Pharos University

Electrical Engineering Dept

Course Titled: Energy Systems (EE 271)

Lecture: Illumination (3)

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Presentation 10

Illumination System:

Light Sources

Lecturer Schedule: 11th Week
1. Generation of Light

2. Light Sources
   - Incandescent lamps
   - Halogen lamps
   - Fluorescent lamps
   - High pressure mercury vapor lamps
   - Metal halide lamps
   - High pressure sodium vapor lamps
1. Incandescence

- Solids and liquids emit visible radiation when they are heated to temperatures above 1,000 K.

- The intensity increases and the appearance becomes whiter as the temperature increases.

- **Application**: incandescent lamps.
2. Luminescence

- Gas Discharge
- Fluorescence

phosphorous coated material
3. *Electroluminescence*

- *Electroluminescence is the emission of light when low voltage direct current is applied to a semi-conductor device containing a crystal and a p-n junction.*

- **Application:** *Light Emitting Diode (LED)*

![High Flux Power Chip LED](image1)

![Linear housing](image2)
Light Sources

1. **Incandescent Lamps**

- **Efficacy**: Low
  - 70 to 90% of energy converted into heat

- **Quality of light rendition**: High
  - Similar to sunlight (CRI=97%)
  - Worm color appearance

- **Average rated life**: Short
  - Incandescent lamp loses filament material by evaporation
  - Typical 1000 hours

- **Purchase cost**: Low
  - Inexpensive lamp

- **Operating cost**: High
  - Lowest efficacy (10 to 35 lm/W)
### Incandescent Lamp Types

<table>
<thead>
<tr>
<th>Different shapes of incandescent lamps</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Incandescent Reflector lamp" /></td>
</tr>
<tr>
<td><strong>Incandescent Reflector lamp</strong></td>
</tr>
</tbody>
</table>
2. **Tungsten Halogen Lamps**

- The tungsten halogen lamp is *another type* of incandescent lamp.

- In a halogen lamp, a small quartz capsule contains the filament and a *halogen gas*.

- The halogen gas combines with the evaporated tungsten, re-depositing it on the filament. This process *extends the life of the filament* and keeps the bulb wall from blackening and reducing light output.
## Tungsten Halogen Lamp Types

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>High wattage double envelope halogen lamp</td>
<td><img src="image1.png" alt="Image" /></td>
</tr>
<tr>
<td>Spot type halogen lamp</td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>Reflector Par halogen lamp</td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>Low voltage types</td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td><em>typical 12 V (20, 50, 65 W)</em></td>
<td><em>used mainly for display lighting</em></td>
</tr>
</tbody>
</table>
3. **Fluorescent (or low pressure mercury) Lamps**

- An *electric discharge* (current) is maintained between the electrodes through the mercury vapor and inert gas.
- This current excites the mercury atoms, causing them to emit *non-visible ultraviolet* (UV) radiation.
- This UV radiation is *converted into visible* light by the phosphors lining the tube.
### Fluorescent Lamps Range

<table>
<thead>
<tr>
<th>Type</th>
<th>Color Temperature (k)</th>
<th>CRI (in%)</th>
<th>Light Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incandescent White</td>
<td>≥ 1800</td>
<td>≥ 80</td>
<td>827</td>
</tr>
<tr>
<td>Worm White</td>
<td>≥ 2300</td>
<td>≥ 80</td>
<td>830</td>
</tr>
<tr>
<td>White</td>
<td>≥ 3000</td>
<td>≥ 80</td>
<td>835</td>
</tr>
<tr>
<td>Cool White</td>
<td>≥ 4000</td>
<td>≥ 80</td>
<td>840</td>
</tr>
<tr>
<td>Daylight</td>
<td>≥ 6000</td>
<td>≥ 80</td>
<td>850</td>
</tr>
<tr>
<td>Cool Daylight</td>
<td>≥ 6500</td>
<td>≥ 80</td>
<td>865</td>
</tr>
</tbody>
</table>

*Modern Technology by Philips* offers Extreme Cool “snow white” light of color temperature as 12000 K
### Standard Lamp Designation

**F40 TI2 / CW**

<table>
<thead>
<tr>
<th>F</th>
<th>Fluorescent lamp</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>Wattage</td>
</tr>
<tr>
<td>T</td>
<td>Tubular bulb shape</td>
</tr>
<tr>
<td>12</td>
<td>Maximum tube diameter - in eighths of an inch ((12/8 = 1.5”))</td>
</tr>
<tr>
<td>CW</td>
<td>Cool White Color</td>
</tr>
</tbody>
</table>
Fluorescent Lamps Characteristics

- **Efficacy**: higher than incandescent (40 to 100 lm/W)
- **Quality of light rendition**: Low or High, depending on phosphorus coating
  - FL T12 "Worm White" : CRI=53%
  - FL T12 "Cold White" : CRI=62%
- **Average rated life**: Long
- **Purchase cost**: Low
  - fixture: moderate
  - lamp: inexpensive
- **Operating cost**: Low
  - good efficacy

Most common one is 120 cm (36 W), 1½ inch diameter (T12)

More efficient FL lamps are now available in smaller diameter, including the T10 (1¼ inch diam) & T8 (1 inch diam)
Modern Types of Fluorescent Lamps

- Miniaturization of FL lamps offers TL5 series with diameter 16 inch and shorter length.
- Improved efficacy (100 lm/W), less material, improved phosphor coating, and less mercury.

<table>
<thead>
<tr>
<th>T5 Series Data (OSRAM)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lamp Characteristics</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Color temp (K)</td>
</tr>
<tr>
<td>Light color</td>
</tr>
<tr>
<td>CRI</td>
</tr>
<tr>
<td>Luminous flux (lm)</td>
</tr>
<tr>
<td>Outer diameter (mm)</td>
</tr>
<tr>
<td>Length (mm)</td>
</tr>
</tbody>
</table>
Fluorescent Lamp Ballasts

✓ The ballast supplies the *right voltage to start* and operate the lamp (about 1000 V).

✓ The ballast *limits current* to a gas discharge lamp during operation

   - *the resistance of a gas discharge lamp becomes negligible once the arc has been struck.*

✓ The standard core-coil magnetic ballasts are essentially core-coil transformers (i.e. series inductor)
**Pre-heat Switch Start**

- A 220 V is used to ionize argon gas enclosed in the glass tube.
- Heat of discharge causes the bi-metallic to expand and to cause the circuit to be on.
- Bi-metallic is then cools and causes the circuit to be off.
- Off-operation results in high induced inductive voltage \( \frac{L}{dI/dt} \) to start up discharge of the lamp.
High Intensity Discharge (HID) Lamps

- High intensity discharge lamps generate light by exciting mercury or metals in a plasma.
- The plasma is generated in an arc tube by current flowing between two electrodes.
- Resistance of plasma inside arc tube during discharge $\approx \text{short-circuit}$.
- Discharge lamps have to be operated with a ballast to limit the value of discharge current. The ballasts consist of high resistance conventional chokes.
- HID lamps including: high-pressure mercury vapor lamps, metal-halide lamps, high- & low- pressure sodium lamps.
Pulse start HID ballast

- Ballast
- Capacitor for PF correction
- Ignitor

220 V

900 V peak on 2 ms width
4. *High Pressure Mercury Vapor Lamp (HPL)*

- Arc tube contains small quantities of mercury and Argon.
- At 220 V argon & neon discharges and the arc is struck between the starting & operating electrodes.
- Mercury ionizes and resistance inside arc tube decreases.
- When the arc resistance becomes less than external resistance, the arc jumps between main electrodes.
Color characteristics of HPL lamps

- The light produced of the ionized mercury is pre-dominated blue-green color with CRI as 15%.

- The phosphorus absorbs the excited UV radiation and re-radiates it as red & orange colored luminous energy and the CRI is increased to 50%.

- Using tungsten filament in series with arc tube makes the lamp to act as incandescent light source & HPL as well. The CRI is increased to 72%.
5. **Metal Halide Lamps (HQL)**

- Light-producing element is the same as high-pressure mercury lamp.
- Halide salts are added as additional additives inside arc tube to improve color rendition. The CRI is improved to 90%.
Use of HQL in floodlighting of sports playgrounds

Conventional single ended 2000W Metal Halide lamp

New Generation Compact Double Ended small burner 2000W Metal Halide lamp
Ceramic Discharge Metal Halide Lamps (CDM) : Master Color

The use of a ceramic burner instead of quartz has several advantages:

- high efficacy (90 lm/W)
- very good color rendering (80 to 95%)
- stable color temperature over life

Available in low wattages : 20, 35 and 50 W
6. **High Pressure Sodium (SON) Lamps**

- Arc tube compared with MH lamps has small diameter to maintain high temperature.

- Light is produced by arc discharge through sodium vapor (yellow mono color appearance).

- Increasing sodium pressure inside arc tube improves color appearance of reds, blues and greens.

- Increasing sodium pressure improves color rendition but it decreases lamp efficacy.
Source Comparison Based on **Equal Lumens** (30,000 lm)

<table>
<thead>
<tr>
<th>Lamp</th>
<th>Qt.</th>
<th>Characteristics per lamp</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Total lumens output</td>
</tr>
<tr>
<td>Incandescent</td>
<td>17</td>
<td>29580</td>
</tr>
<tr>
<td>Tungsten-halogen</td>
<td>4</td>
<td>30000</td>
</tr>
<tr>
<td>Fluorescent</td>
<td>10</td>
<td>31500</td>
</tr>
<tr>
<td>High-pressure mercury</td>
<td>2</td>
<td>26000</td>
</tr>
<tr>
<td>Metal halide</td>
<td>1</td>
<td>34000</td>
</tr>
<tr>
<td>Low-pressure sodium</td>
<td>1</td>
<td>33000</td>
</tr>
<tr>
<td>High-pressure sodium</td>
<td>1</td>
<td>30000</td>
</tr>
</tbody>
</table>