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DOE R&D Workshop - Temporal Lighting Artifacts

Gilles Abrahamse, Jan 31st 2018

AcuityBrands.

Introduction

I am not an expert in this field!

Industry professional with 20 years in LED lighting that cares about quality of light

Spoiler alert:
Increasing amount of studies – and (different) opinions

Adoption of flicker standards / legislation is still ‘early stage’

Subject is mostly ‘stuck’ in research, studies and recommendations – there is little that guides a luminaire manufacturer / specification professionals / building owners to well defined criteria and measurement methods specific to its application

Temporal Light Artifacts (TLA)

flicker: perception of visual unsteadiness induced by a light stimulus the luminance or spectral distribution of which fluctuates with time, for a static observer in a static environment (CIE 2016a, 2.4.2).

stroboscopic effect: change in motion perception induced by a light stimulus the luminance or spectral distribution of which fluctuates with time, for a static observer in a non-static environment (CIE 2016a, 2.4.3).

phantom array effect [ghosting]: change in perceived shape or spatial positions of objects, induced by a light stimulus the luminance or spectral distribution of which fluctuates with time, for a non-static observer in a static environment (CIE 2016a, 2.4.4).

Figure 2 – A schematic illustration of international, regional, and national standardization bodies related to light and lighting, showing particularly those interested in TLM

Why does TLA matter?

Known human impairments:

Distraction

Reduced visual task performance

Apparent slowing or stopping of motion (stroboscopic effect)

Headaches, fatigue, blurred vision, eyestrain

Neurological problems, including epileptic seizure

What affects TLA sensitivity?

Human characteristics

- Sensation vs. perception
- Ability of nervous system to respond

Light source characteristics

- Luminous flux modulation
- Spectral (chromatic) variation

Lighting application characteristics

- Exposure time
- Adaptation luminance
- Contrast
- Size of retinal area being stimulated
- Distance to source and its location in the visual field

What is flicker?

Variation in time (modulation) of light output (luminous flux) – Temporal Light Modulation

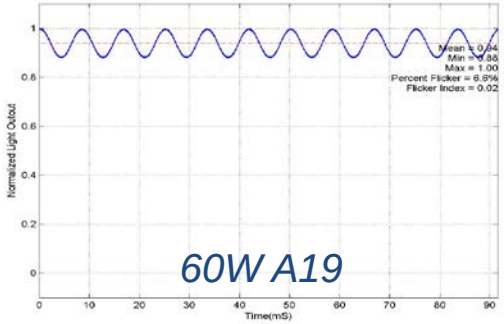
Present in all traditional commercial electric light sources running on AC power

- Including incandescent, halogen, fluorescent, metal-halide
- Typically (but not always) periodic, and property of light source
- Whether you are aware of it or not

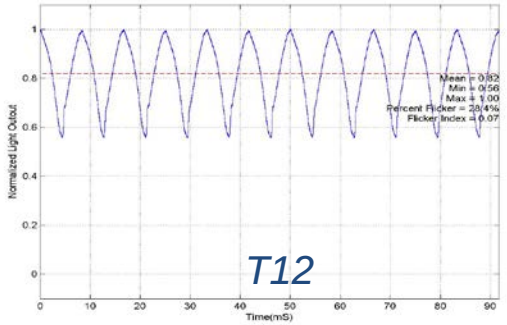
Not to be confused with electrical flicker

- Noise on AC distribution line directly creates additional (light) modulation on resistive (incandescent) loads
- Not a property of the light source

Almost every light source flickers!

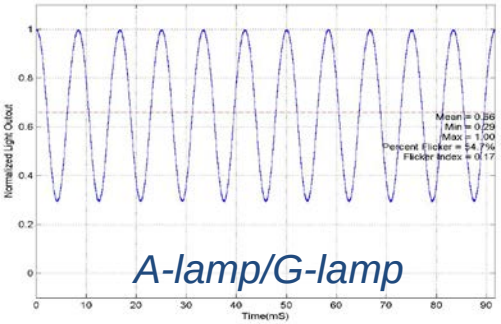


60W A19

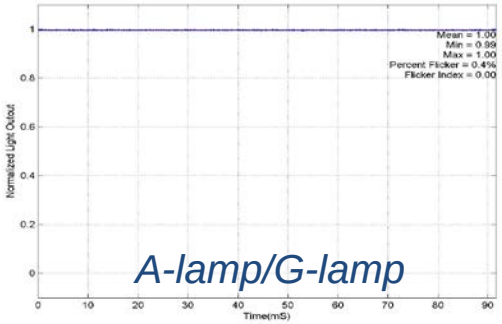


T12

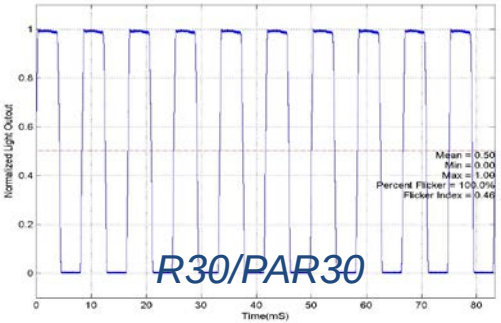
Examples of SSL flicker



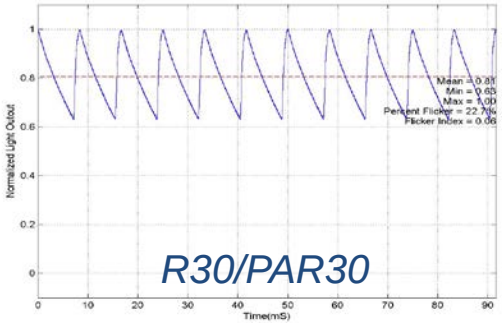
A-lamp/G-lamp



A-lamp/G-lamp



R30/PAR30



R30/PAR30

Why should there be so much focus on flicker with LED’s?

Almost every LED is driven with some sort of modulation / duty cycled power supply (aka LED driver)

and

‘Speed’ of the diode vs traditional sources

in combination with

New applications area’s like tunable color systems

… makes LED systems especially susceptible for TLA

High level there are 3 forms of TLM (Temporal Light Modulation) in LED drivers:

- PWM (modulation between 0 and 100%)
- DC current reduction
- Hybrid versions

Where are we today?

EPA (Energy Star) – first to adopt flicker measures: flicker index **(IES)**. Currently adopting widest variety of TLA metrics
CA title 24 – adoption of modulation and frequency – but only for residential
IEEE 1789 – strict scheme of modulation and frequency
NEMA 77 – development of metrics for flicker and stroboscopic effect
ASSIST – driven by **LRC**, metric similar to NEMA 77
DLC – nothing so far … expected to release later this year

Flicker metrics

IES has defined two…..

Percent flicker

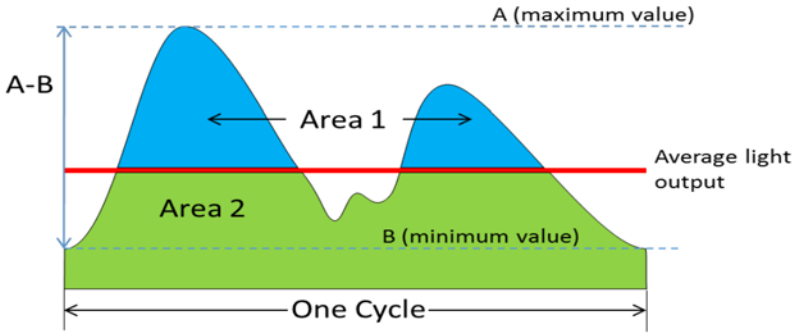
- 0-100% scale
- More well-known and more commonly used

Flicker index

- 0-1.0 scale
- Less well-known and rarely used

Both based on analysis of one cycle of periodic waveform

Neither account for frequency



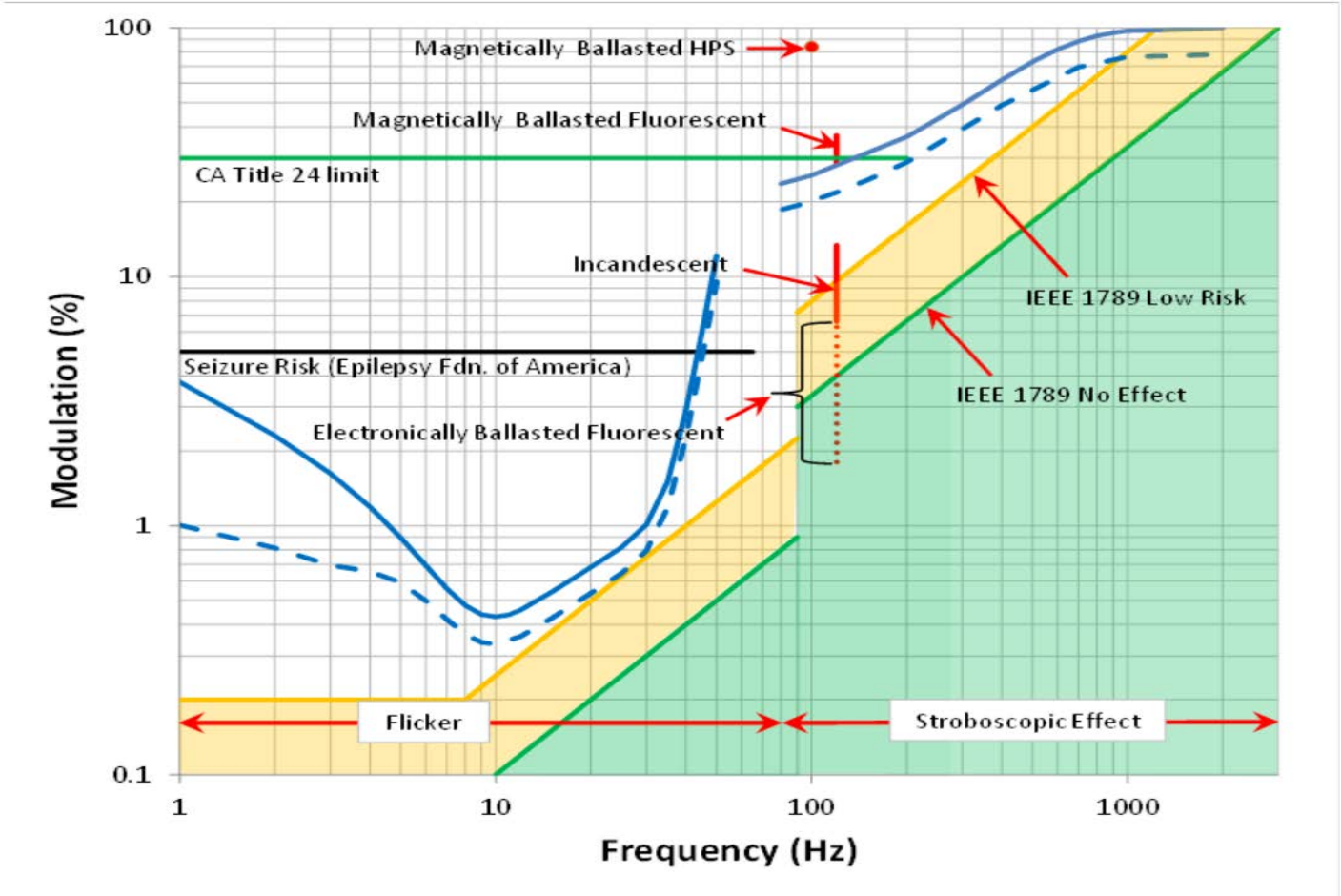
$$\text{Percent Flicker} = 100\% \times \frac{A - B}{A + B}$$

$$\text{Flicker Index} = \frac{Area\ 1}{Area\ 1 + Area\ 2}$$

IEEE 1789

CA title 24

NEMA 77 limits



NEMA 77 and LRC - ASSIST

IEEE 1789 is conversative

NEMA: Adoption of Pst for flicker (<80 Hz), and SVM (Stroboscopic Visibility Measure)

ASSIST: proposes a flicker metric similar to Pst, based on perception measurements with human subject.

The metrics to be used for evaluation of TLA, for a light source, are:

- P_{st}, to quantify flicker (frequencies below 80 Hz). This metric is chosen because it is a well-established standard, having been used in IEC for many years. The suitability of this metric is supported by ASSIST's recent work [11], which produced a metric having similar values and similar dependence on frequency. It is based upon and supported by studies of human perception.
- SVM, to quantify stroboscopic effect, (frequencies between 80 and 2000 Hz). Though a much younger approach than IEC's P_{st}, SVM is based upon and supported by human perception research. [13, 14, 15]

Pst, ASSIST metric and SVM

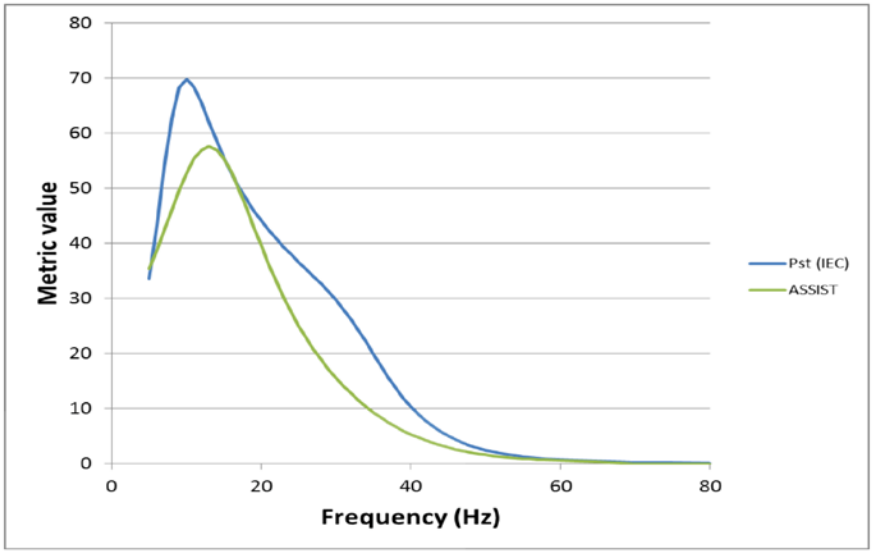
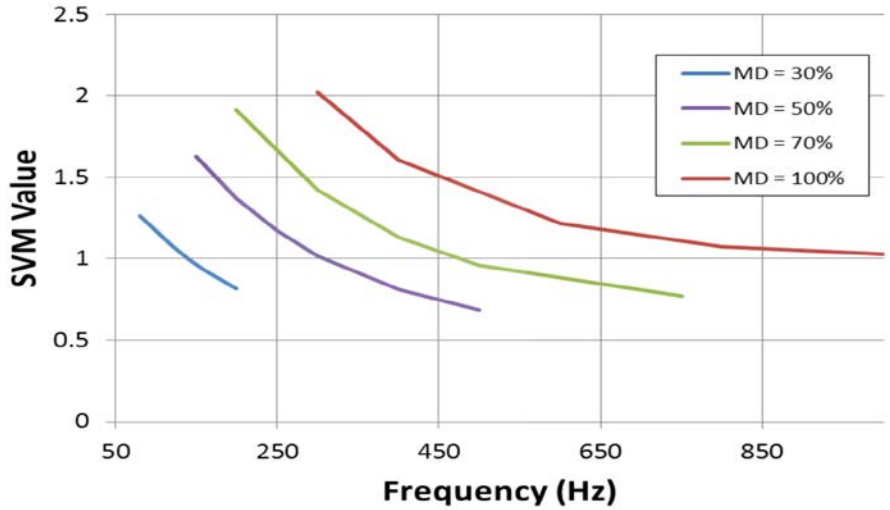


Figure 2. Plot of ASSIST and IEC P_{st} metrics.
Calculated for a 30% modulation depth single-frequency sine wave light waveform.



Energy Star

Lamps 2.1

Multiple methods

- NEMA 77
- ASSIST metric for direct perception

Metrics reporting (no min or max given at this point)

- Percent Flicker
- Flicker Index
- Lamp light output periodic frequency
- Short term flicker indicator (Pst)
- Stroboscopic Visibility Measure (SVM)
- ASSIST Flicker Perception (MP)

Luminaires 2.0 Current standard

Flicker reference: IEEE 1789

Light output frequency >= 120 Hz

Luminaires 2.1 draft

Multiple methods

- NEMA 77
- IEEE 1789

Requirement of frequency >= 120 Hz and reporting of:

- Short term flicker indicator (Pst) – using NEMA 77
- Stroboscopic Visibility Measure (SVM) – using NEMA 77

Risk drivers

All other things being equal:

Higher modulation amplitude/depth = higher risk

Lower modulation frequency = higher risk

Lower duty cycles = higher risk

Faster eye motion = higher risk

Higher adaptation luminance = higher risk

Higher contrast with surround luminance = higher risk

Larger retinal area being stimulated = higher risk

More central retinal area being stimulated = higher risk

Review

Almost all light sources flicker

Unprecedented flicker characteristics can be found in commercially available SSL sources

- Wide variation – in amplitude, frequency, shape
- No consistency in claims – the effect of TLA on human health
- Different metrics have been developed – but are not widely used yet
- Difficult to predict – no standard measurement procedure

The impacts of flicker have population and lighting application dependencies – requiring risk analysis

Recommendations

Consolidate – too many different metrics

Standardized measurement (equipment), easy access

Train – not much knowledge with the people that design and specify

Continue studies on TLA affecting human health, comfort, productivity

Do not use flickering sources in high risk lighting applications, like
- Hospitals, clinics
- Classrooms
- Industrial spaces
- Open offices