A Method for Calculating the Maximum Acceptable Intensity of a Disability Glare Source (UL)

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Abstract / Executive Summary

An algorithm has been developed to enable the application of existing disability glare models to the prediction of the maximum acceptable intensity of a glare source directly linked to an operational requirement; namely the permissible reduction in the detection range of a signal light. Disability glare is that which causes a reduction in the sensitivity of the eye through the introduction of a light veil and was first described by Stiles & Holladay in the late 1920's. The calculation of maximum acceptable glare intensity has, in the past, required an assumption about the associated degradation in eye sensitivity. The author has avoided this through the application of a widely accepted empirical function relating eye sensitivity to background luminance. This enables the maximum glare intensity and consequent eye sensitivity to be calculated for any given background luminance and fractional reduction in detection range. The approach adopted reveals relationships in the phenomenon of glare. Examples are given.

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1 Introduction

Spurious light poses a potential threat to the effectiveness of visual aids, or signals, whether to the driver of a vehicle or train, a ship's officer or a helicopter pilot approaching an offshore platform.

Disability glare is that which causes a veiling illumination within the eye, thus reducing its' contrast sensitivity; it should be distinguished from discomfort glare. Disability glare is insidious in that unlike discomfort glare (frequently termed glare, or dazzle) the observer may be unaware of the effect that it has on their visual performance.

In the following paper, a method based on published models has been developed for calculating the maximum acceptable intensity of a source causing disability glare. The example used is that of a helicopter approaching a landing deck on an offshore platform. The effect of glare is illustrated in Figure 1, though it should be noted that a photographic image does not replicate the response of the eye. The present study was initiated subsequent to one carried out by DERA on behalf of the UK CAA (Reference [1]). This had been aimed at supporting helicopter operations at night by lighting both the aiming circle and the 'H' by strips and arrays of LEDs. An obvious application for the method described would be the assessment of lighting systems for ship's flight decks.

Other applications might include establishing criteria for the design and assessment of vehicle turning indicators in headlight clusters; the detection of cyclists viewed against oncoming vehicle headlights and the conspicuity of railway signals. Yet further applications might include the preservation of an aircraft pilot's, air traffic controller's, locomotive driver's, or ship's officer's view of the outside world at night in the presence of internal lighting and displays.

2 Method

In this study the criterion used to determine the maximum acceptable intensity of a glare, is the operational effect that disability glare has in reducing the detection range of a signal light. This might be evidenced as a minimum stopping distance of a train, or road vehicle, or the distance required by a ship or aircraft to execute a manoeuvre. The approach adopted avoids any assumptions about the loss of contrast sensitivity. In this respect it differs from that used by TNO (Reference[2]) where the level of acceptable glare intensity was based on a criterion of acceptable loss of contrast sensitivity in an observer. The present approach is regarded as being both operationally appropriate and practical and can be used under both day and night conditions.

For any given set of conditions the method that has been adopted can be summarized as follows:

1) Allard's law (Reference[3]) describes the illuminance (E) at the eye at a range (R) from a light of effective intensity (I) in a given visibility expressed as an extinction coefficient (σ). Here initially it is used to deduce the implied illuminance threshold (E_t) at the eye at a specified visual range from a signal light and subsequently that due to a specified change in visual range due to a glare source, I and σ being held constant.

2) Since an illuminance threshold cannot be directly measured under operational conditions an empirical law is usually used to deduce an implied value due to a measured, or assumed background luminance (L) (Reference[4]). However in this instance the raised level of illuminance threshold from Allard, is used to deduce the implied causative level of background luminance and hence that component (L_{eq}) due to the glare source.

   Due to the large dynamic range of both the variables they are conventionally expressed in terms of common logarithms.

3) The angular separation (θ) of the glare source from the signal light is calculated for a series of points along a particular approach path to the helideck.

4) The illuminance (E_{eq}) at the eye due to the glare source can be calculated from the veiling luminance (L_{eq}) and the angular separation (θ) by means of a disability glare model.

5) The intensity of the glare source (I_g) can be calculated from the illuminance (E_{eq}) due to the glare source by means of Allard's law.

6) For completeness the required intensity (I_s) for the signal light to be seen under the particular disability glare conditions can be calculated using Allard's law.

Having developed the mathematical expressions to calculate the maximum acceptable glare intensity, they have been implemented as formulae in a Microsoft Excel spreadsheet.

3 The Theory

3.1 Sensitivity of Eye Illuminance to Visual Range

The illumination at the eye due to a point source can be obtained through the application of the inverse square law, however for completeness the effect of visibility, through Allard's law, has been included.

A simplifying assumption in applying Allard's law is that the source may be regarded as so-called "point source". This means that, at the range from which it is viewed, it's angular subtense is below a critical angle (Ricco's law, Reference[3]) and that it can be described solely by it's intensity. The critical angle for a wide range of background luminances is shown in Figure 2.

Allard's law may expressed as

$$E_t = \frac{I}{R^2}.e^{-\sigma.R} = Term_1 \text{ ....(i)}$$

where E_t is the illuminance at the eye (lux)

I is the intensity of the light (candela)

R is the visual range of the light (metres)

σ is the atmospheric attenuation expressed as extinction coefficient (m^-1)

To suit the purposes of the current study

$$E_t = I.Term_1$$

Taking natural logarithms

$$\mathrm{Ln}(E_t) - \mathrm{Ln}(I) = -2\,\mathrm{Ln}(R) - \sigma.R$$

For the glare condition E_i and R_i

$$\mathrm{Ln}(E_{ti}) - \mathrm{Ln}(I) = -2\,\mathrm{Ln}(R_i) - \sigma.R_i$$

Subtracting

$$\mathrm{Ln}(E_{ti}) - \mathrm{Ln}(E_t) = 2\,\mathrm{Ln}(\frac{R}{R_i}) - \sigma(R_i - R)$$

Re-arranging

$$\mathrm{Ln}(E_{ti}) - \mathrm{Ln}(E_t) = -2\,\mathrm{Ln}(1 + \frac{\delta R}{R}) - \sigma.\delta R$$

Where δR is a finite difference in visual range

and $\frac{\delta R}{R}$ is the fractional difference in visual range

However, the relationship between Meteorological Visibility and extinction coefficient can be shown to be given by:

$\sigma = 2.996 / M$

Where M is the Meteorological Visibility (metres)

Substituting for σ

$$Ln(E_{ti}) - Ln(E_t) = -(2\,\mathrm{Ln}(1 + \frac{\delta R}{R}) + 2.996\frac{\delta R}{R}.\frac{R}{M})$$

but conventionally (E_t) is expressed in terms of common logarithms as per Figure 3

$$Lg(E_{ti}) - Lg(E_t) = -0.4343(2\,\mathrm{Ln}(1 + \frac{\delta R}{R}) + 2.996\frac{\delta R}{R}.\frac{R}{M}) = Term_2 \text{ ......(ii)}$$

The presence of the term $\frac{R}{M}$ is noted. This is the ratio of the visual range to the Meteorological Visibility, elsewhere termed the range factor.

3.2 The Sensitivity of Background Luminance to Eye Illuminance Threshold

The relationship of eye illuminance threshold to background luminance can only be obtained empirically. One such relationship given in Reference [4] (figure 3) is intended to represent the visually dynamic situation of a pilot making an approach to an aerodrome in poor visibility. The curve depicts the relationship in logarithmic axes.

In his seminal paper Blackwell (Reference[5]) demonstrated that the effect of changing the probability of detection was equivalent to factoring the contrast threshold. The bulk of his trials related to the detection of lit spots of varying size and luminance projected on to a screen whose luminance could be controlled from whence the Weber contrast was calculated. The relationship between contrast and illuminance thresholds is demonstrated in Appendix 1. Thus when plotted against logarithmic axes, the curve of illuminance threshold against background luminance will be bodily raised, or lowered according to the probability of detection, but the shape and hence the 1st derivative will be unaffected.

By inspection it can be seen that figure 3 could be represented by a number of straight line segments such as:

$$Lg(E_t) = k.Lg(L) + c$$

Where k is the gradient

L is the luminance of the background

c is the intercept

In order to reduce the errors incurred by this process the published 5 tabular points have been interpolated at their midpoints. The values are shown in the table below.

Published values	Log (L) nits	Log(Et) lux
*	0.46	-6.46
	1.10	-6.00
*	1.75	-5.52
	2.35	-5.03
*	3.02	-4.49
	3.54	-4.03
*	4.06	-3.49
	4.51	-2.98
*	4.96	-2.42

Over the range of the curve the slopes of the straight-line segments between the tabular points vary from 0.69 to 1.24.

Suppose a glare source be directed at the eye, then for the raised condition E_{ti} and L_i

$$Lg(E_{ti}) = k.Lg(L_i) + c$$

Subtracting for the original condition

$$Lg(E_{ti}) - Lg(E_t) = k.(Lg(L_i) - Lg(L))$$

Rearranging

$$Lg(\frac{L_i}{L}) = \frac{1}{k}(Lg(E_{ti}) - Lg(E_t))$$

Substituting from (ii)

$$Lg(\frac{L_i}{L}) = \frac{1}{k}.Term_2$$

Taking antilogs

$$\frac{L_i}{L} = 10^{(\frac{1}{k}.Term_2)}$$

hence

$$L_i = L.10^{(\frac{1}{k}.Term_2)}$$

But

$$L_i = L + L_{eq}$$

Where L_{eq} is the veiling luminance due to glare

$$L_{eq} = L(10^{(\frac{1}{k}.Term_2)} - 1) \quad \text{...(iii)}$$

3.3 Modelling the Effects of Disability Glare

3.3.1 Stiles-Holladay Glare Equation

The disability glare equation due to Stiles-Holladay is given by

$$\frac{L_{eq}}{E_{eq}} = \frac{10}{\theta^2} = Term_{3a}$$

Where L_{eq} is the veiling luminance due to the glare source (nits)

E_{eq} is the illuminance due to the glare source (lux)

θ is the angle between the glare source and the signal light (degrees).

However, for some years the Stiles-Holladay model has been thought to be deficient in modelling disability glare at both large and small angles. Other known shortcomings are the neglect of the effect of the age of the observer and colour of his, or her eyes.

When Reference [6] was published in 1999 the jury was still out on a final definitive model. However the models presented, were likely to be the best available at the time. On examination they show a marked departure from the original Stiles-Holladay (Figure 4). For the present purposes 2 of these models have been adopted in order to cover the range of angles of interest. They are:

3.3.2 The Simplified Glare (CIE: Equation 10)

This model is intended for use where the angle lies between 0.1 and 30 degrees

$$\frac{L_{eq}}{E_{eq}} = \frac{10}{\theta^3} + (1 + (\frac{A}{62.5})^4)\frac{5}{\theta^2} = Term_{3b}$$

Where the usage of L_{eq}, E_{eq} and θ is as before

and A is the age of the observer in years

3.3.3 The Small Angle Part (CIE: Equation 3)

(Point Spread Function Proper)

This model is intended for use where the angle is below 0.1 degrees.

$$\frac{L_{eq}}{E_{eq}} = \frac{9.7 * 10^6}{(1 + (\frac{\theta}{0.0046})^2)^{1.5}} + \frac{1.56 * 10^5}{(1 + (\frac{\theta}{0.045})^2)^{1.5}} = Term_{3c}$$

A pupil diameter of 4 mm is assumed.

Care should be exercised in applying this model as at angles of 0.03 degrees or less, as dependant on their relative intensities, it may not be possible to resolve the signal light from the glare source.

3.4 Helideck Viewing Geometry

The purpose of this section is to calculate the angular separation between the signal light and the glare source. A particular application of the theory is to examine the potential for disability glare on a helideck, caused by the helideck lighting itself. For this purpose it is assumed that:

a) The signal light and glare source lie in the ground plane

b) The eye will approach the signal light along a straight line (above the x-axis) terminating over the signal light (the origin).

c) The approach path is defined by its height at the origin (H) and the angle (γ) it makes to the ground plane (the glide slope).

d) The position of the glare source is defined by its distance from the signal light (s) and the angle it makes with the line of approach (ϕ).

e) The point of regard will be the signal light

The viewing geometry is illustrated in Figure 5

For a given ground range (d) from the signal light the height is given by

$$h = Z + d.\mathrm{Tan}(\gamma)$$

Where Z is the eye height at the origin (m)
γ is the angle the approach path makes with the horizontal (deg)
h is the eye height at the ground range d (m)

Thus the look down angle along the x-axis from the eye to the signal light is

$$\phi = Tan^{-1}(\frac{h}{d})$$

There is no azimuth component because the approach is by definition above the x-axis.

Projecting from the ground plane into a picture plane orthogonal to the sight line to, and passing through the signal light, the longitudinal position of the glare source becomes

$$x_p = (d + s.\mathrm{Cos}(\gamma)).\mathrm{Cos}(\phi) - h.\mathrm{Sin}(\phi)$$

Where

s is the distance of the glare source from the signal light.

γ is the angle s makes with the x-axis.

x_p is the value in picture plane co-ordinates

While the vertical position of the glare source becomes

$$h_p = h.\mathrm{Cos}(\phi) + (X + s.\mathrm{Cos}(\gamma)).\mathrm{Sin}(\phi)$$

Where

h_p is the value in picture plane co-ordinates

(Rotating in elevation into the sight line to the signal light has no effect on the lateral position of the glare source)

(It should be noted that the rotation has been into a plane and not a spherical surface. As a consequence errors will occur at extreme angles from the line-of-sight.)

The slant range from the eye to the glare source is given by

$$t = ((d + s.\mathrm{Cos}(\gamma))^2 + ((s.\mathrm{Sin}(\gamma))^2 + h^2)^{0.5}$$

The Azimuth deviation from the line-of-sight to the signal light is given by

$$\alpha = \mathrm{Tan}^{-}1(\frac{(s.\mathrm{Sin}(\gamma)}{x_p})$$

The Elevation deviation from the line-of-sight to the signal light is given by

$$\beta = \mathrm{Sin}^{-1}(\frac{h_p}{t})$$

The angle between the glare source and the signal light is given by

$$\theta = (\alpha^2 + \beta^2)^{0.5}$$

This being the angle required by the glare models.

3.5 Application of the Models

In general

$$L_{eq} = E.Term_{3(a,b,c)}$$

Substituting for σ from (i) gives

$$L_{eq} = I.Term_1.Term_3$$

For the present purpose it is assumed that the light and the glare source are at the same distance from the observer.

Substituting in (iii) for L_{eq}

$$I.Term_1.Term_3 = L(10^{(\frac{1}{K}.Term_2)} - 1)$$

Finally the maximum acceptable glare intensity **is given by:**

$$I = \frac{1}{Term_1}.\frac{1}{Term_3}.L(10^{(\frac{1}{K}.Term_2)} - 1)$$

Where, summarizing

$Term_1 = \frac{1}{R^2}.e^{(-\sigma.R)}$ and $Term_2 = -0.4343(2\,\mathrm{Ln}(1+\frac{\delta R}{R})+2.996\frac{\delta R}{R}.\frac{R}{M})$

for comparison purposes only (Stiles-Holladay)

$$Term_{3a} = \frac{10}{\theta^2}$$

more appropriately for angles between 0.1 and 30 degrees

$$Term_{3b} = \frac{10}{(\theta)^3} + (1+(\frac{A}{62.5})^4).\frac{5}{(\theta)^2}$$

while for angles less than 0.1 degrees

$$Term_{3c} = \frac{9.7*10^6}{(1+(\frac{\theta}{0.0046})^2)^{1.5}} + \frac{1.56*10^5}{(1+(\frac{\theta}{0.045})^2)^{1.5}}$$

Care should be exercised in applying these models as at angles of 0.03 degrees or less, and dependant on their relative intensities, it may not be possible to resolve the signal light from the glare source.

4 Results of Modelling

A number of figures have been produced to demonstrate the results of applying the models. Care should be exercised when considering these, as an intensity which may be acceptable from the perspective of disability glare, might cause an unacceptable level of discomfort glare. In the figures the maximum acceptable disability glare intensity is shown as a function of range. They use the baseline conditions given below:

-0.10	Acceptable fractional reduction in visual range $(\delta R / R)$
0.46	Background luminance (Log(nits) (L)
10000	Meteorological Visibility (m) (M)
40	Age of observer (years) (A)
25, 2.8	Height above origin (m) and angle of approach (deg) (Z, γ)
10, 0.0	Polar co-ordinates of glare source relative to signal light (s, ϕ) (m, deg)

The latter 2 pairs of values are used to calculate the offset angle θ

a) Figure 7

The maximum acceptable glare intensities predicted by both the Stiles-Holladay and the CIE models are shown for comparison purposes. The disparity between the results given by the 2 models is apparent whereby the maximum acceptable glare intensity predicted by Stiles-Holladay is some 3 times greater at short ranges rising to 10 times at longer ranges.

It also shows the effect that range has on the maximum acceptable glare intensity, increasing to 386 candela at 0.1 nautical miles, whereat the increased angular separation of glare and signal light overcomes the increased illuminance at the eye. At longer ranges the maximum acceptable intensity diminishes to a few tens of candela until a point is reached where the signal light can no longer be resolved from the glare source.

b) Figure 8

The effect of reduced visibility is demonstrated through the introduction of a second curve where the visibility has been reduced from 10000m to 2000m. The effect of reducing the visibility is to allow an increase in the maximum acceptable glare intensity due to the atmospheric attenuation. This capability could have application where lighting intensities are switched in response to the visibility.

c) Figure 9

The effect of the relative position of the glare source to the signal light is illustrated by introducing a second curve. Here although the distance of the glare source from the signal light is the same, the angle to the approach path is changed from 0 to 90 degrees with a colossal resultant effect.

d) Figure 10

The effect of reducing the background luminance is demonstrated by introducing a second curve where the luminance is reduced from 0.46 Log(nits) to 0.0 Log(nits).

5 Discussion

For oblique viewing such as that experienced by a pilot approaching to land, the maximum acceptable glare source intensity is strongly dependant on whether the glare source is to the side of, or in front, or behind the signal light (Figure 10). This combined with the limited extent of offshore helidecks, which generally do not exceed 22m in diameter, suggest that it may be unnecessary to consider multiple glare sources for this application.

For example, consider an omni-directional glare source 10m directly ahead of a signal light which is viewed from a range of 0.5 nautical miles (926m) and a height of 70.3m. If the glare source is swung 10 degrees to left, or right (a lateral displacement of 1.74m) the effect of the glare will be decreased by a factor of 9 compared with that from the dead ahead position.. If swung a further 10 degrees (a total lateral displacement of 3.4m) then the effect of the glare will be reduced by a factor of 54. Suppose attention is directed at the centre of the landing circle and the perimeter is marked by a series of identical omni-directional lights placed equidistantly around the deck perimeter. In light of the foregoing it is likely that only the lights directly ahead or behind the point of regard are of any consequence so far as disability glare is concerned.

In practice the glare source may well be directional in nature as in the case of a low level deck floodlight and thus the effective intensity in the direction of the approach path will vary with the orientation of the floodlight and the angle from which it is viewed. In practice, this will further reduce any glare contributions from off axis lights.

The determination of an appropriate value for background luminance may cause some difficulty. It has been customary to use a value of 1.2 log nits (or an illuminance of -6 log lux) in respect of aircraft approaching a runway in reduced visibility at night (Reference[4]). This is likely to represent the effect of cockpit lighting on the head up eye sensitivity (which is always assumed to be photopic, ie not dark adapted) rather than that of the outside world. However the use of simple photometric measurements is likely to be in error since the effect of instrument and other cockpit lighting will depend on their angular offset from the direction of gaze of the pilot in the outside world, ie they constitute disability glare sources.

In addition, it can be shown that the rate of change in eye contrast threshold is the same as that in illuminance threshold (Appendix A). For a disability glare source which causes a 10% reduction in visual range, the change in illuminance threshold is some 0.09 Log Nits at 0.1 nautical miles (or 24.1%), or some 0.12 Log Nits (or 30.5%) at 1 nautical mile under the conditions pertaining to Figure 6. Surprisingly the change is not dependent on the value of illuminance threshold.

6 Application to a Real Life Situation

Having predicted the maximum acceptable glare intensity for a particular configuration it is necessary to establish whether a potential glare source is in practice acceptable. In order to achieve this it is necessary to know the effective intensity directed at the observer. This requires a knowledge of the 2 dimensional intensity distribution of the luminaire and its' 2 dimensional orientation in relation to the approach path. One option would be to adapt the software VISEQ, which was developed by the author to examine the performance of aerodrome ground lighting (approach and runway) during an approach in reduced visibility. This contains all the geometric constructs and the necessary elements for modelling effective luminaire intensity using either a super-ellipse (based on elevation & azimuth axis data), or a grid intensity distribution.

A further refinement would be to examine the effect of scattering from the glare source into the line-of-sight to the signal light in conditions of reduced visibility, which produces a veiling external to the eye. This would require models for the angular scattering function as a function of visibility. Those due to Barteneva (Reference[7]) could be useful in this respect.

7 Conclusions

It has been shown that a general method for calculating the maximum acceptable intensity of a disability glare source can be obtained. The method includes the effects of the inverse square law and visibility on both signal light and glare source, but not any effect that atmospheric scattering from the glare source may have on the conspicuity of the signal light.

It is postulated that at each required range a real (or hypothetical) point source light can just be seen and that a specified reduction in visual range due to glare can be tolerated. By this means the effect on the eye illuminance threshold and consequently the implied change in background luminance may be obtained.

It has been shown that:

- The maximum acceptable intensity for a disability glare source, for a given signal light and glare source configuration is a function of their range from the observer.
- The maximum acceptable glare intensity can be calculated for any background luminance for which there is an illuminance threshold versus background luminance model. The eye sensitivity might range from that appropriate to night through to that for bright day (ie from scotopic, through mesopic to photopic vision).
- The maximum acceptable disability glare source intensity for a particular configuration is directly proportional to the background luminance.
- The modified value of target contrast sensitivity due to a glare source can be calculated for the point where a hypothetical signal light is placed.
- The ratio of Visual Range to Meteorological Visibility (elsewhere known as the Range Factor) is a controlling factor in determining the maximum acceptable glare source intensity rather than the range alone.
- In calculating the maximum acceptable intensity of the disability glare source, the intensity of the signal light whilst implied, is in practice eliminated from the calculations.

8 Recommendations

It has been shown that the maximum acceptable glare intensity is highly dependant on the assumed value of background luminance. It is therefore recommended that a defensible method of measuring, either the effective background luminance, or the eye illuminance threshold in an aircraft cockpit, ships' bridge, or locomotive cab be developed which takes in consideration the effect of instrument panels and displays.

9 References

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[6] CIE 135/1, CIE Collection, Research Note: Disability Glare, 1999.

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10 Glossary of Terms

Allard's law

A law for finding the illumination at a distance from a light with due regard to the effects of the inverse square law and absorption and, or scattering in the intervening atmosphere.

More usually a threshold value of illuminance is assumed and the corresponding visual range for a given effective intensity and extinction coefficient obtained. Allard's law is incapable of direct solution for range.

Background luminance

The luminance of the background against which an object, or light is viewed.

An unstructured background such as fog, or cloud will greatly improve the reliability of any visual range calculated through the application of Allard's law.

Candela

The luminous intensity of $1/60^{th}$ of a square centimetre of a blackbody radiator at the temperature of solidification of platinum (2045 K) normal to the surface is 1 candela.

Contrast

The preferred definition of contrast due to Weber is defined as the difference between the luminance of the source, or object and the background divided by that of the background.

Thus a perfectly black object will have a contrast of –1, while a luminous source may have a large positive contrast.

Extinction coefficient

Defined as the rate at which luminous flux in a collimated beam is scattered, or absorbed with respect to distance.

Specifically, the ratio of one over the distance over which the luminous flux is reduced to the reciprocal of the Euler Number (2.7183).

It has dimensions of inverse distance.

Illuminance

The value of the luminous flux falling on unit area.

The Lux is a unit of illumination equal to 1 lumen/m^2.

Illuminance threshold

The minimum illuminance at the eye required to render a light visible.

N.B. In practice the nature of the background, the size and shape of the source, whether steady, or flashing, white, or coloured and the probability of detection and/or recognition need to be considered.

Lumen

The luminous flux due to an intensity of 1 candela in all directions through a solid angle of 1 steradian.

Luminance

Luminance is defined as the luminous intensity emitted (or passing through) a unit surface area orthogonal to the direction of interest

A unit of luminance is the nit which is equal to 1 candela/m^2

Meteorological Optical Range

Defined as the distance at which the luminous flux from a collimated light source falls to 5 percent of the value, at the same distance, in a perfectly transmitting atmosphere. This definition avoids the effect of the inverse square law.

Meteorological Visibility

Reference [4] defines Meteorological Visibility as: "that distance appropriate to a pilot contrast threshold of 5%".

A more robust definition is the distance is the Meteorological Optical Range.

Point Source

This is a luminous source which obeys Ricco's law. That is to say one which, as viewed, has a detectability due solely to its intensity without regard to apparent size, or shape.

Range factor

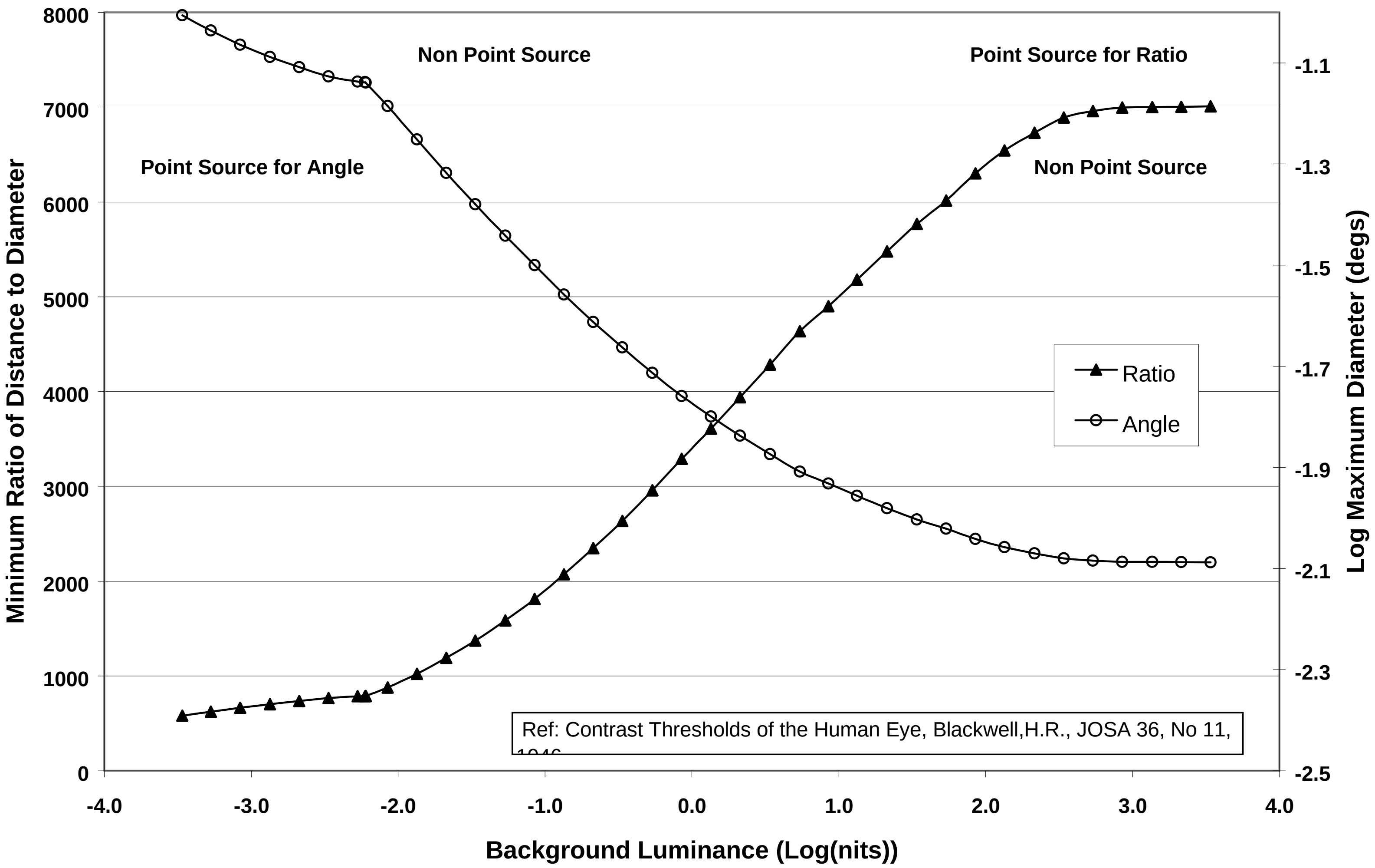
For the present purpose it is defined as: The ratio of the visual range of a point source to the Meteorological Optical Range in homogeneous conditions.

Visual range

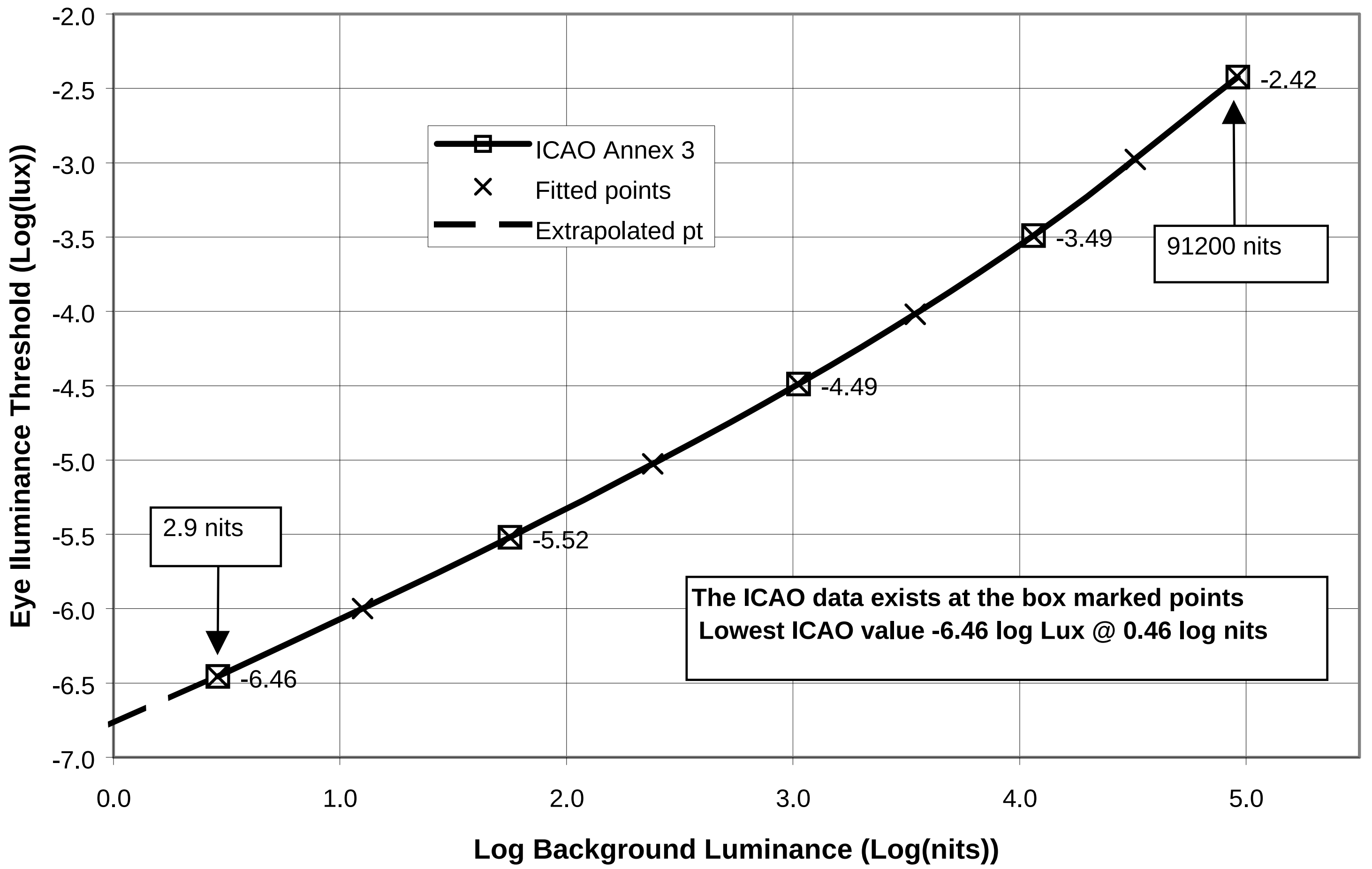
Sometimes referred to as the luminous range. The maximum distance, usually horizontal, at which a given light is visible under particular conditions of atmospheric transmission and background luminance,

11 Figures

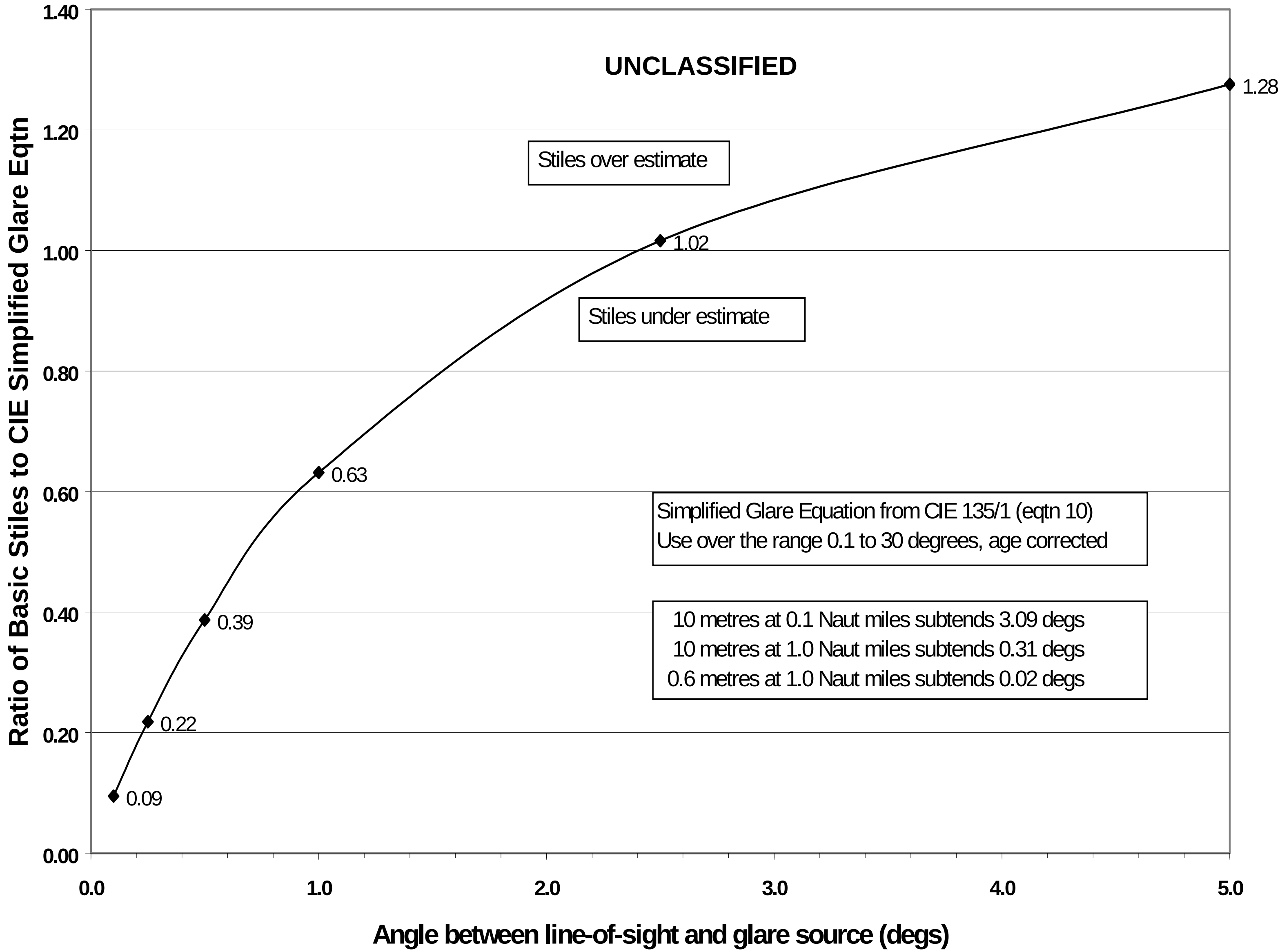
11.1 Figure 1: Example of Glare on a Helideck



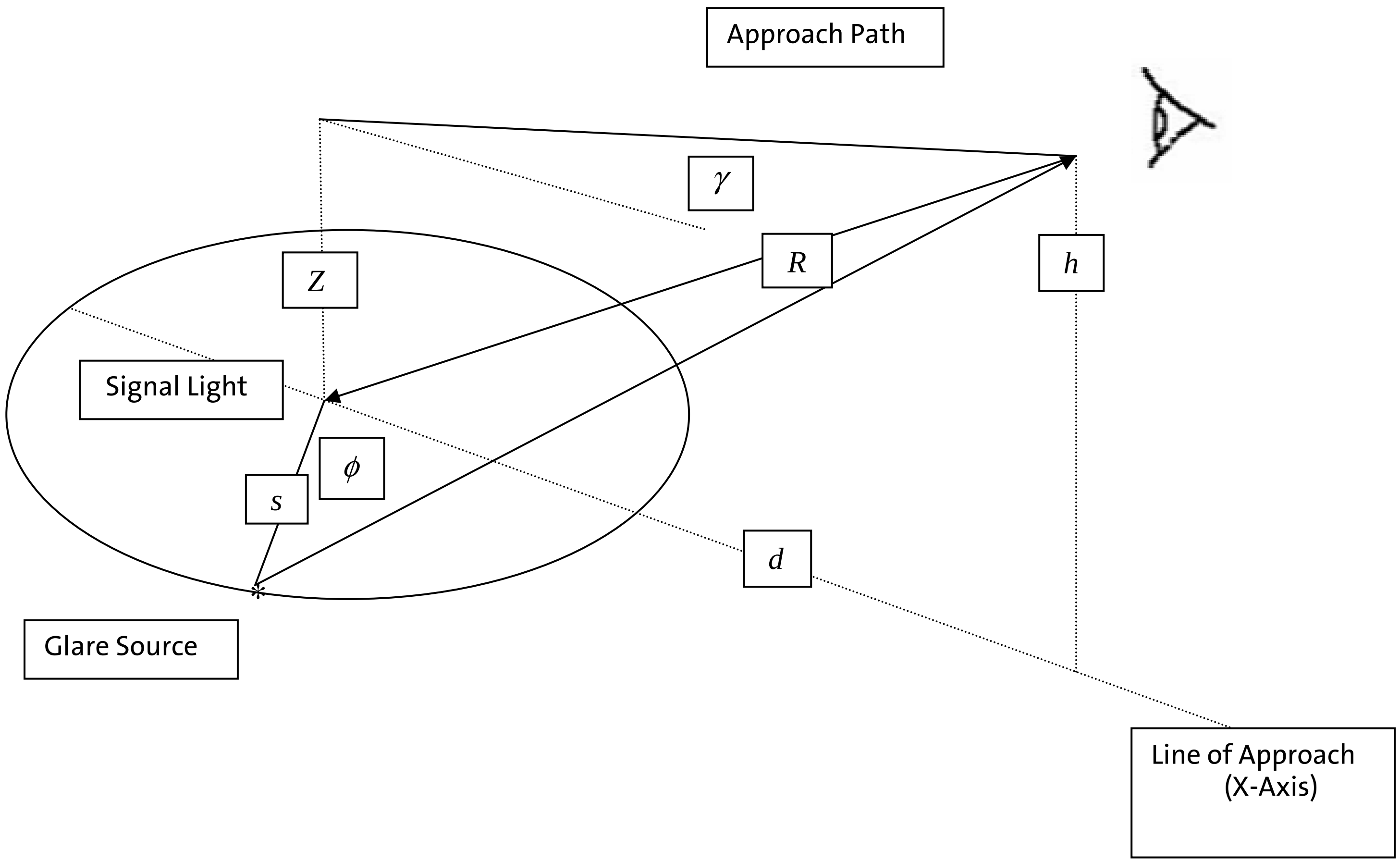
11.2 Figure 2: Critical Size for a Point Source



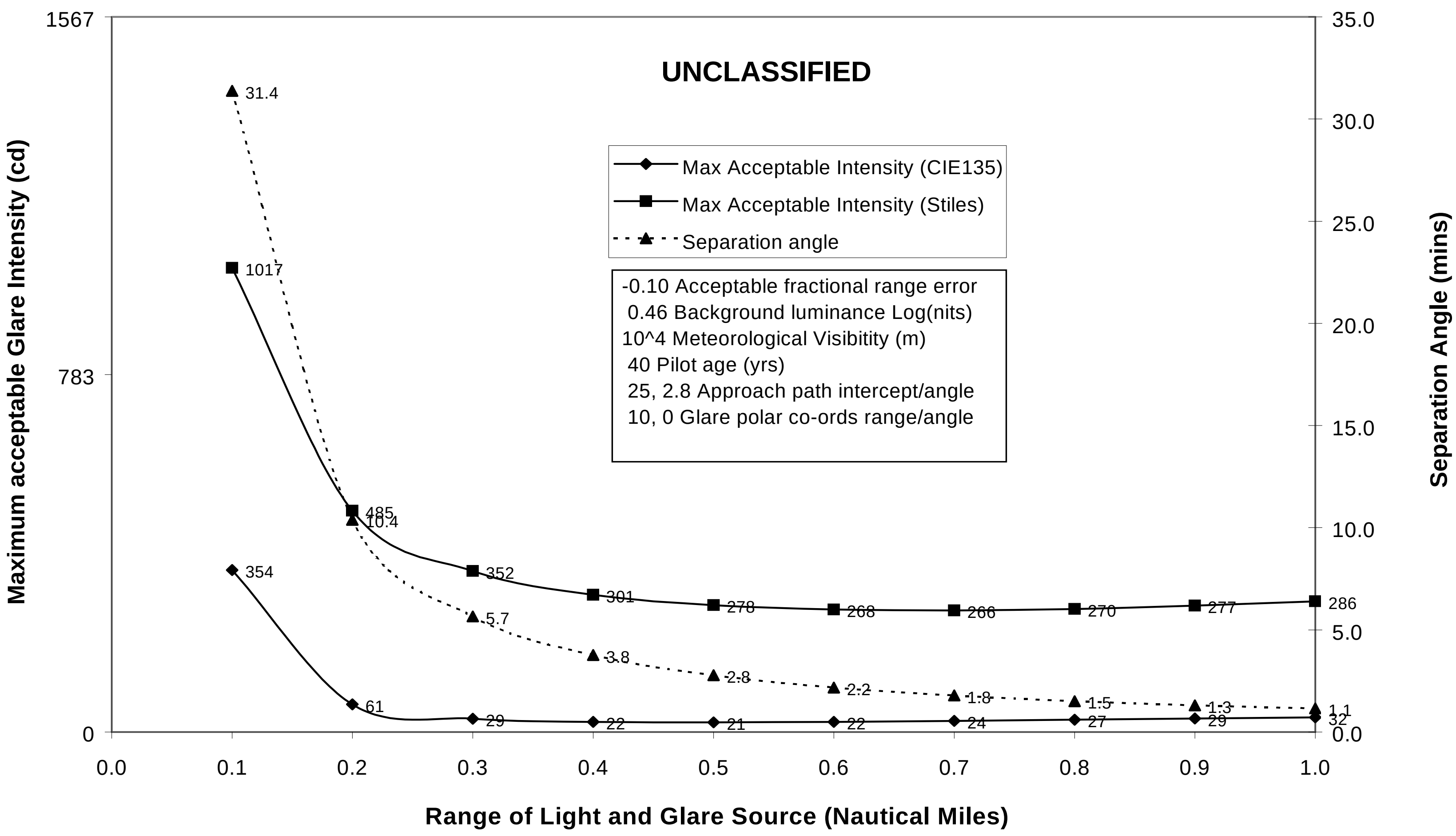
11.3 Figure 3: The ICAO Illuminance Threshold Versus Background Luminance Curve



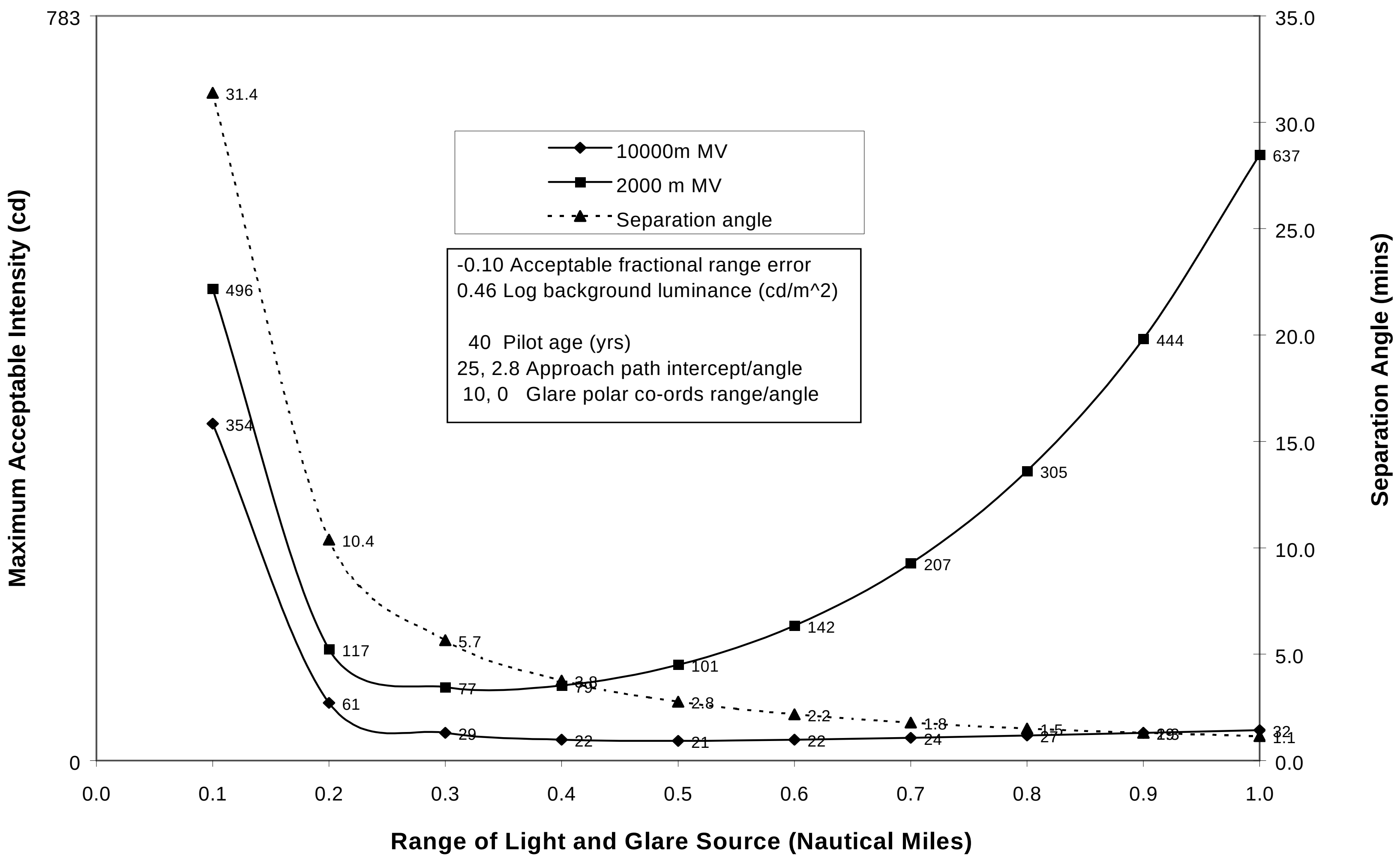
11.4 Figure 4: Comparison of Stiles-Holladay with CIE Simplified Glare Equation



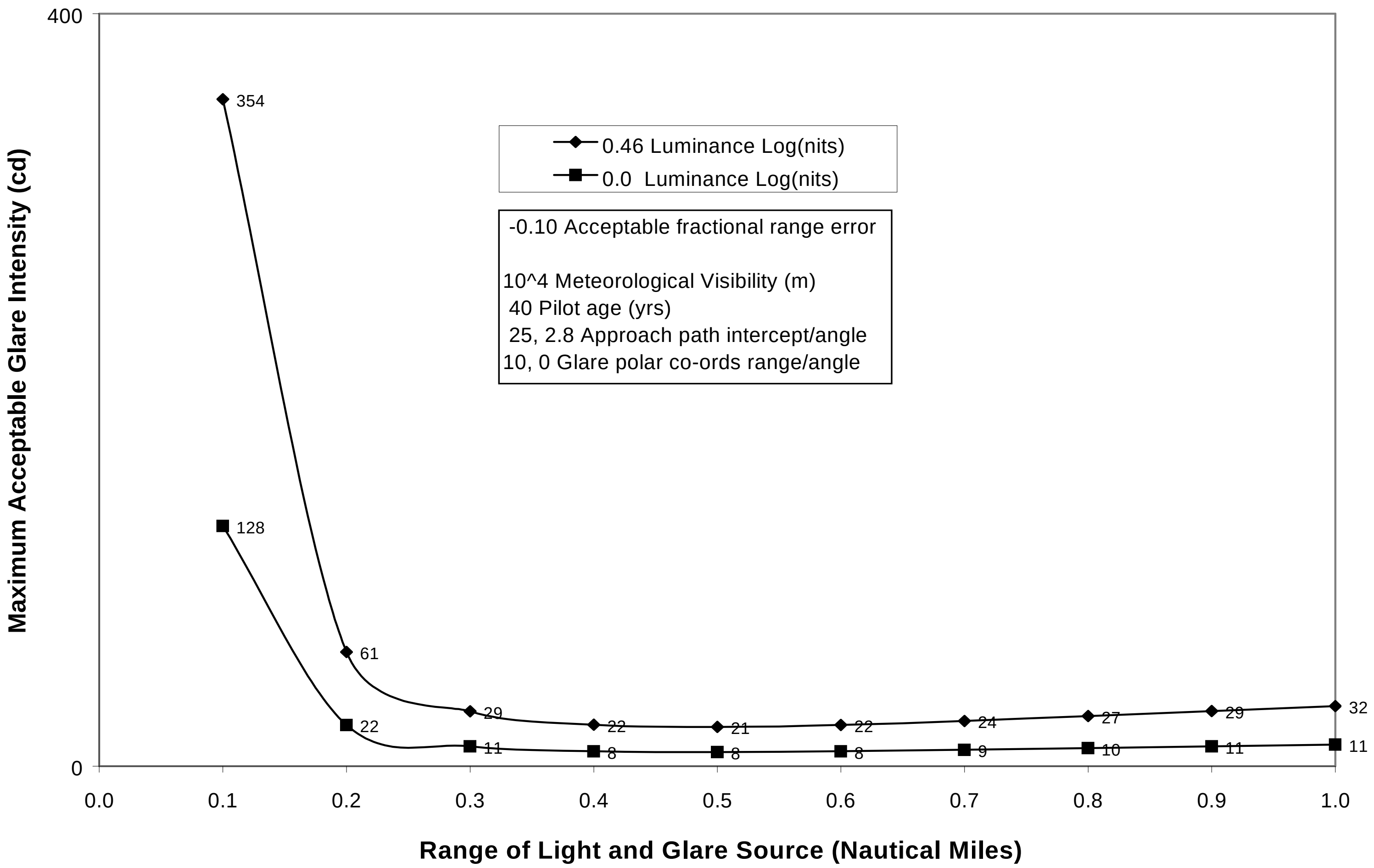
11.5 Figure 5: Viewing Geometry for an Approach to an Offshore Helideck



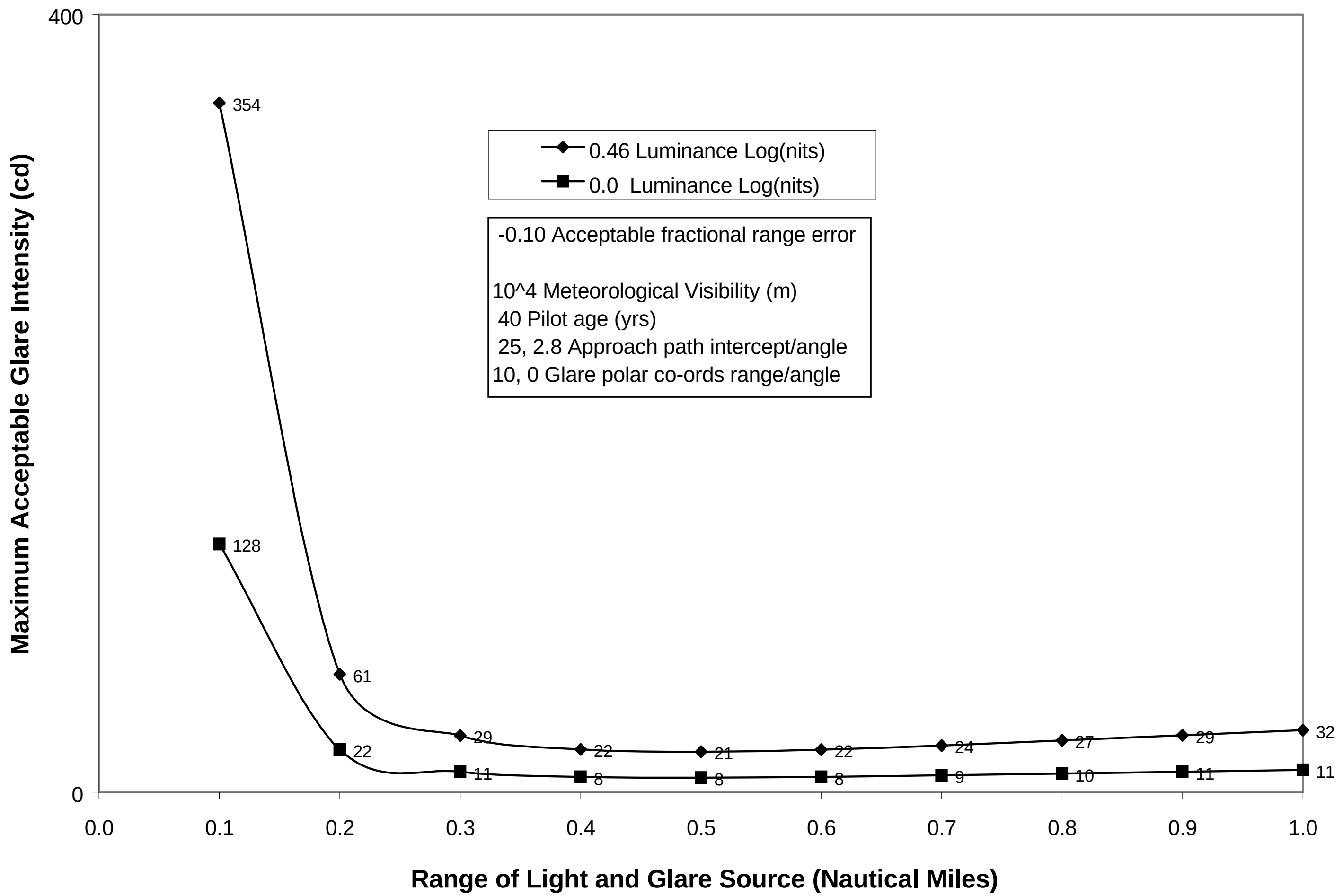
11.6 Figure 6: Comparison of Stiles-Holladay and CIE 135 Glare Model



11.7 Figure 7: Effect of Visibility on Maximum Acceptable Glare Intensity



11.8 Figure 8: Comparison of Stiles-Holladay and CIE 135/1 Glare Model



11.9 Figure 9: Effect of Background Luminance on Maximum Acceptable Glare Intensity

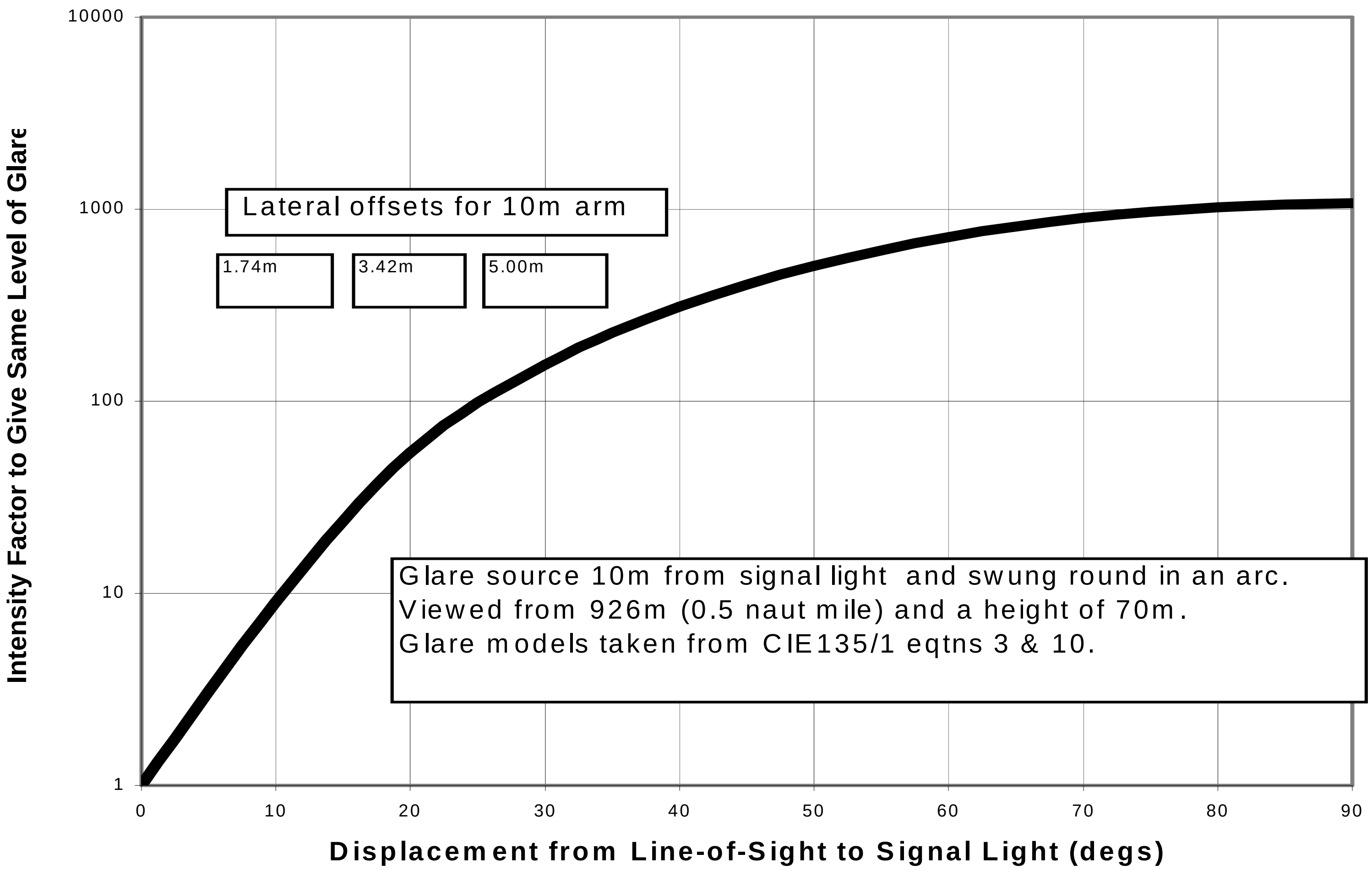


Figure 10: Effect of Relative Position of Disability Glare Source

A. Appendix A

The Relationship between Contrast and Illuminance Thresholds.

Definition

Luminance is defined as intensity per unit projected area

$$L = \frac{I}{A}$$

or

$$I = L.A$$

Definition

Weber's law states that the just noticeable differences in stimuli are proportional to the magnitude of the original stimulus.

In this context the fractional difference in luminance is given by $\frac{\Delta L}{L}$

Where the source/target is placed against an extensive and uniform background the effective source intensity becomes:

$$I = (L_1 - L_0).A$$

where L_1 is the luminance of the source

L_0 is the luminance of the background

A is the area of the source

Definition

A steradian is defined as the solid angle subtended at the centre of a sphere of radius R by an area of R^2 on the surface. (Thus the entire surface of the sphere subtends 4π steradians).

Thus

$$\omega = \frac{A}{R^2}$$

re-arranging for A gives

$$A = \omega R^2$$

Substituting for A gives

$$I = (L_1 - L_0).\omega.R^2$$

Definition

> The inverse square law states that the illuminance at an elementary surface normal to a point source is proportional to the intensity of the source and inversely proportional to the square of the distance.

Thus

$$E = \frac{I}{R^2}$$

Substituting for I above gives

$$E_t \cdot R^2 = (L_1 - L_0).\omega.R^2$$

hence

$$E_t = (L_1 - L_0).\omega$$

Definition

> ***Weber contrast is defined as the difference between the luminance of the stimulus and that of the background divided by that of the background.***

Thus the threshold contrast is given by

$$C_t = \frac{(L_1 - L_0)}{L_0}$$

Substituting for $(L_1 - L_0)$ gives

$$E_t = C_t \cdot L_0.\omega$$

Thus for a given background luminance, source solid angle subtense and probability of detection then:

The Illuminance Threshold is directly proportional to the Weber Contrast Threshold and vice versa.

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Abstract An algorithm has been developed to enable the application of existing disability glare models to the prediction of the maximum acceptable intensity of a glare source directly linked to an operational requirement; namely the permissible reduction in the detection range of a signal light. Disability glare is that which causes a reduction in the sensitivity of the eye through the introduction of a light veil and was first described by Stiles & Holladay in the late 1920's. The calculation of maximum acceptable glare intensity has, in the past, required an assumption about the consequent degradation in eye sensitivity. The author has avoided this through the application of a widely accepted empirical function relating eye sensitivity to background luminance. This enables the maximum glare intensity and eye sensitivity to be calculated for any given background luminance and fractional reduction in detection range. The approach adopted reveals relationships in the phenomenon of glare. Examples are given.			
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