New Considerations in LED Tunnel Lighting
Presented by Michael N. Maltezos, MIES
Chairman, IESNA Tunnels Committee
Bonjour!!!!

Michael N. Maltezos, MIES

Michael is the International Transportation Sales Manager for Kenall Manufacturing Co. Michael possesses over 25 years’ experience in the field of roadway, tunnel and transit lighting. In particular, Michael is considered a subject matter expert in the very specific application of roadway and transit tunnel lighting. Michael is currently Chairman of the IESNA Tunnels/Underpasses Committee, which is responsible for the ANSI/IESNA RP-22 Recommended Practice for Tunnel Lighting.

Before joining Kenall, Michael was the Tunnel and Transit Specialist for Schreder Lighting. Prior to Schreder, he was the President of Maltezos & Associates, performing Transportation lighting design and related consulting services. Michael was previously employed by CTE Engineers as a Senior Associate, working with DOTs around the country in implementing their project/program management and design.

Michael earned several lighting design awards from 1999-2008 through the International Illumination Design Awards (IIDA) and Illuminating Engineering Society of North America (IESNA). He is a Member of the IESNA Street & Area Lighting Committee and the IESNA Roadway Lighting Committee, and is also a Member of the CIE’s Liaison Committee with the IESNA.
Definition of a Tunnel (Literally)
A structure over a roadway which restricts the normal daytime illumination of a roadway section such that the drivers visibility is substantially diminished
Attendees of this presentation will learn:

• The Needs of the User (and of the End User)
• Problems & Challenges with Tunnel Topology
• Lighting Application Techniques
• LED Lighting Design Considerations
• LED Lighting System Economics
• LED Maintenance Considerations
• The True “Definition” of a Tunnel
• LED Luminaires
• Controls with LED Luminaires
This Presentation is Also Designed to Help You Write Effective Specifications Based on the Industry’s Best Practices for LED Tunnel Lighting
The Needs of the User (and of the End User)

- Driven by common theme: Public Safety
- Safety in operating the lighting system
- Safety/visibility in the driving task
- Life Safety
Problems & Challenges with Tunnel Topology – The Tunnel Zones

At this time there are no national standards for security detention facilities. There are standards for Federal Institutions...
It All Starts with…Tunnel Topology…

A = Fixation Point
B = Adaptation Point
C = Portal
Ø = 22 to 25°

…per CIE-88 or ANSI/IESNA RP-22.
Problems & Challenges with Tunnel Topology

Access Zone L20

- Light Contrast
- “Black Hole”
- Adaptation
Problems & Challenges with Tunnel Topology

Threshold Zone $L_{th}$

- Spatial Adaptation: Driver goes from wide field of vision outside tunnel...to narrow field of vision entering tunnel
- Temporal Visual Adaptation: Upon entering tunnel, driver suddenly goes from high luminance levels (i.e., daylight) outside to low a very luminance level inside the tunnel
Problems & Challenges with Tunnel Topology

Transition Zone Ltr

- Luminance gradually reduced over a distance determined by the posted speed limit (CIE88)
- Luminance in Transition Zone reduced to meet level required in the Interior Zone
- Reduction stages not to exceed a 1:3 ratio. Supports: the curve of acceptability for reduction of light levels perceived by human eyes; and, Temporal Adaptation
Problems & Challenges with Tunnel Topology

Interior Zone \( L_{in} \)

- Once crossed into Interior Zone from Threshold Zone, Spatial Adaptation is done; eye adaptation is completed

- Interior Zone luminance levels dictated by vehicular traffic speed and density

Recommended Interior Zone Luminance (cd/m²)

<table>
<thead>
<tr>
<th>Stopping Distances</th>
<th>Traffic Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;100 v/h</td>
<td>&gt;100/1000 v/h</td>
</tr>
<tr>
<td></td>
<td>&gt; 1000 v/h</td>
</tr>
</tbody>
</table>
Problems & Challenges with Tunnel Topology

Exit Zone $L_{ex}$

Typically not required except in very long tunnels, where the eye has adapted to low light levels for some time and must now re-adapt to high light levels at the exit portals.
Problems & Challenges

Other Considerations in the brave new world of LEDs
Lighting Application Techniques
Symmetrical Distribution
Lighting Application Techniques
Asymmetrical Distribution (Negative Contrast)

Light emission above 45° vertical must be strictly controlled
Lighting Application Techniques
Asymmetrical Distribution (Positive Contrast)
Lighting Design Considerations – Tunnel Geometry, Architectural Features, & Materials

- Tunnel lighting systems are expensive to install and operate; as such, minimizing luminance of Exterior Portal surfaces and increasing luminance of interior tunnel surfaces will reduce $$

- Tunnel Pavement: Reflectance AND Luminance Contrast must be taken into accord; some pavement surfaces will have higher reflectance, but may NOT enhance contrast because of diffuse reflectance characteristics (e.g., Portland Cement Concrete)

- Tunnel Architectural Features: Different tunnel cross-sections and shapes will influence luminaire placement and light inter-reflection; e.g., “horseshoe”-shape tunnels tend to absorb light
- Tunnel lighting systems are expensive to install and to operate; take note of ALL considerations shown in IES RP-22 Section 9.1

- LEDs: Interesting to note….ALL jobs we are currently involved with, in design, will go LED. Further interesting note…SSL is the ONLY light source technology currently funded by the U.S. DOE

- LEDs: Based on recent efficacies...Threshold Zone was ALWAYS the problem, and relegated cost payback analyses to a proverbial circular file! However, LED chip efficacies are ever-improving…so…tunnel lighting cost payback analyses are as well

- LEDs: Drive Current in the Threshold/Transition Zones? Hmm..
# Maintenance Factor (LLF) Considerations

Reflects old light source technologies; how valid is this now, for LEDs??

<table>
<thead>
<tr>
<th>Maintenance Considerations Above</th>
<th>Range of Possible Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamp Lumen Maintenance</td>
<td>0.50 to 0.95</td>
</tr>
<tr>
<td>Lamp Burnouts</td>
<td>0.30 to 0.99</td>
</tr>
<tr>
<td>Luminaire Dirt Depreciation (LDD)</td>
<td>0.10 to 0.95</td>
</tr>
<tr>
<td>Equipment Factors (EF)</td>
<td>0.50 to 0.95</td>
</tr>
<tr>
<td>Ambient Temperature</td>
<td>0.20 to 0.99</td>
</tr>
<tr>
<td>Voltage</td>
<td>0.87 to 1.13</td>
</tr>
<tr>
<td>Ballast &amp; Lamp Factor</td>
<td>0.85 to 0.90</td>
</tr>
<tr>
<td>Tunnel Surface Reflectance</td>
<td>0.20 to 0.90</td>
</tr>
<tr>
<td>Luminaire Cleaning</td>
<td>0.10 to 0.90</td>
</tr>
<tr>
<td>Total Typical Maintenance Factor (TMF)</td>
<td>0.30 to 0.65</td>
</tr>
</tbody>
</table>
Plastic or Glass?
Plastic Burns.
Glass Doesn’t.
*Remember…NFPA 502!!!*
Lighting System Economics

- Selected light level
- Type of light source
- Quality of lighting equipment
- Method of equipment installation
- Maintenance and operation procedures
- Cost of Energy
Lighting System Economics

-- Initial Cost

- Cost of System Installation
- Includes both equipment and labor
- Obviously important, given today’s tight public budgets; but…
- Provides incomplete information re: relative system costs
- Maintenance and operation costs not considered
- Energy, efficacy costs not considered
Lighting System Economics
-- Life Cycle

- Cost of System Installation is only the start...
- Includes equipment & labor for installation AND replacement
- Includes any interest on capital investment (initial installation)
- Provides complete set of information re: relative system costs
- Maintenance and operation costs are considered
- Energy, efficacy costs considered
TRUE Definition of a Tunnel?

- A Highly Challenging Environment, including...
  - Exhaust Fumes Consisting of Hydrocarbons and Other Organics
  - High Humidity and Air Salinity
  - Structural Vibration
  - Salts & Sulfur Corrosives
  - Galvanic Coupling Differences (electrolytic ionization)
  - Wind Tunneling Effect from large vehicles
  - Ingress by Water & Detergents from Washing
  - Fire and Life Safety Issues (e.g., NFPA 502)
Highly Challenging Environments
Highly Challenging Environments
The Worst Case....
Transportation

Best Practices

Light Distributions For Tunnel Lighting
Tunnel lighting is available in a variety of distribution types—both symmetric and asymmetric—each with specific benefits and applications. When selecting tunnel lighting, thoughtful consideration should be given to this variety of distribution types available. The goal is to maximize the driver's visual experience and minimize potential obstacles, thereby optimizing their safety and comfort.

Symmetrical-Transversal Lighting
- Uniform luminance throughout tunnel interior
- Generally two contrast values
- Minimize wall luminances
- Maximize lamp spacing to reduce glare

Symmetrical-Axial Lighting
- Uniform luminance throughout tunnel interior
- Generally two contrast values
- Maximize lamp spacing to reduce glare
- Maximize card spacing to reduce glare

Asymmetrical-In Positive Contrast (Pro-Beam)
- Primarily directed towards the driver
- Provides high pavement luminance and low object luminance to enhance negative contrast
- Light above 45° must be strictly controlled

Asymmetrical- Negative Contrast (Counter-Beam)
- Primarily directed towards the driver
- Provides high pavement luminance and low object luminance to enhance negative contrast
- Light above 45° must be strictly controlled

Tunnel Lighting Zones
The human eye requires more time to adapt from brightness to darkness than the reverse. For this reason, tunnel lighting must gradually transition to interior light levels. During nighttime hours, the area outside the tunnel is dark, whereas interior levels are similar to those of an illuminated open roadway, making the transition gradual. Tunnel lighting is comprised of distinct zones, each with unique lighting needs:

Approach Zone
During the approach zone, drivers open their eyes and begin to adjust to lower light levels. Adequate lighting is critical for establishing a safe and predictable environment for drivers.

Threshold Zone
This zone, also known as the transition zone, is where the driver's eyes begin to adapt to the lower light levels. Special care must be taken to ensure that this zone is well-lit and predictable.

Transitional Zone
This zone is where the driver's eyes fully adjust to the lower light levels, ensuring a safe and comfortable driving experience.

Interior Zone
The interior zone is where the tunnel itself is illuminated, and the vehicle's headlights are no longer necessary. Adequate lighting is crucial to maintain safety and comfort.

Exit Zone
During the exit zone, drivers begin to adjust to higher light levels. Adequate lighting is necessary to ensure a safe and smooth transition back to normal driving conditions.

Flicker Effect
In addition to lighting each zone of the tunnel appropriately, the design must mitigate the flicker effect caused by the interaction of vehicular speed and luminance spacing. Flicker frequencies of 12 to 63 flashes per second can cause headaches, eye strain, and vertigo.

Redundant Circuity
Redundant circuitry is also engineered into the system to ensure that if a circuit or transformer fails, there will be an adequate amount of light delivered to the space. In addition, a specified number of fixtures can be dedicated to an emergency circuit, enabling them to remain on should more than one circuit or transformer fail.

Vibration Testing
Vehicles traveling at high speeds often experience vibration due to road roughness, which can affect the performance of tunnel lighting systems. To ensure safety and reliability, the lighting system must be tested to ensure it can withstand the vibrations and maintain proper performance.
Transportation

Listings & Descriptions

Limitations of Wet and Hosedown Ratings – UL Standards
UL standards for wet location ratings simulate an outdoor rain condition. UL standards for type “P” or NEMA 4 “hosedown” ratings use a 1 in. diameter the hose size containing 65 gallons of water per minute. Various conditions might dictate that a feature requires a rating better than a wet location label, but not NEMA 4. These conditions typically exist in washdown applications where a hose or orifice water will direct at the fixture.

Benefits of Ingress Protection Ratings – IEC Standards
The IP water rating of “6,” described in IEC Standard 529, provides an intermediate step between the rain rating and the NEMA 4 rating. It also provides an internationally accepted standard which can be used to evaluate fixtures or any other electrical equipment, and the test it can be performed by an independent third-party testing agency for verification. Underwriters Laboratories in Northbrook, Illinois tests to the IEC standard.

Dust-tight Protection
An additional test criteria that can be applied to fixtures is the ability to exclude solid matter. The IP code rating of “6” (IP6X) means the fixture will be dust tight. The specified test requires that the fixture be placed in a corroding salt atmosphere for 3 hours. The particle size of the salt ranges from one to seven microns, and the fixture is placed under negative pressure in an attempt to blow the BEH into the fixture. Neither should be found inside the fixture after the test.

The Importance of Recognized Standards & Independent Testing
Lighting manufacturers that claim a hosedown rating other than NEMA or UL are not testing to recognized standards and have not had the tests confirmed or audited by an independent testing agency.

Example: IP65

DEGREES OF PROTECTION INDICATED BY THE FIRST CHARACTERISTIC NUMERAL

<table>
<thead>
<tr>
<th>Numerical</th>
<th>Short Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No special protection</td>
</tr>
<tr>
<td>1</td>
<td>Protected against solid objects greater than 150 mm</td>
</tr>
<tr>
<td>2</td>
<td>Protected against solid objects greater than 125 mm</td>
</tr>
<tr>
<td>3</td>
<td>Protected against solid objects greater than 10 mm</td>
</tr>
<tr>
<td>5</td>
<td>Dust protected</td>
</tr>
<tr>
<td>6</td>
<td>Dust-tight</td>
</tr>
</tbody>
</table>

DEGREES OF PROTECTION INDICATED BY THE SECOND CHARACTERISTIC NUMERAL

<table>
<thead>
<tr>
<th>Numerical</th>
<th>Short Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No special protection</td>
</tr>
<tr>
<td>1</td>
<td>Protected against dripping water</td>
</tr>
<tr>
<td>2</td>
<td>Protected against dripping water when tilted to 15°</td>
</tr>
<tr>
<td>3</td>
<td>Protected against splashing water</td>
</tr>
<tr>
<td>4</td>
<td>Protected against splashing water</td>
</tr>
<tr>
<td>5</td>
<td>Protected against water jets</td>
</tr>
<tr>
<td>6</td>
<td>Protected against heavy seas</td>
</tr>
<tr>
<td>7</td>
<td>Protected against the effects of immersion</td>
</tr>
<tr>
<td>9</td>
<td>Protected against submersion</td>
</tr>
</tbody>
</table>

Vibration Testing
ANSI (1982) 3.11-2001 details the American National Standard for Racking Lighting Equipment-Luminaire Vibration Test criteria, designed to simulate wind- and traffic-induced vibration, recommends that luminaire with damage, mast-arm, and aluminum housing used in bridge and overpass applications be tested at specific accelerations intensities. Select EMI test” luminaire are independently tested for vibration and shock according to ANSI standards, ensuring their ability to withstand the challenges of potentially damaging environments.

Example: IP65

<table>
<thead>
<tr>
<th>Measurement</th>
<th>IP-6</th>
<th>IP-5</th>
<th>IP-6</th>
<th>NEMA4</th>
<th>Marine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>0.5</td>
<td>1</td>
<td>1.5</td>
<td>2.5</td>
<td>4</td>
</tr>
<tr>
<td>Nema diameter</td>
<td>36.9</td>
<td>51.2</td>
<td>62.5</td>
<td>62.5</td>
<td>62.5</td>
</tr>
<tr>
<td>Volume</td>
<td>197</td>
<td>259</td>
<td>329</td>
<td>329</td>
<td>329</td>
</tr>
<tr>
<td>Length</td>
<td>320</td>
<td>410</td>
<td>510</td>
<td>620</td>
<td>620</td>
</tr>
<tr>
<td>Width</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>Height</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Weight</td>
<td>10.8</td>
<td>11.5</td>
<td>11.5</td>
<td>11.5</td>
<td>11.5</td>
</tr>
<tr>
<td>Dimensions</td>
<td>51.8</td>
<td>51.8</td>
<td>51.8</td>
<td>51.8</td>
<td>51.8</td>
</tr>
<tr>
<td>Vibration</td>
<td>0.15</td>
<td>0.15</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
</tr>
<tr>
<td>Duration</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>

When used above specific, they will know the ability to withstand the effects of immersion under defined conditions of pressure and time. The equipment is suitable for continuous submergence in water under conditions which shall be specified by the manufacturer.

NOTE: This will mean that the equipment is hermetically sealed. However, with certain types of equipment, it can mean that water can enter only in such a manner that it produces no harmful effects.
Certified Performance

- Ensures that the selected tunnel fixture has been independently test and certified to deliver all the main aspects of the fixture performance claimed.
- Ensures that the specifier and end-user will get the appropriate and required performance needed for transportation lighting fixtures in harsh, demanding and environmentally challenging environments.
- It means going beyond existing industry fixture specs and typical features, many of which don’t guarantee the product will satisfy its ultimate intended purpose
- Luminaires include 10-Year Warranty!!
Certified Performance

UL/CUL Listed — The UL symbol signifies that Underwriters Laboratory (UL) has determined that a manufacturer has demonstrated the ability to produce a product conforming with UL's requirements with respect to specific risks, performance under specific conditions, compliance with regulatory codes and standards, or any other conditions as determined by UL.

ETL — A product bearing the ETL Listed Mark is determined to have met the minimum requirements of prescribed product safety standards as certified by a Nationally Recognized Testing Laboratory (NRTL). The mark also indicates that the manufacturer's production site conforms to a range of compliance measures and is subject to periodic follow-up inspections to verify continued conformance.

IP64 — UL Certified IP64 per IEC 60529 ensures that the enclosure is dust-tight and protected against splashing water without any harmful effects.

IP65 — UL Certified IP65 per IEC 60529 ensures that the enclosure is dust-tight and protected against jet sprays of water from any direction without any harmful effects.

NFPA 101 — The National Fire Protection Agency (NFPA) Life Safety Code pertains to ignition facilities. The code establishes minimum criteria for the design of igniter facilities so as to prevent accidental escape of contaminants from buildings or where desirable, into safe areas within buildings.

ISO 5 — Suitable for ISO 5, Clean 100 Raised Room (Fed. Std. 209E). Measures the number of particles equal to or greater than 0.5 micrometers in one cubic foot of air. The measurement must not exceed specified particle counts for the space to be considered a controlled "clean room" environment.

K230 — The K230 performance standard determines a fixture's ability to restrict the passage or penetration of contaminants when subjected to a prescribed pressure level in either positively or negatively pressured environments.
Certified Performance Listings for Transportation Luminaires

- Ingress Protection (IP) Ratings per IEC 60598
- Intertek / ETL Listed to UL 1598 Standards
- ANSI Luminaire Vibration Standard C136.31
- ANSI Tunnel & Underpass Standard C136.27
- Rated as NEMA 4X Enclosure for Outdoor Use
Ingress Protection (IP Ratings)

- IEC 60598
- “Ingress Protection for Lighting Fixtures”

**Ingress Protection**

IP65 or IP66

1\(^{st}\) number = protection from solid objects
2\(^{nd}\) number = protection from water
## IP Ratings: Numerical Assignments & Explanations

**Protection From Solid Objects**

### Example:

**IP65**

<table>
<thead>
<tr>
<th>Numeral</th>
<th>Short Description</th>
<th>Brief details of objects which will be “excluded” from the enclosure</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Non-protected</td>
<td>No special protection</td>
</tr>
<tr>
<td>1</td>
<td>Protected against solid objects greater than 50 mm</td>
<td>A large surface of the body, such as a hand (but no protection against deliberate access). Solid objects exceeding 50 mm in diameter.</td>
</tr>
<tr>
<td>2</td>
<td>Protected against solid objects greater than 12 mm</td>
<td>Fingers or similar objects not exceeding 80 mm in length. Solid objects exceeding 12 mm in diameter.</td>
</tr>
<tr>
<td>3</td>
<td>Protected against solid objects greater than 2.5 mm</td>
<td>Tools, wires, etc., of diameter or thickness greater than 2.5 mm. Solid objects exceeding 2.5 mm in diameter.</td>
</tr>
<tr>
<td>4</td>
<td>Protected against solid objects greater than 1.0 mm</td>
<td>Wires or strips of thickness greater than 1.0 mm. Solid objects exceeding 1.0 mm in diameter.</td>
</tr>
<tr>
<td>5</td>
<td>Dust-protected</td>
<td>Ingress of dust is not totally prevented but dust does not enter in sufficient quantity to interfere with satisfactory operation of the equipment.</td>
</tr>
<tr>
<td>6</td>
<td>Dust-tight</td>
<td>No ingress of dust</td>
</tr>
</tbody>
</table>

### DEGREES OF PROTECTION INDICATED BY THE FIRST CHARACTERISTIC NUMERAL
Particulate Test

Testing for the IP6 (Dust-tight) portion of rating
No Leakage from Environment
### IP Ratings: Numerical Assignments & Explanations
#### Protection From Water

<table>
<thead>
<tr>
<th>Numeral</th>
<th>Short Description</th>
<th>Brief details of objects which will be “excluded” from the enclosure</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Non-protected</td>
<td>No special protection</td>
</tr>
<tr>
<td>1</td>
<td>Protected against dripping water</td>
<td>Dripping water (vertically falling drops) shall have no harmful effect.</td>
</tr>
<tr>
<td>2</td>
<td>Protected against dripping water when tilted up to 15°</td>
<td>Vertically dripping water shall have no harmful effect when tilted up to 15° when the enclosure is tilted at any angle up to 15° from its normal position.</td>
</tr>
<tr>
<td>3</td>
<td>Protected against spraying water</td>
<td>Water falling as a spray at an angle up to 60° from the vertical shall have no harmful effect.</td>
</tr>
<tr>
<td>4</td>
<td>Protected against splashing water</td>
<td>Water splashed against the enclosure from any direction shall have no harmful effect.</td>
</tr>
<tr>
<td>5</td>
<td>Protected against water jets</td>
<td>Water projected by a nozzle against the enclosure from any direction shall have no harmful effects.</td>
</tr>
<tr>
<td>6</td>
<td>Protected against heavy seas</td>
<td>Water from heavy seas or water projected in powerful jets shall not enter the enclosure in harmful quantities.</td>
</tr>
<tr>
<td>/</td>
<td>Protected against the effects of immersion</td>
<td>Ingress of water in a harmful quantity shall not be possible when the enclosure is immersed in water under defined conditions of pressure and time.</td>
</tr>
<tr>
<td>8</td>
<td>Protected against submersion</td>
<td>The equipment is suitable for continuous submersion in water under conditions which shall be specified by the manufacturer.</td>
</tr>
</tbody>
</table>

**NOTE:** Normally, this will mean that the equipment is hermetically sealed. However, with certain types of equipment it can mean that water can enter, but only in such a manner that it produces no harmful effects.
Water Test
No Leakage Into Fixture
ETL / UL Testing

- Dielectric Voltage Withstand Testing
- Ground Continuity Testing
- Thermal Testing
- IP Testing per IEC 60598
- Typical Listings: UL 1598, UL 1598A, CSA 22.2
ANSI Standard Tunnel and Underpass Fixture Tests

- Temperature Cycling Tests in accordance with ANSI C136.27
- Water Spray Tests (100psi) in accordance with ANSI C136.27
- Vibration Test in accordance with ANSI Standard C136.31
- These Standards provides level of specification protection and integrity that cannot be valued
ANSI C136.31 (3G) Vibration Test
Photometric Testing and Certification

- Photometric Test Lab is NVLAP and IAS Certified
- US DOE LED Lighting Facts & Energy Star Label Partner
- Full LM-79 Testing capability
- Both relative and absolute photometry can be provided
- Will verify with Independent Test Lab Photometry
Corrosion... Always the Big Question...

- Aluminum Housings...what can one really expect re: lifetime?
- Aluminum alloys typically used
- Re: Aluminum Housings...its all about overall material process
- Pre-treatment and coatings
- What are site’s environmental conditions and salinity levels?
- Types of stainless steel used?
- Stainless steel vs. Aluminum?
A Case for Stainless Steel

- 316 Stainless Steel is exempt from salt spray testing because it's so robust.
- Typical uses include Exhaust Manifolds, Furnace Parts, Heat Exchangers and Jet Engine Parts.

- All welds are passivated restoring a uniform chromium oxide film on the materials surface thus eliminating the potential for corrosion of rouging.
- Isolate the housing and the heat sink from galvanic reactions while sealing the fixtures to IP66.
- Coordinate mounting arrangements with fixture housing.
- *Put it in the spec!!*
When Done Right
Tunnel/Underpass, LED

LINEAR LUMINAIRES

PRODUCT FEATURES:
- Wall or ceiling mount, 48” L
- Continuous or non-continuous
- Up to 80W led; remote or integral
- IES Type I, II, V, & PB/CB optics

LISTINGS:
UL/CUL Listed for Wet Locations.
UL certified IP66 per IEC 60598.
ANSI C136.27, C136.31 compliant.
“BOX-TYPE” LED SERIES

PRODUCT FEATURES:
- Wall or ceiling mount
- 2-piece stainless steel housing/door
- Up to 400W led; remote or integral
- IES Type I, II, V, & PB/CB optics

LISTINGS:
UL/CUL Listed for Wet Locations.
UL certified IP66 per IEC 60598.
ANSI C136.27, C136.31 compliant.
Tunnel/Underpass, LED

REMOTE DRIVER OPTIONS/

PRODUCT FEATURES:
- Wall mount driver cabinet, stainless steel housing/door
- Powers up to six 400W led fixtures
- Powers up to 24 100W led fixtures

LISTINGS:
UL/CUL Listed for Wet Locations. UL certified IP66 per IEC 60598. ANSI C136.27, C136.31 compliant.
Modular LED System:

- **Module:**
  - 48 LED Boards → in steps of 4 LEDs
  - Flat MCPCB, Lensed Optic Principle
  - CRI = Minimum 70, Typical
  - Neutral White (WW & CW also available)
  - Cree XP-L LEDs: 107lm/W @700mA*, 96 LEDs
  - Cree XP-L LEDs: 110lm/W @700mA*, 192 LEDs

**Lensed Optics**
- Multiple LVKs
- Superposition
- Scalable principle
- *Reduces glare*
- Does manufacturer assemble LED boards

* LED Type Standard, February 2016*
Port of Miami Tunnel Project – 2015
Lytle Tunnel; Cincinnati, OH – 2016
Hugh L. Carey Tunnel; New York, NY – 2017
Controls for Tunnel Lighting Installations; How has LED Lighting Impacted Them?
Controls for Tunnel Lighting Installations; Dimming and Energy Savings?

Linear fall from 100% of $L_{th}$ to 40% of $L_{th}$

\[ L_{tr} = L_{th} (1.9 + t)^{-1.4} \]

Threshold Zone

Transition Zone

Interior Zone

SD/2

SD/2
## Relative Influence of Energy Consumption

<table>
<thead>
<tr>
<th>Length of tunnel</th>
<th>$L \leq 500\ m$</th>
<th>$500\ m &lt; L \leq 3\ 000\ m$</th>
<th>$L &gt; 3\ 000\ m$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>System / Tube</strong></td>
<td>Uni and Bi</td>
<td>Uni</td>
<td>Bi</td>
</tr>
<tr>
<td><strong>Lighting</strong></td>
<td>Very high</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Ventilation</strong></td>
<td>N.A.</td>
<td>Very small</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Safety equipment</strong></td>
<td>Very small</td>
<td>Small</td>
<td>Small</td>
</tr>
<tr>
<td><strong>Pumps</strong></td>
<td>Small</td>
<td>Small</td>
<td>Small</td>
</tr>
<tr>
<td><strong>Auxiliaries</strong></td>
<td>Very small</td>
<td>Small</td>
<td>Small</td>
</tr>
</tbody>
</table>
Call to action

- What do you want a manufacturer to do?
One last thing

- Project Services
- Layout and Design
- Quote and Ordering “Check & Balance”
- Palletized and Labeled
- Shipment Tracking
- Installation and Wiring Instructions
- Rebates with LEDs?
FINAL WORD/QUESTIONS