TRB 2003 Annual Meeting
Workshop 101
Glare and Nighttime Roadway Visibility

Basic Glare Definitions and Terminology

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Webster's

glare

Function: *noun*

Date: 15th century

1 a : a harsh uncomfortably bright light
<the *glare* of a neon sign> <the *glare*
of publicity>; *especially* **:** painfully
bright sunlight

IESNA Lighting Handbook

- Glare occurs in two ways:
  - Too much light
  - Luminance range is too large

- Too much light
  - Produces a simple photobiological response
    - Squinting, blinking, gaze aversion
  - Only solution is reduction of retinal illuminance

Large Luminance Range

- Can have two effects:
  - Reduction in visual performance (disability glare)
  - A feeling of discomfort (discomfort glare)

- Disability glare
  - An effect of light scattering in the eye the reduces the luminance contrast of the retinal image
  - Can be mimicked by adding a uniform "veil" of luminance to the target

Disability Glare

- The magnitude of disability glare can be estimated by the veiling luminance L_v,

$$L_v = 9.2 \sum_{i=1}^{n} \frac{E_i}{\theta_i(\theta_i + 1.5)}$$

- Where
  - E_i=illuminance from the ith glare source (lux)
  - θ_i=angle between the target and i[th] glare source (deg)

Disability Glare

◨ Luminance contrast

$$C = \left(\frac{L_t - L_b}{L_b} \right)$$

Where L_t is the luminance of the target and L_b is the luminance of the background

◨ To include the effects of disability glare on luminance contrast add the equivalent veiling luminance

$$C = \left(\frac{(L_t + L_v) - (L_b + L_v)}{L_b + L_v} \right) = \left(\frac{L_t - L_b}{L_b + L_v} \right)$$

Discomfort Glare

- Sensation of annoyance or pain caused by high luminance in the field of view

- By definition discomfort does not cause a direct decrease to visual performance

- Cause of discomfort glare is *not* well understood

Discomfort Glare

- Often measured through subjective ratings
- In transportation typically De Boer scale is used
  - De Boer, J. B. (1967) *Visual perception in road traffic and the field of vision of the motorist*. In J. B. De Boer (Ed.) Public lighting (pp 11-19).

- 1: Unbearable
- 2:
- 3: Disturbing
- 4:
- 5: Just Acceptable
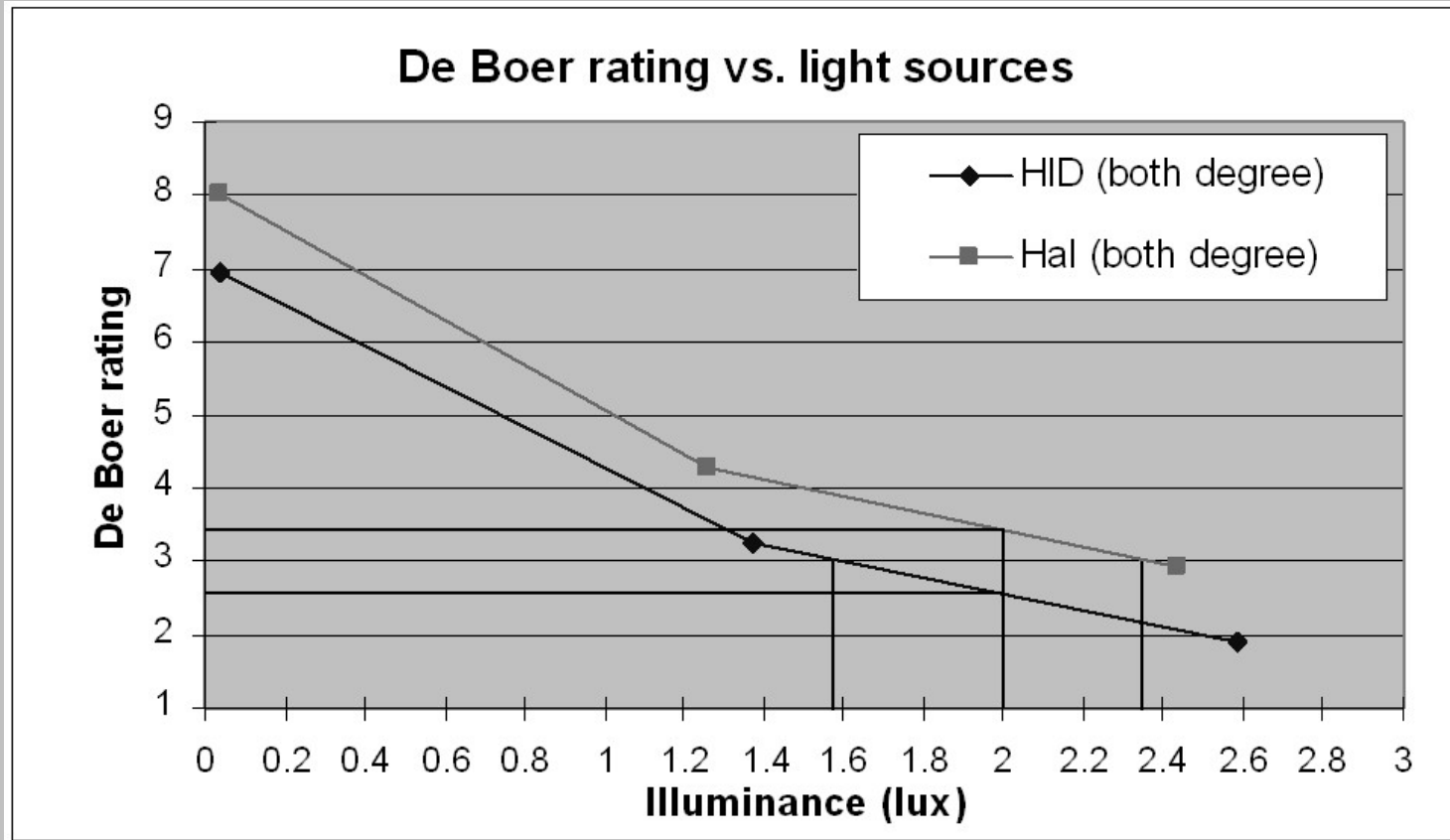- 6:
- 7: Satisfactory
- 8:
- 9: Just Noticeable

Calculate De Boer Rating

$$W = 5.0 - 2\log \frac{E_B}{C_{poo} * [1 + \sqrt{\frac{L_u}{C_{pL}}}] * \theta^{0.46}}$$

- W: Discomfort glare rating on the de Boer scale
- E_B : the illumination at the observer's eye point in lx
- C_{poo} : a constant equal to 3.0 * 10 ^-3 (lx*min^-0.46)
- L_u : the adaptation luminance of observer in cd/m^2.
- C_{pl} : a constant equal to 4.0 * 10 ^-2 (cd/m^2)
- Θ: visual angle in minutes between the glare source and the observer's fixation point

[Bhise, 1977]

Discomfort Glare: Spectral Effects

De Boer rating vs. light sources

Legend: HID (both degree), Hal (both degree)

Y-axis: De Boer rating
X-axis: Illuminance (lux)

Large spectral effect

CIE Standard Observer (J.J. Vos, 1999)

☰ Stiles-Holladay disability glare formula

$$L_{eq} = \frac{10E_{gl}}{\theta^2}$$

Where L_{eq} = veiling luminance (cd/m2),
E_{gl} = glare illuminance on the eye (lux),
and θ = glare angle (deg)

☰ Only valid between 3° and 30°

CIE Standard Observer (J.J. Vos, 1999)

■ Proposed new observer

$$L_{eq} = \frac{10}{\theta^3} + \left[\frac{5}{\theta^2} + \frac{0.1p}{\theta}\right]\left[1 + \left(\frac{A}{62.5}\right)^4\right] + 2.5 \times 10^{-3} p$$

Where L_{eq} = veiling luminance (cd/m2),
E_{gl} = glare illuminance on the eye (lux),
and θ = glare angle (deg), A = age in years,
p ranges from 0.5 for brown eyes, to 1.2 for blue eyes

■ Valid between 0.1º and 100º

New Glare Nomenclature (J. J. Vos)

- New glare terms to distinguish three dimensions
  - Temporal, spatial, intensity
- These are:
  - Dazzle
  - Light damage
  - Light adaptation
  - Flash blindness
  - Discomfort glare
  - Disability glare
  - Distraction glare
  - Paralyzing glare