

ADB Airfield Solutions Answers Questions about LED Fixture Reliability, Cost Savings and Future Applications



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In the fall of 2002, LED airfield lighting products began appearing on taxiways around the world. These products emerged because a new class of very high intensity Light Emitting Diode (LED) light source had been developed. Initially, products were only available for elevated taxiway edge lighting applications. Next, products appeared for in-pavement taxiway centerline and obstruction lighting applications. Not long after, heaters were added to LED products for those airports where snow and ice are a concern. Research is now being conducted to push the envelope using the latest generation of high-intensity LEDs. Runway lights, in-pavement Runway Guard Lights, Medium-Intensity Approach Lights (MALSR), and other applications have all seen various levels of LED development and testing in recent years.

Although LED-based airfield lighting fixtures have been around for years, questions still come up about various performance aspects of these high-intensity LED products. This article aims to answer many of those questions.

Are the LEDs used in airfield lighting fixtures really reliable?

The type of high-intensity LED light source used in airfield lighting fixtures was initially used in highway traffic light applications. A report by one of the LED manufacturers, Lumileds, states that "Since 1998, Luxeon (high-intensity LED) has been installed in over 1,000,000 traffic signal heads, each with 12 to 18 Luxeon emitters per head. Based on the number of Luxeons installed in traffic signals, and the lack of field returns, it is suggested that a MTTF of 100M device hours at a junction temperature of 80°C be used until further data is available." (Luxeon Reliability, Application Brief AB25, Lumileds, 2/04)

LEDs used in airfield lighting applications, however, are subject to a different, and we think, more difficult environment. Vibration, controlling electronics powered by series circuits, and lightning, all put additional stress on the LED, but these robust, high-intensity light sources are unfazed. The single LEDs used in some of ADB Airfield Solutions' (SAS) airfield lighting products have a theoretical average LED life of up to 100,000 hours under high-intensity conditions and more than 200,000 hours under actual operating conditions. This is because under actual operating conditions, taxiway circuits are most often operated on one of the Constant Current Regulator's (CCR) lower intensity step settings.

But what about actual experience?

ADB Airfield Solutions has shipped more than 130,000 LED fixtures in the US alone since the fall of 2002. To date, there have been <1% non-warranty fixture returns (for all LED types) and no failures due to the LED itself have occurred. So, LEDs have more than proven themselves to be

reliable replacements for traditional incandescent or tungsten-halogen light sources. Also, many airports have become so confident in the performance of LEDs, they are simply specifying them instead of incandescent.

Are heaters used in LED fixtures reliable?

SAS uses rugged nichrome wire—similar to the type of wire used in space heaters—to heat an elevated LED fixture's optical window. When the outside temperature falls below 40°F (4°C), a high-current-rated thermostat switches the heater on.

As an example, the calculated Mean Time Between Failure (MTBF) of an entire L-861T taxiway edge LED fixture *without* heater is at least 190,000 operating hours. The calculated MTBF of the entire LED fixture *with* heater is at least 180,000 operating hours. In either case, this equates to a calculated MTBF of much more than 20 years if the fixture is operated 12 hours per day.

But what about actual experience?

Approximately a third of airports in the US have determined that their local environmental conditions require the use of a LED fixture heater. Many of these fixtures have been in use over three winter seasons, and there have been no heater or thermostat failures. That's not surprising: thick nichrome wire is one of the most reliable components in a fixture.

It should be noted, however, that other manufacturers have implemented different heating methodologies. Other heating techniques may not have the same reliability. We recommend that the airport investigate this (and other issues discussed in this article) with all potential suppliers.

The price of LED fixtures is higher than traditional fixtures. Why are they considered more cost-effective?

There are various factors that justify the higher initial purchase price of LED fixtures. In fact, many customers are surprised to learn that labor savings provide the largest percentage of cost savings with LED fixtures followed by reduced capital equipment costs. See Figure A below for a typical breakdown of benefit savings with LED fixtures for a new installation.

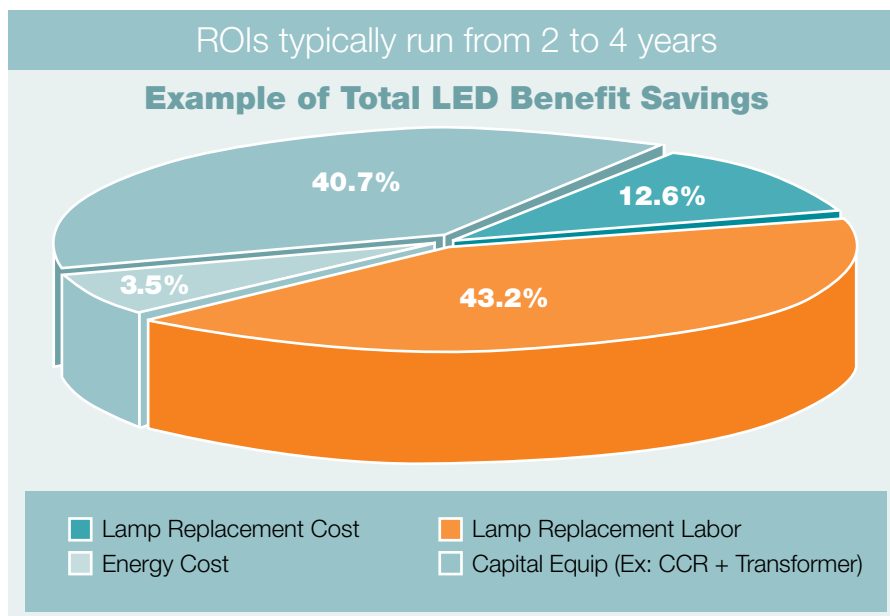
When considering the total fixture acquisition cost difference, a typical return on investment (ROI) calculation shows that LED fixtures pay back the initial investment in two to four years.

Another, more practical approach, to look at the ROI question is to examine the issue from the local airport's perspective. If the portion of the federal AIP investment is subtracted from the acquisition cost equation, the local or state portion of the investment is typically only 5% to 15% of the total acquisition cost.

This can result in an ROI of less than one year, depending on the application.

Because LED fixtures will function for many years after that, the local airport gets the full financial benefit of the entire investment compared to traditional fixtures for every year after their initial investment is paid back.

Figure A



Green Savings

30222.0 KWH: Total Energy Consumption per year for 200 incandescent taxiway edge lights

— **9723.6 KWH:** Total Energy Consumption per year for 200 LED taxiway edge lights

20498.4 KWH: Total Energy Consumption Reduction per Year

The CO₂ emissions reduction per year was determined using the EPA Greenhouse Gas Equivalencies Calculator at the web site shown below. The total energy consumption reduction per year was entered using a unit of kilowatt-hours of electricity. Clicking on the "Calculate Equivalent" button showed that the Carbon Dioxide Equivalent savings for 20,498.4 KWH is 15.9 Metric Tons per year.

The site also shows various equivalents in avoiding greenhouse gas emissions. Some examples from the calculator show that the use of 200 LED taxiway edge lights instead of incandescent lights is equivalent to avoiding the greenhouse gas emissions from:

2.9 Passenger vehicles per year

2.1 Homes per year, due to electricity use

EPA Greenhouse Gas Equivalencies Calculator

<http://www.epa.gov/cleanenergy/energy-resources/calculator.html>

When heaters are used with LED fixtures, the electrical load is higher. Are there really energy savings if a heater is used?

We use a high-current-rated thermostat to switch the heater on when the outside temperature falls below 40°F (4°C). Once the temperature in the optical window area reaches a level that is equivalent to traditional fixtures, the thermostat switches the heater off.

Less overall energy is consumed due to two reasons. First, during the warmer season, the heater is off. Second, during the colder season, the heater is on only for the amount of time needed to melt ice or snow in a manner comparable to traditional fixtures. Environmental validation tests we conducted demonstrated that the heater was on only 40% of the time when the ambient temperature was 24°F (-4°C).

An ROI calculation will show there is only a slightly longer payback period when heaters are present. For example, we calculated an example ROI for comparable fixtures both with and without a heater. For our ETES L-861T fixture, we calculated an ROI (using the full acquisition cost difference) of 2.1 years without the heater and 2.6 years with the heater. So LED fixtures that use heaters show justifiable ROIs.

How much reduction in CO₂ emissions occur if LEDs are used?

Although greenhouse gas (CO₂) emission reductions have always been a factor in an airport's decision to purchase LEDs, in recent years there has been an increasing focus on this issue. In order to determine the greenhouse gas savings, you would first calculate the total LED energy savings per year as seen at the input of the power source (the Constant Current Regulator for series circuit applications or commercial power supply input for voltage powered applications). You would then use to the EPA Greenhouse Gas Equivalencies Calculator at <http://www.epa.gov/cleanenergy/energy-resources/calculator.html> to determine the reductions. Figure B shows an example calculation of the greenhouse gas reduction benefits based on the energy savings of 200 taxiway edge lights.

I have heard that LED fixtures will not operate correctly with SCR-type CCRs. Is this true?

ADB Airfield Solutions LED fixtures were designed to operate on any type of CCR architecture. Our fixtures now operate at many airports all over the world on the CCR architectures made by many different manufacturers. Our fixture's electrical

design takes into consideration the higher harmonic waveshapes that often occur with SCR-type (also known as Thyristor) CCRs. This may not be true, however, for other manufacturers— inquire with other manufacturers regarding any operating limitations.

If you'd heard that LEDs won't operate properly on SCR-type CCRs, it may be that other manufacturers have simplified their design (to reduce cost) to the point where a lower harmonic current waveshape is needed for proper operation. Again, it pays to investigate this issue with all potential suppliers.

I have heard various opinions about whether or not LED fixtures should be mixed with traditional fixtures on the same circuit. What research has been done to answer this question?

First, let's examine the issue. Traditional fixtures use filtering to obtain the desired color, but the process is inefficient and results in a broad spectral bandwidth as other wavelengths remain mixed with the primary filtered wavelength. Also, variations in color already exist with traditional fixtures. Traditional fixtures have well-known color shifts with different CCR intensity settings when viewed at a wide angle or when the lamp ages.

An LED fixture produces light at the desired wavelength without the need for filters. The resulting light has a very narrow spectral band to the point where it is virtually monochromatic. This is primarily why the output of an LED fixture looks very color saturated when compared to adjacent tungsten-halogen or incandescent fixtures.

UK airport operator BAA, in association with the Airport Operators' Association (AOA), formed a Technology Working Group to study this and other issues associated with LED fixtures. New ADB taxiway centerline Cat III LED fixtures were installed in a taxiway crossing on one of Heathrow's (LHR) main runways (27R/09L) in August 2003. The LED fixtures were alternately installed in a straight portion of the taxiway with new tungsten-halogen fixtures. No changes were made to the existing infrastructure. The LED fixtures crossed the runway in the touchdown-zone area and, therefore, have sustained thousands of landings and takeoff loads.

A report was issued in September, 2005. No issues were found with mixing LED and tungsten-halogen fixtures. LED fixtures, however, were found to have some important optical advantages.

Some of conclusions regarding this issue were:

- The LED fixture performance in low visibility suggests they will provide relevant color information earlier than a similar tungsten-halogen fixture.
- The perceptions of all who have formally viewed the taxiway route indicates that the color saturation is better and more distinguishable as green, when viewed alongside tungsten-halogen fixtures.
- The conspicuity of a light source will always be relative to the context in which it is viewed. The contrast between the light source and the background, or light noise in which it is viewed will have an impact upon the perceived conspicuity. The ability to detect a lighted cigarette at a significant distance in pitch darkness is an extreme example of this. The lack of spectral bandwidth in an LED light source enhances the contrast with surrounding noise (including the scatter effect of low visibility conditions) enabling greater conspicuity for a given luminosity.

In addition, some other conclusions stated in the report are:

- Removal and testing of three sample LED fixtures following two years in a high traffic area (including high frequency of wide bodied aircraft) has shown no signs of physical damage or distress.
- The MTBF of the Cat III LED fixtures is already significantly better than the equivalent tungsten-halogen fixtures.
- The inclusion of additional electronics in the LED fixture does not reduce reliability or increase risk of multiple failures, provided the electronics are carefully designed and tested to cope with the airfield environment.
- The tested LED photometric performance meets requirements and anecdotal evidence suggests they will maintain this longer. One reason is that the lens will remain cleaner as a result of lower operating temperature. The lower temperature of the lens prevents the "baking effect" that causes contaminants to stick to the surface of the lens.

- The claimed reduction in power consumption is realized in both laboratory tests and in the field operation.
- There is a significant potential for savings in both maintenance costs and reduction in operational disruptions.

Following the successful trial of these Cat III Taxiway LED fixtures at Heathrow, the UK Civil Aviation Authority has accepted the use of LED fixtures that can be demonstrated to meet the standards for the appropriate taxiway illumination. Consequently, the BAA has been installing significant amounts of LED taxiway fixtures.

An important advantage of LED fixtures is that they produce a pure color wavelength that stays consistent in all CCR steps.



Are LED fixtures brighter than incandescent or tungsten-halogen fixtures?

There are two different time frames when we have heard this question. This was a common question when LEDs were first being used for airfield applications. One of the first manufacturers of an L-861T taxiway edge light produced a fixture that had a linear light output vs. CCR step response.

This caused the light output to be brighter than traditional fixtures in the lower CCR steps. See the *Figure C* on next page.

The upper dotted line shows the natural LED light output response curve. The green and white lines show a typical nonlinear curve for tungsten-halogen or incandescent lamps. The horizontal axis of the curve shows current output levels for a 5-step CCR. If we take step B4 (5.2A) as an example, it can be seen that traditional fixtures produce ~20% of the light output at the highest CCR setting; B5 (6.6A). An LED has a linear response to input current, so the light output of

these early fixtures was ~70%. The FAA subsequently issued Engineering Brief No. 67, which defined the minimum and maximum light output limits for LED fixtures. These limits were based on the typical range of light output seen on traditional fixtures powered by either 3- or 5-step CCRs.

Today, all manufacturers must design their LED fixtures to be within these limits. A typical corrected LED response curve (lower orange dotted line) for ADB Airfield Solutions LED fixtures is shown in the figure.

In addition, Engineering Brief No. 67 states "The average measured intensity may not be more than three times the specified average intensity. For fixtures with a minimum, but no average intensity requirement, the measured minimum may be no more than three times the specified minimum intensity."

LED fixtures cannot be photometrically brighter than traditional fixtures, because they are additionally limited by this FAA requirement.

We have also occasionally heard this question in recent times. Let's look at some actual data from a large sampling of production tests:

FAA AC 150/5345-46

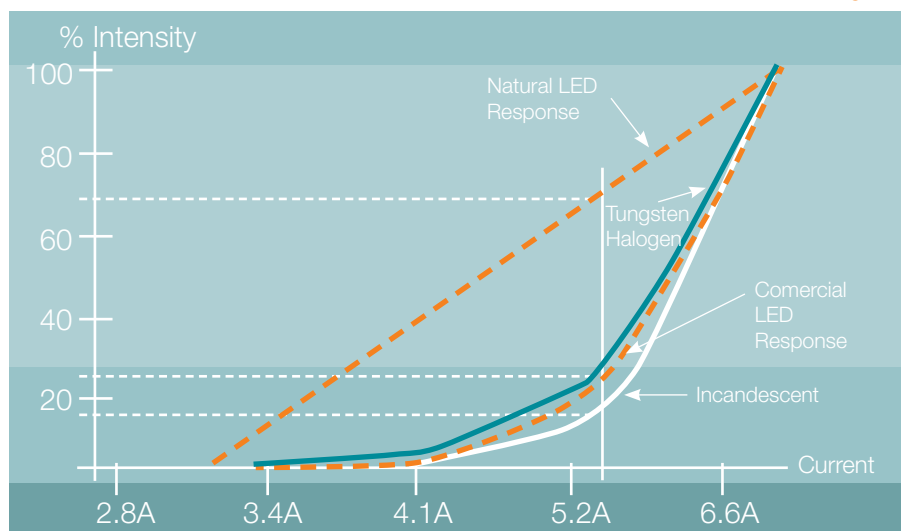
Photometric Requirements

Fixture	Requirements in Candela (Cd)	Tungsten-Halogen	LED
L-861T	Min. 2Cd, 0°-6°V	9.1Cd	8.1Cd
L-852C	Min. Avg.- 200Cd	433Cd	389Cd
L-852D	Min. Avg.- 100Cd	142Cd	137Cd

This data shows that the measured light for LED fixtures is similar to or less than traditional fixtures.

An important advantage of LED fixtures is that they produce a pure color wavelength that stays consistent in all CCR steps. They are not susceptible to effects seen on traditional fixtures such as color shifting when observed at wide angles or at reduced CCR steps. It is also important to remember that an existing fixture may have older lamps with reduced light output or have sand or dust on the optical window, which also reduces light output. Therefore, there may be an incorrect perception that the LED fixture is brighter.

If an airport still has reservations about this issue, a 5-step CCR could be used, which would provide additional light output control. In fact, FAA AC 150/5340-30,



par. 4.8.e (2) states: "Series circuits for... taxiway centerline lighting systems should be powered from an appropriately-sized L-828 or L-829, Class 1, Style 2 (5-step) (preferred) or Style 1 (3-step) constant current regulator..." All ADB Airfield Solutions LED fixtures operate on a 5-step (2.8A to 6.6A) CCR and match the light output of traditional fixtures.

Will LEDs operate on both 3 and 5-step CCRs?

This question often comes up at some airports that have standardized on 5-step CCRs for all applications to minimize spare parts needs, even on taxiway circuits. It also has been a concern for airports that may need to use a spare 5-step CCR on a circuit that is normally powered by a 3-step CCR. ADB Airfield Solutions LEDs are designed to operate on both. However, this may not be true for other manufacturers—inquire with other manufacturers regarding any operating limitations.

I am more concerned with lightning issues. How are LED fixtures protected against lightning?

Lightning testing is specified in FAA Engineering Brief No. 67, par. 2.11, which states that an LED fixture "...shall be designed to withstand and/or include separate surge protection devices which have been tested against defined waveforms detailed in Table 4, Location Category C1 of ANSI/IEEE C62.41-1991 Recommended Practice on Surge Voltages in Low Voltage AC Power Circuits, namely, 3000 Amps, 8/20 microsecond - short circuit current pulse and 6000 Volt, 1.2/50 microsecond - open circuit voltage pulse."

Category C1 is defined as Low Exposure—Systems in geographical areas known for low lightning activity, with little load or capacitor switching activity. Because LED fixtures are in an exposed area on the airfield—and may be in a high lightning area—we believe that Category C2 is a more appropriate standard. Category C2 is defined as Medium Exposure—Systems in geographical areas known for medium to high lightning activity or with significant switching transients. Category C2 is 5,000 Amps, 8/20 microsecond - short circuit current pulse and 10,000 Volt, 1.2/50 microsecond - open circuit voltage pulse. We have designed and internally tested our LED fixtures to this higher standard.

But what about actual experience?

Our elevated and in-pavement LED fixtures were installed at Miami International Airport in February 2003.

The airport has reported the following:

- Since the installation, there have been no failures or problems of any type with the fixtures. In fact, we have received many positive comments from flight crews regarding the visual effects of your products on that taxiway.
- Additionally, there have been multiple lightning strikes in the area and directly on the same circuit the SAS fixtures are installed on. There was no damage to the LED fixtures at all. As you know, Miami is in the heart of the lightning belt in Florida, the lightning capital of the U.S. We average 76 days with lightning annually. Equipment that is able to continue to operate after lightning strikes is critical for the success of our airfield.

Figure D

At my airport, I lose many elevated fixtures during snow season.

How can the use of LED fixtures sustain an ROI in these conditions?

We created an example ROI calculation, assuming the full acquisition cost, using 400 L-861T ETES fixtures on a new circuit. This yielded an ROI of 1.5 years. Next, we assumed that there would be 20 knockdowns per year for 20 years. We then assumed that 10 of these fixtures are repairable, because the SAS ETES fixture is designed so that the internal electronics easily withstand knockdowns. In addition, the ETES has a guard ring that protects the glassware for many knock over events (see photo below). This allowed us to assume that, when compared to the cost of a traditional fixture, there would be no price difference for these 10 fixtures since the parts that would be replaced would be the frangible coupling and glassware. We then added the increased cost for 10 replacement LED fixtures per year for 20 years (200 total). The new ROI calculation was just 2.2 years.

The ROI savings per year can easily overcome complete fixture losses.



Figure F



When are LEDs going to be available for other airfield lighting applications, especially the runway?

Introduction of the latest generation of High Brightness LEDs (HBLED) has allowed development of new airfield lighting applications where higher levels of photometrics are required. Examples are:

- L-849 REILs — LED Runway End Identification Lights in all Styles (Style A—High Intensity/Single step; Style C—Low-Intensity/Single-Step; Style E—High-, Medium-, and Low-Intensity/Three-Step) are now available and ETL certified for both series circuit powered and voltage powered applications. Key advantages of LED REILs are that they eliminate expensive xenon flash lamp replacements and, for series circuit applications, they eliminate the need for power adapters, which place a high electrical load on the CCR.
- L-804 RGL—Elevated Runway Guard Lights are now available and ETL certified for both series circuit powered and voltage powered applications.
- L-858 signs—LED signs in sizes 1 through 4 are now available and ETL certified for series circuit powered applications. A key advantage of LED Distance Remaining signs is that they eliminate the need to shut down the runway for lamp maintenance.
- Wind Cones—Internally lit L-807 LED wind cones are now available and ETL certified for both series circuit-powered and voltage-powered applications. L-806 internally lit LED wind cones are also available for series circuit-powered and voltage-powered applications. Another key advantage of LED wind cones for series circuit applications is that they also eliminate the need for power adapters.
- L-852G RGL—In-pavement Runway Guard Lights were developed and tested in the summer of 2008 (see Figure D) and are now ETL certified. A key advantage of LED L-852G fixtures is that, since they are often operated 24 hours per day, they eliminate the need for frequent lamp replacements.
- Runway applications—LED fixtures for runway centerline (L-850A, see Figure E) and touchdown zone (L-850B) are now appearing on the market. Initial installation of these products will begin in the fall of 2008. A key advantage of LED runway fixtures is that they eliminate the need to shut down the runway for lamp maintenance.

Will there be vibration issues when LEDs are installed on a runway?

Because an in-pavement LED fixture uses all solid-state or passive components, they are inherently more vibration resistant than incandescent fixtures. Incandescent lamps use a wire filament, which is at a higher risk of filament breakage, usually occurring more frequently at the lamp's end-of-life.

This issue has already been put to the test. In January 2007, SAS L-852N LED fixtures were installed at the Naval Air Facility in El Centro, California. L-852N fixtures (often called tail-hook fixtures) are used in Simulated Carrier Deck applications by the US Navy. A total of 216 fixtures on three Simulated Carrier Decks were installed (*see Figure F*). These fixtures have now seen thousands of landing and tail-hook strikes. They have been proven to be reliable and effective since that time and have had no vibration failures.

Figure E



Do you have any additional questions about application issues with LED airfield lighting products? Send an e-mail to Ed Runyon at [**ed.runyon@adb-air.com**](mailto:ed.runyon@adb-air.com)

Author Profile: *Ed Runyon has worked in airfield lighting since 1981 and has served on various FAA committees, including the ones that developed the Runway Guard Light, the L-890 ALCMS specification and also the LED Engineering Brief 67.*

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