SAE Aerospace
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AEROSPACE RECOMMENDED PRACTICE

SAE ARP4168

REV. A

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Superseding ARP4168

Night Vision Goggle (NVG) Compatible Light Sources

FOREWORD

Changes in this revision are format/editorial only.

1. SCOPE:

1.1 This ARP covers three common lamp light sources, incandescent, electroluminescent and light emitting diode that, when NVG filtered, can be used to illuminate NVG compatible aerospace crew stations. It is recognized that many other different light sources can also be used for this purpose.

1.2 This ARP sets forth recommendations for the design of NVG compatible lighting, utilizing these light sources, that will meet the requirements of MIL-L-85762A Lighting, Aircraft, Interior, Night Vision Imaging System (NVIS) Compatible.

1.3 Although this ARP concentrates on lamp light sources for illumination, the information contained within this ARP may be directly applied to incandescent, electroluminescent and light emitting diode information display devices.

2. PURPOSE:

2.1 This SAE Aerospace Recommended Practice recommends certain basic considerations which the design engineer should observe when designing NVG compatible lighting.

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2.2 Definition:

Night vision goggle compatible lighting is the condition in which the spectral wavelengths, luminance level and uniformity of the cockpit lighting do not interfere with the operation of night vision goggles. NVG compatible lighting permits a crew member to observe outside scenes through night vision goggles while maintaining the ability to recognize master caution/warning indicators inside the cockpit. Also, with NVG compatible lighting, all necessary information in the crew station is easily seen by a crew member with unaided eyes.

3. RECOMMENDATIONS:

When designing for NVG compatible lighting, the designer must consider that all light sources require varying degrees of optical filtration to restrict emissions above 600 nm. The degree of restriction is dependent upon the color and NVIS Radiance (NR) as defined in MIL-L-85762A. This is necessary since night vision goggles are most sensitive to long wavelength emission. Without the proper filtration, the light source will degrade or shut down the operation of a night vision goggle.

NVG filtered lighting must be dimmable to levels as low as 0.1 fL in order to meet NVG compatibility requirements. If a combination of NVG light sources are utilized in a single piece of equipment, it is desirable to have one control that will dim all the light sources simultaneously. When using a common dimming circuit, considerations should be given to the luminance tracking characteristics of the different light sources. The possible requirement for sunlight readability should also be considered when selecting the light sources.

3.1 Incandescent Lamps:

3.1.1 Lamp Types: Some typical military specifications for incandescent lamps that are used in aerospace vehicle panels are listed in Table 1. The size and type of lamp should be selected to meet the specific requirements of the application. Military specified lamps should be used whenever possible. However, in some instances it may be necessary to deviate from MIL specifications in order to meet special lighting and packaging requirements.

TABLE 1 - Military Specifications for Incandescent Lamps

MILITARY SPECIFICATION	LAMP TYPE
MS 90452	T-3/4, 5.0 Volt, Wire Terminals
MS 24367	T-1, 5.0 Volt, Wire Terminals
MS 90451	T-1, Short Length, 5.0 Volt, Wire Terminals
MS 24515	T-1, 5.0 Volt, Based
MS 3338	T-1, 28.0 Volt, Based
MS 25237	T-1 3/4, 2.5 to 28.0 Volt, Based
MS 25238	G-5, 28.0 Volts, Based
MS 15570	G-6, 6.0 to 28.0 Volts, Based
MS 25478	S-8, 6.0 to 28 Volts, Based
MS 25235	S-11, 28.0 Volts, Based

3.1.2 Design Considerations:

3.1.2.1 Light Output: Incandescent lamps emit light by the resistance heating of a tungsten wire filament to incandescent temperatures above 1200°K inside a vacuum or inert gas filled envelope. They are broad band illuminators that follow the typical black body radiation curves. Most subminiature lamps operate in the 1600 - 2400°K filament color temperature range as shown in Fig. 1. Less than 8% of the energy emitted is within the visible spectrum from blue to red. The remaining energy is in the infrared where NVIS systems are most sensitive. When properly filtered, incandescent light sources will meet the NR and color requirements of MIL-L-85762A.

Incandescent lamps range from 0.001 mean spherical candelas (MSCD) to 1.0+ MSCD in the subminiature sizes. An NVG filter will reduce the available light and should shift the observed spectral distribution from white to the desired NVG color. Thus, incandescent lamps must be selected to provide sufficient illumination through the NVG filter.

3.1.2.2 Size of Lamp: The physical size of the lamp must fit within the available space. Miniature and subminiature incandescent lamps are available in a wide range of sizes from less than 0.030 inches to more than 1.5 inches in diameter. The selected lamp should be configured with the proper base design to meet maintenance requirements.

3.1.2.3 Power Dissipation: The designer needs to select an incandescent lamp that is compatible with available power. Either AC or DC power may be used. Typical incandescent lamps in aerospace applications use 5.0 or 28 V, 0.02 - 1.0 A.

3.1.2.4 Thermal Considerations: Ambient temperatures of -55°C to +100°C will normally not affect the life or operation of standard incandescent lamps. It is recommended that the designer allow for sufficient heat dissipation, where applicable, in order to maintain the proper lamp surface temperature.

3.1.2.5 Dimming: Incandescent lamps are voltage operated devices. The light output is dimmed by reducing the applied voltage. The dimmed light output varies exponentially, as determined by Equation 1.

$$\text{Dimmed Light Light Output (MSCD)} = \left(\text{Rated Light Output Light Output (MSCD)}\right) \times \left(\frac{\text{Dimmed Voltage}}{\text{Rated Voltage}}\right)^{3.5} \quad (1)$$

As an incandescent lamp is dimmed, a spectral shift occurs towards longer wavelengths. This spectral shift causes a color shift towards red, a change in the spectral relationship with respect to the filter's transmission characteristic and will affect the NR value. These effects must be factored into the overall lighting system design to assure that the spectrum (color) of the NVG filtered incandescent lamp is within the desired NVIS color range at the dimmed brightness level specified in MIL-L-85762A.

3.2 Electroluminescent (EL) Lamps:

3.2.1 Lamp Types: AC thick-film electroluminescent lamps use phosphors to convert electrical energy into light energy. Only a small amount of infrared energy is emitted by an EL lamp. AC thick-film EL lamps are available in both blue-green and yellow, and when NVG filtered, may be used for NVG compatible lighting. When properly NVG filtered, EL lamps meet the NVG compatibility requirements of MIL-L-85762A.

3.2.2 Design Considerations:

3.2.2.1 Light Output: The spectral distribution of a blue-green AC EL lamp is presented in Fig. 2. The light output for a blue-green EL is typically 20 fL at 115 V AC, 400 Hz. The light output will be reduced by an NVG filter and the designer needs to take this into account. The light output of an EL lamp degrades exponentially with operating life.

3.2.2.2 Size of Lamps: EL lamps are flat, thin (0.015 in - 0.040 in) capacitive devices. EL lamps are available in any size from 0.1 in x 0.1 in - 12 in x 12 in, or larger, if necessary. Each lamp design may be custom configured in shape, with cutouts and other features to meet the needs of a specific application.

3.2.2.3 Power Dissipation: AC EL lamps are typically driven from 0 - 115 V AC, 400 Hz. The drive current required is typically 2 mA/in^2 of illuminated area at full rated voltage. With a 70 deg or 80 deg leading phase angle, power dissipated is typically 40 - 80 mW/in^2. The power dissipated in an EL lamp is equal to the voltage applied to the lamp x current x cosine of the phase angle, Equation 2.

$$P(\text{EL Lamp}) = V \times I \times \text{Cos}\ \theta \quad (2)$$

3.2.2.4 Thermal Considerations: Because no heating of the phosphor is required for luminescence, an extremely low amount of heat is generated by an EL lamp. Long term, extended use at elevated temperatures (greater than 55°C) is not recommended as operating life is reduced. During operation at elevated temperatures, light output degradation is accelerated. Light output degradation does return to normal when the ambient temperature falls below 55°C.

3.2.2.5 Dimming: EL lamps should be considered to be voltage operated devices. Dimming is accomplished by reducing the applied voltage. Light output varies as shown in Fig. 3. There is no shift in spectral distribution with voltage dimming. Since there is a small spectral shift with frequency variation, large frequency variations should be avoided.

3.3 Light Emitting Diode (LED) Lamps:

3.3.1 Lamp Types: LED lamps are solid state devices in two basic configurations, individual lamps and light bars, and are available in military and plastic packages. With the correct NVG filters, LED lamps meet the NVG compatibility requirements of MIL-L-85762A. Typical LED colors are given in Table 2.

TABLE 2 - Typical Colors of LED Devices Used With Night Vision Goggles

LED COLOR	DOMINANT WAVELENGTH (λ_d)	SATURATED COLOR
Green	565 - 572 nm	yellow-green
Yellow	582 - 592 nm	yellowish-orange

3.3.2 Design Considerations:

3.3.2.1 Light Output: LED devices are narrow band emitters that generate light by electron-hole recombination across a semiconductor p-n junction. The radiated spectra for green and yellow LED's are shown in Fig. 4. The light output of an LED lamp is specified as luminous intensity, flux per unit solid angle. The unit used is the candela (cd), lumens per steradian. The luminous intensity for an LED lamp is typically on the order of microcandelas (µcd) to millicandelas (mcd). Some LED devices have sufficient light output to be readable in daylight conditions, when filtered by the correct night vision goggle/daylight viewing (NVG/DV) filter.

3.3.2.2 Size of Lamp: Military grade LED lamps use a T0-46 hermetic package. NVG military grade LED panel mount lamps are available with an NVG filter incorporated as an integral part of the panel mount sleeve.

Plastic encapsulated LED lamps are available in T-1 3/4, T-1 and subminiature packages. Plastic light bars, typically used as annunciators, come in illuminated area sizes ranging from 0.10 in x 0.20 in to 0.4 in x 0.80 in.

3.3.2.3 Power Dissipation: LED lamps are current operated devices, and a current limiting resistor is required (see Fig. 5). The value of the current limiting resistor may be determined from Equation 3. Maximum DC drive currents range between 30 and 50 mA, with a typical forward voltage drop of 2.2 V. LED lamps may also be pulse driven (strobed) with typical power dissipations in the range of 0.090 to 0.140 mW.

$$R(\text{Limiter}) = \frac{V_{CC} - (V_{SAT} + V_F(\text{LED}))}{I_F(\text{LED})} \quad (3)$$

3.3.2.4 Thermal Considerations: The light output and operating life of LED lamps are functions of the LED junction temperature. As the LED junction temperature is increased due to a high thermal resistance, the light output and operating life decrease accordingly. LED light output decreases approximately 1.5% per 1°C increase in junction temperature. Also, mean time between failure (MTBF) decreases by a factor of 2 for each 20°C increase in junction temperature. Therefore, it is desirable to design the LED mounting configuration with as low a thermal resistance to ambient as possible to keep the LED junction temperature as low as possible. This will help to assure sufficient light output and expected operating life performance.

The ambient operating temperature range is depending upon the type of LED lamp (see Table 3). Any LED lamp may be operated at its specified operating temperature limit without undue degradation.

TABLE 3 - Typical Operating Temperature Ranges for Green LED Devices

TYPE OF LED LAMP	OPERATING TEMPERATURE RANGE
Military Grade Lamps	-55°C to +100°C
Plastic Lamps	-20°C to +100°C
Plastic Light Bars	-20°C to +85°C

3.3.2.5 Dimming: Dimming of a DC driven LED lamp is accomplished by reducing the forward drive current. Dimming of a strobed LED lamp at a fixed refresh rate is accomplished by pulse width modulation (PWM) of the on time pulse. When PWM is used, the light output of an LED varies directly with the proportioned on time pulse; that is, 50% on time appears as 50% brightness, 10% on time appears as 10% brightness.

4. RELIABILITY TESTING:

4.1 Incandescent Lamps:

Incandescent lamps are generally tested per MIL-STD-202 and MIL-STD-810. Lower voltage lamps are typically selected for their resistance to mechanical shock and vibration.

4.2 Electroluminescent Lamps:

Electroluminescent lamps are typically tested to the requirements specified in a source control drawing. The critical part of the construction of an EL lamp is the moisture seal.

4.3 Light Emitting Diodes:

LED lamps are tested per MIL-D-87175, test procedures per MIL-STD-750. The detail drawing for a specific LED lamp specifies which tests are relevant. Military grade hermetic LED lamps are tested per MIL-S-19500, test procedures per MIL-STD-750. A source control drawing may also be used to specify reliability screening requirements for an LED lamp.

5. PHOTOMETRIC CONSIDERATIONS:

Care must be taken in making light output and color measurements of NVG filtered light sources. The measurement method, equipment used and set-up, electrical operating conditions, ambient lighting, temperature and other pertinent parameters must be defined and recorded to assure accuracy and repeatability.

5.1 Light Output Measurement:

Light output should be measured through the NVG filter using a calibrated photometer. The measurements are typically luminous sterance in either footlamberts (fL) or candelas per square meter (cd/m^2). The area used in making a luminous sterance measurement must be precisely defined in order to assure accuracy and repeatability.

5.2 Color Measurement:

Color measurements are typically done through the NVG filter with a calibrated spectroradiometer. Incandescent and EL light sources are considered non-saturated light sources. Their colors are specified as u' and v' coordinates in the 1976 Uniform Color Space. LEDs are saturated color light sources and their colors are specified in terms of dominant wavelength (λ_d).

6. REFERENCES:

SAE ARP881B, Lamps for Aircraft Lighting
SAE ARP4169, Night Vision Goggle (NVG) Filters

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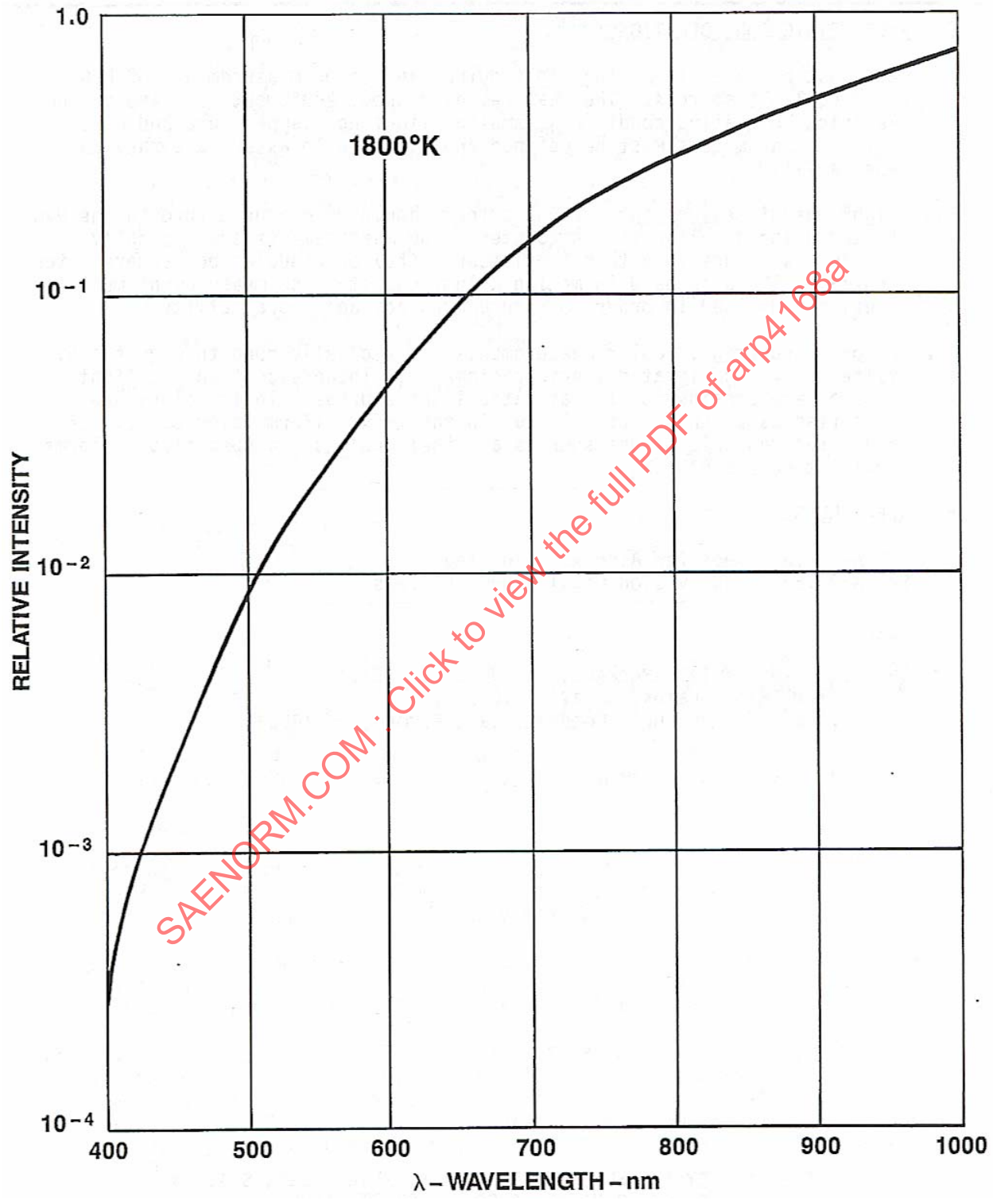

FIGURE 1 - Typical Radiated Spectrum of an Incandescent Lamp

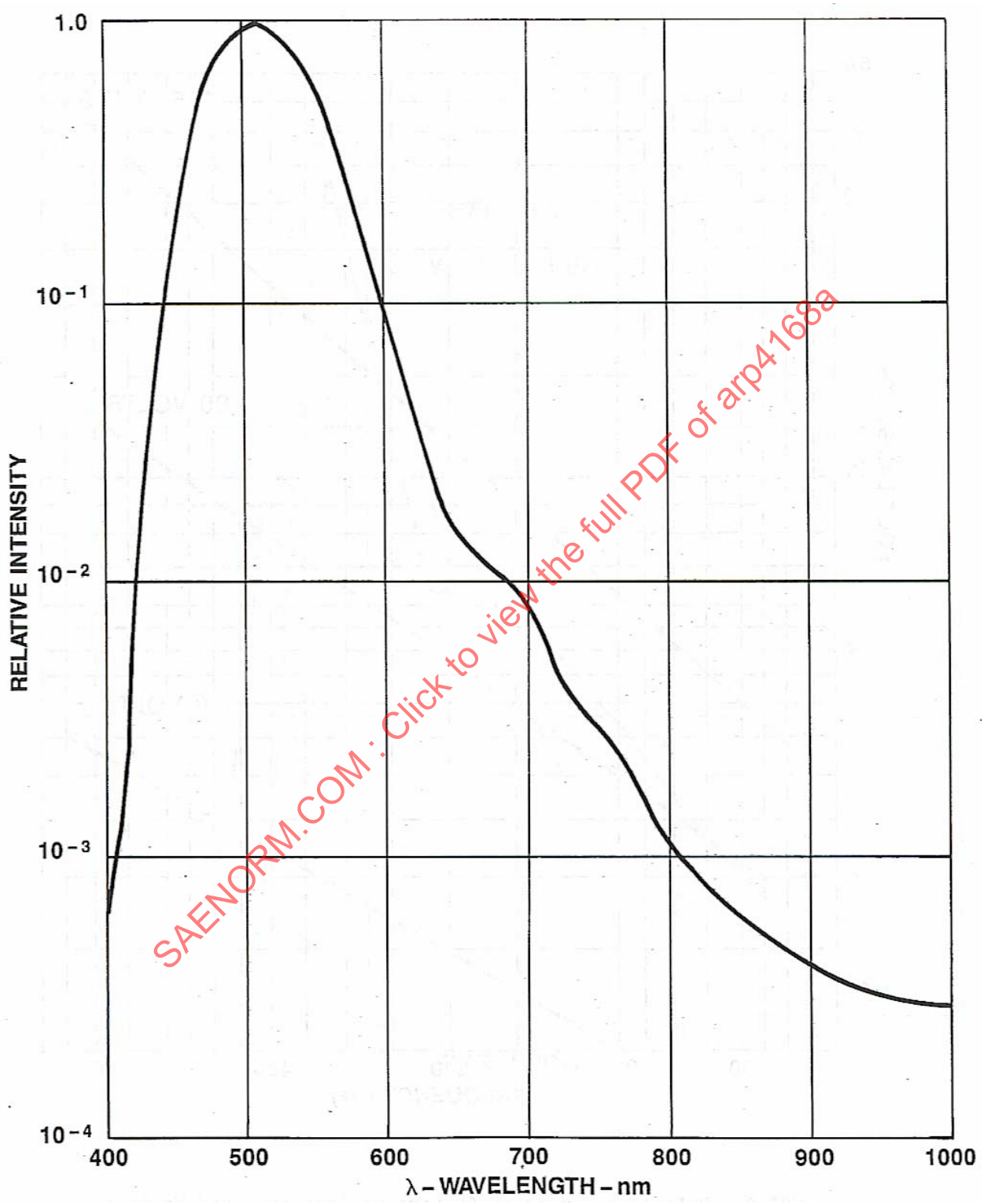

FIGURE 2 - Typical Radiated Spectrum of a Blue-Green AC EL Lamp