From: Martinez, Pierre@Energy
To: Todd Stewart;
Subject: FW: Brightness and Glare Discussion for BrightSource
Date: Tuesday, November 06, 2012 3:52:30 PM
Attachments: BrightnessGlareDiscussion.docx

Todd, at the October 29, 2012 Rio Mesa PSA Workshop, a couple of questions were asked regarding Glint and Glare.

1. Can the Energy Commission provide additional supporting information on disability glare and perceived glare and brightness?
2. Can the Energy Commission we provided an annotated set of references?

In response to those questions, Energy Commission staff has provided the attached document.

I will be docketing this response shortly.

Pierre

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From: Flores, David@Energy
Sent: Thursday, November 01, 2012 2:30 PM
To: Martinez, Pierre@Energy
Cc: Koch, Andrea@Energy
Subject: FW: Brightness and Glare Discussion for BrightSource

Pierre, based on the comment from Brightsource's attorney to Gregg Irvin on Glare, this is his response. I have reviewed and commented back to Gregg and is ready to be docketed..Dave

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From: Gregg Irvin [mailto:gregg_irvin@yahoo.com]
Sent: Thursday, November 01, 2012 1:26 PM
To: Flores, David@Energy

Cc: Koch, Andrea@Energy; Mourkas, Melissa@Energy; Hill, Candace@Energy
Subject: Brightness and Glare Discussion for BrightSource

Dave (and team),

Attached please find the response to the Bright Source request made during the latest teleconference.
Thanks for the earlier review.

If this is OK would you go ahead and post it, or sent it to wherever it goes.
I'm not certain of the hows and wheres of that process.
If you need changes let me know. If you want to make some minor changes of your own please feel free.

Thanks,
Gregg

"Don't go towards the light!"

Brightness Perception

In physics, the luminance of an object is exactingly defined as the luminous flux per unit of projected area per unit solid angle leaving a surface at a given point and in a given direction. A more useable definition is the amount of visible light that that reaches the eye from an object. But, when an observer describes how "bright" an object appears, he/she is describing his/her brightness perception of the object. This brightness is the perceptual correlate to luminance and depends on both the light from the object and from the object's background region (as well as a variety of additional contextual and adaptation states).

Human visual perception of brightness and lightness involves both low-level (retinal) and higher levels (cortical) of processing that interact to determine the brightness and lightness of parts of a scene (Adelson, 1999). If a scene was scanned by a photodetector, it would measure the amount of luminance energy at each point in the scene; the more light coming from a particular part of the scene the greater the measured value. The human eye's retinal receptors (cones) respond in a similar manner when a scene is imaged unto it. However the appearance (perception) of a region of the scene can be drastically altered without affecting the response of retinal receptors. The well-known simultaneous contrast effect demonstrates this phenomenon (**Figure 1** below). In reality, the two center regions have the same luminance, but their apparent greyness' (luminance) are different and depend upon spatial interactions with the surround. The grey region surrounded by a dark area looks (is perceived) brighter than the same grey region surrounded by a light region. Hering (1878) attributed this effect to adaptation and local interactions. This phenomenon is just one example of a number of illusions that illustrate problems that can arise when one visual element is viewed in the context of others. While the human visual system is very good at such complex tasks as edge detection and compensation for ambient lighting conditions, it sometimes can alter the appearance of the stimulus in unexpected ways before its message reaches the conscious part of the brain (Flinn, 2000).

Perceived brightness, as well as glint and glare effects, depends on a variety of factors including the luminance of the global ambient, target size and the relationship between the luminance of the target and background. The global ambient luminance sets the state of visual adaptation and hence the spatial and temporal processing characteristics of the human visual system. Within this context perceived brightness and glare depend critically on the luminance relationships and size of the target, which presumably are the solar receiver steam generators (SRGS) and background (sky).

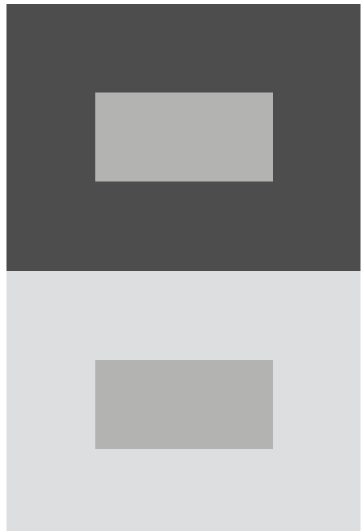

Figure 1. Differential brightness perception induced by simultaneous contrast.

The SRSGs are a stimulus not normally found in nature. The only stimulus that could be considered as functionally equivalent would be that of the Sun. The luminance of the Sun is clearly a saturating stimulus with a sufficient magnitude to cause pain when directly fixating, very powerful afterimages of extended duration, and potentially damage if localized to a specific retinal region. Although the SRSGs are approximately 1.6 orders of magnitude less luminous than the Sun they are still 2.3 orders greater than the nominal background sky, a factor of 187 times greater in luminance. At these ambient levels the SRSGs are also a visually saturating stimulus, albeit of lesser magnitude. Although it is difficult to assign a brightness value to saturating visual stimuli, all saturating stimuli produce discomfort glare. This is due to the nature of scatter in the human eye at saturating levels in which the point spread function (PSF) broadens due to the multiple sources of scatter including the lens and ocular media, the iris, the sclera and the fundus (van den Berg, et al., Hennelly, et. al., Ginis, et. al., and Pinero, et. al.). This produces a prominent Equivalent Veiling Luminance for the PSF. For the PSF with scatter present straylight is quantified by means of a straylight parameter s(θ) where s(θ) =

$$PSF = \left[\frac{L_{eq}}{E_{bl}}\right] \qquad [sr^{-1}]$$

Where L_{eq} = Equivalent Veiling Luminance, in cd/m^2 and

E_{gl} = Glare illuminance in the eye, in lux

The detailed equations for disability glare were recently adopted by the CIE (Commission International de l’Eclairage, or International Commission on Illumination) (Vos, 1984 and Vos, 1999).

No stimuli equivalent in size and magnitude to the SRSGs has existed prior to the development of the SRSGs for experimentation. Thus it is not surprising that there is no literature descriptive of the perceived brightness or glare of such stimuli as a function of viewing distance. However there are powerful guides in the literature. The use of Steven's Power Law at longer ranges, when approaching acuity limits, is actually a conservative approach as it is the most compressive of the functions cited in the psychophysical literature (**Figure 2**). At closer ranges, perceived brightness is subject to the inverse square law for reflective surfaces and perceived brightness remains constant as a function of viewing distance for visually extended reflective surfaces. Although the SRSGs are reflective, at such extreme luminance values an observer tends to perceive them as an emissive source. This perception can alter the observers' perceived brightness as a function of viewing distance.

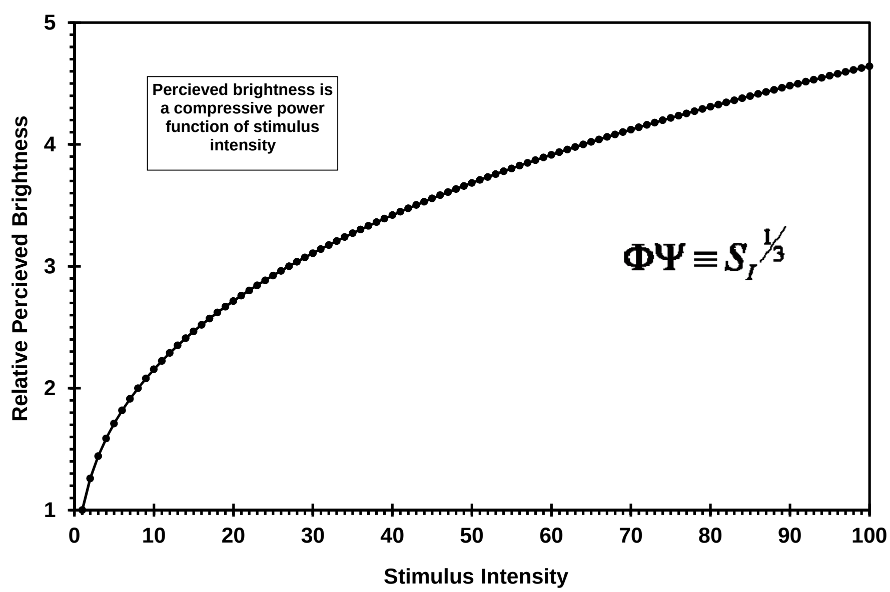

Figure 2. Plot showing Stevens Power Law, exponent = 1/3.

Since the SRSGs are reflective they were considered as reflective, and at closer ranges are subject to the inverse square brightness law. For an emissive point source of light brightness gets smaller as distance increases by $1/d^2$, the inverse square of the distance. In contrast, for an extended surface (reflective), as distance increases the visual subtense also decreases proportionally such that the flux density at the retina remains constant, hence brightness remains constant. An example of this would be standing next to a white barn wall. It nearly fills your visual field and has a certain perceived brightness. As the observer steps back from the wall to greater and greater distances perceived brightness remains constant. The luminance of the barn wall remains constant despite the shrinking visual subtense. This again, is the inverse square relationship but in a different form. The brightness and perceived glare of an extended surface will remain constant as a function of viewing distance for considerable ranges and only be reduced by atmospheric effects (attenuation) or psychophysical effects, approaching the limits of resolution, acuity. When the acuity limits are approached, brightness decreases substantially as a function of viewing distance. During this transition, from approximately 10 min arc to 1 min arc perceived brightness is assumed to transition to Stevens power law. The criteria of 75% of the maximum relative brightness is considered as the transition where the brightness/ glare is reduced to the point of no longer being visually disruptive. This is shown schematically in **Figure3** below.

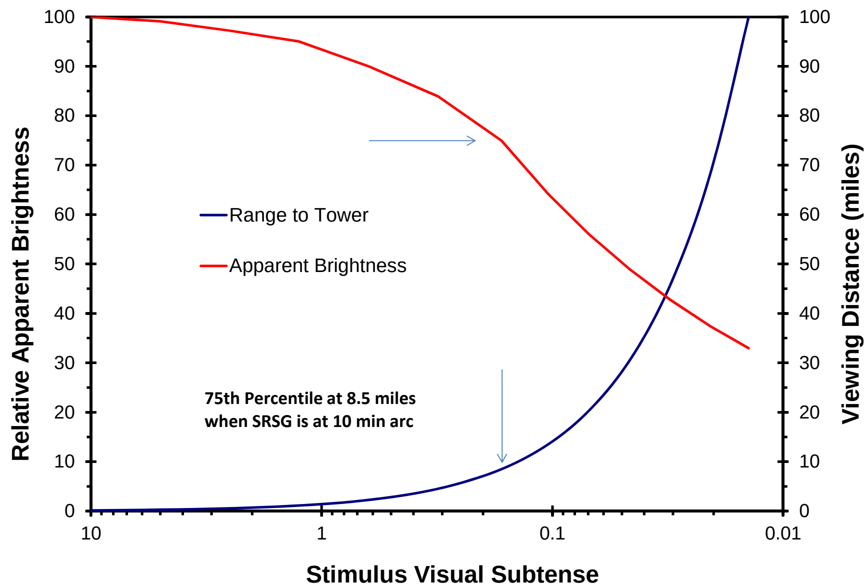

Figure 3. Apparent brightness (left Y-axis) and viewing distance (right Y-axis) as a function of visual subtense of a 130 ft stimulus.

The upper arrows show the 75th percentile brightness at a visual subtense of 10 min arc. This corresponds to the lower arrow where at 10 min arc the viewing distance is 8.5 miles for the 130 ft stimulus. The 75th percentile is traditionally a standard psychophysical value for significant transitions in perceived magnitude and is adopted here for the threshold distance at which a state of discomfort glare and visual disruption are diminished to a point where the SRSGs no longer constitute a discomfort stimulus (although they still considered as a bright source). This value is a best estimate and importantly, the perceived brightness and glare effects from the SRSGs are not considered as visually disabling at any viewing distance. Much like the Sun, an observer has the option to not directly fixate the glare source and to explore their visual environment while maintaining the glare source (Sun or SRSG) in the peripheral visual field.

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