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AEROSPACE RECOMMENDED PRACTICE

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ARP4169

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NIGHT VISION GOGGLE (NVG) FILTERS

1. PURPOSE:

1.1 This SAE Aerospace Recommended Practice describes the functions and characteristics of NVG filters used in NVG compatible lighting.

1.2 Definition - Night Vision Goggle Compatible Lighting: 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.

2. SCOPE:

2.1 This ARP discusses the desired characteristics of night vision goggle (NVG) filters that can be used with incandescent, electroluminescent (EL) and light emitting diode (LED) light sources to achieve NVG compatible lighting of aerospace crew stations. This ARP also discusses the parameters that need to be considered when selecting a night vision goggle/daylight viewing (NVG/DV) filter for proper contrast enhancement to achieve readability in daylight.

2.2 The recommendations set forth in this ARP are to aid in the design of NVG compatible lighting that will meet the requirements of MIL-L-85762A Lighting, Aircraft, Interior, Night Vision Imaging System (NVIS) Compatible.

3. FUNCTIONS OF AN NVG FILTER:

3.1 The three primary functions of an NVG filter are:

3.1.1 Suppress the deep red and infrared wavelengths emitted by a light source required for NVG compatibility as defined by the Class of NVIS minus blue filter (see Section 5 of this ARP and Section 1.3 of MIL-L-85762A).

3.1.2 Limit visible transmission values for wavelengths amplified by the particular class NVIS.

3.1.3 Provide a color shift to the desired NVG color range.

3.2 Contrast Enhancement: An NVG/DV filter is used to provide sufficient contrast enhancement to achieve viewability in daylight or sunlight ambients. For this ARP, a daylight ambient is considered to be less than 10 000 fc and above 6000 fc, as may be defined by the end use application, and sunlight ambient is considered to be 10 000 fc.

4. TYPES OF NVG FILTERS:

4.1 Two Basic Types of NVG Filters: This ARP defines and discusses two basic types of NVG filters: the night vision goggle (NVG) and the night vision goggle/daylight viewing (NVG/DV).

4.1.1 Night Vision Goggle (NVG) Filter: The night vision goggle (NVG) filter defined in this ARP is a short wavelength pass filter, designed primarily to provide red and infrared (IR) suppression to achieve NVG compatibility. Contrast enhancement for readability in bright ambients is not provided by the NVG filter.

4.1.2 Night Vision Goggle/Daylight Viewing (NVG/DV) Filter: The night vision goggle/daylight viewing (NVG/DV) filter defined in this ARP is a bandpass filter, designed to provide both red and IR suppression for NVG compatibility and contrast enhancement for viewability in daylight or sunlight ambients.

4.2 NVG Filter Materials: The basic materials used to make NVG filters are glass, glass composite and plastic.

4.2.1 Glass NVG and Glass Composite NVG/DV Filters: Glass NVG and glass composite NVG/DV filters may be obtained with or without a front surface antireflection (AR) coating to enhance viewability. Glass and glass composite filters provide superb IR suppression for incandescent light sources and are excellent with EL and LED light sources. Glass composite filters for use in NVG applications typically do not contain circular polarizers.

4.2.2 Plastic NVG Filters: Plastic NVG filters are typically made from either polycarbonate or acrylic and provide good IR suppression for EL and LED light sources. Plastic filters may provide only marginal IR suppression for incandescent light sources. Typically, plastic NVG filters do not provide sufficient contrast enhancement for sunlight viewing.

4.3 Environmental Requirements and NVG Filter Materials: The NVG filter material selected must be capable of withstanding the military environmental requirements specified for the particular piece of equipment in which the filter is to be used. The equipment environmental specification may include requirements for such items as temperature, mechanical shock, moisture resistance, salt spray, chemical resistance and UV stability.

Glass and glass composite filters can withstand temperatures from -55°C to +100°C. Plastic NVG filters can withstand temperatures from -40°C to +100°C. Some plastic NVG filter materials, such as polycarbonate, are not recommended for use in high humidity environments above 85% RH, noncondensing. Plastic filters can be obtained with a scratch resistant front surface.

5. GEN III NVIS MINUS BLUE FILTERS:

GEN III night vision imaging systems use filters, termed minus blue filters, in conjunction with the objective lenses to reduce the NVIS sensitivity to visible light. These minus blue filters are long pass filters, attenuating the visible spectrum below the red region and passing infrared.

5.1 Minus Blue Filters for NVIS Class A and NVIS Class B: GEN III NVIS are classified by Figs. 1 and 2 of MIL-L-85762A as to wavelength where the value of the relative transmission of their minus blue filters is 50%. Fig. 1 shows the relative GEN III responses: $G_A(\lambda)$ for NVIS Class A and $G_B(\lambda)$ for NVIS Class B. The GEN III response curves of Fig. 1 are plotted with data from Tables VI and VII of MIL-L-85762A.

6. NVIS RADIANCE AS DEFINED BY MIL-L-85762A:

6.1 Definition of NVIS Radiance: MIL-L-85762A defines acceptable spectral radiance levels, as detected by a GEN III night vision imaging system, for various lighting configurations. This spectral radiance is termed NVIS Radiance, NR, and is determined from Equation 1:

$$\text{NVIS Radiance (NR)} = G(\lambda)_{MAX} \int_{450}^{930} G(\lambda) S N(\lambda) d\lambda \qquad (1)$$

Where:
- $G(\lambda)$ = Relative NVIS response, Class A or Class B.
- S = Measurement scaling factor, which is the ratio of required luminance for NVIS Radiance to the luminance needed by the spectroradiometer to make the measurement, or 15 fL, whichever is less.
- $G(\lambda)_{MAX}$ = 1 mA/W
- $d\lambda$ = 5 nm
- $N(\lambda)$ = $f(\lambda)T(\lambda)$ $W/cm^2/sr/nm$
  - $f(\lambda)$ = Radiated spectrum of light source.
  - $T(\lambda)$ = Relative transmission of NVG filter.

6.2 The relative transmission characteristic, T(λ), for the NVG filter in the IR region has the most influence on the value of NVIS Radiance. The amount of IR suppression and the relationship of the NVG filter T(λ) long wavelength characteristic with respect to the $G_A(\lambda)$ or $G_B(\lambda)$ short wavelength characteristic strongly influences the NR value for a given light source.

7. SUGGESTED NVG FILTER CHARACTERISTICS:

7.1 Suggested NVG Filter IR Suppression Characteristics: This ARP suggests criteria for two primary parameters of NVG filter characteristics, described in relationship to NVIS relative response characteristics, for obtaining sufficient IR suppression to meet the requirements of MIL-L-85762A. These two NVG filter characteristics are 1) the intersection of the NVG filter long wavelength characteristic with the NVIS relative response short wavelength characteristic and 2) the slope of the NVG filter long wavelength characteristic. The filter transmission characteristics should be graphed as a semi-log plot, as shown in Fig. 2, since a linear plot does not show the necessary IR attenuation.

7.1.1 The suggested IR suppression characteristics of an NVG filter are illustrated in Fig. 2. The IR suppression should be continuous out to 930 nm. For incandescent light sources, the IR suppression should be not less than six orders of magnitude beyond 650 nm. For EL and LED light sources, the IR suppression should be not less than four orders of magnitude beyond 650 nm.

The peak wavelength of the NVG filter characteristic shown in Fig. 2 is located with the color range for NVIS A. The peak wavelengths of the NVG/DV filters characteristics shown in Figs. 3, 4 and 5 are located within the respective NVIS color ranges, NVIS GREEN B, NVIS YELLOW and NVIS RED.

The above criteria should be used with judgment. Actual transmission characteristics are not usually as smooth and regular as those shown. Irregularities of filter characteristic within the region of IR suppression may result in failure to meet the NVIS Radiance requirements. When this is suspected, actual NR measurements, as described in MIL-L-85762A, should be obtained prior to incorporating the filter into the lighting design.

NVG/DV filtered low color temperature incandescent sources may not produce sufficient luminance for daylight readability.

7.1.2 Different light sources filtered by the same NVG or NVG/DV filter will produce different colors. In the interest of color matching of components, it should be noted that the full range of allowable NVIS colors cannot be with all light sources. For example, LED lamps, being narrow band emitters, produce colors of high saturation and are well suited for NVIS GREEN B, NVIS YELLOW and NVIS RED, but cannot produce the desaturated color NVIS A. The use of a narrow band NVG/DV filter with an incandescent light source for NVIS GREEN A increases color saturation, moving the resulting color closer to the locus of NVIS GREEN B.

7.2 NVG Filter T(λ) and Minus Blue G(λ) Relationship: The intersection of the NVG filter T(λ) long wavelength characteristic with the NVIS relative response $G_A(\lambda)$ or $G_B(\lambda)$ short wavelength characteristic is the first primary parameter controlling the value of NVIS Radiance.

7.2.1 General Crew Station Lighting, NVIS GREEN A: It is desirable to have the 1%, (10^{-2}), point on the NVG filter T(λ) long wavelength characteristic intersect the NVIS relative response $G_A(\lambda)$ or $G_B(\lambda)$ short wavelength characteristic at the 1% point, or below.

7.2.2 General Crew Station Lighting, NVIS GREEN B: It is desirable to have the 1%, (10^{-2}), point on the NVG filter T(λ) long wavelength characteristic intersect the NVIS relative response $G_A(\lambda)$ or $G_B(\lambda)$ short wavelength characteristic at the 1% point, or below. This is illustrated in Fig. 3 for the GEN III Class A.

7.2.3 Master Caution and Warning Lights, NVIS YELLOW: It is desirable to have the 5%, (5×10^{-2}), points on the NVG filter T(λ) long wavelength characteristic intersect the NVIS relative response $G_A(\lambda)$ or $G_B(\lambda)$ short wavelength characteristic at the 5% point, or below. This is illustrated in Fig. 4 for the GEN III Class A.

7.2.4 Master Caution and Warning Lights, NVIS RED: It is desirable to have the 5%, (5×10^{-2}), points on the NVG filter T(λ) long wavelength characteristic intersect the NVIS relative response $G_B(\lambda)$ short wavelength characteristic at the 5% point, or below. This is illustrated in Fig. 5 for the GEN III Class B.

Note: NVIS RED is intended for use only with Class B GEN III goggles. The use of NVIS RED NVG filtered light sources with GEN III Class A is not allowed. The reason is that NVIS RED falls within the active passband of GEN III Class A goggles.

7.3 NVG Filter T(g) Long Wavelength Characteristic: The slope of the NVG filter T(λ) long wavelength characteristic is the second primary parameter controlling the value of NVIS Radiance. The long wavelength slope can be expressed in terms of decibel attenuation per nanometer (db/nm) between the 1% transmission point and the 0.001% transmission point, Equation 2. For effective IR suppression, the long wavelength slope should be -0.5db/nm or steeper.

$$\text{Long Wavelength Cut-Off Slope (db/nm)} = \frac{10\text{Log}\left[\frac{T(\lambda_1 \text{nm})}{T(\lambda_2 \text{nm})}\right]}{[T(\lambda_1 \text{nm}) - T(\lambda_2 \text{nm})]} = -0.5 \text{ db/nm} \qquad (2)$$

Where: $T(\lambda_1)$ = Wavelength where filter transmission = 1%, (10^{-2})
$T(\lambda_2)$ = Wavelength where filter transmission = 0.001%, (10^{-5})

7.4 NVG Filter Visible Transmission Characteristics:

7.4.1 Peak Transmission for NVIS Color: MIL-L-85762A defines specific NVIS color ranges for NVG filtered light sources. The NVG filter peak transmission must fall at a wavelength within the desired color range to assure the proper NVIS color, as illustrated in Figs. 3, 4 and 5.

7.4.2 Peak Transmission for Contrast Enhancement:

7.4.2.1 Contrast Enhancement for Saturated Light Sources: To achieve effective contrast enhancement for daylight viewability of saturated light sources, such as LEDs and EL, the NVG/DV filter's transmission at the peak wavelength within the desired NVIS color range (GREEN B, YELLOW or RED) should be 11% to 17%, see Figs. 3, 4 and 5. The total amount of emitted visible light transmitted by the filter should be 10% to 17%.

7.4.2.2 Contrast Enhancement for Broad Band Light Sources: Contrast enhancement of a NVIS GREEN A light source used for general lighting is typically not required, and an NVG filter is sufficient. Effective contrast enhancement of an NVIS GREEN A light source, when using a broad band source such as an incandescent lamp, may necessitate the use of an NVG/DV filter with a wider visible wavelength passband and higher transmission at the peak wavelength than that required for a saturated light source, depending upon the requirements of the particular lighting application.

7.4.2.3 Measuring the Contrast Performance of an NVG/DV Filter: The contrast performance of an NVG/DV filter can be ascertained by comparing the percent relative luminous energy transmitted from the NVG light source, %T(Y), the photopic single pass transmission of the filter, to the percent relative luminous energy from a CIE Illuminant B source being transmitted through the filter twice, $\%T^2$ (CIE B), the broad band double pass transmission of the filter. The spectral distribution of a CIE Illuminant B source has approximately the same spectral distribution as direct sunlight.

$$\%T(Y) = 100 \frac{\int_{400\ nm}^{740\ nm} f(\lambda)\bar{y}(\lambda)T(\lambda)d\lambda}{\int_{400\ nm}^{740\ nm} f(\lambda)\bar{y}(\lambda)d\lambda}$$

Percent Relative Energy Photopic Single Pass Transmission of NVG Light Source

$$\%T^2(CIE\ B) = 100 \frac{\int_{400\ nm}^{740\ nm} B(\lambda)\bar{y}(\lambda)T^2(\lambda)d\lambda}{\int_{400\ nm}^{740\ nm} B(\lambda)\bar{y}(\lambda)d\lambda}$$

Percent Relative Energy Broad Band Double Pass Transmission of CIe Illuminant B Source

Where: $f(\lambda)$ = Radiated spectrum of light source.
$T(\lambda)$ = Relative transmission of NVG/DV filter.
$B(\lambda)$ = CIE Illuminant B spectrum.
$\bar{y}(\lambda)$ = CIE Photopic Curve.
$d(\lambda)$ = 5 nm.

7.4.2.3 (Continued):

The ratio %T(Y)/%T^2 (CIE B) is used as the figure of merit to rate the contrast enhancement performance of an NVG/DV filter. The higher the value of the %T(Y)/%T^2 (CIE B) ratio, the better is the contrast enhancement performance of the NVG/DV filter. The value of the single pass %T(Y) should be between 10% and 17% and the value of the double pass %T^2 (CIE B) should be less than 1%. A %T(Y)/%T^2 (CIE B) ratio of 17 or more provides effective contrast enhancement.

The value of the photopic single pass transmission, %T(Y), of an NVG/DV filter may affect the value of the broad band double pass transmission, %T^2 (CIE B). Therefore, when a luminous level is specified for the NVG/DV filtered light source at full brightness, preference should be given to the highest possible %T(Y)/%T^2 (CIE B) ratio. This may necessitate a higher value of photopic single pass transmission, %T(Y), than 17% to accommodate the luminous output requirement of the NVG filtered light source at rated drive conditions while keeping the broad band double pass transmission, %T^2 (CIE B), as low as possible.

%T(Y) and %T^2(CIE B) may be viewed simply as relative ratios of luminous intensity measurements of the NVG and CIE Illuminant B light sources with and without the NVG/DV filter in place. Since %T(Y) and %T^2 (CIE B) are relative measurements, the luminous levels needed for measurement are at the discretion of the engineer.

7.4.2.4 NVIS Requirements vs Sunlight Viewability: It should be noted that NVG compatibility and sunlight viewability are requirements in opposition to each other. Therefore, it may not be possible to obtain both NVG compatibility and viewability in 10 000 fc sunlight conditions with the same NVG/DV filtered light source. NVG compatibility and viewability in daylight conditions less than 10 000 fc are more easily achieved.

8. REFERENCE:

SAE ARP4168, Night Vision Goggle (NVG) Compatible Light Sources

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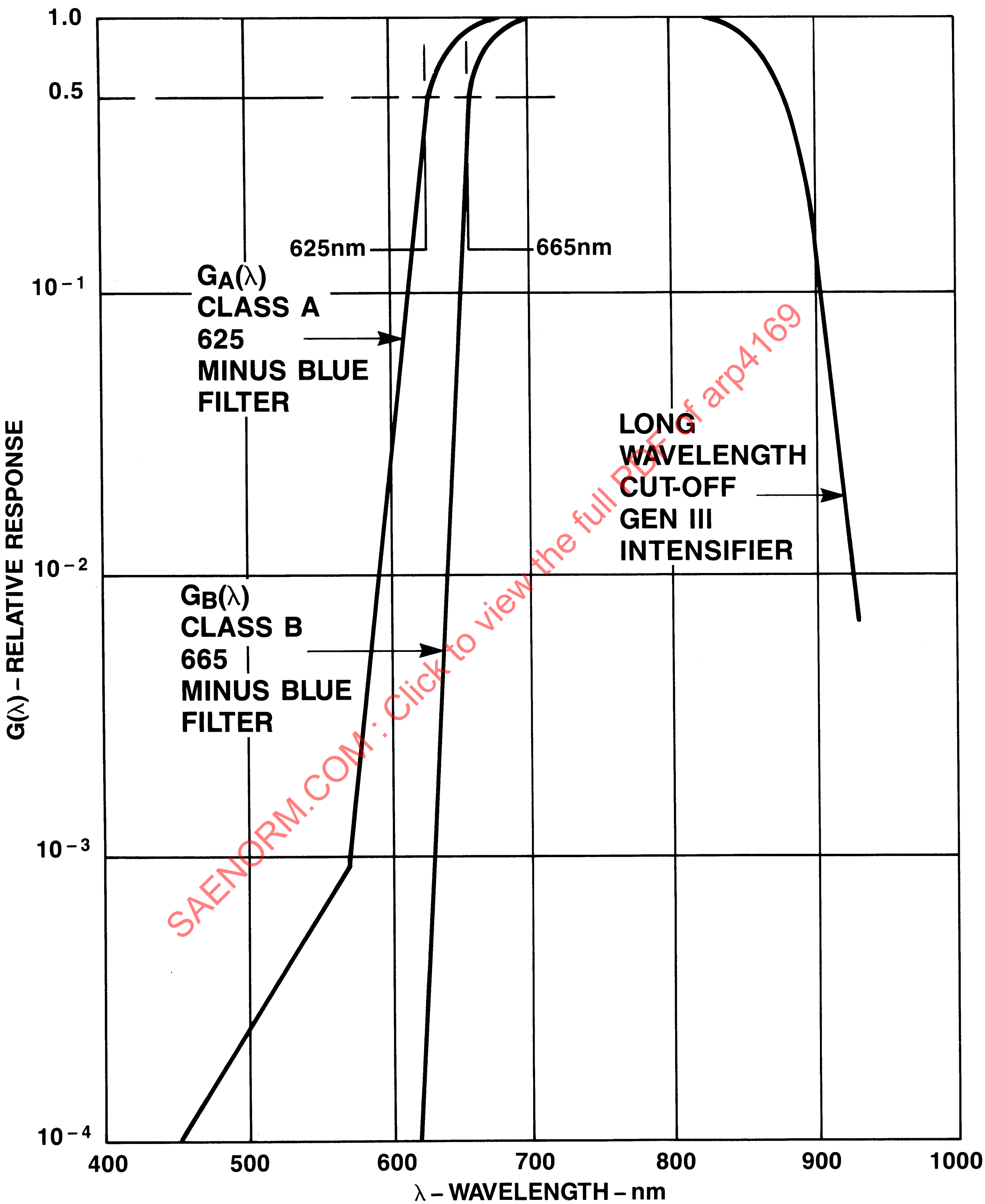

FIGURE 1 - Classes of GEN III NVIS

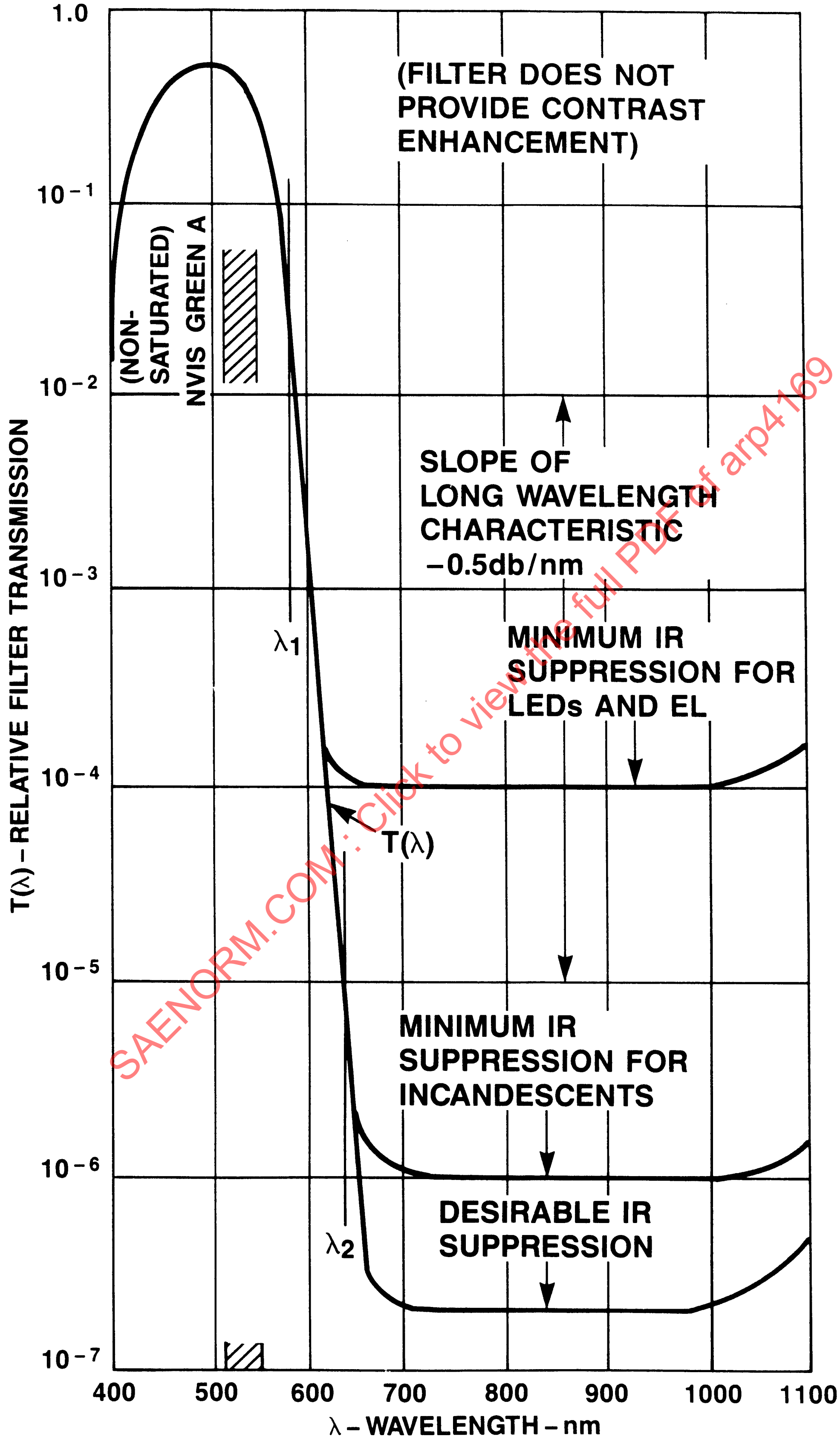

FIGURE 2 - Ideal NVIS GREEN A NVG Filter