The Evaluation of Flicker in LED Luminaires

Michael Grather, President
Luminaire Testing Laboratory, Inc.
mike@LuminaireTesting.com
Flicker – Introduction

• Flicker is the periodic change in the instantaneous light output of a light source.

• In most conventional light sources driven by line current, the frequency of the flicker is two times the frequency of the line current.

• The increased use of high frequency electronic ballasts has greatly decreased the amount of flicker present in the indoor environment.
The Evaluation of Flicker in LED Luminaires

Why is flicker a problem?

1) People are noticing it...

• People have their own ways of looking for it.
• Flicker Fusion Frequency in humans is ~16Hz
• Fast movement causes flicker to become more obvious – The stroboscopic effect, Phantom arrays, Ghost images.
Why is flicker a problem?

2) It has an effect on people...

- They don’t necessarily notice the flicker
- Nausea (motion sickness)
- Women more sensitive to flicker than men, younger people more than older. (Rubenstein, 1992)
Why is flicker a problem?

3) Certain applications may be more sensitive...

- Roadway
- Sports lighting
- Lighting for video applications
- Industrial Applications
The Evaluation of Flicker in LED Luminaires

Why is flicker a problem?

4) It contributes to the general perception of the technology...

• If most LEDs exhibit flicker, the public will most likely decide that all LEDs flicker.
• Energy Star requirements currently only address flicker by the frequency of the drive current.
• Energy Star Requirements for Solid State Luminaires (DOE) version 1.1 => 120Hz
• Energy Star RLF version 4.3 => 120Hz
The Evaluation of Flicker in LED Luminaires

Why does flicker exist in LED Luminaires?

- $$ - $$ DC Power Supply Design (ripple on DC)
- High switching speed of LEDs
- Duty Cycle variations to control power
- $$ and efficiency – in some cases, LEDs could be used as the diodes in the rectifier circuit.
The Evaluation of Flicker in LED Luminaires

Why does flicker exist in LED Luminaires?

- Half-Wave Rectifier
- Full-Wave Rectifier
The Evaluation of Flicker in LED Luminaires

What about Conventional Sources?

• Yes, there is flicker associated with conventional sources and there has been much study on its effects.
• High Frequency Ballasts (~20kHZ)
• Persistence of phosphor in fluorescent lamps
• Flicker of conventional sources does not typically drop to 0 intensity within a waveform
The Evaluation of Flicker in LED Luminaires

Metrics for flicker measurement

\( P_{ST} \) and \( P_{LT} \) – (short term and long term flicker)

- Described in IEC 61000-4-15
- Uses a “flickermeter” (described in the standard)
- Generally for measurement of sub-harmonic changes in the AC waveform
- A \( P_{ST} > 1.0 \) is considered unacceptable flicker (found annoying)
The Evaluation of Flicker in LED Luminaires

Metrics for flicker measurement

Percent Flicker
• Percent Flicker = 100*(A-B) / (A+B)
The Evaluation of Flicker in LED Luminaires

Metrics for flicker measurement

Percent Flicker
• Described in early versions of the IESNA Handbook
• Percent modulation of the intensity waveform
• Range is from 0% to 100%
• 0% is a pure DC waveform
• 100% would occur when the range extends to 0 light output at any time during the waveform
• Does not include information about the duty cycle
The Evaluation of Flicker in LED Luminaires

Metrics for flicker measurement

Flicker Index
- Flicker Index = \[
\frac{\text{Area 1}}{\text{Area 1} + \text{Area 2}}
\]
The Evaluation of Flicker in LED Luminaires

Metrics for flicker measurement

Flicker Index

• Relates the area under the curve above the average light intensity to the area under the curve below the average light intensity
• Range is from 0 to 1.0
• 0 is a pure DC waveform
• 1.0 can only occur with the most dramatic changes in light output
• Includes the effects of duty cycle
The Evaluation of Flicker in LED Luminaires

Metrics for flicker measurement

Flicker Index
Vs
Percent Flicker
(from IESNA Handbook Reference Volume 1981)

![Fig. 8-38. Flicker Index and Per Cent Flicker Values for “White” Fluorescent Lamps](image)
The Evaluation of Flicker in LED Luminaires

Block Diagram of Test Setup
The Evaluation of Flicker in LED Luminaires

Incandescent Lamp (60Hz)
Frequency: 120Hz
Max: 12.180
Min: 10.745
Ave: 11.460
Percent Flicker: 6.2594
Flicker Index: 0.0194
The Evaluation of Flicker in LED Luminaires

100W Metal Halide (clear)
Frequency: 120Hz
Max: 9.1472
Min: 3.2066
Ave: 6.5147
Percent Flicker: 48.088
Flicker Index: 0.1398
The Evaluation of Flicker in LED Luminaires

T12 Lamp with Magnetic Ballast
Frequency: 120Hz
Max: 9.6281
Min: 4.6256
Ave: 11.460
Percent Flicker: 35.096
Flicker Index: 0.0897
The Evaluation of Flicker in LED Luminaires

T5HO with HF Electronic Ballast
Frequency: ~100kHz
Max: 10.52
Min: 9.960
Ave: 10.20
Percent Flicker: 2.734
Flicker Index: 0.0036
The Evaluation of Flicker in LED Luminaires

LED powered by DC current
Frequency: N/A
Max: 43.4
Min: 41.0
Ave: 42.2
Percent Flicker: 2.84
Flicker Index: 0.0037
The Evaluation of Flicker in LED Luminaires

LED with Significant Flicker
Frequency: 120Hz
Max: 15.996
Min: 0.0555
Ave: 6.3026
Percent Flicker: 99.309
Flicker Index: 0.4498
## The Evaluation of Flicker in LED Luminaires

<table>
<thead>
<tr>
<th></th>
<th>Max</th>
<th>Min</th>
<th>Ave</th>
<th>% Flicker</th>
<th>Flicker Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incandescent</td>
<td>12.180</td>
<td>10.745</td>
<td>11.460</td>
<td>6.2594</td>
<td>0.0194</td>
</tr>
<tr>
<td>100W MH</td>
<td>9.1472</td>
<td>3.2066</td>
<td>6.5147</td>
<td>48.088</td>
<td>0.1398</td>
</tr>
<tr>
<td>T12 Magnetic</td>
<td>9.6281</td>
<td>4.6256</td>
<td>7.1565</td>
<td>35.096</td>
<td>0.0897</td>
</tr>
<tr>
<td>T5HO Elec</td>
<td>10.52</td>
<td>9.960</td>
<td>10.20</td>
<td>2.734</td>
<td>0.0036</td>
</tr>
<tr>
<td>LED at DC</td>
<td>43.4</td>
<td>41.0</td>
<td>42.2</td>
<td>2.84</td>
<td>0.0037</td>
</tr>
<tr>
<td>LED w/ Flicker</td>
<td>15.996</td>
<td>0.0555</td>
<td>6.3026</td>
<td>99.309</td>
<td>0.4498</td>
</tr>
</tbody>
</table>
The Evaluation of Flicker in LED Luminaires

Conclusions

• Flicker Frequency alone is an inadequate measure of flicker.
• More studies will be needed to develop appropriate thresholds for flicker metrics.
• Flicker from LED luminaires can be much more significant than flicker from conventional sources.
• The Flicker Index metric is a useful tool for evaluating both the percent modulation and duty cycle of flicker in all types of light sources.
The Evaluation of Flicker in LED Luminaires

Thank You!

Michael Grather
mike@LuminaireTesting.com