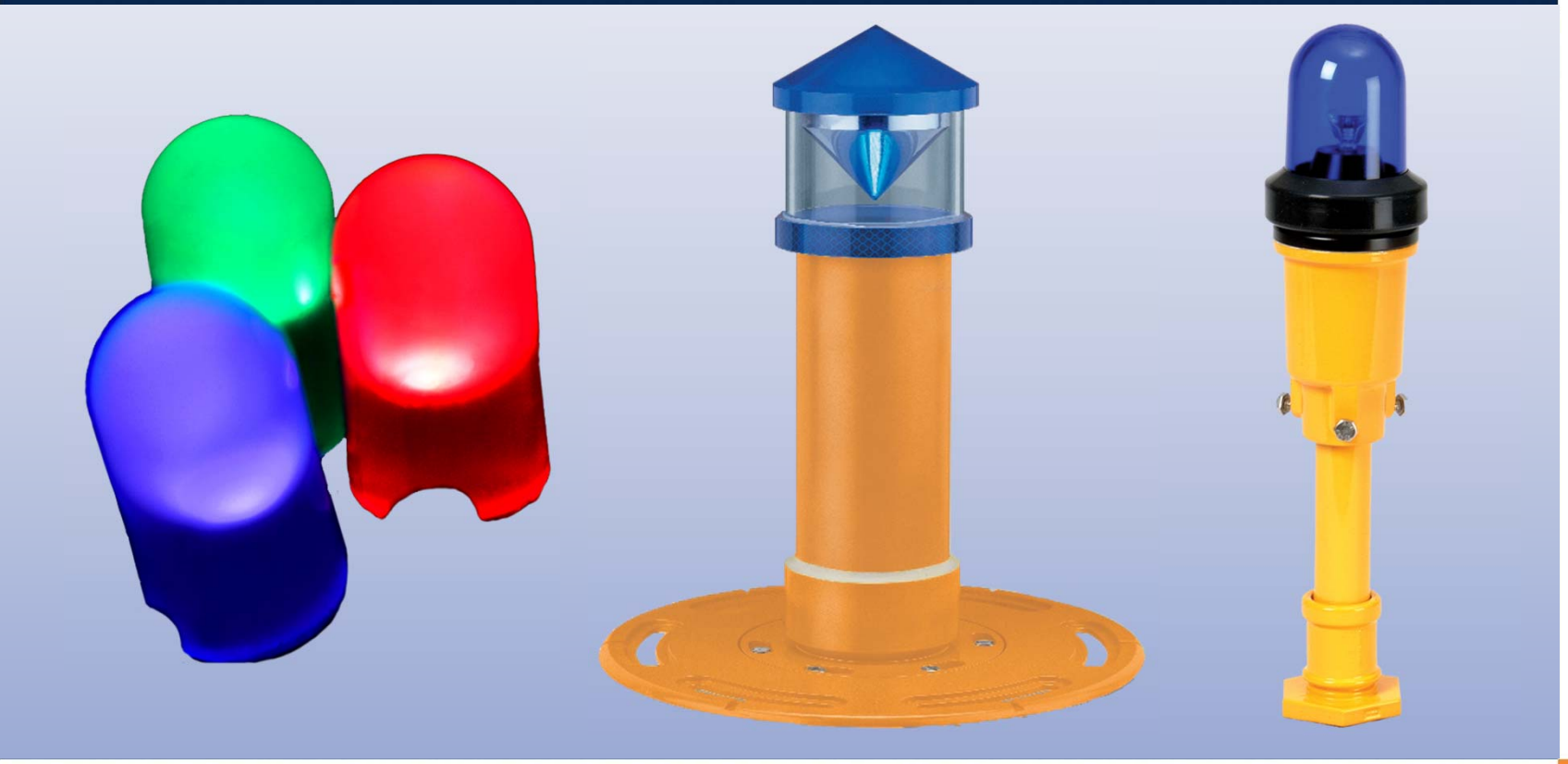
LEDs - Past, Present and Future



IES Aviation Lighting Committee
2011 Annual Conference

18 October 2011

Presented by: Pete Butler, P.E.

CH2MHILL

2011-IESALC
Wilmington, NC

Agenda

- Definition of LED
- Characteristics of LED Fixtures
- Evolution of LEDs in Airfield Lighting Systems
- Recent Developments
- Airport LED Trends
- Future Implementation
- Design Considerations

Definition of LED

- Light Emitting Diode
- Semiconductor light source
- Within device, electrons jump a gap to recombine with electron holes

- During jump, energy is released in form of photons
- Result - phenomenon called electroluminescence
- Color of LED determined by energy gap of semiconductor

Characteristics of LEDs

Positive Characteristics

- Lower energy consumption
- Longer lifetime
- Improved robustness
- Smaller size
- Faster switching
- Greater durability
- Higher reliability

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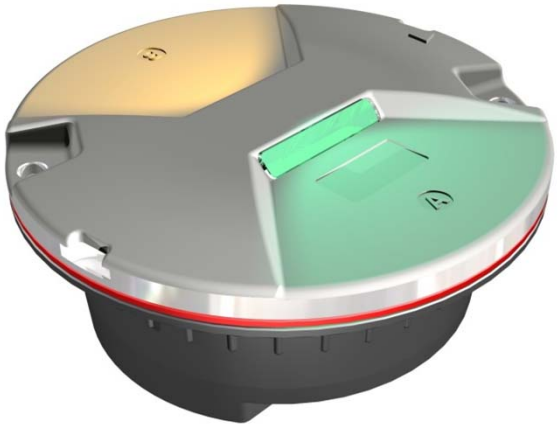

Characteristics of LEDs

Negative Characteristics

- More expensive
- Require more precise current
- Sensitive to high temperatures
  - Light output decreases
  - Light spectrum negatively impacted
  - Heat sinks / beveled or ridged exterior introduced

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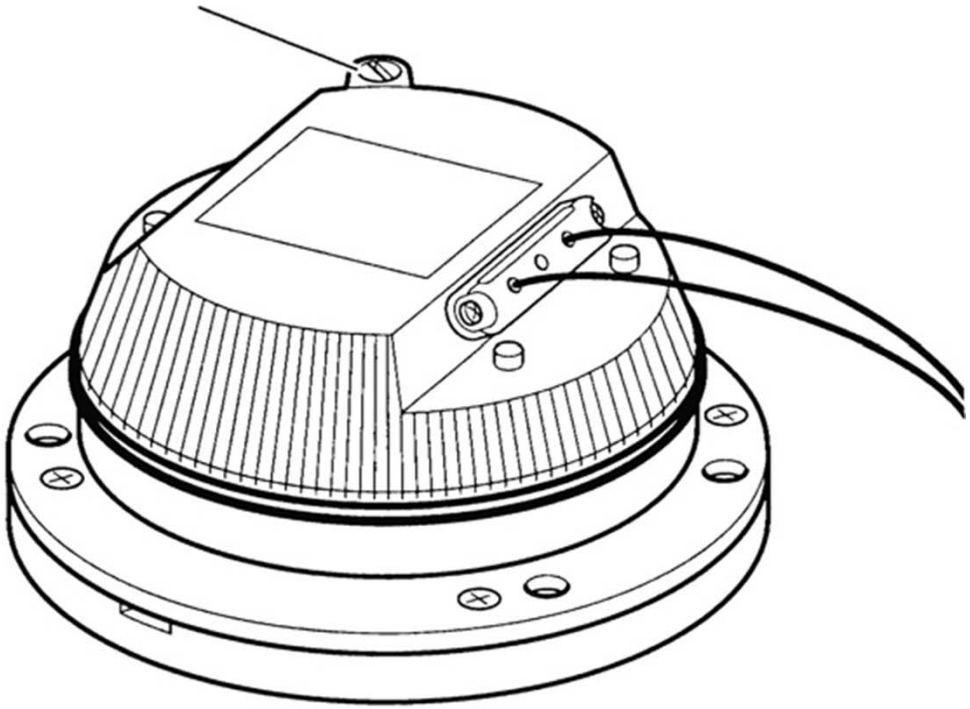
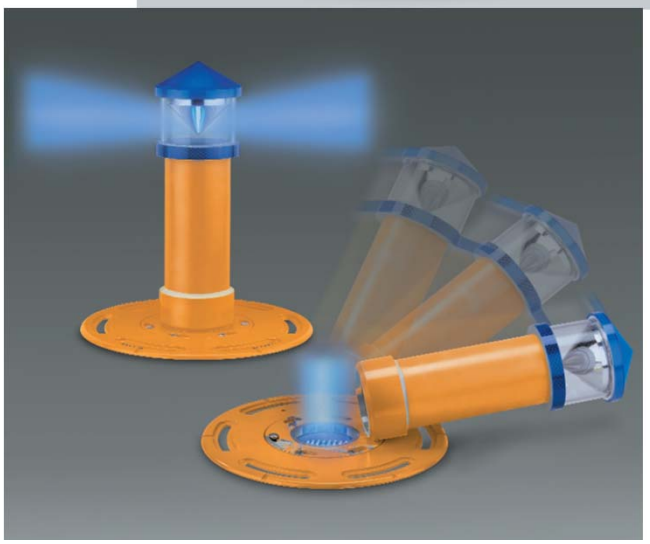
Characteristics of LEDs



Evolution of LEDs in Airfield Lighting Systems

- Implemented in clusters
- Taxiway elevated edge lights emerged in early 2000s
- Original fixtures resembled lighthouses with cluster at base
- Inherent maintenance issues
- Water infiltration

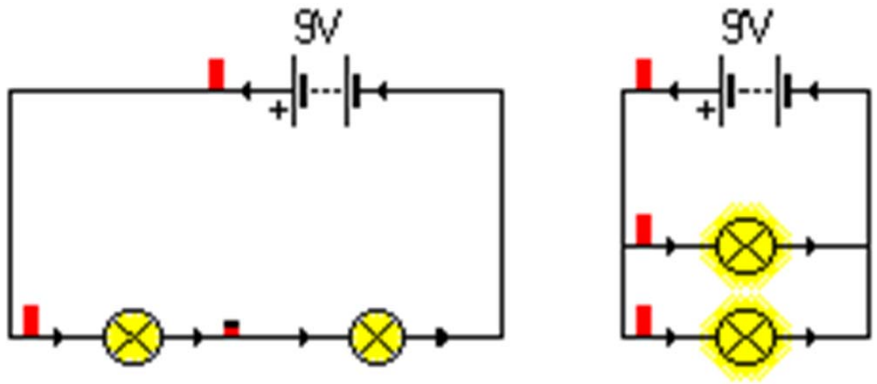


Evolution of LEDs in Airfield Lighting Systems

- LED technology improved, airport interest increased - additional manufacturers developed lights
- Mid 2000s, at least three vendors of edge lights
- Fixtures better resemble typical edge lights

Evolution of LEDs in Airfield Lighting Systems

- Fixtures installed in existing 5kV airfield lighting environment
- LEDs are DC-based devices that operate in milliamp range
- As LED technology improved, experts discussed alternate power sources
- Test beds analyzed alternate power sources



Evolution of LEDs in Airfield Lighting Systems

Prescott Municipal Airport Testing

- Utilized traditional series lighting circuits
  - Constant current regulators, series lighting cable, isolation transformers, connector kits
- System includes
  - Modified LED edge lights
  - Incandescent edge lights
  - LED guard lights

Evolution of LEDs in Airfield Lighting Systems

Prescott Municipal Airport Testing

- Modified edge lights – 2.8A maximum
- System utilized 0.28/0.84/2.8A circuit
  - Steps percentages same as 6.6A circuit
- Testing proved successful
- System still operating after five years with no fixture failures

Evolution of LEDs in Airfield Lighting Systems

Hartsfield-Jackson Atlanta International Airport Test Bed (2006 – present)

- DC-based system (600V DC)
  - LED taxiway centerline
  - LED edge lights
- Modification to Standards
- Airport-funded project

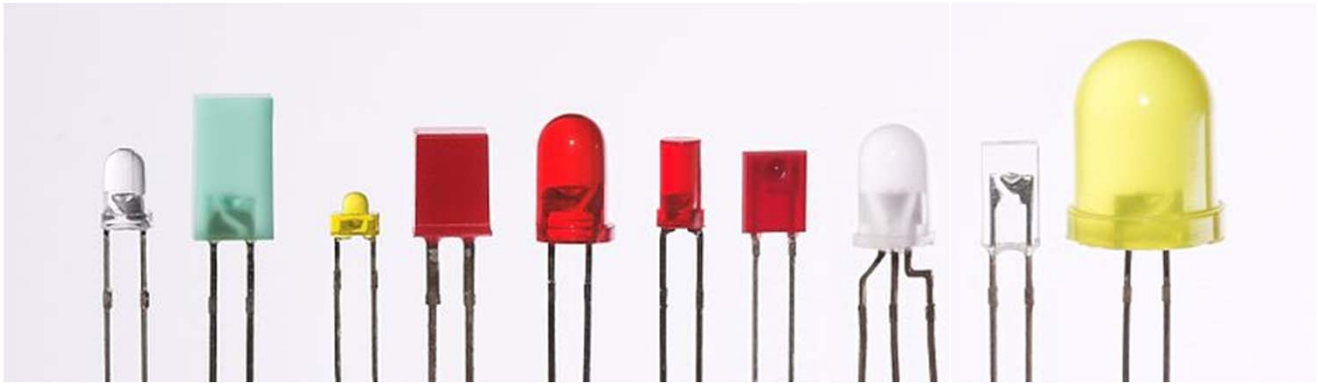
Evolution of LEDs in Airfield Lighting Systems

Hartsfield-Jackson Atlanta International Airport Test Bed (2006 – present)

- Small, rack-mounted power supply
  - In lieu of constant current regulator
- Fixtures directly connected to circuit
  - Standard connector kits

Evolution of LEDs in Airfield Lighting Systems

- LED Equipment has evolved significantly
- List of available LED-based lighting equipment has expanded
  - Obstruction lights
  - Elevated and in-pavement lights
  - Signs
  - Windcones



Evolution of LEDs in Airfield Lighting Systems

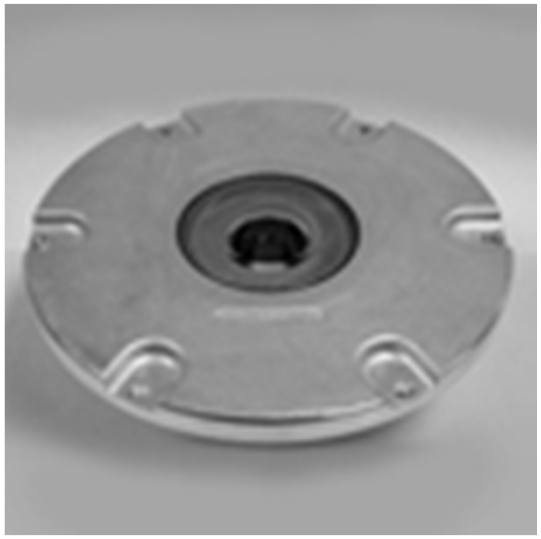
- Obstruction Lights
  - Multiple vendors
  - ADB, Dialight, Crouse-Hinds, Point Lighting, TWR, etc.

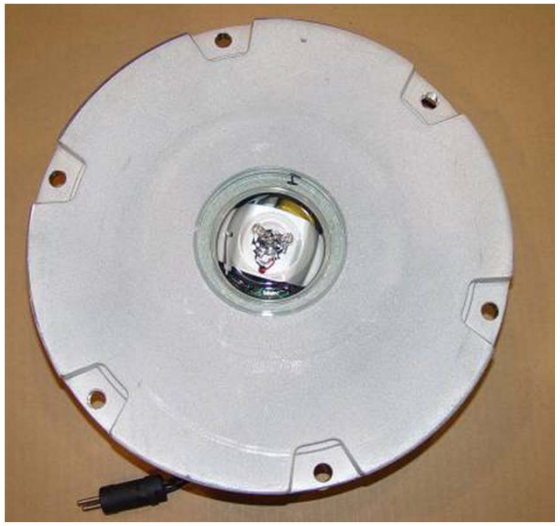
Evolution of LEDs in Airfield Lighting Systems

- Elevated Taxiway Edge Lights
  - Multiple vendors
    - Crouse-Hinds, ADB, Airport Lighting Co., Astronics/DME, others
  - Smooth Lens, Rigged Lenses

Evolution of LEDs in Airfield Lighting Systems

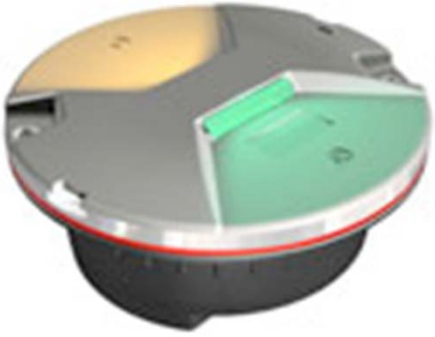
- In-pavement Taxiway Edge Lights
  - No true FAA specification
  - 8” or 12” diameter
  - Crouse-Hinds, ADB, Multi-Electric

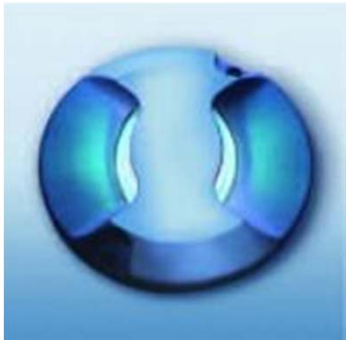




Evolution of LEDs in Airfield Lighting Systems

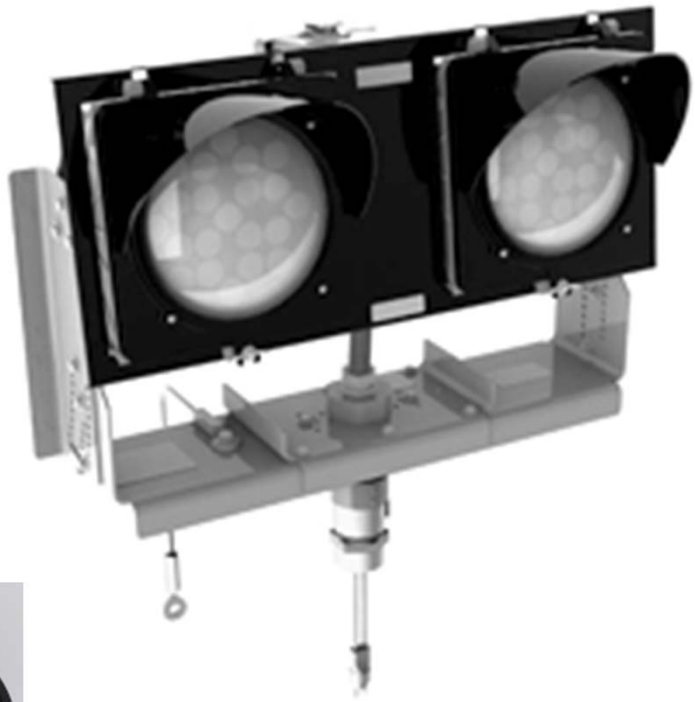
- Taxiway Centerline Lights
  - 8” and 12” diameter
  - Multi-Electric, Crouse-Hinds, ADB, Safegate, ATG Airports, others





Evolution of LEDs in Airfield Lighting Systems

- Elevated Runway Guard Lights
- ADB, Safegate, Crouse-Hinds



Evolution of LEDs in Airfield Lighting Systems

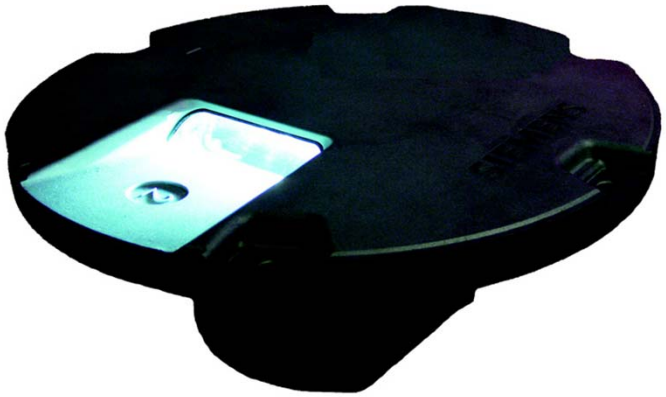
- In-pavement Runway Guard Lights
  - ADB

Evolution of LEDs in Airfield Lighting Systems

- Medium-Intensity Runway Edge Lights
  - ADB

Evolution of LEDs in Airfield Lighting Systems

- Runway Centerline and Touchdown Zone Lights
- ADB, Multi-Electric



Evolution of LEDs in Airfield Lighting Systems

- Signage
  - ADB, AGM, Crouse-Hinds, Lumacurve (Standard Signs)

Evolution of LEDs in Airfield Lighting Systems

- Wind Cones
  - Isolation Transformer Connection
  - Hali-Brite, ADB

Evolution of LEDs in Airfield Lighting Systems

- REILS
  - Isolation Transformer Connection
  - ADB

Evolution of LEDs in Airfield Lighting Systems

- LED-supporting equipment
  - Smaller constant current regulators
    - 1kW, 2kW, 4kW
  - Liberty Airport Systems, Manairco

Evolution of LEDs in Airfield Lighting Systems

- LED-supporting equipment
  - Smaller isolation transformers
  - 10/15W, 20/25W
  - Amerace, Integro

Evolution of LEDs in Airfield Lighting Systems

- LED-supporting equipment
  - Sign Retrofit Kits
  - AGM, ADB, Lumacurve

Recent Developments

Orlando International Airport Test Bed (2010 to present)

- DC-powered circuits, pulse width modulated
- Two interleaved circuits
- LED Taxiway Centerline Lights
- No isolation transformers
- Rack-mounted power supply

Recent Developments

False River Airport Test Bed (2010 to present)

- Funded by State of Louisiana
- DC power supply fed by batteries connected to solar panels
- Two interleaved circuits
- 160 LED Taxiway Edge Lights
- Rack-mounted power supply
- LED Runway Lights

Recent Developments

- Runway centerline & touchdown zone lights
  - Certified in last eighteen months
  - Installed at Raleigh-Durham Airport
- Pilot Complaints
  - Fixtures too bright at lower steps
- Moratorium on acquisition and installation
  - Issued in September 2010
  - Impacted project bidding

Recent Developments

- FAA tested circuit performance, verified regulator operation, and flight checked lighting
- Test Results
  - LED fixtures brighter at lower steps than incandescent fixtures
  - Light curves differ between LED and incandescent fixtures

Recent Developments

- Incandescent fixture output is linear, while LED output is non-linear
- Light Dimming Curve modified for white LED lights only
- Engineering Brief 67C issued, moratorium lifted

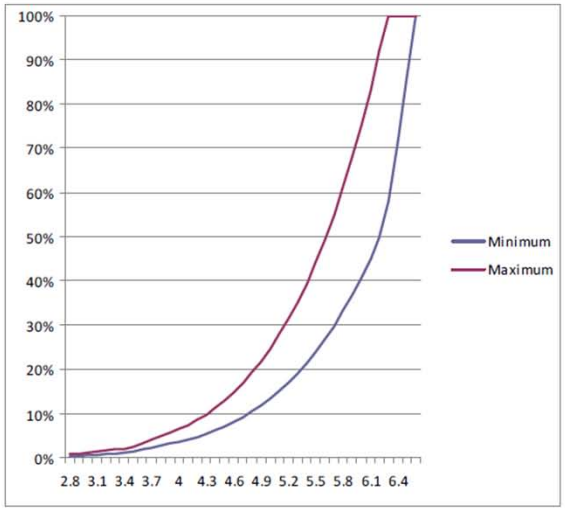


Figure 1: Dimming Curve (Applies To White Light Only)

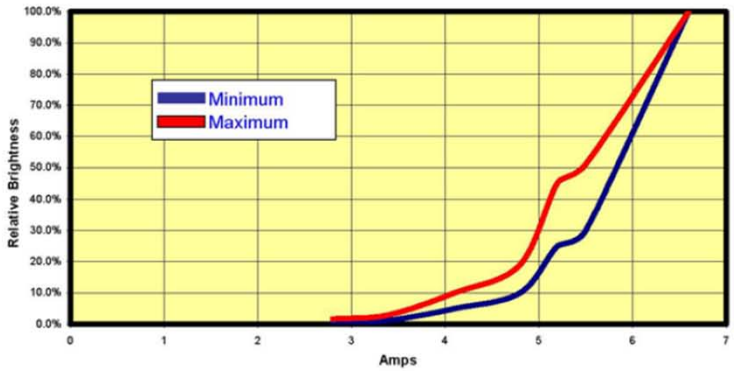


Figure 1: Dimming Curve

Recent Developments

- Airport / manufacturer focus on runway edge lights
- Will impact majority of airports
- Main restriction to previous development
  - Intensity of white LEDs
- Medium-Intensity Lights developed within last year

Recent Developments

- High-intensity elevated edge lights
  - Anticipated in late 2011/early 2012
- High-intensity in-pavement edge lights required to coincide with elevated fixtures
- Development of in-pavement edge light has not progressed as quickly
  - Slowing HIRL implementation

Airport LED Trends

- O'Hare Airport
  - Taxiway edge and centerline lights only
  - Arctic kits
- Columbus and Rickenbacker Airports
  - Implementation of lights, signs, wind cones, etc.
  - No arctic kits
- Tampa Airport
  - Taxiway edge and centerline lights only
  - No arctic kits

Airport LED Trends

- Denver International Airport
  - Few test fixtures in place
  - Testing DC-based system on a remote taxiway
  - No arctic kits
- Calgary International Airport
  - Implementation of taxiway centerline and edge lights, signs, and elevated guard lights in near future
  - No arctic kits

Airport LED Trends

- Philadelphia Airport
  - Random taxiway edge and centerline lights to date
  - Runway centerline and touchdown zone to implemented in near future
- National and Dulles Airports
  - No LED lighting
  - Bad experience with original version

Airport LED Trends

- Pittsburgh Airport
  - Random taxiway edge and centerline lights only
  - No clear direction of arctic kits
- Bishop Airport (Flint, Michigan)
  - Taxiway edge and centerline lights
    - No arctic kits
- Rochester Airport (Minnesota)
    - Taxiway edge lights and signs
    - No arctic kits

Future Implementation

- System Approach needed
  - Embrace LED properties
  - Maximize efficiency
  - Cease adapting to existing environment / infrastructure

Future Implementation

- Two approaches evolving
  - Lower current series circuit
    - Possible maximum current of 2.8A
  - DC-based system with pulse width modulation
  - FAA has committee considering approaches
  - Decision not anticipated for couple years

Future Implementation

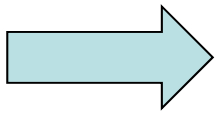
- Determination of when LED fixtures become industry standard
- Airports are requesting LED fixtures
  - GO GREEN
  - Lower power consumption
- When will incandescent bulbs be obsolete?
- Will FAA provide a mandate?
  - Similar to federal mandate on fluorescent light bulbs
- What can done in the meantime?

Design Considerations

- Consider LEDs for lights, signs, wind cones, etc.
  - Maximize energy savings
  - Reduce energy costs
- Match transformer sizes, maximize efficiency
- Don't forget infrastructure

Design Considerations

- Plan designs for future LED implementation
- Separate circuits for incandescent and LED fixtures
- Segmenting of circuiting / operations
  - FAA AC does not permit interspersing of LED and incandescent fixtures



Design Considerations

- Analyze impact on circuit loads, vault, etc.

	LED	Incandescent
Light Fixture	**Wattage (VA)**	**Wattage (W)**
L-804 – Elevated Runway Guard Light	**92**	**120**
L-852A/B - Taxiway Centerline Light - Narrow Beam /Wide Beam	**Uni: 12 Bi: 16**	**Uni: 32 Bi: 64**
L-852G - In-Pavement Runway Guard Light	**55**	**120**
L-850A - Runway Centerline Light	**29**	**96**
L-850B - Touchdown Zone Light	**15**	**45**
L-850C - In-Pavement Runway Edge / Displaced Threshold Light	**-**	**45**
L-858 - Taxi - Guidance Sign / Distance Remaining Sign	**100**	**192**
L-861-T - Elevated Taxiway Edge Light	**12**	**45**
L-862 - Elevated Runway Edge / Threshold / Displaced Threshold	**-**	**120**

Design Considerations

- Perform Life Cycle Cost Analysis
- Analysis Factors to consider
  - Infrastructure held as a constant
  - Material cost
  - Lamp life
  - Energy consumption
  - Replacement cost for incandescent bulbs

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Design Considerations

- Life Cycle Cost Analysis
  - During the design phase
    - Include in Design Report
  - Designer best suited for task
    - Perspective on airport request, needs and future development
    - Knowledgeable on impacting factors
  - Can FAA provide a standardized format for the analysis?

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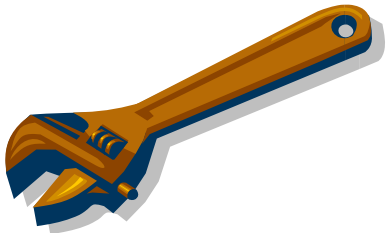
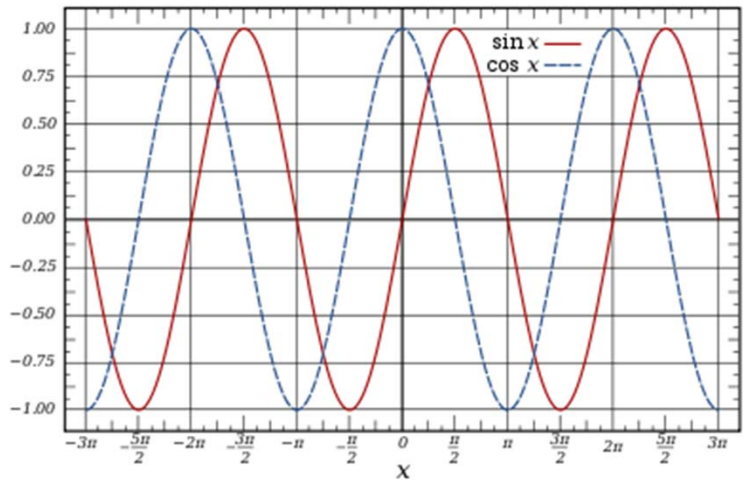
Design Considerations

- Training of maintenance staff
  - Electricians and contractors not completely familiar with the technology
  - Require training session in design documents
  - Develop a second spare parts inventory
    - Specify spare parts during design



Design Considerations

- LED equipment typically use pulse-width modulated power supplies
  - Input a AC sine wave
  - Sine wave is sampled and recreated as DC wave to feed the light fixture
  - Inherent concerns created with PWM power supplies



Design Considerations

- Harmonics
  - FAA testing has not identified major concerns to date
  - Typical of equipment in place
- Electromagnetic Interference (EMI)
  - Airfield is noisy environment
    - Introduction of PWM power supplies and other switching devices
    - LED fixtures, Runway guard lights, Guidance Signs

Design Considerations

- EMI results differ from airport to airport
- Conducted emissions have been identified
  - Interference created with existing equipment
  - Review compatibility of proposed equipment with existing equipment in place
  - Compatibility can not be tested at manufacturer's site
  - Field Testing required to develop best solution

Design Considerations

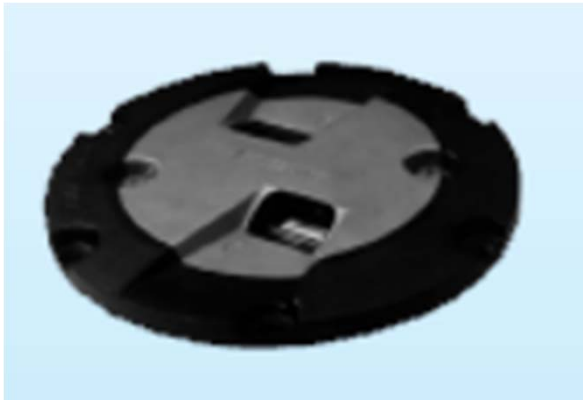
- Arctic Kit or no Arctic Kit
  - Northern Airports apprehension to use LED lights
    - Fixtures won't melt snow
  - Snow melting is inherent property of incandescent fixture
  - Disadvantage - arctic kit negates lower LED energy consumption
  - Selection impacts circuit load, regulator size

Design Considerations

- Test Beds – w/ and w/o Arctic Kits
  - Multiple sites in Midwest
    - Rochester (MN), Flint (MI), O'Hare, Columbus (OH), Toledo (OH)
  - Vendors provided sample fixtures and signs
    - Installed side-by-side prior to winter (two years ago)
    - Heavy year for snowfall
    - Operations and Maintenance staff
      - No discernable difference in light output

Design Considerations

- JFK Test Bed
  - Taxiway Centerline Lights w/o kits on Taxiway S
  - Multiple vendors installed
  - Functioning to date
  - Snow melting - not an issue
    - Snow plow operations begin at ½" accumulation, snow does not inhibit light output



Conclusions

- LED Technology has evolved very quickly
  - Light house to edge light to runway centerline lights
- LEDs just like all other has technologies
  - Advantages and disadvantages
  - Evolution has become commonplace with some items
- LEDs are ‘Here to Stay’
  - Pressure to ‘GO GREEN’ and lower energy costs
  - Embrace and Utilize the technology
  - Be smart about implementation

THANK YOU