INDUSTRIAL LIGHTING
Introductions

- Today’s team
- Why we are here
- What is your takeaway
Class Outline

- Industrial spaces and applications
- Lighting design standards
  \((IES\ and\ others)\)
- IES Recommended Practices for Industrial Lighting
- Environmental issues and codes
- Legacy sources and LED options
- Industrial lighting design trends
- Industrial lighting new product review

Introductions and Overview
Learning Objectives

- Insight into industrial spaces and recommended practices for industrial lighting
- Identify and address environmental and code requirements
- Explore industrial lighting trends
- Learn about new products
Types of Space and Applications

- Manufacturing: fabrication, processing and assembly
- Functions and tasks: inspection, fine detail work, critical processes
- Staging and storage: receiving, packing, dock area and warehouses
- Special spaces/applications: clean rooms, food processing, etc.
Lighting Standards

*(IES and others)*

- IES and ANSI/IES Recommended Practices
- Industry documents, lighting application bulletins *(Lamp and luminaire manufacturers)*
- Government: GSA, etc. *(General Services Administration)*
Environmental Issues and Codes

- Government - OSHA, EPA & DOE (safety, environmental and energy)
- Unions & trade organizations (lighting requirements in contracts)
- Title 24 - California energy code (LPD’s, controls and daylighting)
Test Your Knowledge
and take a quick poll - #1
Knowledge Test *(Answers)*

- Which is not considered an industrial space type and/or application? *(Printing and copying)*
- Three federal government agencies that regulate standards for industrial lighting *(OSHA, EPA & DOE)*
LIGHTING STANDARDS DESIGN
Lighting Standards - Design

- Proper quality & quantity of illumination for visibility & performance
- Luminaire classifications & lighting distribution
- Safety, environmental & code requirements
- Economic, energy & maintenance considerations
Proper quality and quantity of illumination for processes, functions and tasks

• Quality of illumination
  - Point source \textit{(sparkle, shadow & contrast)}
  - Diffuse source \textit{(soft, flat & uniform)}
  - Color rendering - CRI \textit{(level required)}

• Quantity of illumination
  - Light level high enough for tasks/functions
  - Illumination zones \textit{(task/ambient)}
Quality of Illumination

Point Source (*sparkle, shadow & contrast*)

Quality – Point source

- Sparkle helps define specular nature of item being illuminated
- Contrast helps define shape/form of item being illuminated
- Shadow further defines shape & form
Quality – Diffuse source

• Soft uniform light fills in shadows to better define form
• Diffuse sources exhibit less glare, distributes light over a broader surface
• Soft diffuse illumination usually results in lower contrast ratios
Quality of Illumination - Color Rendering

*Color appearance & CRI*

**Color appearance**
- Pleasant work atmosphere
- Productive work environment

**Color Rendering Index (CRI)**
- Color important - 70 CRI or greater
- Color critical tasks - 85 CRI or greater
- LED color quality based on more than CRI

![Color Rendering Index](image)
Light levels must be adequate to perform designated tasks/functions.

- Design to the highest maintained level required for tasks/functions.
- Use IES recommended light levels to set illumination targets.
Quantity of Illumination Zones *(task/ambient)*

**Quantity – Illumination zones**

- Facility lighting needs, including light levels, will vary significantly
- Lighting requirements should be planned and implemented via zones
- Combining task/ambient within zones can maximize performance and energy efficiency
Luminaire Classifications and Distribution

Methods of classification

• Classify by source
• Classify by mounting and construction
• Classify by application
• Classify by photometric characteristics
Luminaire Classifications and Distribution

Classification by source

- Source characteristics
  (diffuse or point source)

- Lamp type and shape
  (linear T8/T5 or focused PAR/MR, etc.
  LED sources can emulate both.)
Luminaire Classifications and Distribution

Classification by mounting and construction

- Surface, recessed or suspended
- Open, enclosed or sealed
Luminaire Classifications and Distribution

Classification by application

- General illumination
- Wall washing
- Flood lighting
- Task illumination
Luminaire Classification by Photometric Characteristics

- CIE – Commission Internationale de l’Éclairage (International Commission on Illumination)
- NEMA (National Electrical Manufacturers Assoc.)
INDUSTRIAL LIGHTING

Lighting Standards - Design

CIE Luminaire Classifications

- Direct illumination
- Semi - direct illumination
- Direct - indirect illumination
- General diffuse illumination
- Semi - indirect illumination
- Indirect illumination
CIE Luminaire Classifications

Direct illumination
  • Downlight distribution
  • 90% to 100% downward output
  • Focus light onto horizontal plane
CIE Luminaire Classifications

Semi-direct illumination

- Majority downlight
- 60% to 90% downward output
- Some light upward
- Most light on work plane with some also on ceiling and upper wall
INDUSTRIAL LIGHTING

Lighting Standards - Design

CIE Luminaire Classifications

Direct - indirect illumination

- Equal up light & downlight
- Batwing distribution uplight
- More side light than general diffuse
CIE Luminaire Classifications

General diffuse illumination

- Balance of downlight and uplight
- 40% to 60% balance of downward and upward light
- Equal distribution – horizontal and vertical planes
- Similar to direct/indirect
CIE Luminaire Classifications

Semi-indirect illumination

- Majority upright (*indirect*)
- 60% to 90% upward light
- Some light downward
CIE Luminaire Classifications

Indirect illumination

- Primarily uplight
- 90% to 100% upward light
- No downward contribution

Lighting Standards - Design
NEMA Flood and Spot Classifications

NEMA beam spreads

- NEMA types 1 to 7
- Type 1: Very narrow spot
- Type 7: Very wide flood
NEMA Beam Pattern Classifications – Spots & NFL Lights

**INDUSTRIAL LIGHTING**

**NEMA Beam Pattern Classifications**

- **TYPE 1**: 10 - 18 degrees
- **TYPE 2**: 19 - 29 degrees
- **TYPE 3**: 30 - 46 degrees

**NEMA NARROW BEAMS** *(Long Distances and “Spot”)*

---

**Lighting Design Standards**

<table>
<thead>
<tr>
<th>Beam Type</th>
<th>Field Angle Range (degrees)</th>
<th>Projection Distance (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10 to 18</td>
<td>240 ft and greater</td>
</tr>
<tr>
<td>2</td>
<td>&gt; 18 to 29</td>
<td>200 ft to 240 ft</td>
</tr>
<tr>
<td>3</td>
<td>&gt; 29 to 46</td>
<td>175 ft to 200 ft</td>
</tr>
<tr>
<td>4</td>
<td>&gt; 46 to 70</td>
<td>145 ft to 175 ft</td>
</tr>
<tr>
<td>5</td>
<td>&gt; 70 to 100</td>
<td>105 ft to 145 ft</td>
</tr>
<tr>
<td>6</td>
<td>&gt; 100 to 130</td>
<td>80 ft to 105 ft</td>
</tr>
<tr>
<td>7</td>
<td>&gt; 130 and Up</td>
<td>Under 80 ft</td>
</tr>
</tbody>
</table>
NEMA Beam Pattern Classifications – Flood Lights

**TYPE 4**
47 -70 degrees

**TYPE 5**
71 -100 degrees

**NEMA MEDIUM BEAMS** *(Medium Distances and “Flood”)*

<table>
<thead>
<tr>
<th>Beam Type</th>
<th>Field Angle Range (degrees)</th>
<th>Projection Distance (D)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10 to 18</td>
<td>240 ft and greater</td>
</tr>
<tr>
<td>2</td>
<td>&gt; 18 to 29</td>
<td>200 to 240 ft</td>
</tr>
<tr>
<td>3</td>
<td>&gt; 29 to 46</td>
<td>175 to 200 ft</td>
</tr>
<tr>
<td>4</td>
<td>&gt; 46 to 70</td>
<td>145 to 175 ft</td>
</tr>
<tr>
<td>5</td>
<td>&gt; 70 to 100</td>
<td>105 to 145 ft</td>
</tr>
<tr>
<td>6</td>
<td>&gt; 100 to 130</td>
<td>80 to 105 ft</td>
</tr>
<tr>
<td>7</td>
<td>&gt; 130 and Up</td>
<td>Under 80 ft</td>
</tr>
</tbody>
</table>
NEMA Beam Pattern Classifications – Wide Flood Lights

**TYPE 6**
101 - 130 degrees

**TYPE 7**
Over 130 degrees

**NEMA WIDE BEAMS** *(Close Distances and “Wide Flood”)*

---

**Beam Type** | **Field Angle Range (degrees)** | **Projection Distance (D)**  
--- | --- | ---  
1 | 10 to 18 | 240 ft and greater  
2 | > 18 to 29 | 200 to 240 ft  
3 | > 29 to 46 | 175 to 200 ft  
4 | > 46 to 70 | 145 to 175 ft  
5 | > 70 to 100 | 105 to 145 ft  
6 | > 100 to 130 | 80 to 105 ft  
7 | > 130 and Up | Under 80 ft
Safety & Environmental Requirements

• Safety requirements and issues
  - Flicker and strobe
  - Start-up times and emergency back-up
  - Classified areas (*flammable/c Combustible*)

• Environmental requirements and issues
  - Lighting clean rooms
  - Food and drug processing
Safety Requirements and Issues

Flicker & strobe

- Caused by operating on single-phase alternating current (AC)
- Can degrade task visibility
- At minimum annoying, but also dangerous
- Flicker strobe effect creates appearance of moving objects to slow or stop

[ Dangerous when object moving is machinery or equipment ]
Safety Requirements and Issues

Start-up & emergency back-up

- HID lamps (MH, CMH & HPS)
  - Do not instantly re-strike
  - Require quartz re-strike back-up
- LED sources exhibit instant re-strike
- In addition to instant re-strike, emergency lighting back-up required
  - Emergency generator or battery
  - Battery pack luminaires
Classified areas (Article 500 of NFPA 70)

- Flammable & combustible
- Defined by NEC (National Electrical Code)
  - **Class I Division 1:** Hazardous gas normally present
  - **Class I Division 2:** Hazardous gas not normally present
  - **Class II Division 1:** Hazardous dust normally present
  - **Class II Division 2:** Hazardous dust not normally present
  - **Class III Division 1 & 2:** Fibers/flying particles normally present

- Specially rated luminaires
Environmental Requirements and Issues

Clean rooms

- Sealed enclosed environments
- Special ceiling/wall systems
- IEST clean room classifications
  - Class 1 to Class 100,000
    *micron particles per cubic foot of air*
  - Class 1 minimum allowed to Class 100,000
    *maximum allowed particles*
    *(quantity of particles determined by micron size)*

IEST: Institute Environmental Sciences and Technology
INDUSTRIAL LIGHTING

Environmental Requirements and Issues

Clean rooms

• Specially rated luminaires
  - Gasketed and sealed
  - Totally smooth exposed surfaces
Environmental Requirements and Issues

Food & drug processing

- NSF & USDA requirements
  - No exposed glass
  - Nontoxic paints
  - Withstand pressure washing
  - Smooth exposed surfaces

- Luminaires rated to meet or exceed NSF/USDA requirements

- Color rendering is important

NSF – National Sanitary Foundation
USDA – US Department of Agriculture
Economics, Energy and Maintenance

Economics
- First cost versus operating cost
- Life cycle costing and ROI (return on Investment)

Energy issues
- Code requirements and compliance
- Use versus performance

Maintenance
- Ease of maintenance (re-lamping, ballast or driver changes)
- Required maintenance interval (less is better)
Economics, Energy and Maintenance

Economics

• The cheapest lamp is often not the lowest cost
• Look at the “big picture” – total cost of ownership
  - first cost
  - cleaning and re-lamping
  - energy costs
  - other costs
• Conduct “life cycle” costing to determine the best ROI
## Economics, Energy and Maintenance

**ECONOMICS:** The cheapest luminaire is often not the lowest cost

<table>
<thead>
<tr>
<th>Luminaire</th>
<th>First Cost [lamp/socket]</th>
<th>25000 Hr. Maintenance [lamp replacements]</th>
<th>25000 Hr. Energy [$0.15 KWH]</th>
<th>25000 Hr. Total Cost</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>100W A Lamp 750 hours</td>
<td>$8.00</td>
<td>$33.00</td>
<td>$375.00</td>
<td>$416.00</td>
<td>$0.00</td>
</tr>
<tr>
<td>72W Halogen 1000 hours</td>
<td>$10.50</td>
<td>$84.00</td>
<td>$270.00</td>
<td>$364.50</td>
<td>$51.50</td>
</tr>
<tr>
<td>23W CFL 10000 hours</td>
<td>$12.00</td>
<td>$10.00</td>
<td>$86.00</td>
<td>$108.00</td>
<td>$308.00</td>
</tr>
<tr>
<td>14W LED 25000 hours</td>
<td>$14.00</td>
<td>$0.00</td>
<td>$53.00</td>
<td>$67.00</td>
<td>$349.00</td>
</tr>
</tbody>
</table>

**Dusk to Dawn Night Light – Equivalent Maintained Illumination**

**Industrial Lighting**

**Lighting Design Standards**
Economics, Energy and Maintenance

Energy issues

• New design – energy use tied to code compliance (*typically new luminaires*)
• Older design – consider a retrofit
• More energy does not equal better performance
  - Advanced lighting technologies offer higher light levels, better color and use less energy
  - Daylight enhances performance and quality while reducing energy
Economics, Energy and Maintenance

Maintenance

• Re-lamping and ballast changes
  - Number of lamps/ballasts
  - Lamp life and maintenance
  - Re-lamping and/or ballast changes

• Maintenance intervals – **LESS IS BETTER**

• Maintenance in industrial spaces can be difficult and costly

• Spaces with maintenance challenges are prime candidates for LED lighting
Test Your Knowledge
and take a quick poll #2
Knowledge Test (Answers)

• Three characteristics of a diffuse light source are \textit{(soft, flat & uniform)}

• Name the organization that defines luminaires by six photometric distributions \textit{(CIE International Commission on Illumination)}

• What two agencies govern food processing? \textit{(NSF National Sanitary Foundation and USDA US Department of Agriculture)}
INDUSTRIAL LIGHTING
RECOMMENDED PRACTICES
Recommended Practices for Industrial Lighting

Quantity of lighting in industrial facilities

- IES recommended lighting levels \((fc/lux)\)
- Horizontal and vertical illuminance recommendations (available in IES Handbook and RP-7)

Quality of lighting in industrial facilities

- Luminance/luminance ratios
- Reflectance values
- Interaction with objects
- Glare and visual comfort
- Material characteristics
- Source-task-eye geometry
- Color rendering
- Daylight integration
# ANSI/IES Quantity & Quality of Lighting in Industrial Facilities

## Recommended Practices for Industrial Lighting

<table>
<thead>
<tr>
<th>Task</th>
<th>Horizontal FC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly (vertical illumination equal of horizontal)</td>
<td></td>
</tr>
<tr>
<td>Simple</td>
<td>30 fc</td>
</tr>
<tr>
<td>Difficult</td>
<td>100 fc</td>
</tr>
<tr>
<td>Exacting</td>
<td>300 fc</td>
</tr>
<tr>
<td>Component Manufacturing (vertical illumination equal of horizontal)</td>
<td></td>
</tr>
<tr>
<td>Large</td>
<td>30 fc</td>
</tr>
<tr>
<td>Medium</td>
<td>50 fc</td>
</tr>
<tr>
<td>Fine</td>
<td>100 fc</td>
</tr>
<tr>
<td>Control Panel and/or Computer Viewing (vertical illumination equal of horizontal)</td>
<td>20 FC to 30 fc</td>
</tr>
</tbody>
</table>
## ANSI/IES Quantity & Quality of Lighting in Industrial Facilities

<table>
<thead>
<tr>
<th>RECOMMENDED QUANTITY OF LIGHT</th>
<th>TASK</th>
<th>HORIZONTAL FC</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Footcandles – Visual age range 25-65)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Inspection  
(verticle illumination equal of of horizontal) | Simple     | 30 fc         |
|                   | Difficult  | 100 fc        |
|                   | Exacting   | 300 fc        |
| Laboratories  
(verticle illumination 1/3 of horizontal) | General    | 50 fc         |
|                   | Benches    | 100 fc        |
| Shipping and Receiving  
(verticle illumination 1/3 of horizontal) | Dock       | 10 fc         |
|                   | Staging    | 30 fc         |
## RECOMMENDED QUANTITY OF LIGHT

*(Footcandles – age range 25-65)*

<table>
<thead>
<tr>
<th>TASK</th>
<th>Raw Material Processing (vertical illumination equal of horizontal)</th>
<th>Warehousing and Storage (vertical illumination 1/3 to ½ of horizontal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Course</td>
<td>10 fc</td>
<td>Inactive</td>
</tr>
<tr>
<td>Medium</td>
<td>30 fc</td>
<td>Bulky items</td>
</tr>
<tr>
<td>Fine</td>
<td>50 fc</td>
<td>Small items</td>
</tr>
<tr>
<td>Very fine</td>
<td>100 fc</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE:** Additional illuminance recommendations for specialized industrial applications can be found in the IES Handbook and RP-7.
### Recommended Maximum Luminance Ratios

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between task and adjacent darker surroundings</td>
<td>3:1</td>
<td>3:1</td>
<td>5:1</td>
</tr>
<tr>
<td>Between task and adjacent lighter surroundings</td>
<td>1:3</td>
<td>1:3</td>
<td>1:5</td>
</tr>
<tr>
<td>Between task and more remote darker surfaces</td>
<td>10:1</td>
<td>20:1</td>
<td>Not Practical</td>
</tr>
<tr>
<td>Between task and more remote lighter surfaces</td>
<td>1:10</td>
<td>1:20</td>
<td>Not Practical</td>
</tr>
<tr>
<td>Between luminaires (or windows, skylights) and surfaces adjacent to them</td>
<td>20:1</td>
<td>Not Practical</td>
<td>Not Practical</td>
</tr>
<tr>
<td>Anywhere within normal field of view</td>
<td>40:1</td>
<td>Not Practical</td>
<td>Not Practical</td>
</tr>
</tbody>
</table>

### Environmental Classifications

**A:** Interior areas where reflectance can be controlled in line with recommendations

**B:** Where reflectance of immediate area can be controlled, but control of remote surround limited

**C:** When completely impractical to control reflectance and/or control environmental conditions
### ANSI/IES Quantity & Quality of Lighting in Industrial Facilities

#### Recommended Reflectance Values

<table>
<thead>
<tr>
<th>SURFACES</th>
<th>REFLECTANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceilings</td>
<td>50% to 70%</td>
</tr>
<tr>
<td>Walls</td>
<td>40% to 60%</td>
</tr>
<tr>
<td>Desks, Bench Tops &amp; Equipment</td>
<td>25% to 45%</td>
</tr>
<tr>
<td>Floors</td>
<td>20%</td>
</tr>
</tbody>
</table>
Modeling objects (*interaction with light*)

- Light reveals depth, shape and texture
- Critical to assessing quality of materials
- Critical to assessing degree of consistency and tolerances in manufacturing
- Diffuse ambient light only is inadequate for assessing fine texture and surface variances – add point source task lighting

ANSI/IES Quantity & Quality of Lighting in Industrial Facilities

Recommended Practices for Industrial Lighting
INDUSTRIAL LIGHTING

ANSI/IES Quantity & Quality of Lighting in Industrial Facilities

Molding objects

Light reveals depth, shape and texture

Recommended Practices for Industrial Lighting
**Types of glare**
- **Direct** *(high luminance from source)*
- **Reflected** *(high luminance of off shiny surfaces)* *(veiling reflections – semi-specular surface)*

**Degree of glare**
- **Discomfort** *(quicker fatigue but minimal performance loss)*
- **Disability** *(reduced visibility effects performance)*
Glare and visual comfort

ANSI/IES Quantity & Quality of Lighting in Industrial Facilities

Recommended Practices for Industrial Lighting
Tips to reduce glare

- **Luminaires**
  - Pay attention to UGR (Unified Glare Rating) [not always on spec sheet]
  - Pay attention to luminaire cut-off
  - Use lower luminance luminaires

- **Environment**
  - Attention to surface reflectance
  - Shield windows and skylights
Material characteristics

- Task specularity
- Shadows
- Source – task – eye geometry
- Visibility – flicker and strobe
- Color rendering
- Safety colors
- Daylight integration and control
Task specularity issues

- Task specularity
  - May create veiling reflections
  - Reflections reduce task visibility
  - Re-orient task *(work bench, etc.)*

- Block view of offending luminaires
  - Improve luminaire shielding
  - Re-orient luminaires
  - Re-orient task *(work bench, etc.)*
Shadows & shadow issues

- Shadows can be good or bad
- “Good” shadows
  - Play of highlight/shadow defines form
  - Balance horizontal/vertical illuminance
- “Bad” shadows
  - Interfere with task visibility (*lose details*)
  - Can lower illumination to unsafe level
Source – task – eye geometry

- Angular relationship between viewer and task
- Viewing angles are dynamic
  - Affects source/task/eye geometry
- Importance of geometry
  - Correct geometry aids visibility
  - Poor geometry hinders visibility
Visibility – flicker & strobe

- Rapid lamp intensity variation
- Flicker sequenced to alternating current creates strobe effect
  - Objects appear to slow down/stop
- Flicker index - cyclic variation
  - Flicker index values from 0 to 1.0
  - 0 = no flicker
  - Higher values indicate potential strobe effect and lamp flicker
Flicker & strobe (continued)

• HID lamps (MH/HPS) are flicker prone
  - Degree of flicker depends on the type of HID ballast used

• Fluorescent lamps exhibit low flicker

• LED lamps/modules exhibit low flicker

• Electronic ballasts/drivers eliminate flicker
Flicker & strobe (continued)

- HID lamp flicker index depends on type of ballast
  - HPS flicker index as high as 0.2
  - MH flicker index on CWA ballast as high as 0.121 and as low as 0.067

- Alternate phases (three-phase power supply) minimizes flicker/strobe

- Electronic ballast/drivers also minimize flicker and strobe
Color rendering

- Color quality task dependent
- Color quality measure is CRI
  - High CRI not critical for bulk storage
  - Minimum 70 CRI for general tasks
  - 80+ or 90+ CRI for color critical tasks
  - CRI not sole measure of LED color quality
- LED lighting exhibits good to excellent CRI
Safety colors

- ANSI safety colors *(indicates hazards)*
- Illumination reference *(CIE standard illuminant C)*
- Where/when safety colors are present, lighting must accurately render color

ANSI: American National Standards Institute

Recommended Practices for Industrial Lighting
Daylight integration and control

- Daylight - ideal ambient illumination
- Daylight must be controlled - intense sunlight causes glare
- Light shelves, louvered skylights and side lights combined with controlled electric light provide an ideal energy efficient workspace
Recommended Practices for Industrial Lighting (continued)

Lighting maintenance in industrial facilities
• Lumen maintenance (*maintained light levels*)
• Lighting system maintenance

Lighting system maintenance characteristics
• Legacy systems (*fluorescent and high intensity discharge*)
• LED lighting systems
• Color rendering
• Daylight integration
Lumen maintenance

- Light Loss Factors (LLF)
  - Dirt depreciation
  - Lumen depreciation

- Lighting control
  - Motion & vacancy sensors
  - Dimming ballasts
ANSI/IES Lighting Maintenance in Industrial Facilities

Lighting system maintenance

- Industrial facilities challenges
  - High mounting locations
  - Equipment obstructions
  - Plant disruptions

- Lighting maintenance plan
  - Lower lighting power density
  - Better maintained illumination
  - Follow ANSI standards – lamp ballast and driver replacements
Legacy fluorescent systems

- Excellent lumen maintenance
- No color shift or loss with age
- T5/HO and super T8 lamps exhibit excellent lamp life and minimal lumen depreciation
- Group re-lamped at 60% - 80% lamp life
T5/HO & Super T8 systems excellent lamp life with minimal lumen loss

Recommended Practices for Industrial Lighting
Legacy HID systems

- Metal halide with magnetic ballasts average lumen maintenance
- High-pressure sodium and ceramic MH with electronic ballasts excellent lumen maintenance
- Some color shift with age
- Group re-lamped at 60% - 80% lamp life
Metal Halide with Electronic Ballast Exhibits minimal lumen loss

Recommended Practices for Industrial Lighting
LED maintenance characteristics

- LED with electronic drivers excellent lumen maintenance
- Minimal to no color shift with age
- Group re-lamping not required
  \(\text{replace at end of useful life}\)
LED Extremely Long Life with little lumen loss

Recommended Practices for Industrial Lighting

ANSI/IES Lighting Maintenance in Industrial Facilities
Color rendering & maintenance

- Legacy metal halide lamps color shift with age
  - Re-lamp earlier in life cycle
  - Electronic ballasts help to minimize shift
  - Ceramic metal halide lamps have less shift
- Legacy fluorescent lamps – no color shift
  \((T8, \ T5\ \textit{CFL} \ \textit{and} \ \textit{Induction})\)
- LED lamps/modules have long life and minimal color shift
- With daylight present – use cool color lamps
Daylight & maintenance

- Keep skylights and side lights clean and free of obstructions
- Assure daylight controls are operational and maintained
- Overall cleaning of the industrial environment should work in concert with lighting maintenance
Lighting design components in industrial facilities

- General lighting
- Task lighting
- Special effects
- Emergency, safety and security
Industrial space general lighting

- Provides uniform illumination throughout
- Distribution should vary no more than 1:6 of maximum or minimum
- Wall illumination should be similar to center illumination at center of floor space
- General lighting best suited to illuminate circulation, safety and simple visual tasks
Industrial space task lighting

- Additional illumination for difficult visual tasks
- Supplementary luminaire used to:
  - Provide higher light levels
  - Direct attention to specific areas
  - Provide local higher color rendition
  - Aim or position light to provide/avoid highlights or shadows
  - Reveal details of the visual task
- Luminance ratios must be controlled
  (IES/ANSI maximum ratio recommendations)
- Shield luminaires to prevent glare
Industrial lighting special effects

- Use of color for contrast
  - Black on yellow for maximum contrast
  - Green, red and blue on white are more effective than black on white
  - Lamp color (*chromaticity*) also a good tool for color contrast
Industrial lighting special effects

- Strong directional illumination produces highlighted shadows (emphasizes textures and defects)
- Silhouette – effective means of checking contour against a pattern template
- Many more applications and techniques listed in IES RP-7
Emergency, safety and security lighting for industrial spaces

• **Emergency lighting**
  - Governed by codes and ordinances
  - Geometry of industrial environments requires a walk-through

• **Safety lighting**
  - Dangerous environment of industrial spaces requires heightened safety
  - IES FC requirements based on degree of hazard

• **Security lighting**
  - Consult with owner for requirements
  - Input from code authorities also Helpful
## Safety Lighting

### IES Recommended Illuminance Levels for Safety

<table>
<thead>
<tr>
<th>HAZARDS REQUIRING VISUAL DETECTION</th>
<th>DEGREE OF HAZARD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Slight</td>
</tr>
<tr>
<td><strong>Normal Activity Level</strong></td>
<td>Low</td>
</tr>
<tr>
<td><strong>Illuminance Levels (FC)</strong></td>
<td>0.5</td>
</tr>
</tbody>
</table>
Most cases battery pack standard luminaires or “Bug Eyes” **OK**

Extreme environments require special luminaires – Standard emergency lighting **NOT OK**

Emergency and Safety Lighting for All Environments

Recommended Practices for Industrial Lighting
MORNING BREAK
Lighting specific tasks/areas in industrial facilities

- Molding metal/plastic parts
- Parts assembly
- Control rooms
- Warehouse (*storage*)
ANSI/IES Lighting Specific Tasks/Areas in Industrial Facilities

Molding metal/plastic

- Be aware of potential issues
  - Glare (*potential visual disability issues*)
  - Excessive heat (*LEDs don’t like heat*)

- Metal molding and casting
  - Dirty operation: require luminaires that resist dirt and/or easy to clean
  - Use enclosed (*sealed*) or luminaires with filters

- Plastic molding (*injection molding*)
  - Clean operation: vented or industrial luminaires with filters luminaires good option
  - Provide ceilings/upper walls with reflective surface
Parts assembly

• Required visual tasks
  - Delivery: identify incoming materials
  - Active storage: read tags/labels
  - Parts manufacturing/assembly *(general and task lighting required)*
  - Testing: general and task lighting
  - Inspection: general and task lighting; required: good color rendition!
  - Packaging and shipping: general lighting and possible task lights
INDUSTRIAL LIGHTING

ANSI/IES Lighting Specific Tasks/Areas in Industrial Facilities

Parts & Manufacture Assembly

Required Visual Tasks – Specialized Inspection

Recommended Practices for Industrial Lighting
Control room lighting

- Two common lighting systems
  - Diffuse lighting – indirect low luminance luminaires, luminous ceilings or light panels
  - Directional lighting – recessed cut-off luminaires
    (locate to keep reflected light out of glare zone)

- Operator must read gauges and perform routine office functions

- Reflections and glare on instruments and gauges must be minimized

- Luminaires with excellent cut-off and/or that minimize glare are ideal
Control Room Advanced Lighting

Recommended Practices for Industrial Lighting

ANSI/IES Lighting Specific Tasks/Areas in Industrial Facilities

LED Luminous Panels

LED Task Lights
Warehouses

- Warehouse storage systems
  - Open storage (floor and pallet)
  - High-rise (rotational bins, up to 100 ft. high)
  - Fixed racking (3 to 12-ft. wide X 8 to 30-ft. high)
  - Mobile racking (move on floor rails)
- Cold and hazardous areas

- Warehouse Illuminance
  - Vertical critical – majority of tasks are vertical (especially important at racking)
  - Horizontal not as critical as vertical but still required for navigation and reading tasks
Warehouse lighting

- Warehouse lighting design
  - Lighting layout must pay attention to aisle layout pattern (*high stacks typical*)
  - Locate luminaires at tall racks in center of aisles
  - Geometry of aisles - RCR 10 or more
  - Use “point-by-point” not lumen method for determining foot-candle targets
  - Minimize glare (*especially source glare*), bright luminaires can cause disability glare
  - Mounting height guidelines
    - LED Low Bay at 20-feet and below
    - LED High Bay at 20-feet and above
Warehouse lighting design (continued)

- Luminaire considerations
  - LED high or low bay wide distribution luminaires for low stack (pallets) and narrow distribution luminaires closely spaced for narrow rooms or corridors.
  - Luminaires with up-light component can address upper stack luminous drop-off provided ceilings have high reflectance.
  - Luminaires with bat-wing and/or asymmetric distribution (aisle lighters) are ideal for lighting vertical stacks.

- Control strategies
  - Controls ideal for warehouses as they are often unoccupied.
  - Vacancy sensors.
  - LED luminaires with dimming or step drivers.
  - Energy codes may mandate controls.
Test Your Knowledge
and take a quick poll #3
Knowledge Test *(Answers)*

- Name the two degrees of glare *(Discomfort and disability)*
- L70 target for LED lamps is: *(25000 hours)*
- When/where molding metal or plastic occurs which are issues that effect lighting? *(Excessive heat and dirt)*
Recommended Practices for Industrial Lighting (continued)

Lighting specific visual tasks
- Convex surfaces
- Flat surfaces
- Scribed marks & center punch marks
- Concave specular surfaces
- Flat specular surfaces
- Convex specular surfaces

Lighting sheet metal fabrication tasks
- Punch press
- Shearing

Lighting large component assembly
Convex surfaces

• Lighting objectives
  - Proper contrast between highlights and shadows
  - Minimize reflective glare

• Application recommendations
  - Avoid close in *(near)* high luminance point source lighting
  - Large area, low luminance source is best for lighting convex surfaces
  - Luminaires should be placed at angles to convex surfaces to provide the desired highlights and shadows
Flat surfaces

- Lighting objectives
  - Minimize reflective glare
  - Watch out for reflective image of the light source

- Application recommendations
  - Avoid close in (near) high luminance point source lighting
  - Select large surface low luminance lighting to illuminate flat surfaces (low brightness luminaires)
  - Place luminaires at angles to the flat surface that minimize source images
Scribe marks and center punch marks

- **Lighting objectives**
  - Minimize reflective glare
  - Avoid reflective image of the light source

- **Application recommendations**
  - Avoid close in *(near)* high luminance point source lighting
  - Large area low luminance sources are best for lighting flat surfaces *(use low brightness luminaires)*
  - Place luminaires at angles to scribe marks for desired highlight and minimum shadow
Concave and convex specular surfaces

- **Lighting objectives**
  - Minimize reflective glare
  - Avoid reflective image of light source

- **Application recommendations**
  - Avoid high luminance point source lighting
  - Large area, low luminance sources best for lighting flat surfaces (*low brightness luminaires*)
  - Luminaire (*light source*) size based on light over area of the task
  - Use IES formula to establish luminaire width on convex surfaces
Concave and convex specular surfaces

- Lighting objectives
  - Determine size of source for uniform illumination on target
  - Soft uniform reflection with low brightness for visual acuity
  - Technique shown for convex surfaces also appropriate for concave surfaces
Flat specular surfaces

- **Lighting objectives**
  - Use diffuse light to minimize strong visual disabling reflections
  - Even uniform illumination desirable

- **Application recommendations**
  - Luminaire footprint (*source size*) large enough and intensity (*brightness*) low enough to minimize hot spots
  - Use IES procedure for establishing proper luminaire size/source reflections
  - Large panel or indirect light luminaires are best
**Flat specular surfaces**

- **Lighting objectives**
  - Determine source size for uniform target illumination
  - Soft low brightness reflections maintain visual acuity
Lighting sheet metal fabrication tasks

• Punch press
• Shearing

Lighting large component assembly
Punch press

- Lighting objectives
  - Illumination on stock moving into the press
  - Illumination to inspect the dye for scrap and inspect the product

- Application recommendations
  - General lighting around punch press for basic tasks *(wide distribution for even illumination)*
  - Possible supplementary lighting to create proper reflective brightness of the dye
  - Paint reflectance on the punch press should not be less than 40%
Shearing

- Lighting objectives
  - Illumination for operator to view measuring scale
  - Also view location of cut

- Application recommendations
  - General lighting for area around the shearing equipment for basic tasks
  - Local lighting to indicate (highlight) the cut and scrap trimmed
  - Local lighting also highlights area of the guard (safety feature)
Large assembly fabrication

• Unique facility geometry
  - Large footprint bays \((300,000\ \text{feet})\)
  - High vertical profile \((80\ \text{feet floor to truss})\)
  - Presents design and maintenance challenges

• Lighting objectives
  - Key consideration: lighting maintenance
  - Address obstructions – blocked light

• Application recommendations
  - General lighting for base illumination \((\text{wide distribution for even illumination})\)
  - Supplementary flood lights for underside of large objects and portable lighting for localized tasks

Recommended Practices for Industrial Lighting
Large Assembly Fabrication

- Large foot-print bays *(300,000 feet)*
- High vertical profile *(80 feet floor to truss)*

Recommended Practices for Industrial Lighting
Recommended Practices for Industrial Lighting (continued)

• Lighting economics in industrial facilities
  - First level analysis *(simple payback)*
  - Second level analysis *(time value of money)*

• Special considerations in industrial facilities
  - Classified areas *(flammable/combustible & corrosive)*
  - High temperature zones
  - Clean rooms
  - Food and drug processing
### ANSI/IES Lighting Economics

#### First-level simple payback

- Evaluate “how long” to recoup cost
- Simple payback usually excludes cost of money and equipment life
- Simple payback versus simple return
- Payback formula

<table>
<thead>
<tr>
<th>Light Source</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>400W PSMH High Bay</td>
<td></td>
</tr>
<tr>
<td>T5/HO High Bay</td>
<td></td>
</tr>
<tr>
<td>LED High Bay</td>
<td></td>
</tr>
</tbody>
</table>

**Simple Payback** = \[
\frac{\text{Incremental investment}}{\text{Incremental Annual Cash Flow}}
\]
## COST COMPARISON MH: versus T5/HO versus LED – Single luminaire

<table>
<thead>
<tr>
<th>Luminaire</th>
<th>Equivalent Systems</th>
<th>Initial Cost (with lamps)</th>
<th>50,000 Hour (lamp maint.)</th>
<th>50,000 Hour (energy cost)</th>
<th>Total Cost</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>400 W Metal Halide Base System</td>
<td></td>
<td>$250.00</td>
<td>$100.00</td>
<td>$2300.00</td>
<td>$2650.00</td>
<td>None (baseline)</td>
</tr>
<tr>
<td>6-58 W T5/HO</td>
<td>[400 W MH equivalent]</td>
<td>$175.00</td>
<td>$100.00</td>
<td>$1800.00</td>
<td>$2075.00</td>
<td>$575.00</td>
</tr>
<tr>
<td>200 W LED High Bay</td>
<td>[400 W MH equivalent]</td>
<td>$500.00</td>
<td>$0.00</td>
<td>$1000.00</td>
<td>$1500.00</td>
<td><strong>$1150.00</strong></td>
</tr>
</tbody>
</table>

---

**Recommended Practices for Industrial Lighting**
Second level economics: time value of money

- More complex & detailed analysis
- Includes “time value of money” formula
- Usually by financial professional not designers

Typical second level analysis
- Saving investment ratio
- Internal rate of return
- Net present value
- Life cycle cost/benefit
Flammable gases, dust, fibers, etc.
- Space types as defined by NEC (National Electrical Code) and NFPA (National Fire Protection Association) anticipated temperature extremes

Classified rating nomenclature
- Class 1: hazardous gas; Class 2: dust
- Division 1: present; Division 2: not present

Independent (3rd party) rating
- Verifies, via testing, suitability of luminaire for specific class ratings
High humidity and corrosives

• Potential areas
  - Indoor areas; corrosive chemicals/moisture in manufacture/processing
  - Outdoor applications, especially industrial production/manufacturing

• Use corrosion-resistant materials
  - Non-metallic luminaire housings
  - Special paints and sealers
  - Air tight gasketing and fittings
High temperature zones

- Extreme hot or cold environments
  - Luminaires rated to meet or exceed anticipated temperature extremes
  - Rated as hot as 65°C/149°F
  - Rated as cold as -40°C/-40°F

- LED design for very hot environments
  - Robust heat sinks
  - Active cooling

- Other solutions
  - Special heat resistant housings
  - Light pipe (remote lighting)
  - Remote LED driven fiber optic illumination
Clean rooms

- Institute of Environmental Science
  - Classifies clean room types
  - Classification by micron particles present
  - 100 up to 100,000 parts per cubic foot

- Requires specialized luminaires
  - Gasketed recessed troffers
  - Tear-drop surface luminaires
  - Flow-through recessed luminaires
  - Flush luminaires integral to T-grid (*sealed*)

- Surfaces smooth & cleanable
  - Prismatic lenses upside down
  - No gaps, reveals or textures, etc.
Food processing areas

- No exposed glass (*lamps, lenses, etc.*)
  - safety issue – broken glass in food

- Luminaires sealed/gasketed
  - allows pressure washing luminaire

- Non-toxic luminaires (*paint, parts, etc.*)
  - preventative food contamination

- Gasketed unfinished stainless steel luminaires good choice

- Check NSF & USDA for additional info
Other Industrial Lighting Standards & Requirements

- Lighting requirements part of union contract
  - May require white light or minimum CRI
  - May request minimum light levels
  - Other possible lighting related requirements

- Owner lighting requirements
  - Light levels above IES recommended
  - Specific lamp of luminaire criteria
  - Other owner specific standards/criteria
Test Your Knowledge
and take a quick poll #4
Knowledge Test *(Answers)*

- Two convex surface objectives: *(1: Proper contrast between highlights and shadows / 2: minimize reflective glare)*
- Flat specular surface lighting objectives: *(Diffuse light and even uniform illumination)*
- Which luminaire attributes are mandatory for clean rooms? *(Sealed/gasketed with smooth surfaces)*
INDUSTRIAL LIGHTING
CALIFORNIA ENERGY CODE
Title 24 Requirements for Industrial Lighting

- Daylighting requirements
- Demand response requirements
- Required controls
- Allowed lighting power densities (LPDs)
## DAY LIGHTING REQUIREMENTS

**Skylit and Daylit Zones** *(Top-light and Sidelight)*

- Large enclosed spaces *(most spaces > 5,000 ft.²)*
- Spaces within climate zones 2 through 15
- At least 75% of conditioned/unconditioned enclosed space directly under roof subject to daylighting requirement
- Spaces where/when ceiling height > 15 ft.
- LPD for general lighting ≥ 0.5 W/ft.²
**DAY LIGHTING REQUIREMENTS**

Skylit and Primary Sidelit Zones - Daylight Controls Required

<table>
<thead>
<tr>
<th>Skylit and sidelit daylight areas shall be shown on plans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daylight controls mandatory for general lighting luminaires that are in, or at least 50% in, skylit or sidelit daylit zones</td>
</tr>
<tr>
<td>Automatic daylighting control devices must meet California Energy Commission certification and Title 20 requirements</td>
</tr>
<tr>
<td>Comply with multi-level and uniformity requirements and installed in accordance with Section 130.1 of Title 24-2019</td>
</tr>
</tbody>
</table>
### DAY LIGHTING REQUIREMENTS

**Exceptions**

- Auditoriums, churches, movie theaters, museums, and refrigerated warehouses
- Buildings with lighting LPD < 0.5 W/ft.\(^2\) or unfinished buildings with plans for spaces < 5000 ft.\(^2\) or ceilings < 15 ft.

Some, but not all other daylighting controls exceptions:

- When adding sky lights to existing building and existing lighting is not being altered
- Where controllable lighting LPD < 0.3 W/ft.\(^2\), multi-level control is not required
- When structures/objects block direct sunlight more than 1500 daytime hours per year between 8 a.m. and 4 p.m.
DEMAND RESPONSE
Mandatory Load Shed and Controls Requirements

<table>
<thead>
<tr>
<th>Buildings &gt; 10,000 ft.²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce building power by at least 15% (<em>per compliance testing</em>)</td>
</tr>
<tr>
<td>All climate zones</td>
</tr>
<tr>
<td>Uniformity requirements per Table 130.1-A of the Standards</td>
</tr>
<tr>
<td>Automatic load shed response to utilities DR signal</td>
</tr>
<tr>
<td>Non-habitable space cannot be used for DR compliance and spaces</td>
</tr>
<tr>
<td>&lt; 0.5 W/ft.² total lighting not counted</td>
</tr>
</tbody>
</table>

Energy Efficiency Standards and Code
<table>
<thead>
<tr>
<th>DEMAND RESPONSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voluntary Requirements and Exceptions</td>
</tr>
</tbody>
</table>

- Buildings/spaces < 10,000 ft.$^2$ *(exempt)*
- Reduce building power more than 15% *(possible incentives?)*
- Spaces < 10,000 ft.$^2$ that voluntarily participate in DR are eligible for Power Adjustment Factor [PAF] credit of 0.05 (5%)
**LIGHTING CONTROLS REQUIREMENTS**  
Non-Residential Spaces *(in addition to daylighting and DR)*

<table>
<thead>
<tr>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>All luminaires shall be controlled with manual ON and OFF functionality lighting controls <em>(base requirement)</em></td>
</tr>
<tr>
<td>Multi-level lighting controls: General lighting of enclosed space 100 ft(^2) or larger that exceeds 0.5 W/ft.(^2) shall comply with multi-level controls in accordance with Table 130.1-A of the code</td>
</tr>
</tbody>
</table>

**Separately Controlled Lighting Systems**

- General lighting separately controlled from all other lighting systems in area
- Floor, wall, window display and casework, ornamental, special effects lighting all separately controlled
- When track lighting used, each function *(see above)* separately controlled *(multi-circuit for multiple tracks)*
<table>
<thead>
<tr>
<th>Luminaire Type</th>
<th>Minimum Control Steps (through full rated power)¹</th>
<th>Uniform level of illuminance achieved by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line voltage sockets except GU-24</td>
<td></td>
<td>Continuous dimming 10 -100%</td>
</tr>
<tr>
<td>Low-voltage incandescent systems</td>
<td></td>
<td>Continuous dimming 20 -100%</td>
</tr>
<tr>
<td>LED luminaires and LED source systems</td>
<td></td>
<td>Minimum one step between 30-70 percent</td>
</tr>
<tr>
<td>GU-24 rated for LED</td>
<td></td>
<td>Stepped dimming, continuous dimming or switching alternate lamps in luminaire</td>
</tr>
<tr>
<td>GU-24 sockets rated for fluorescent &gt; 20 watts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pin-based compact fluorescent &gt; 20 watts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GU-24 sockets rated for fluorescent ≤ 20 watts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pin-based compact fluorescent ≤ 20 watts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear &amp; U-bent fluorescent &gt; 13 watts</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹ Full rated input power of ballast and lamp, corresponding to maximum ballast factor
² Includes only pin based lamps: twin tube, long twin tube, multiple twin tube, and spiral lamps
<table>
<thead>
<tr>
<th>Luminaire Type</th>
<th>Minimum Control Steps (through full rated power 1)</th>
<th>Uniform level of illuminance achieved by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear &amp; U-bent fluorescent &gt; 13W</td>
<td>Minimum one step through each</td>
<td>Stepped dimming, continuous dimming or switching alternate lamps in luminaire</td>
</tr>
<tr>
<td></td>
<td>20 - 40% 50 - 70% 75 - 85% 100%</td>
<td></td>
</tr>
<tr>
<td>Track lighting</td>
<td>Minimum one step between 30-70%</td>
<td>Stepped dimming, continuous dimming or switching circuits in multi-circuit track</td>
</tr>
<tr>
<td>HID &gt;20 watts</td>
<td>Minimum one step through 50-70%</td>
<td>Stepped dimming, continuous dimming or switching alternate lamps in luminaire</td>
</tr>
<tr>
<td>Induction &gt;25 watts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other light sources</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Full rated input power of ballast and lamp, corresponding to maximum ballast factor
2. Includes only pin based lamps: twin tube, long twin tube, multiple twin tube, and spiral lamps
## LIGHTING CONTROLS REQUIREMENTS

**Controls Exceptions: Non-Res Spaces** *(not all shown here)*

### Area Controls
- Up to 0.2 W/ft.\(^2\) of lighting for emergency egress may be continuously illuminated provided area designated as emergency egress area on plans and specifications
- The egress lighting is controlled by switches not accessible except to authorized personnel

### Shut-off Controls
- Up to 0.1 W/ft.\(^2\) may be continuously illuminated for emergency egress provided area designated as emergency egress on plans and specifications submitted to enforcement agency

---

**NOTE:** All exceptions to mandatory lighting control requirements for non-res indoor lighting are shown in Section 130.1 of the 2019 Building Energy Efficiency Standards for Residential and Non-Residential Buildings
## Power Adjustment Factor – Table 140.6-A

<table>
<thead>
<tr>
<th>TYPE OF CONTROL</th>
<th>TYPE OF AREA</th>
<th>PAF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daylight Dimming plus OFF</td>
<td>Luminaires in skylit daylit or primary sidelit daylit zone</td>
<td>0.10</td>
</tr>
<tr>
<td>Occupant Sensors – Large Open Plan Offices</td>
<td>Open plan offices &gt; 250 ft.(^2) - one sensor controlling area:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No larger than 125 ft.</td>
<td>0.40</td>
</tr>
<tr>
<td></td>
<td>126 ft. to 250 ft.</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>251 ft. to 500 ft.</td>
<td>0.20</td>
</tr>
<tr>
<td>Institutional Tuning (<em>Dimming</em>)</td>
<td>Luminaires in non-daylit areas (may be combined with other qualifying PAF’s on this table)</td>
<td>0.10</td>
</tr>
<tr>
<td></td>
<td>Luminaires in daylit areas (may be combined with other qualifying PAF’s on this table)</td>
<td>0.05</td>
</tr>
<tr>
<td>Demand Responsive Control</td>
<td>Buildings 10,000 feet or smaller (may be combined with other qualifying PAFs on this table)</td>
<td>0.05</td>
</tr>
</tbody>
</table>
**INDUSTRIAL LIGHTING**

**ENERGY STANDARDS: California Title 24-2019**

<table>
<thead>
<tr>
<th>TYPE OF USE</th>
<th>LPD (W/ft.²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial/Manufacturing facility buildings</td>
<td>0.60</td>
</tr>
<tr>
<td>All other buildings</td>
<td>0.40</td>
</tr>
</tbody>
</table>

**NOTE**: Title 24-2019 Area Compliance offers more LPD options and is therefore typically used for compliance. Tailored Compliance, however, is not allowed for industrial lighting compliance.
<table>
<thead>
<tr>
<th>PRIMARY FUNCTION</th>
<th>LPD (W/ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto Repair/Maintenance *1</td>
<td>0.70</td>
</tr>
<tr>
<td>Commercial and Industrial Storage</td>
<td></td>
</tr>
<tr>
<td>Warehouse</td>
<td>0.45</td>
</tr>
<tr>
<td>Shipping &amp; Handling</td>
<td>0.60</td>
</tr>
<tr>
<td>Electrical, Mechanical, Telephone Rooms *1</td>
<td>0.40</td>
</tr>
<tr>
<td>General/Commercial &amp; Industrial Work Area</td>
<td></td>
</tr>
<tr>
<td>Low Bay *1</td>
<td>0.60</td>
</tr>
<tr>
<td>High Bay *1</td>
<td>0.65</td>
</tr>
<tr>
<td>Precision *2</td>
<td>0.85</td>
</tr>
</tbody>
</table>

*1: Additional 0.20 Watts Sq. Ft allowed for detailed task work
*2: Additional 0.70 Watts Sq. Ft allowed for precision specialized work
## AREA CATEGORY ALLOWED LIGHTING POWER DENSITIES (continued)

<table>
<thead>
<tr>
<th>PRIMARY FUNCTION</th>
<th>LPD (W/ft²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locker Room</td>
<td>0.45</td>
</tr>
<tr>
<td>Kitchen/Food Preparation Area</td>
<td>0.95</td>
</tr>
<tr>
<td>Scientific Laboratory Area *3</td>
<td>1.00</td>
</tr>
<tr>
<td>Laundry Area</td>
<td>0.45</td>
</tr>
<tr>
<td>Restroom *4</td>
<td>0.65</td>
</tr>
</tbody>
</table>

*3: Additional 0.35 Watts Sq. Ft allowed for specialized task work

*4: Additional 0.35 Watts Sq. Ft allowed for accent, display, feature and ornamental lighting

**NOTE:** Allowed lighting power for spaces such as offices, stairwells, breakrooms, training and vocational areas (*appropriate to specific industrial environments*) are also shown in Area Compliance Table 140.6-C
INDUSTRIAL LIGHTING

ENERGY STANDARDS: California Title 24-2019

Indoor Lighting Section of Nonresidential Standards

Compliance Manual Nonresidential Standards

Available online:
- Building Energy Efficiency Standards Title 24
- 2019 Building Energy Efficiency Standards
- 2019 Standards, Manuals and Forms

Hot-Line Help Desk
800-772-3300 (in California)
916-654-5106 (outside California)

Energy Efficiency Standards and Code
Test Your Knowledge
and take a quick poll #5
Knowledge Test *(Answers)*

- A space with a 14’-6” ceiling: *(Is not subject to daylighting requirements)*
- Mandatory demand response requires: *(Minimum of 15% load shed)*
- Allowed LPD for an auto repair facility: *(0.90 W/ft² – 0.70 for primary function and an additional 0.20 for detailed task work)*
LUNCH BREAK
LEGACY LIGHTING AND LED OPTIONS
Legacy Lighting and LED Options

- High-pressure sodium lamp/luminaire - LED options
- Metal halide lamp/luminaire – LED options
- T8 and T5/HO lamp/luminaire – LED options
LED Options for HPS Sources

- HPS versus LED performance
- LED replacement lamps for HPS lamps
- Equivalent LED luminaires
Legacy High Pressure Sodium

- **Positive**
  - Long life (*up to 40,000 hrs.*)
  - Excellent lumen maintenance (*80%+*)

- **Negative**
  - Poor color rendering (*20 CRI*)
  - Dimming possible but not ideal and has limitations
Light Emitting Diode

• Positive
  - Extremely long life 
    (50,000 to 100,000 + hrs.)
  - Excellent lumen maintenance (80%+)
  - Good color rendering (70 - 90+ CRI)

• Negative
  - Weight and size 
    (luminaires with high lumen options)
  - Potential dimming protocol issues
LED Replacement Lamps

• Positive
  - Long life (50,000 hrs.)
  - Lumen maintenance (*L*<sub>70</sub> at 50,000 hrs.)
  - Good color rendering (70+ CRI)

• Negative
  - No equivalent lumen replacement for 1000 W lamps (400W max equiv.)
  - Potential short lamp life (*heat issues*)
  - Few lamps offer dimming option
Equivalent LED Luminaires

• Positive
  - Long life (50,000 to 100,000 hrs.)
  - Lumen maintenance ($L_{70}$ at 100,000 hrs.)
  - Excellent color rendering (80 to 90 CRI)
  - Rugged (durable) construction

• Negative
  - Weight and size
    (luminaires with high lumen options)
  - Limited dimming options
LED Options for MH Sources

- MH versus LED performance
- LED replacement lamps for MH lamps
- Equivalent LED luminaires
Legacy Metal Halide

• Positive
  - Fair to good color quality (65-80 CRI)
  - Excellent lumen maintenance (80%+)
    [Electronic ballast ceramic metal halide]

• Negative
  - Limited dimming (not ideal dimming)
  - Poor lumen maintenance (50%+)
    [Probe-start metal halide]
  - Color instability (non-ceramic MH)
Light Emitting Diode

• Positive
  - Extremely long life (50,000 to 100,000 + hrs.)
  - Excellent lumen maintenance (80%+)
  - Good color rendering (70 - 90+ CRI)

• Negative
  - Weight and size (luminaires with high lumen options)
  - Potential dimming protocol issues
LED Replacement Lamps

• Positive
  - Long life (50,000 hrs.)
  - Lumen maintenance ($L_{70}$ at 50,000 hrs.)
  - Good color rendering (80+ CRI)
  - Lamps have potential to dim

• Negative
  - Potential short lamp life (heat issues)
  - Few lamps offer dimming option
Equivalent LED Luminaires

• Positive
  - Long life \((50,000 \text{ hrs.})\)
  - Lumen maintenance \((L_{70} \text{ at 50,000 hrs.})\)
  - Good color rendering \((70+ \text{ CRI})\)

• Negative
  - Limited options for 1000W metal halide and 1500W sports lights
  - High lumen luminaire packages are typically large and heavy
LED Options for Fluorescent Sources

- Fluorescent versus LED performance
- LED Replacements for fluorescent lamps
- Equivalent LED luminaires
T8/T5HO Fluorescent

- Positive
  - Instant start - on/off
  - Excellent CRI (80+)
  - Excellent lumen maintenance (80%)
  - Long lamp life (40,000 hrs.)
  - Suitable for dimming

- Negative
  - Physical size (luminaires with high lumen options)
  - Poor performance in extreme hot and cold conditions

Legacy Lighting and LED Options
Light Emitting Diode

• Positive
  - Extremely long life (50,000 to 100,000 + hrs.)
  - Excellent lumen maintenance (80%+)
  - Good color rendering (70 - 90+ CRI)

• Negative
  - Weight and size (luminaires with high lumen options)
  - Potential dimming protocol issues
  - Poor performance in hot environments
LED Replacement Lamps

• Positive
  - Long life (*50,000 hrs.*)
  - Lumen maintenance (*L_{70} at 50,000 hrs.*)
  - Good color rendering (*80+ CRI*)
  - Lamps have potential to dim

• Negative
  - Potential short lamp life (*heat issues*)
  - Various lamp replacement issues with light output, performance and safety
Equivalent LED Luminaires

• Positive
  - Long life (50,000 hrs.)
  - Lumen maintenance ($L_{70}$ at 50,000 hrs.)
  - Good color rendering (70+ CRI)

• Negative
  - Limited lumen replacement for 1000 W and 1500 W lamps
  - Potential short lamp life (heat issues)
  - High lumen options heavy and large
Equivalent LED Luminaires

- **Positive**
  - Equivalent life *(50,000 - 100,000 hrs.)*
  - Lumen maintenance *(\(L_{70}\) at 50,000 hrs.)*
  - Good color rendering *(70 to 90 CRI)*
  - Wide range of color temperatures

- **Negative**
  - Potential short lamp life *(heat issues)*
  - Potential dimming and flicker issues when drivers/controls mismatched
Test Your Knowledge
and take a quick poll #6
Knowledge Test (Answers)

• Color rendering (CRI) of HPS is a negative attribute because:
  (Poor color rendering of 20 CRI)

• LED extremally long life ranges from:
  (50,000 to 100,000 hours)

• Lumen maintenance of T5/ T8 lamps:
  (L80 at 20,000 to 40,000 hours)
LIGHTING TRENDS FOR INDUSTRIAL APPLICATIONS
Lighting Trends

- Task lighting
- Bi-level lighting
- Flexibility
- Advanced technology lighting + daylight
- Improved lighting quality
Lighting Trends for Industrial Applications

Task lighting

- Direct high-level illumination where needed at lower LPD
- Excellent way to control source-task-eye geometry
- Eliminate shadows
- Provide localized high CRI
- Easy on-off (*use as needed*)
- Numerous design options
Multi-level lighting

- Higher illumination with a lower LPD
- Saves energy – levels not occupied can be turned off
- Ideal “demand response” tool
- Reduce shadows
- Can provide localized high CRI
Lighting Trends for Industrial Applications

Multi-level Lighting
Flexible lighting

- Modify lighting faster/easier in response to work/task changes
- Easier to maintain and/or upgrade Lighting components
- Usually higher 1\textsuperscript{st} cost; however, cost effective ROI
- Code or union may not allow flexible systems \textit{(check local code)}
Lighting Trends for Industrial Applications

Advanced lighting + daylight

- Driven in part by code requirements
- Ideal for maximizing efficiency where/when daylight present
- Not all spaces work with daylight integration
LED with dimming drivers and daylighting

- Ideal for maximizing daylight utilization
- Design options growing
- Technology advancement good
- Color quality (improved CRI) versus legacy sources
- LED sources maintain color quality
- Dim-to-warm and color tuning options
Lighting Trends for Industrial Applications

Not all spaces work well with daylight integration.
Lighting Trends for Industrial Applications

Improved Quality of Lighting

- Higher CRI
- Better lumen maintenance
- Longer lamp life
- Higher level control
- Integration with daylight

Cumulative result = Lower LPD and excellent ROI
Test Your Knowledge
and take a quick poll #7
Knowledge Test *(Answers)*

- These two are features/benefits of industrial task lighting *(control source, task-eye geometry and high-level illumination with a low LPD)*

- Fixable/modular wiring cannot be used for all lighting applications. *(Code or union may not allow flexible systems - check local code)*

- LED dimming driver luminaires in daylit areas are ideal for: *(maximizing daylight utilization)*
INDUSTRIAL LIGHTING
NEW PRODUCT REVIEW
New Product Review for Industrial Space
New Product Review for Industrial Plant

- Assembly plant lighting upgrade
  - Fairly dirty environment with materials moving in and out
  - Some part-time production and assembly work
    - Small visual tasks need more light
    - Some heat generated by environment
  - 40’ x 60’ space with 18’ dark open ceiling

- Lighting criteria
  - Energy efficient – better than HID system that it is replacing
  - Low maintenance/long life important
  - IP65 rated (dust-tight, water-tight) and for high temperatures
Lighting Concept

• High bay general lighting
  - Dimmable with low light level when there is no one present
  - 4000K, 80+ CRI
  - Target fc approx. 45 fc

• Task lighting
  - Adjustable
  - High output, wide angle
  - Cleanable, safe for dusty environment
New Product Review
High Bay 1

High efficacy
IP65 for tough environments
Can withstand high temps
New Product Review
High Bay 1

ORDERING EXAMPLE: GC - L250/850 - G - OPTIONS - DIM - UNV

ORDERING INFO (Some configurations have limited availability, consult factory)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>GC</td>
<td></td>
<td>8</td>
<td>4000K</td>
<td>G - Glass lens</td>
</tr>
<tr>
<td></td>
<td>L120 12,000lm</td>
<td>80</td>
<td>4000K</td>
<td>N - 50° Narrow frosted polycarbonate lens</td>
</tr>
<tr>
<td></td>
<td>L190 19,000lm</td>
<td>80</td>
<td>4000K</td>
<td>M - 90° Medium frosted polycarbonate lens</td>
</tr>
<tr>
<td></td>
<td>L250 25,000lm</td>
<td>80</td>
<td>5000K</td>
<td>W - 120° Wide frosted polycarbonate lens</td>
</tr>
<tr>
<td></td>
<td>L310 31,000lm</td>
<td>80</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

OPTIONS [3]
- OCC-GC Passive infrared occupancy sensor
- SRP-GC Remote controller for occupancy sensor

DRIVER
- DIM Dimming driver prewired for 0-10V low-voltage applications

VOLTAGE
- 120V 277V
- UNV 120-277V
New Product Review
High Bay 2

- High efficacy
- Sophisticated control capabilities
- Damp location only

Utilibay™ High Bay
- Available in a high output version (24,000 lumens), a medium output version (18,000 lumens) and a low output version (12,000 lumens)
- Efficacy up to 170 lm/W
- NX Distributed Intelligence™ wired and wireless control capability available
- Five reflector options to meet any lighting need
- Three optional lenses to meet your shielding needs
- Lightweight construction for easy installation
- Symmetrical design for consistent installed results
- CSA certified to UL1598 for Damp Location and UL924
- Five year warranty (Terms and Conditions Apply)
New Product Review
High Bay 2

Communicates easily

Occupancy sensor

Daylight sensor
New Product Review
High Bay 2

Industry Lighting New Product Review

Many control options
**INDUSTRIAL LIGHTING**

**New Product Review - High Bay 1 Calculations**

<table>
<thead>
<tr>
<th>ROOM SIZE</th>
<th>REFLECTANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>80 ft</td>
</tr>
<tr>
<td>Width</td>
<td>40 ft</td>
</tr>
<tr>
<td>Height</td>
<td>18.0 ft</td>
</tr>
<tr>
<td>Workplane Height</td>
<td>2.50 ft</td>
</tr>
<tr>
<td>Suspension Length</td>
<td>1.50 ft</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ROOM SIZE</th>
<th>REFLECTANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceiling</td>
<td>20 %</td>
</tr>
<tr>
<td>Walls</td>
<td>75 %</td>
</tr>
<tr>
<td>Floor</td>
<td>50 %</td>
</tr>
</tbody>
</table>

45 fc  8 luminaires  0.38 W/ft²  
Layout: 4 x 2  Spacing: 19.7 x 19.4 ft

Room: 80 x 40 x 18.0 ft  Workplane Height: 2.50 ft  Luminaire Height: 16.5 ft
New Product Review
Task Light 1

ROCIA.planar is a robust task light which lends itself specifically to industrial environments. The full-metal design protects the inside workings from dust, particles and moisture very often found in these types of areas. The 3D head joint and spring-balanced arm guarantee easy positioning and ergonomic comfort. Maintenance-free LED technology offers 50,000 hours of LED life. Wide area illumination lights up a sizeable area with 5000K neutral white light - an optional dimming function is also available.

- Rugged aluminum housing for long life
- 50,000 hour maintenance-free LED operation
- 100-240V - Integrated power supply built in
- 10-foot cord and plug included
- Dimming function optional
- High-resistance coating against heat, wear and corrosion
- Switch conveniently located on luminaire head
- IP67 protection against water, oil, etc.
- 5000K color temperature
New Product Review - Task Light 2

**ROCIA.focus compact**

- Colour temperature neutral white 5000 K
- Colour rendering Ra >80
- 10° or 40° angle of illumination
- Black and colourless anodised aluminium housing, 3 mm thick safety glass
- Partially spring-balanced arm, flexible tube or head joint
- With switch in the luminaire head (arm-mounted/flexible-tube luminaire) for switching and dimming or without switch (pivoting-head luminaire)
- Supply voltage 100 – 240 VAC (with transformer) or 12 – 28 VAC/12 – 40 VDC (without transformer)

- Maximum permissible ambient temperature $T_{a,\text{max}}$ up to 40 °C (without transformer)
- LED service life (L70) > 60000 h
- Degree of protection IP67; protection class I (with transformer) or III (without transformer)
- Supplied with approx. 3 m connecting line and grounded plug, type CEE 7/7 (with transformer) or free strand ends (without transformer)
- Different mounting elements as accessories
New Product Review – Other types as needed

• Machine lights
  - Repels lubricants, coolants
  - Withstands vibrations
  - Sealed IP68/69

MACHINE LIGHT | LUMATRIS

- Sealed IP68/IP69K rated - highly resistant to liquids and dust, including submersion
- Strong anodized aluminum construction
- Flicker-free light with no IR or UV content
- 4mm thick safety glass
- Two-step switchable operation
- Low surface temperature for comfort and safety
New Product Review – Other types as needed

- Workbench/lab lights
  - Safety sealed
  - Suitable for clean room applications

SPECIFICATIONS:
- Voltage: 120-277V
- Light Source: LED
- Lumens Range: 1400 - 4500
- Controls: rocker switch
- Color Temperature: 4000K or 5000K
- Color Rendering Index (CRI): 80
- Luminaire Head Material: anodized aluminum
- Lens Material: PMMA acrylic
- Luminaire Dimension: varied lengths, 7.4” width
- Power Consumption: various
- Protection Rating: IP20
WRAP UP

Closing Remarks & Evaluations