HEWLETT® PACKARD

Visible LED Devices and Eye Safety With Respect to MPE Values as Defined in the European Standard IEC 825-1

Application Brief I-009

Introduction

Some LED devices utilizing new high performance LED technologies can produce sufficient luminance to raise a concern for eye safety when viewed under non-normal use conditions. Under normal use conditions, LED luminance and eye safety are usually not a concern. Manufacturers utilizing high luminance LED devices in their products should take into account eye safety in the intended use and design of those products.

This Application Brief is intended to alert users of high luminance LED devices to the potential for eye injury when viewed under non-normal use conditions. The criteria for evaluating the luminous output of LED devices and eye safety are **M**aximum **P**ermissible **E**xposure (MPE) values as measured under specific test conditions. To that end, this Application Brief compares the luminous output of various LED devices with MPE values and discusses any possibility of causing eye injury under normal and non-normal use conditions.

Viewing Criteria for MPE Values

The European IEC-825-1 Standard defines MPE values at **a viewing distance based on the apparent optical diameter of the LED device for a time period of 100 seconds (1 minute, 40 seconds)**, herein called the “MPE test conditions”. Viewing an LED device at the MPE test conditions is considered to be a non-normal use condition, having the possibility of causing eye injury to an observer when the high luminance of an LED device exceeds the MPE value for that device. The safety of LED devices when viewed under this situation is compared against accepted MPE values.

It must be noted, however, that for a human observer to view an illuminated LED at the MPE test conditions is an abnormal and very unlikely situation. An observer viewing an illuminated visible high luminance LED device, or any other visible light source, under the MPE test conditions must be doing so consciously, and who may be experiencing eye pain, should realize that the feeling of pain in the eyes indicates the light is too bright for comfortable viewing and the observer should immediately look away.

It also must be noted that the possibility of a human observer experiencing eye injury when viewing an illuminated visible LED device at distances greater than and for time periods much less than the MPE test conditions is extremely remote.

MPE and AEL Values and Product Labeling per CENELEC EN60825-1 Standard

Accessible **E**mission **L**imit (AEL) values, as defined in the IEC 825-1 and CENELEC EN60825-1 Standards, come into play under intrabeam viewing conditions where the visual angle subtended by the apparent LED source is equal to or less than α_{MAX} (see page 5). Intrabeam viewing results in a minimal size image of the apparent LED source on the retina of the eye of an observer. This minimal size image has the potential of containing sufficient energy to cause injury to the retina.

AEL values are wavelength dependent, aperture dependent, and at the aperture of 7 mm, MPE and AEL values are essentially the same. AEL values are used for the classification of LED devices and the labeling of products using LED devices per the IEC 825-1 and CENELEC EN60825-1 Standards. For information on AEL values, LED classifications, and product labeling per the IEC 825-1 and CENELEC EN 60825-1 Standards, refer to Hewlett-Packard Application Brief I-015.

Visible LED Devices are Safe for Normal Viewing by Human Observers

LED devices are safe for normal viewing in final product assemblies where eye safety considerations have been included in the design of those products and those products are utilized under normal intended use conditions. Normal use conditions of final product assemblies usually place visible LED devices at distances very much greater than that of the MPE test condition, and are typically observed for viewing times much less than that of the MPE test condition. For status indicators and numeric/alphanumeric displays, the distance for comfortable viewing is typically, as a minimum, 305 mm (12 inches) to 1/2 arm's length for hand held equipment, and at or longer than arm's length, 610 mm (24 inches) as a minimum, for equipment that is not hand held. Many fixed-in-place types of equipment utilizing LEDs are at much greater viewing distances, such as roadway changeable message signs and traffic signals. Normal viewing times by human observers are usually just long enough to read and understand the message being displayed, whether it be a status indication of a single LED lamp (usually 1 to 3 seconds), an alphanumeric message (usually 5 to 15 seconds), or a traffic signal (usually less than 15 seconds before a driver looks away to see the traffic situation around him/her, and then back again), all significantly less than 100 seconds.

The "Blink, Look-Away" Reflex Reaction

The human natural, instantaneous, "blink, look-away" reflex reaction factor must be taken into account when determining the possibility of an observer experiencing eye injury when viewing an illuminated LED device, or any other kind of light source. The human, as an observer of any light source, has a natural automatic "blink, look-away" protective reflex reaction that occurs in less than one second and protects the eye from experiencing injury should that light source appear too bright. The definition of a light source being viewed as too bright is a function of the ambient lighting condition surrounding the light source. The brighter the ambient lighting condition, the less is the effect on an observer from the light source being viewed. The most common illustration of this affect is that of automotive headlights. When viewed at night by a motorist, the headlights of an approaching vehicle in the oncoming lane appear too bright for the motorist to look at directly. The motorist's natural, instantaneous, reflex reaction is to blink and look away from the oncoming vehicle and headlights to the side of the road to protect his/her eyes, until the oncoming vehicle and headlights pass behind the motorist. This same situation in bright sunlight is much different. To the motorist, the illuminated headlights of an oncoming vehicle do not appear as excessively bright light sources, there is no automatic blink, look-away reflex reaction, and the illuminated headlights are nothing more than an indication that the oncoming motorist forgot to turn them off.

Types of Visible LED Devices and the Possibility for Causing Eye Injury

The possibility of a human observer experiencing eye injury when viewing an illuminated LED device under the MPE test conditions is dependent upon the type of LED device and the drive current through the LED device. Not all LED devices at all drive currents are capable of causing eye injury when viewed under

Table 1. Visible LED Packaged Types and the Possibility for Causing Eye Injury When Viewed at the MPE Test Conditions.

Visible LED Device Package Type	Possibility for Eye Injury
Alpha Numeric Dot Matrix Displays	Least Possibility
Light Bars	Least Possibility
Seven Segment Displays	Least Possibility
Wide Angle Diffused Lamps	Minimal Possibility
Wide Angle Nondiffused Lamps	Some Possibility
Narrow Angle Nondiffused Lamps	Good Possibility

this abnormal situation. Only the latest LED technologies introduced to the market in the 1990's, packaged in certain nondiffused lamp packages that focus the LED emitted light into a narrow beam spatial radiation pattern, have some possibility of causing eye injury when viewed under this abnormal situation.

The types of visible LED device packages may be grouped as to the possibility for causing eye injury when viewed at this abnormal situation. Table 1 gives this general grouping. For each device type, the LED device is considered to be in a steady state operating mode, i.e. lamp devices are assumed to be driven dc at maximum rated current.

Alphanumeric dot matrix LED displays: Alphanumeric dot matrix LED displays have fixed drive currents and strobe the characters within the display device at some on-time duty factor that limits the maximum illumination of each LED pixel, therefore have the least possibility of inflicting eye injury when viewed at the MPE test conditions.

LED light bars and large character seven segment LED displays: Visible light sources that have a diffused light emitting area disperse light over a wide spatial radiation pattern, and therefore do not produce a concentration of flux sufficient to inflict eye damage when viewed at this abnormal situation. Visible LED light bars are large area diffused light sources, with a Lambertain spatial radiation pattern, therefore have the least possibility of inflicting eye injury when viewed at this abnormal situation. Visible LED large character seven segment displays have diffused, narrow area light sources with a Lambertain spatial radiation pattern for each segment, thus have the least possibility to inflict eye injury when viewed at the MPE test conditions.

Diffused LED lamps: Visible diffused T-1$^{3}/_{4}$, T-1, subminiature lamp, and SMT indicator LED devices have wide spatial radiation patterns that disperse the LED emitted light into viewing cone angles equal to and greater than 28°, thus, have only a minimal possibility to inflict eye injury when viewed at the MPE test conditions.

Wide viewing angle nondiffused LED lamps: Visible wide viewing angle nondiffused visible LED lamps, such as the T-1$^{3}/_{4}$, T-1, subminiature lamp devices, focus LED emitted light into medium wide cone angle spatial radiation patterns (medium wide beam angles) larger than 15°. These medium cone angle spatial radiation patterns may be mathematically described as a function of cosine^{n}, where n is typically less than 5. The concentration of LED emitted flux from these medium angle lamp devices has some possibility of inflicting eye damage when driven at sufficiently high drive currents and viewed at the MPE test conditions. The possibility of incurring eye injury from medium wide cone angle lamp devices when viewing at the MPE test conditions is also a primary function of the luminous efficacy of the LED chip technology within the particular lamp package.

Narrow viewing angle nondiffused LED lamps: Visible narrow viewing angle nondiffused LED lamps, such as high intensity T-1$^{3}/_{4}$ lamp devices, focus LED emitted light

Table 2. Visible LED Technologies Rated as to the Possibility of Causing Eye Injury, When Packaged in Nondiffused, Narrow Cone Viewing Angle, Plastic Lamps, and Viewed at the MPE Test Conditions.

Visible LED Technology	LED Colors	Efficacy (lm/W)	Possibility for Eye Injury
SiC	Blue	less than 0.1	Least Possibility
GaAsP/GaAs	Std. Red	~ 0.15	Least Possibility
GaAsP:N/GaP	HER, Yellow	~ 1.0	Minimal Possibility
GaP:N/GaP	Greenish-Yellow	1.0 to 2.5	Minimal Possibility
DH AlGaAs/GaAs	Deep Red	4.0 to 5.0	Some Possibility
GaN/Sapphire	Blue	~ 6.0 to 8.0	Good Possibility
TS AlGaAs	Deep Red	8.0 to 10.0	Good Possibility
AS AlInGaP/GaAs	Amber, Reddish-Orange	~ 20.0	Good Possibility
TS AlInGaP/GaP	Amber, Reddish-Orange	30.0 to 40.0	Good Possibility

into narrow cone angle spatial radiation patterns (narrow beam angles) equal to and less than 15°. These narrow cone angle spatial radiation patterns may be mathematically described as a function of cosine^n, where "n" can be numerically as large as 12. The concentration of LED emitted flux from these narrow angle lamp devices has a good possibility of inflicting eye damage when driven at sufficiently high drive currents and viewed at the MPE test conditions. The possibility of incurring eye injury from narrow cone angle lamp devices when viewing at the MPE test conditions is, however, a primary function of the luminous efficacy of the LED chip technology within the particular lamp package.

Luminous Efficacies of Visible LED Technologies and the Possibility for Causing Eye Injury

Visible LED technologies may be categorized as to their efficacy, defined as the luminous flux output vs. electrical power input (lm/W), in similar fashion as is done for incandescent lamps. As the efficacy of each LED technology increases, so does the possibility of eye injury when being viewed at the MPE test conditions. Using their efficacy values, visible LED technologies may be rated as to the possibility of causing eye injury when viewed by an observer at the MPE test conditions, as presented in Table 2. The device packages used for this rating are the nondiffused, T-1$^3/_4$, plastic lamp devices, which closely represent the package configurations of miniature incandescent lamp devices, and that focus the LED emitted light into a narrow beam spatial radiation pattern on the order of 8°.

LED Drive Currents and the Possibility for Causing Eye Injury When Viewing Visible Nondiffused, Narrow Cone Viewing Angle, Plastic Lamps, Viewed at the MPE Test Conditions.

The visible LED technologies to consider are the new AS and TS AlGaAs red and AS and TS AlInGaP amber and reddish-orange. Only these high efficiency LED technologies have light output efficacies sufficient to produce enough radiated flux at elevated drive currents to possibly cause eye injury when viewed at the MPE test conditions. At a drive current of 20 mA, the LED emitted flux can be on the order of 250 mlm to 800 mlm. The narrow beam spatial radiation patterns from non-diffused plastic lamps can concentrate this flux into a viewing cone angle of approximately 8°. At drive currents of 2 mA or less, the total flux is on the order of 25 mlm to 80 mlm and the probability of causing eye injury is minimal. As the drive current is increased above 2 mA, the amount of total flux increases in proportion to the drive current. At some elevated drive current condition, an observer looking at a narrow viewing cone angle T-1$^3/_4$, nondiffused, TS AlGaAs or AlInGaP LED device directly on axis at the MPE test conditions could experience sufficient flux output from the LED lamp that his/her natural, instantaneous, blink-look-away reflex reaction will occur, protecting the observer's eyes from possible injury. The observer may elect to view the LED device at some off-axis angle and at an increased viewing distance (usually greater than 1/2 arm's length) where the radiated flux is at a sufficiently reduced level to permit comfortable viewing of the device. At this off-axis angle and increased viewing distance, the possibility of incurring eye injury is extremely small.

Typical Visible LED Applications and the Possibility of Incurring Eye Injury

It must be restated, LED devices when viewed by an observer under normal design use situations are safe. Visible LED devices designed into modern day products where eye safety has been taken into account pose no possibility of inflicting eye injury to observers who are properly using those products. Table 3 lists various applications that use LED devices and the possibility of eye injury occurring when those products are viewed under normal use conditions. The reader should observe that for every listed application, the possibility of incurring eye injury under normal use conditions is **NONE**, regardless of the LED technology incorporated into the LED device.

Normal use excludes situations where a product with visible LED devices is in the manufacturing process, being repaired by skilled technicians, or is under measurement in a laboratory environment. Under these and other non-normal use conditions, personnel should be properly trained to prevent the possibility of eye injury resulting from their eyes coming in close proximity to illuminated LED devices. Intentional misuse of products containing visible LED devices which places the observer at risk of eye injury is considered to be solely the responsibility of the user.

Caution - The Single Fault Condition

It is conceivable that a single fault condition could occur within a product that utilizes an LED device. This single fault condition could increase the drive current through the LED device above design and maximum rated

Table 3. Applications Using Visible LED Devices and the Possibility of an Observer Incurring Eye Injury While Viewing LED Devices Under Normal Use Conditions.

LED Application	LED Device	Possibility of Eye Injury
Front Panel Status Indicator for Consumer and Industrial Equipment, Toys.	T-1, T-1 3/4 Diffused, Subminiature Lamps	None
Status Annunciators for All Kinds of Equipment, Automotive Tell-tale Lights, Consumer Appliances, etc.	Light Bars, Illuminated Light Pipes.	None
Numeric/Alphanumeric Displays in Laboratory Test Equipment, Automotive Instrument Clusters, Office and Computer Equipment, Avionics and Military Equipment, Hand Held Portable Units, etc.	7-Segment Displays, Alphanumeric Displays	None
Changeable Message Signs for Indoor Use, EXIT Signs, Electronic Clocks, etc.	T-1, T-1 3/4 Diffused Lamps	None
Automotive High Mount Stop Lights,Tail Light/Stop Lights, Vehicle Running Lights, Automotive Interior Tell-tale Indicator Lights.	T-1 3/4 and Specialty Nondiffused Automotive Lamps	None
Variable Message Signs for Outdoor Use, Roadway Traffic Management and Commercial Advertising.	T-1 3/4 Nondiffused Lamps	None
Traffic, Pedestrian, and Railroad Signals.	T-1 3/4 Nondiffused Lamps	None

limits. The light output at this single fault condition could possibly be at a level sufficient to cause eye injury when the LED device is viewed at the MPE test conditions. Therefore, it is important that service technicians and other observers working in close proximity to the product avoid viewing the LED device at close range until the fault condition has been corrected.

Maximum Permissible Exposure (MPE) Limits

An MPE is that level of electromagnetic radiation, infrared, visible, or ultraviolet, that the eyes of a human observer may be exposed to over a given period of time without incurring adverse effects. Based on experimental studies, MPE values are intentionally set on the order of 1/10th known hazard levels. MPE levels should be regarded as guides for safe exposure, rather than sharp dividing lines between safe and unsafe levels of exposure.

MPE values are wavelength dependent, exposure time or pulse duration dependent, and are defined in terms of the angular subtense of the source (which determines the image size on the retina). MPE values for LEDs should be determined for the peak wavelength, as the wavelength distribution from LED devices is narrow band, on the order of 20 nm spectral half width centered around the peak wavelength.

The amount of near infrared radiation produced by visible LED devices (761 nm to 950 nm) is less than 1% of the total emitted light. Thus, for visible LED devices, MPE values represent the maximum levels of visible radiation from 400 nm to 700 nm to which the human eye can be exposed over a given period of time without incurring consequential damage to the retina. *Note: Emissions from LED devices pose absolutely no threat of injury to human skin.*

SiC and InGaN blue visible LED devices do produce a small amount of ultraviolet-a radiation at a level insufficient to cause injury to the eye when driven at maximum dc drive current and viewed at the MPE test conditions.

MPE values are defined in the IEC 825-1 Standard in terms of visible flux from an LED source measured in the evaluation setup diagrammed in Figure 1:

1. A viewing aperture of 7 mm in diameter, an area of 3.8485 x10^{-5} m^2, which simulates a dilated eye,

2. An acceptance, α, angle between $\alpha_{MIN} = 0.63°$ (11 mrad) and $\alpha_{MAX} = 5.73°$ (100 mrad) with the vertex at the center of the aperture,
3. A viewing distance, r (mm), between the LED device and the 7 mm aperture, based on the apparent optical diameter of the LED device, and
4. A minimum exposure time of 100 seconds.

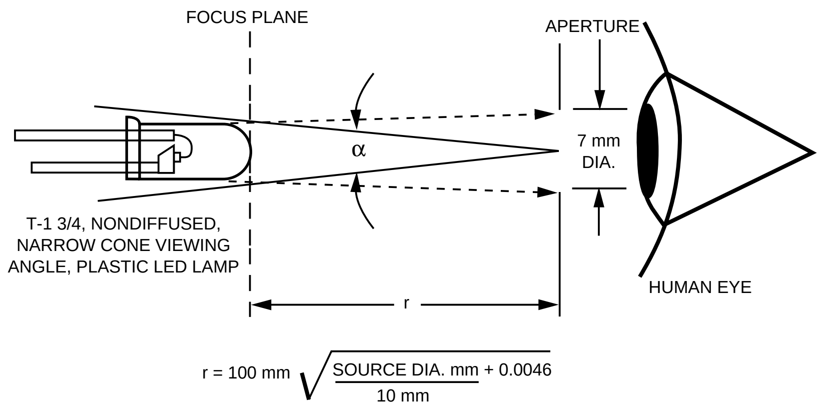

Figure 1. IEC 825-1 Standard Physical Configuration for Determining Exposure Values.

MPE Values for Nondiffused, Narrow Viewing Angle, T-1$^3/_4$ LED Lamps

Tests performed by Hewlett-Packard on various LED device type configurations have shown that nondiffused, narrow viewing angle, T-1$^3/_4$ LED lamps have the highest possibility of exceeding MPE levels due to the high values of on-axis luminous intensity associated with these devices. Therefore, the following discussion is confined to only these lamp devices.

MPE values are wavelength dependent and are given in units of irradiance, watts/square meter (W/m^2), for LED peak wavelengths from 450 nm to 654 nm in Table 4.

Luminous Intensity Limit Values at MPE Values, I_v MPE

The maximum permissible luminous intensity at MPE values, I_v MPE, can be calculated for T-1$^3/_4$, nondiffused, LED lamps. From the geometry of Figure 1, the following expression for luminous intensity in terms of MPE values can be written. See equation (1) in the table below.

Table 4 contains the I_v MPE values calculated from Equation 4 for LED peak wavelengths from 450 nm to 654 nm. Exceeding these I_v MPE values has the possibility on causing injury to the eye of an observer when viewed under the MPE test conditions.

LED I_v (dc MAX) Scaling Ratios

An I_v value at the maximum rated dc current is obtained by multiplying the I_v value obtained at the data sheet test current by an I_v (dc MAX) Scaling Ratio listed in Table 5. The I_v (dc MAX) Scaling Ratios are derived from the information contained in the graph of Figure 3 on each data sheet, *Relative Luminous Intensity vs. DC Forward Current.* The I_v value obtained at the maximum rated dc current is then compared against the I_v MPE limit value.

To obtain the I_v value at the maximum rated dc current, I_v (DC MAX), the luminous inten-

Equations:

$I_{v\ MPE(cd)} = MPE(W/m^2) \cdot \eta_v(lm/W) \cdot A(m^2) / \alpha(sr) = lm/sr = candela$ **(1)**

Noting:

$\alpha(sr) = \text{Aperture Area}(m^2) / [\text{distance (m)}]^2$ **(2)**

Substituting Equation 2 for α(sr) into Equation 1 and using dimensional analysis cancellations, Equation 3 is derived to calculate the on-axis luminous intensity limit, I_V, for a defined MPE value:

$I_{v\ MPE(cd)} = MPE(\cancel{W/m^2}) \cdot \eta_v(lm/\cancel{W}) \cdot \cancel{A(m^2)} / [\cancel{A(m^2)} / (d\ (\cancel{m^2})] = lm/sr$

$I_{v\ MPE(cd)} = MPE \cdot \eta_v \cdot d^2 = lm/sr$ **(3)**

Noting:

$d^2 = (0.100\ m)^2 = 0.01\ m^2$

Then:

$I_{v\ MPE(cd)} = MPE \cdot \eta_v \cdot (0.01)$ **(4)**

Table 4. MPE and Luminous Intensity Limit Values for Nondiffused Narrow Viewing Angle T-$1^3/_4$ LED Lamps (Calculated Values)

LED λ_{PEAK} (nm), Color LED Technology	450 Blue SiC	565 Yellow-Green AlInGaP	594 Amber AlInGaP	621 Reddish-Orange AlInGaP	630 Red AlInGaP	654 Deep Red AlGaAs
Luminous Efficacy, η_V (lm/W)	85	595	480	263	197	85
MPE Value (W/m^2)	4.55	7.63	20.8	25.9	25.9	25.9
I_V MPE Limit (cd)	1.6	18.9	31.2	21.3	15.9	9.2

Table 5. I_V (dc MAX) Scaling Ratios; I_V at Maximum DC Current / I_V at I_F Test Current

LED Peak Wavelength, Color	**LED Technology**	**I_{DC} Max - I_F Test**	**I_v Scaling Ratio**
450 nm, Blue	InGaN	50 mA - 20 mA	1.8
565 nm, Yellow-Green	TS AlInGaP	50 mA - 20 mA	3.2
594 nm, Amber	AS AlInGaP	50 mA - 20 mA	2.5
594 nm, Amber	TS AlInGaP	50 mA - 20 mA	3.2
621 nm, Reddish-Orange	AS AlInGaP	50 mA - 20 mA	2.5
621 nm, Reddish-Orange	TS AlInGaP	50 mA - 20 mA	3.2
630 nm, Red	TS AlInGaP	50 mA - 20 mA	2.5
654 nm, Deep Red	TS AlGaAs	50 mA - 20 mA	2.4

sity bin category must be known for the LED lamp in question. Once the luminous intensity bin category is known, the upper I_v limit value for that bin category can be used to calculate I_v (DC MAX), and determine if the value exceeds the I_v MPE value, and thus will exceed the MPE for the device. The luminous intensity bin category values may be obtained by contacting your local Hewlett-Packard Field Sales Engineer.

Highest Category I_v Bins for Eye Safety

Table 6 lists the highest category I_v bins where operation at maximum data sheet dc drive conditions is not a concern for eye safety when viewed without optical magnification. The corresponding maximum luminous intensity values for each I_v bin, I_v MAX (cd), are also listed. I_v bins below those listed in Table 6 pose no threat to eye safety when the lamps are operated at maximum data sheet dc current limits when viewed without optical magnification.

The I_v upper limit value for each I_v bin may be multiplied by the corresponding I_v Scaling Factor from Table 5 for comparison with the I_v MPE (cd) values listed in Table 4.

I_v bins above those listed in Table 6 should be considered for eye safety when lamps are viewed at the MPE test conditions and operated within data sheet dc current limits.

Example LED Lamp Exposure Calculation

The following is an example of the calculations that determine the exposure of a narrow viewing angle LED lamp.

Device type:	T-$1^3/_4$, untinted, nondiffused.
Lamp dome diameter:	5 mm
LED technology:	TS AlInGaP
I_v (20 mA):	3700 mcd TYP.
Viewing angle:	$2\theta^1/_2 = 15°$
Peak wavelength:	594 nm (amber)
Maximum dc drive current:	50 mA

Table 6. Highest Category I_V Bins for Eye Safety for Nondiffused Narrow Viewing Angle T-1 3/4 LED Lamps, Viewed Without Optical Magnification (Measured at 20 mA).

LED λ_{PEAK} (nm) Color LED Technology	450 Blue SiC	565 Yellow-Green AlInGaP TS	594 Amber AlInGaP AS	 TS	621 Reddish-Orange AlInGaP AS	 TS	630 Red AlInGaP TS	654 Deep Red AlGaAs TS
I_V MPE Bin Limit	O	T	W	W	Y	X	W	V
I_V Bin (20 mA) Upper Limit (cd)	1.2	12.0	30.0	30.0	25.1	17.4	12.0	8.4

Step 1. MPE distance:
r = 100 • (5 mm/10 mm + 0.0046) $^{1/2}$ = 71 mm

Step 2. Visual angle subtended by the LED lamp to the eye:
α = ArcTan[(LED lamp dome dia.) / r] = ArcTan [5 mm / 71 mm]
α = 0.0703 rad (4.03°)
0.0703 rad (4.03°) is between α_{MIN} and α_{MAX}, thus MPE limit value does apply to this device.

Step 3. I_V Bin Categories
Hewlett-Packard production test specifications define light output I_V (20 mA) Bin categories established on a 2:1 ratio, maximum light output / minimum light output, within each bin. The Hewlett-Packard production test specification I_V (20 mA) Bin categories for this particular lamp device are shown in Table 7.

Step 4. Maximum Possible I_V (dc MAX):
From the data sheet:
Maximum Rated DC Current = 50 mA
From Hewlett-Packard production test specifications for this device:
The upper limit for I_V (20 mA) Bin W category is
12000 mcd = 12 cd.
From Table 5, the I_V (dc MAX) scaling ratio for this device = 2.5.
I_V (50 mA) = (12 cd) • (2.5) = 30 cd

Step 5. Comparison of I_V (50 mA) and I_V MPE Limit Value
From Table 4: I_V MPE limit value for 594 nm amber = 31.2 cd.
For this I_V Bin W, TS AlInGaP amber LED device, the luminous intensity of 30 cd, when driven at the maximum dc drive current of 50 mA, is essentially at the I_V MPE limit value. Thus, for this device, products utilizing I_V Bins W and above should be considered for eye safety and product labeling per the CENELEC EN60825-1 Standard.

Table 7. I_V Bin Categories

I_V Bin Category	I_V MIN (mcd)	I_V MAX (mcd)
S	1400	2800
T	2000	4000
U	2900	5800
V	4200	8400
W	6000	12,000
Y	8500	17,000
Z	12,000	24,000

www.hp.com/go/components
For technical assistance or the location of your nearest Hewlett-Packard sales office, distributor or representative call:
Americas/Canada: 1-800-235-0312 or (408) 654-8675
Far East/Australasia: Call your local HP sales office.
Japan: (81 3) 3335-8152
Europe: Call your local HP sales office.

Obsoletes 5964-3805E
Printed in U.S.A. 5967-5810E (6/98)