability of replacement parts discussed above is also applicable in both remodeling and retrofit projects.

Conclusion

LED lighting technology offers significant benefits to the built environment in the form of energy savings, reduced maintenance and access to electronic controls that allow closer calibration of the lighting system's overall performance. However, converting an emergency lighting system originally designed for use with fluorescent lamps over to LEDs requires more work than simply finding LED tube lamps that physically fit the existing lampholders. LEDs usually require re-engineering and retesting to verify that an emergency lighting system still complies with applicable requirements.

The lack of standardization with this emerging technology requires that emergency LED driver battery packs be properly paired with specific LED luminaires. Remodel and retrofit operations need to account for both light output and light distribution patterns. Finally, future access to compatible replacement parts for LED components that fail over time should be an essential consideration in long-term system upkeep planning.

For further information about the use of LEDs in emergency lighting systems and applicable UL certification programs, contact Michael Shulman, principal engineer, UL, at Michael.Shulman@ul.com.

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