LED Lighting Research & Development

May 16, 2016

Presented by: Donald W. Gallagher

Presented to: Council for Optical Radiation Measurements (CORM) 2016 Annual Technical Conference

LEDs can not be seen as well as Incandescent lights in low visibility?

Fact or Fib?

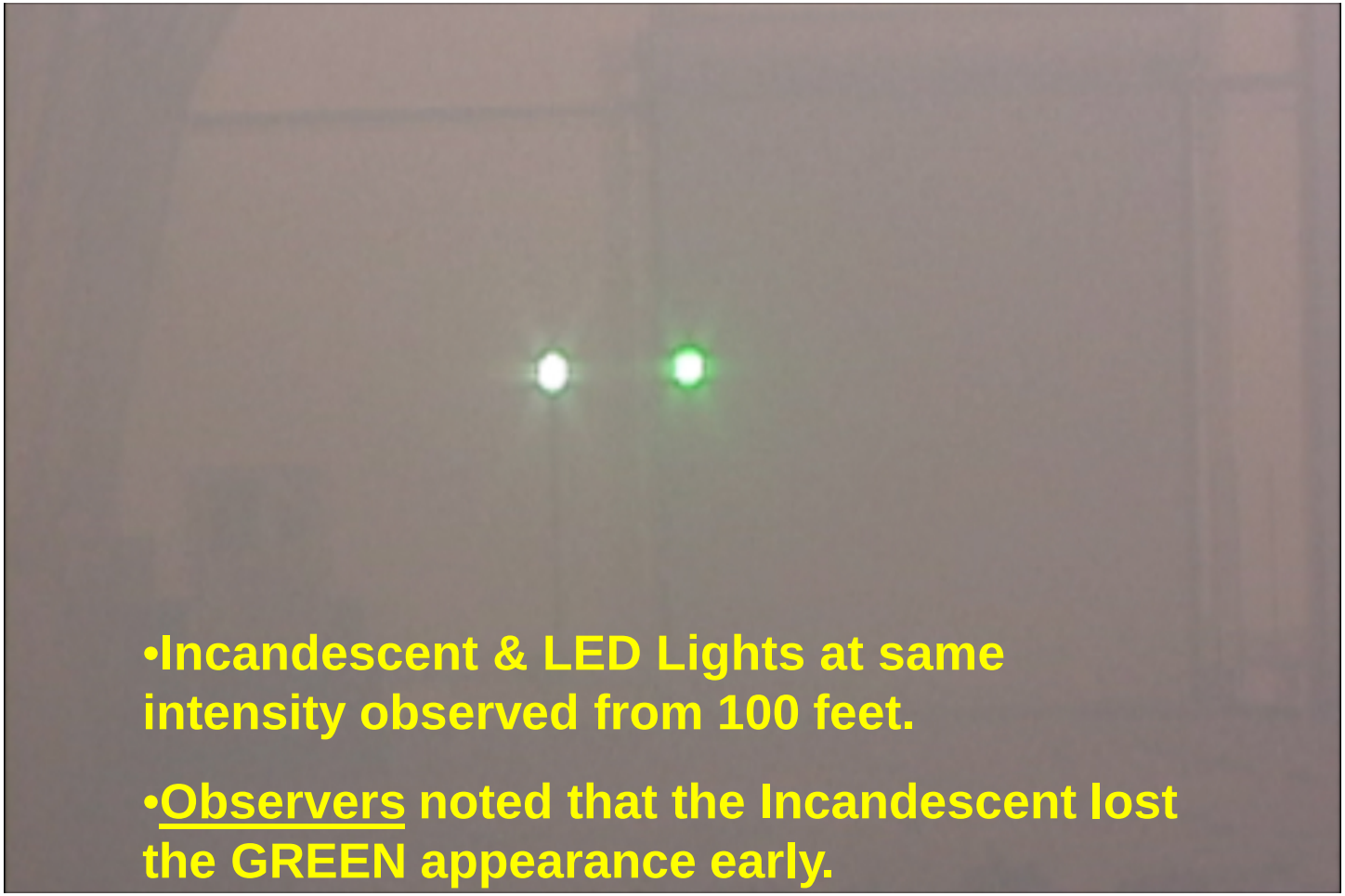
FIB!

A source with the same candela* value can be seen the same in low visibility.

***1 Candela = The luminous intensity equivalent to a 540 x 10^{12} Hz monochromatic radiator with a radiant intensity of 1/683 Watt per steradian.**

Low Visibility Demonstration of LED Technology

Low Visibility Demonstration of LED Technology



- Incandescent & LED Lights at same intensity observed from 100 feet.
- <u>Observers</u> noted that the Incandescent lost the GREEN appearance early.

Brightness/Luminous Intensity Values for Blue, White and Green Aviation Signal Lights Using Light Emitting Diodes

- Research was conducted with Rensselaer Polytechnic Institute's Lighting Research Center
- Signal lights were compared against dark and dimly lighted backgrounds and through simulated fog.
- A new model was developed that could be used to predict signal light brightness perception for FAA blue, white and green signal colors.

Brightness/Luminous Intensity Values for Blue, White and Green Aviation Signal Lights Using Light Emitting Diodes

- Except for very short-wavelength blue signal lights, the model was able to accurately predict brightness perception data obtained in the present experiment as well as those presented in an independent experiment published 30 years ago.

- This independent validation lends confidence to the generality of the model for predicting blue, white and green signal light brightness.

Brightness/Luminous Intensity Values for Blue, White and Green Aviation Signal Lights Using Light Emitting Diodes

- The results confirm that **LED signal lights** are **seen as brighter** than **incandescent signals** at matched luminous intensities when there are **no particles** in the atmosphere to **desaturate** the LED.

- Fog **reduced the relative brightness difference** between the incandescent and the LED signal lights because of light scattering in the **fog** that **desaturated** the signal light colors.

Brightness/Luminous Intensity Values for Blue, White and Green Aviation Signal Lights Using Light Emitting Diodes

- The resulting model developed a **brightness/luminous** ratio (B/L) for test colors resulting in:
  - **Blue 1.4**
  - **White 1.4 to 1.6**
  - **Green 1.4**

when the light source is **desaturated** such as in **lower visibility**

Raleigh-Durham International Airport Runway Lighting System Study

- There have been complaints by pilots at airports of the runway centerline and touchdown zone lighting having been "too bright". These particular airports have LED lights installed for runway touchdown zone and centerline; however they retain incandescent for runway edge.

- While claims had not been received from other airports using LED runway lighting, these claims raised concerns that the design and operational provisions specified in Engineering Brief 67, allow for the intensity of LED RCL and LED TDZ lights to operate at a level of brightness that may create adverse lighting conditions at intensity steps 1 and 2 of a 5 intensity step system.

Raleigh-Durham International Airport Runway Lighting System Study

- Such issues had been reported at Raleigh/Durham Airport's (RDU) runway 23L where claims have been made stating that the intensity of the LED RCL and LED TDZ lights were "too bright" on intensity step 1 and 2.

- To address these concerns, members of the FAA's Visual Guidance Program and supporting personnel traveled to RDU on November 17, 2010 to conduct an examination of this brightness issue.

Raleigh-Durham International Airport Runway Lighting System Study

- **EVALUATION APPROACH**

  - **RDU RCL and TDZ lights examined through field and laboratory measurements and flight testing. These efforts consisted of:**

    1. **Collection of photometric data to determine if performance met requirements specified in Engineering Brief No: 67B "Light Sources Other Than Incandescent and Xenon For Airport and Obstruction Lighting Fixtures"**

Raleigh-Durham International Airport Runway Lighting System Study

- **EVALUATION APPROACH**

2. **Testing lighting circuits to verify performance met requirements specified in AC No: 150/5345-10G, Specification for Constant Current Regulators and Regulator Monitors**

3. **Flight tests of the RCL and TDZ lights to determine whether the lights were visually "too bright" or visually acceptable.**

Raleigh-Durham International Airport Runway Lighting System Study

- After initial flight, the test team agreed that in Visual Meteorlogical Conditions (VMC), while <u>not a safety concern</u>, the intensity for steps 1 and 2 could be lower so additional flights were conducted

- The lights at the subject runway at RDU, at the time of the evaluation, on step 1 were 52.5 candela

- Based in part, on the Brightness to Luminous Ratio in VMC, defined in research conducted, dividing 52.5 cd by a B/L of 1.5 equals 35 cd which also equates to .7% of full brightness for the CCR.

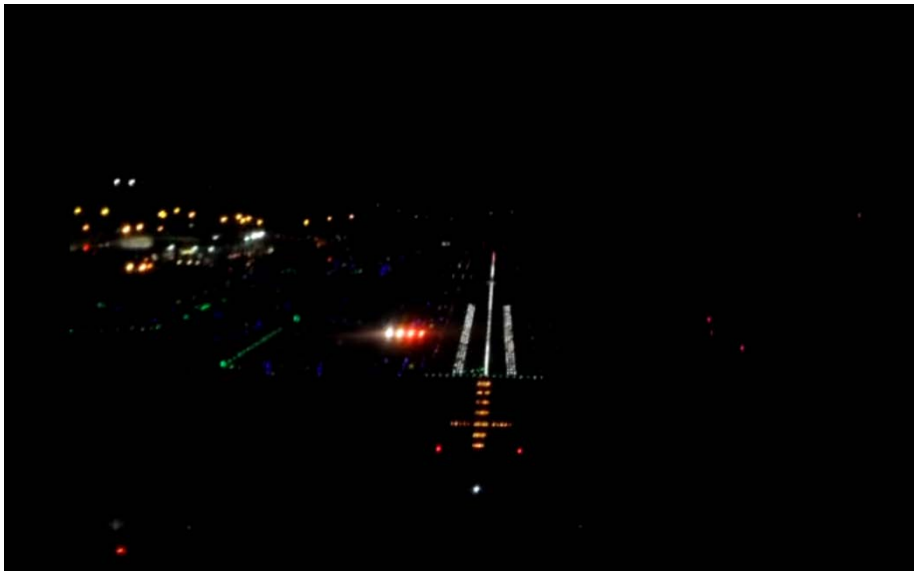
Raleigh-Durham International Airport Runway Lighting System Study

- **Adjustments were made to the percentage of maximum brightness at RDU and in EB67B for steps 1 to .7% and step 2 to 2.0% were recommended.**

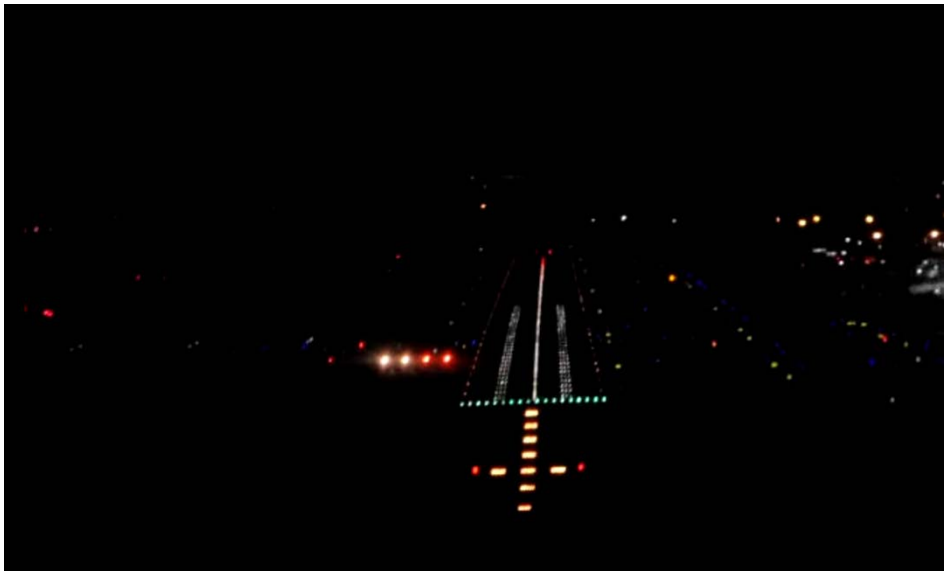
- **Since these adjustments, no other issues have been reported.**

Raleigh-Durham International Airport Runway Lighting System Study

November 17th 2010



November 18th 2010



Memorandum

U.S. Department
of Transportation

Federal Aviation Administration

Subject: **INFORMATION:** Engineering Brief No.67D Light Sources Other Than Incandescent and Xenon For Airport and Obstruction Lighting Fixtures

Date: March 6, 2012

From: Manager, Airport Engineering Division, AAS-100

Reply to Attn. of:

To: All Regions
Attn: Manager, Airports Division

Engineering Brief No.67D provides additional requirements for light sources other than incandescent and xenon technologies subject to certification under Advisory Circular (AC) 150/5345-53, *Airport Lighting Equipment Certification Program*, and other applicable documents as required. It includes the required specific test and design requirements for alternative light sources that will be used in certified airfield lighting fixtures. This Engineering Brief ensures these new lighting technologies are seamlessly integrated with existing lighting technologies on the airfield.

Airfield Lighting Equipment Manufacturers employing alternative light sources in equipment certified under AC 150/5345-53 must meet the requirements contained in each applicable AC. The third party certification activity must verify the airfield lighting manufacturers' equipment meets the design and operational provisions as dictated by changing illuminating technology.

John R. Dermody

Attachment

ENGINEERING BRIEF NO. 67D

LIGHT SOURCES OTHER THAN INCANDESCENT AND XENON FOR AIRPORT AND OBSTRUCTION LIGHTING FIXTURES

I. PURPOSE

This engineering brief provides additional requirements for "Light Sources Other Than Incandescent and Xenon for Airport and Obstruction Lighting Fixtures" subject to certification under AC 150/5345-53, *Airport Lighting Equipment Certification Program*, and/or other applicable documents.

II. DESCRIPTION

This document includes specific test and design requirements for alternative light sources used in certified equipment.

III. BACKGROUND

Manufacturers utilizing alternative light sources, such as Cold Cathode, Light Emitting Diodes (LED), fiber optics, etc. in equipment certified under the U.S. Department of Transportation, Federal Aviation Administration, Advisory Circular No. 150/5345-53, must meet the requirements contained in each applicable equipment Advisory Circular. Additionally, the third party certification body must verify that the manufacturer's equipment meets the following design and operational provisions as dictated by changing illumination technology.

IV. CANCELLATION

Engineering Brief 67C, *Light Sources Other Than Incandescent and Xenon for Airport and Obstruction Lighting Fixtures*, dated December 29, 2010, is canceled.

V. EFFECTIVE DATE

This Engineering Brief is effective 9 months from the date of signature except for the requirements specified in paragraph 1.0 "Intensity Ratios", Table I (white light) and Appendix I, Table 3 (continuous curve for white light) that are effective immediately.

VI. APPLICATION

The Federal Aviation Administration (FAA) recommends the guidelines and standards in this Engineering Brief (EB) for light sources other than incandescent and xenon for use in airport and obstruction lighting fixtures. In general, use of this EB is not mandatory. However, use of this EB is mandatory for all projects funded with federal grant monies through the Airport Improvement Program (AIP) and with revenue from the Passenger Facility Charges (PFC) Program. See Grant Assurance No. 34, "Policies, Standards, and Specifications," and PFC Assurance No. 9, "Standard and Specifications."

1.0 Intensity Ratios — The intensity of a fixture with an alternative light source intended to operate on a 3 or 5 step Constant Current Regulator must vary in accordance with characteristics of an incandescent lamp as described in AC 150/5340-30, *Design and Installation Details for Airport Visual Aids*. Light output must increase with increasing CCR output current and decrease with decreasing CCR output current per Tables 1 (white light) and Table 2 (colored light). The tolerance for the curve as shown below will be added to AC 150/5340-30 at a later date. See Appendix 1 for detailed versions of Tables 1 and 2.

For series circuit applications, the fixture's light intensity shall be based on a continuous curve and shall not use discrete step intensity changes.

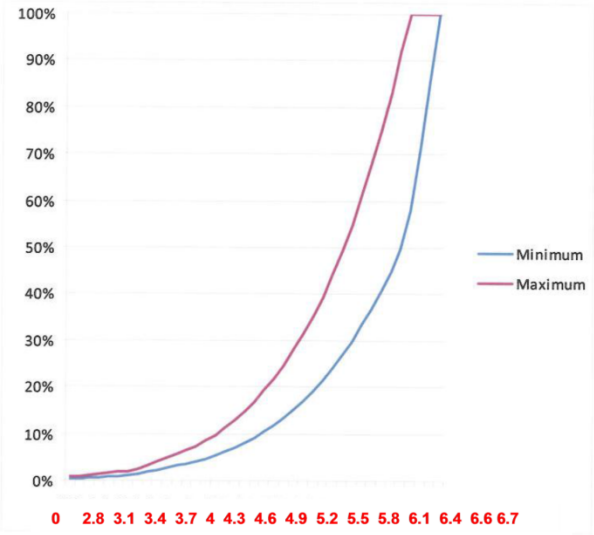


Figure 1: Dimming Curve (Applies To White Light Only)

LAMP CURRENT	% MINIMUM INTENSITY	% MAXIMUM INTENSITY
6.6	100	n/a
5.5	23.9	44.1
5.2	16.9	31.3
4.8	10.4	19.2
4.1	3.9	7.3
3.4	1.0	2.0
2.8	0.15	0.7

Table 1 (Applies To White Light Only)

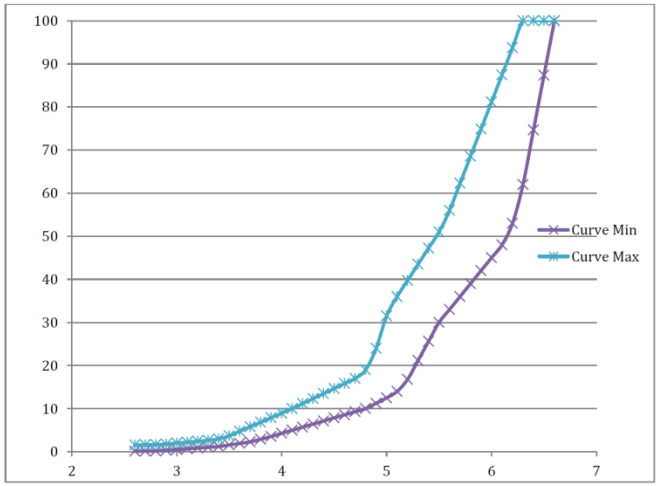


Figure 2. **Detailed Current/intensity Graph of Figure 2 for LED Light Colors Blue, Red, Green, and Yellow**

LAMP CURRENT	% MINIMUM INTENSITY	% MAXIMUM INTENSITY
6.6	100	n/a
5.5	30.0	51.0
5.2	16.8	39.75
4.8	10.0	19.0
4.1	5.0	10.0
3.4	1.2	3.0
2.8	0.15	1.65

Table 2. Applies To Colored Light Only (see Appendix 1 for detailed table)

When testing intensity ratios, the current must be measured at the primary of the isolation transformer.

2.0 Additional Qualification Requirements/Testing

2.1 Chromaticity — **All** fixtures must meet the chromaticity requirements per this paragraph for color of light emitted. Testing must be done using a spectroradiometer in increments of 2nm or less. Testing must be conducted after the applicable photometric test warm-up time specified in the applicable AC, or after stabilization if warm-up time is not specified.

NOTE: This section does not apply to runway and taxiway signs. See AC 150/5345-44 for ALD sign requirements.

2.1.1 Aviation White LED Chromaticity Boundaries — All white LED light fixtures must meet the following chromaticity boundaries for aviation white:

- Yellow boundary: $x = 0.440$
- Blue boundary: $x = 0.320$
- Green boundary: $y = 0.150 + 0.643x$
- Purple boundary: $y = 0.050 + 0.757x$

Boundary Intersection Points for Aviation White:

$x = 0.320, y = 0.356$
$x = 0.440, y = 0.433$
$x = 0.440, y = 0.383$
$x = 0.320, y = 0.292$

NOTE: See AC 150/5345-43 for white obstruction light chromaticity.

2.1.2 LED light fixtures that emit aviation green, blue, yellow or red light color must meet the following boundary equations and boundary intersection points:

a. Green (ICAO Modified)

Blue boundary: $y = 0.768 - 1.306x$
White boundary: $y = 0.600$
Yellow boundary: $y = 3.470 - 9.200x$

Green boundary intersection points:

$x = 0.014, y = 0.750$
$x = 0.129, y = 0.600$
$x = 0.312, y = 0.600$
$x = 0.302, y = 0.692$

b. Blue (ICAO)

Green boundary: $y = 0.805x + 0.065$
White boundary: $y = 0.400 - x$
Purple boundary: $y = 1.668x - 0.222$

Blue boundary intersection points:

$x = 0.090, y = 0.137$
$x = 0.186, y = 0.214$
$x = 0.233, y = 0.167$
$x = 0.148, y = 0.025$

c. Yellow (CIE S 0004/E2001):

Green boundary: $y = 0.727x + 0.054$
White boundary: $y = 0.980 – x$
Red boundary: $y = 0.387$

Yellow boundary intersection points:

$x = 0.547, y = 0.452$
$x = 0.536, y = 0.444$
$x = 0.593, y = 0.387$
$x = 0.613, y = 0.387$

d. Restricted Red (CIE S 0004/E-2001 restricted region)

Yellow boundary: y = 0.320
White boundary: y = 0.980 - x
Purple boundary: y = 0.290

Red boundary intersection points:

x = 0.680, y = 0.320
x = 0.660, y = 0.320
x = 0.690, y = 0.290
x = 0.710, y = 0.290

NOTE: See AC 150/5345-43 for red obstruction light chromaticity.

2.2 High Temperature Test — Unless specified in other Advisory Circulars, alternative light source fixtures must meet the following requirements. Manufacturers must ensure that the light output of the fixture does not drop more than 30% of the photometric requirement of the applicable AC when operated at high temperature. The photometric measurement must be done after 15 minutes of operation (for products covered under AC 150/5345-46) or stabilization (for all other products) at 25C, and again after 4 hours of continuous operation at 55C.

2.3 Fixtures must be designed to operate and interface with all existing airport lighting equipment systems contained in Advisory Circular 150/5345-53.

2.4 Accelerated Fixture Life Test - Alternative light sources must be subjected to the accelerated life test per AC 150/5345-46D, Specification for Runway and Taxiway Light Fixtures, paragraph 4.5.4, Accelerated Life Test, with the following exceptions and additions:

a. The accelerated life test duration shall be 500 hours at 131 degrees Fahrenheit (55 degrees Celsius). A light system shall be operated at highest fixture manufacturer rated voltage or current using approved regulators or a current supply having one percent regulation. The duty cycle shall consist of 20 hours fixture operating time and 4 hours de-energized. A voltage controlled system shall be operated from a supply having three percent regulation. This test may be run in parallel with other accelerated life tests.

b. The manufacturer must report to the 3rd party certifier the LED junction temperature as measured with a pre-approved procedure in the "as-installed" condition for that light fixture. This information will be compared with the LED manufacturer's ratings.

2.5 Light Fixture Performance Criteria - Manufacturers are required to publish the performance criteria for all light generating devices. This performance criteria is defined as worst-case wattage and VA at both the input leads of the fixture and, for fixtures powered from a series circuit, across the primary winding of an appropriately sized isolation transformer. The fixture lead length shall not exceed 24 inches for this test. This information shall be listed on the manufacturer's datasheets and verified by third party certification body. The manufacturer shall also state the operational current range, for series circuit powered fixtures, or input voltage

2.11 Electromagnetic Emissions - The alternate light source fixture and associated on-board circuitry must meet Federal Communications Commission (FCC) Title 47, Subpart B, Section 15, "Unintentional Radiators", regulations concerning the emission of electronic noise. Both conducted and radiated emission limits must be tested.

2.12 Surge Protection - The interface circuitry (if any) and solid state devices 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 C2 of ANSI/IEEE C62.41-1991 "Recommended Practice on Surge Voltages in Low Voltage AC Power Circuits", Standard 1.2/50 microsecond (µS) — 8/20 µS Combination Wave. Peak voltage is 10 kilovolts, peak current is 5 kilo amps with a nominal ratio of peak open circuit voltage to peak short circuit current of 2 ohms. Obstruction Lights per FAA Advisory Circular 150/5345-43, "Specification for Obstruction Lighting Equipment" are excluded from this requirement.

2.13 Optional Arctic Kits - Any fixture (includes in-pavement fixtures), may have an optional arctic kit and/or an appropriate addressing of potential icing conditions to no less extent than present fixtures. An arctic kit may be an optional feature and may be specified by the customer at the time of purchase. The arctic kit, if present, must be self-activating.

2.13.1 Arctic Kit Testing Requirements. The arctic kit must be tested as follows:

a. With light source and arctic kit off, the light fixture must be stabilized for 4 hours at - 20°C.

b. Then, in still air and with the light source activated at the highest intensity setting, the main beam light emitting surface temperature must rise a minimum of 15°C after 30 minutes operation.

c. For elevated fixtures, this test is run in open-air conditions.

2.14 In-Pavement Light Fixture Testing - All light fixtures with alternative light source electronics at or below grade level must be subjected to the in-pavement light tests described in Advisory Circular 150/5345-46, *Specification for Runway and Taxiway Light Fixtures.*

2.15 Light Fixture Flicker - All light fixtures that use pulse width modulation (PWM) to facilitate LED brightness changes must not cause perceptible flicker to a moving human observer (example: pilot in an aircraft) throughout the range of brightness steps.

3.0 Additional Production Testing

3.1 Burn-In Production Test — Alternative light sources must be energized for a minimum of 4 hours, at 100 percent intensity at standard ambient temperature before shipment. Any failure of an alternative light source during burn-in or testing after burn-in will be cause for rejection.

4.0 Minimum Warranties

4.1 All LED light fixtures with the exception of obstruction lighting (AC 150/5345-43) must be warranted by the manufacturer for a minimum of 4 years after date of installation inclusive of all

Aviation Weekly Article

“Approach Lights Problems Lead To Broader Examination Of LED Rollout"

- “The lights are overpowering, blotting out visibility.”
- “The fundamental problem is that these lights have been fielded with no testing done,”
- “… FAA has not conducted testing to determine the potential effect of the lights on pilots at night and in different weather conditions, including rain, fog, smoke, haze and “break out effects” when a pilot descends below low cloud bases on an instrument approach.

- **"The explanations are that LED lights and standard incandescent lights are the same if the basis for comparison is limited to a measure of candela."**
  - **This statement makes it appear that Candela is the only criteria. Candela is the unit of measure used when talking about light through atmosphere only. Experts in the lighting field agree that the intensity of light measured in Candela quantifies the amount of light (no matter what source) the human eyes sees at an established angle, in a given atmospheric condition.**

- **"Since they are the same in this measure, there is no apparent reason to perform the rigors of weather, spatial disorientation, safety assessments, instrument trials, medical studies and the like as was required for incandescent lighting trails several decades ago. "**
  - **I have never heard of anyone from the FAA stating that no testing is needed.**
  - **The knowledge on the ability of the human eye to see light through any type of atmosphere has improved tremendously since the original PAR38 lamp was used in the MALSR adopted in the late 1960's.**
  - **While it is true there were more tests performed when aviation lighting was first adopted, the results of those tests still hold true (no change in physics)**
  - **There has been much more research on the way a light effects the human eye since then, which means that <u>some of the original testing is not required</u>.**
  - **Medical studies have been performed on the affects of LEDs on the human eye (CAMI) and human factors evaluations such as the affect of flicker have been performed (RPI).**

- **"If this is possible under ideal atmospheric conditions my very strong concern is what will the affects be under less than ideal conditions, to include, at a minimum, the following in both day and night conditions:**

  - **Rain evaluated at light, moderate and heavy levels .**
  - **Fog and mist evaluated at varying degrees of visibility values.**
  - **Snow evaluated at light, moderate and heavy levels.**
  - **Low ceiling conditions.**
  - **Low visibility conditions for any type of obscuration.**

  - **Research has been completed (Tech Note available) concerning LEDs and visibility. Results show there is a brightness perception factor in VMC where a white LED will appear 1.4 to 1.6 brighter than an incandescent because a LED is a saturated light source. However as visibility diminishes with more particles in the air (snow, rain etc.) Colored LEDs become desaturated and White LEDs Color Temperature become equivalent to incandescents.**

  - **"Break-out and visual acquisition of the runway during any type of visibility and obscuration condition."**

    - **It is common today on approaches in IMC low visibility and lights are on a higher step, when an aircraft "breaks out" to VMC, pilots request for approach lights to be turned down. This would be the same for an LED Approach Lighting system.**

Experimental MALSR Runway 4 ACY

Step	Candela Requirement	Current Incandescents	Prototype LEDs	1.5 B/L
High	10,000	5,865	9,172	13,758
Med	2,000	1,110	3,851	5,777
Low	400	245	2,513	3,770

Step	Current Incandescents	Prototype LEDs Perceived Brightness
High	5,865	13,758
Med	1,110	5,777
Low	245	3,770

Prototype LEDs have not been adjusted for Step 1 & 2

Prototypes were for Low Visibility flights which would use Step 3

Station	Lamp
200	60W Incandescent
400	Prototype LED
600	Prototype LED
800	150W Incandescent
1000 Left	Prototype LED
1000 Center	Prototype LED
1000 Right	Prototype LED
1200	Prototype LED
1400	150W Incandescent

Our Research on LED use at airports Started 2004

- LED and Incandescent Aviation Signal Brightness.
- LED versus Incandescent Conspicuity in all weather conditions.
- Accuracy of LED Aviation Signal Light Color Identification by Pilots With and Without Color-Deficient Vision versus Incandescent.
- Understanding flicker in airfield lighting applications.
- Photometric testing of Incandescent lights versus LEDs.
- LED System Life - How is the Operational Failure of LED Fixtures Identified?

Summary

- The FAA has been conducting research on LEDs since 2004 **(article claimed no testing had been done)**
- There is a known that LEDs appear brighter than Incandescents only when the LED remain a saturated source.
- A Brightness/Luminous Ratio has been developed and validated by flight testing at RDU in 2010 for adjusting LEDs in VMC to eliminate the "too bright" issue.
- Since the adjustment to-date no known brightness issues reported **(article implies it is a current issue)**
- The "break out" issue is the same whether using Incandescent or LEDs. Pilots today ask ATC to turn down the lights if they are flying in low visibility then descend below a cloud base into clear weather **(article implies this is unique to LEDs)**

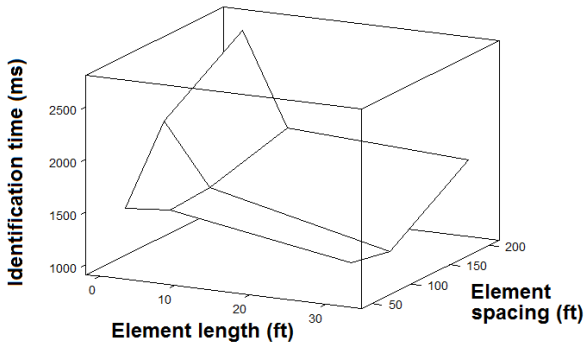
Pictures Are Worth 1000 Words!

With The Right Camera!

Evaluation of Airport Pavement Linear Source Visual Aid

- **PHASE ONE**
  - **Perform a search of LED linear source products available that could be considered for outdoor application on airports.**
- **PHASE TWO**
  - **Conduct a laboratory study to determine if a linear source has advantages in providing visual signal to the user compared to an array of point sources.**
  - **The analysis will include appropriate colors, optimum length of sources, light level modulation and spacing. Identify the key parameters for optimizing this application.**

Evaluation of Airport Pavement Linear Source Visual Aid



$$RT\ (ms) = 286 - 607 \log L + 989 \log S$$

Combinations of delineation element length and spacing to achieve the same relative response times expected from 2-ft-long delineation elements spaced at 50 and 100 ft.

Base Case 1	Element length	2 ft	**6.2 ft**	**12.0 ft**	**19.2 ft**
	Element spacing	50 ft	100 ft	150 ft	200 ft
	Relative response time	1784 ms	1784 ms	1784 ms	1784 ms
Base Case 2	Element length		2 ft	**3.9 ft**	**6.2 ft**
	Element spacing		100 ft	150 ft	200 ft
	Relative response time		2081 ms	2081 ms	2081 ms

Evaluation of Airport Pavement Linear Source Visual Aid

- **PHASE THREE**
  - **Conduct a field evaluation for the most promising application for the linear light source found in Phase Two, which demonstrate the potential to provide a substantially improved visual cue. The field evaluation will be used to validate the linear source laboratory findings and determine the installation's robustness in airfield conditions.**
  - **Develop a photometric equivalence between standard FAA point source lighting and a linear lighting source. The methodology for measuring the intensity will also be developed.**

Evaluation of Airport Pavement Linear Source Visual Aid

PHASE THREE

- Task 1: Conduct a simulation evaluation.
  - Utilizing the FAA Technical Center's Simulation facility.
  - Developing visuals

Evaluation of Airport Pavement Linear Source Visual Aid

PHASE THREE

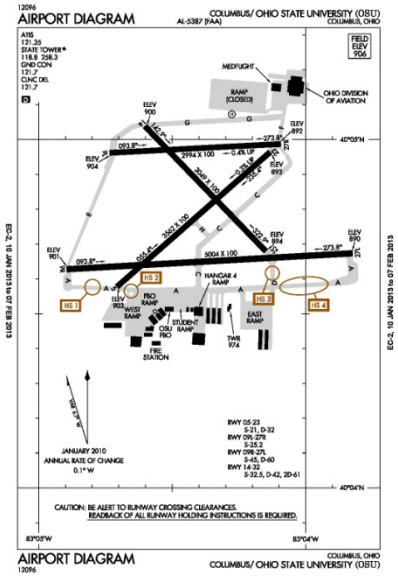
- Task 1: Simulation evaluation status.
  - 40 subjects at completion
    - Former Military Pilots
    - Current/ Former Airline Pilots
    - Ages 21-71
    - Mix in Gender

Evaluation of Airport Pavement Linear Source Visual Aid

Evaluation of Airport Pavement Linear Source Visual Aid

PHASE THREE

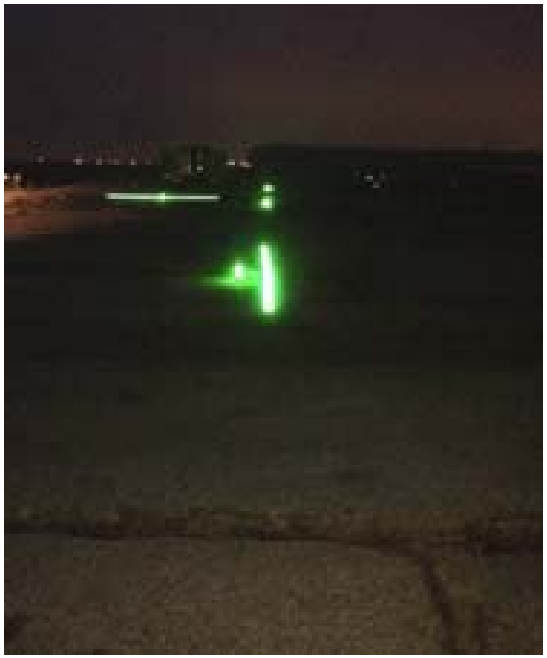
- Task 2: Conduct a field evaluation. (6 months)
  - Utilizing the Partnership to Enhance General Aviation Safety, Accessibility and Sustainability (PEGASAS) Center of Excellence.
  - Start of evaluation at Ohio State's airport 06/15



Federal Aviation Administration

Evaluation of Airport Pavement Linear Source Visual Aid

Pictures of the linear fixtures and point sources on the ramp.



Approximate distance of 350-ft.

Oh no ! Another magazine article:

Considerations for Safely Adopting LEDs in Aerospace Lighting
June 10, 2015

NVGs and LEDs

"*Helicopter pilots wearing night vision goggles have reported that they are unable to see LED lighting, especially during the critical approach phase to the helipad. LEDs are basically invisible to pilots and they are forced to remove their NVGs and land without their support*."

These types of statement while not necessarily incorrect mislead the reader that having NVGs on during an approach to a heliport is what is desired.

It is common practice for pilots when approaching a well lit area to transition from aided to unaided vision before proceeding to land. NVGs amplify available light, when entering a metropolitan hospital heliport there will be a "blooming" effect from the surrounding street lights etc.

“Light Distribution Impacted by Snow and Ice Accumulation”

“Not only do LEDs create challenges with automation systems, their adoption has made it difficult to use visual light cues in adverse weather conditions.

In the past, the heat generated from an incandescent light source, in the form of infrared energy, was enough to melt the snow or ice from the fixture. Because LEDs do not produce heat, snow and ice can accumulate on the light fixture.”

Again, while these statements may be true the fact that there’s an optional heater kit available to provide heat if an airport wants this capability is not mentioned.

It has been a known issue with Incandescent in-pavement fixtures in certain winter conditions, the heat from the incandescent fixture will melt the ice/snow on the top of the fixture but not the area immediately around it causing a “ice dam” which tends to block the light unless cleared. So the presence of heat or no heat is a maintenence issue not a safety issue.

Dimmable White LEDs

"Some have suggested that a solution to the brightness issue is to dim the LEDs; while dimming works for incandescent lighting, LED technology is different. Dimmable LED users in the general and architectural lighting market have reported that they often buzz, flicker, and dim erratically. Dimming may also impact chromaticity; as a result, the fixture may not meet acceptable color parameters defined by the FAA."

LED dimming on aviation lighting has been dealt with successfully and specified in Engineering Brief EB67.

When LEDs used in aviation lighting the color shift is not as noticeable compared to the incandescent version. When a incandescent white runway light is dimmed, a very noticeable change toward yellow is seen. When a LED fixture is dimmed using Pulse Width Modulation (PWM) pilots comment the light stays white!

Article mentions some of the information was obtained at a IESALC Government Contacts Subcommittee meeting

LED Intensity Results in Unfavorable Pilot Reviews

"*Pilots have reported that LED approach lights are too bright and almost blinding and that they can wash out heads-up displays. Prompted by these complaints, the FAA recently distributed a survey to pilots to assess the LED intensity issue and discover how it impacts pilots.*

At the IESALC meeting, the FAA discussed the results of the survey. Approximately 65% of the responders gave a negative rating to LED lighting while approximately 30% gave a positive review."

This survey was distributed by FEDEX not FAA. What questions were asked have not been discussed.

Airport Safety Database Query:

Light Emitting Diode (LED) Issues

Purpose

- Because of the mainly **anecdotal remarks** that have been made at **various venues** concerning LEDs, In March 2016, the FAA's Airport Safety R&D section conducted a search of the FAA Safety Database to determine if **reports** could be found **regarding LEDs at airports.**

Purpose

- The database sources used included:
  1. National Aeronautics and Space Administration (NASA)
  2. Aviation Safety Reporting System (ASRS)
  3. National Transportation Safety Board's (NTSB) Aviation Accident and Incident Data System
  4. FAA Accident and Incident Data Systems (AIDS).

- The time period studied was October 1, 2005 through February, 2016.

Results

- In total, **88056 reports** occurring between October, 2005 and February, 2016 were searched for issues related to LEDs.

Data Source	Total Reports	Most Recent Data Available	Total Reports Found
ASRS	55459	JAN-16	20
NTSB	18353	25-FEB-16	1
AIDS	14244	20-FEB-16	1
Total	88056	N/A	22

Summary

- Of these reports, 22 mentioned of concerns about LED lighting, excessive brightness of lights, or other similar lighting issues. 2014 was the peak year for reports regarding LED lighting, with seven reports. Calendar year 2015 had fewer than half the number of reports concerning airport lighting issues.

Year	# Reports Found
2006	3
2007	2
2008	0
2009	1
2010	0
2011	2
2012	1
2013	1
2014	7
2015	3
2016 (Jan.)	0

Conclusion of Database Search

- The number of reports and incidents of LED lighting issues have been low in number to date; however, the FAA will continue tracking this issue to ensure safety is maintained going forward.

- Although the number from this effort, is small, we are planning to analyze the reports to determine what action is needed.

Flicker or Oscillation Effect when using LED lighting

- LED runway edge lighting fixtures use Pulse Width Modulation (PWM) in the medium and low intensity steps to insure proper light output and color in these lower intensity steps. These fixtures do not PWM at the high intensity step. A constant DC current is applied to the LEDs in the high step. A strobing and/or oscillation issue has been reported by an airplane with a 3-bladed nose-mounted propeller when runway edge lighting uses PWM frequencies at 120 Hz. Some manufacturer's use 120Hz, while others use 200Hz or more.

Flicker or Oscillation Effect when using LED lighting

- The FAA held a LED Symposium in October 2014. During this symposium it was mentioned that three pilots in propeller driven aircraft had experienced a stroboscopic effect when operating at airports with LED runway edge lighting. Experts from this symposium determined that the cause of this effect may be the Pulse Width Modulation frequency used in dimming LED lights.

- Analysis within the FAA's LED Symposium Science group has indicated that, for a 3-bladed propeller, a minimum frequency of 167 Hz should eliminate the potential for strobing.

Flicker or Oscillation Effect when using LED lighting

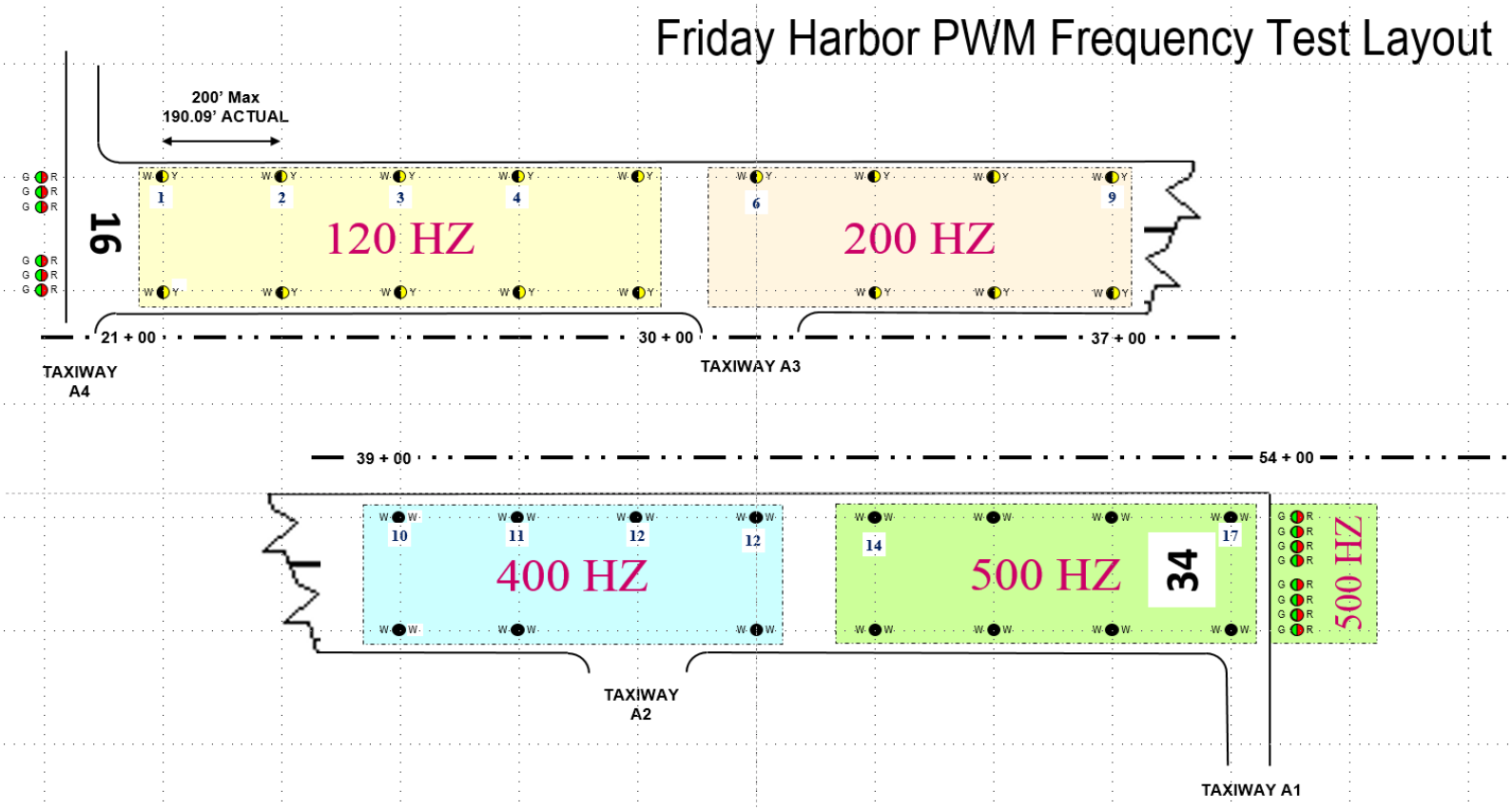
- On December 23, 2014, a letter was received by the Office of Airport Safety and Standards, with a concern of reported "strobing" effect through the propeller of certain aircraft after installation of LED Medium Intensity Runway Edge Lights (MIRLs) at the Friday Harbor Airport (KFR).

- A test plan to conduct a series of flight tests to 1) Duplicate the effect, 2) Determine if using a higher frequency when dimming the lights removes this effect.

Flicker or Oscillation Effect when using LED lighting

- January 20, 2016, several observers from Federal Aviation Administration and from manufacturers were flown in a single three bladed propeller aircraft, approaching the runway from the air and also taxiing along the airfield with different propeller speeds to try to elicit the effect. All observers were able to see the oscillation effect with the lights at the lowest frequency (120 Hz), and to a much lesser extent at the next-lowest frequency (200 Hz). The lights operating at 400 Hz and 500 Hz did not exhibit the oscillation.

Flicker or Oscillation Effect when using LED lighting



Federal Aviation Administration

Flicker or Oscillation Effect when using LED lighting

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Flicker or Oscillation Effect when using LED lighting

- At the conclusion of this effort, there **did not appear to be a safety concern**. Pilots were able to complete their operations safely. However, the **oscillating or flickering can be annoying**.

- Knowing the circumstances under which the phenomenon appears validates previous research that had been performed on flicker.

Flicker or Oscillation Effect when using LED lighting

- This phenomenon only appears when the right type of aircraft at the right propeller speed interacts with a LED lighting fixture operating at medium or low step utilizing a PWM frequency of less than 200Hz, which leads to the conclusion that this is not a common situation.

- The phenomenon may only occur for an instant while all the aforementioned criteria exist. Some manufacturers are already using PWM frequencies greater than 200Hz which has been shown by this demonstration to eliminate this phenomenon.

Questions or Comments?

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