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MINIMUM OPERATIONAL PERFORMANCE STANDARDS FOR INTEGRATED NIGHT VISION IMAGING SYSTEM EQUIPMENT

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Prepared by SC-196

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FOREWORD

This report was prepared by Special Committee 196 (SC-196) and approved by the RTCA Program Management Committee (PMC) on October 12, 2001.

RTCA, Incorporated, is a not-for-profit corporation formed to advance the art and science of aviation and aviation electronic systems for the benefit of the public. The organization functions as a Federal Advisory Committee and develops consensus-based recommendations on contemporary aviation issues. RTCA's objectives include but are not limited to:

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- analyzing and recommending solutions to the system technical issues that aviation faces as it continues to pursue increased safety, system capacity and efficiency;
- developing consensus on the application of pertinent technology to fulfill user and provider requirements, including development of minimum operational performance standards for electronic systems and equipment that support aviation; and
- assisting in developing the appropriate technical material upon which positions for the International Civil Aviation Organization and the International Telecommunication Union and other appropriate international organizations can be based.

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1 PURPOSE

1.1 Introduction

This document contains minimum operational performance standards (MOPS) for the aviation night vision imaging system (NVIS) used to supplement night VFR operations. These standards specify system characteristics that should be useful to designers, manufacturers, installers and users of the equipment.

Compliance with these standards is recommended as one means of assuring that the equipment will perform its intended function(s) satisfactorily under all conditions normally encountered in routine aeronautical operations. Any regulatory application of this document is the sole responsibility of the appropriate governmental agency/authority.

Section 1 (Introduction) provides information on the purpose and scope that is needed to understand the rationale for equipment characteristics and requirements stated in this document. It describes typical equipment applications and operational goals, as envisioned by the members of Special Committee 196, and establishes the basis for the standards stated in sections 2 and 3. Definitions and assumptions essential to proper understanding of this document are also provided in this section.

Section 2 (NVG Performance Requirements and Test Procedures) contains general guidance and minimum performance standards for the night vision goggle (NVG). These standards specify the required performance under the defined operating and environmental conditions. Also included are recommended bench test procedures necessary to demonstrate equipment compliance with the stated minimums.

Section 3 (NVIS Lighting Performance Requirements and Test Procedures) contains general guidance and minimum performance standards for NVIS lighting. These requirements specify the required performance under the defined operating and environmental conditions. Also included are recommended test procedures necessary to demonstrate equipment compliance with the stated minimums.

Section 4 (Installed Integrated NVIS Equipment Performance) describes the minimum acceptable performance requirements for the installed integrated NVIS equipment. Installed equipment tests are conducted to complement, supplement and/or validate bench and component test performance data determined in sections 2 and 3.

Section 5 (Continued Airworthiness) describes the continued airworthiness procedures used to ensure the integrated NVIS equipment installation continues to meet the minimum performance standard once in operational use.

The following appendices are included in this document:

1. Appendix A is a list of abbreviations and acronyms recommended for use with NVIS and associated documents.
2. Appendix B is a bibliography and a list of all references cited in this document.
3. Appendix C is a glossary that defines terms that are used in conjunction with NVIS operations and equipment.
4. Appendix D contains information pertaining to the relative spectral response of Class B NVGs.
5. Appendix E contains recommended design practices for NVIS installations.
6. Appendix F includes a table for converting Snellen acuity to visual angular resolution.
7. Appendix G contains suggested NVG pre-flight and adjustment procedures.

8. Appendix H NVIS Installation Ground Test Checklist.
9. Appendix I contain information for constructing a light source for use during NVG adjustment procedures.

The word "equipment," as used in this document includes all components and features necessary for the system to properly perform its intended function(s). Standards for design and implementation of optional features, beyond those required for a minimum NVIS, only apply if those features are implemented.

If the equipment implementation includes a computer software package, the guidelines contained in RTCA/DO-178B, *Software Considerations in Airborne Systems and Equipment Certification*, should be considered.

1.2 System Overview

The Night Vision Imaging System (NVIS) consists of the following:

- NVG
- Interior and exterior lighting
- Cockpit transparencies (e.g., windshield, windows, chin bubbles, etc.)
- Crewstation design and components (e.g., location of structural components that may hinder use of NVGs, aircraft displays, etc.)

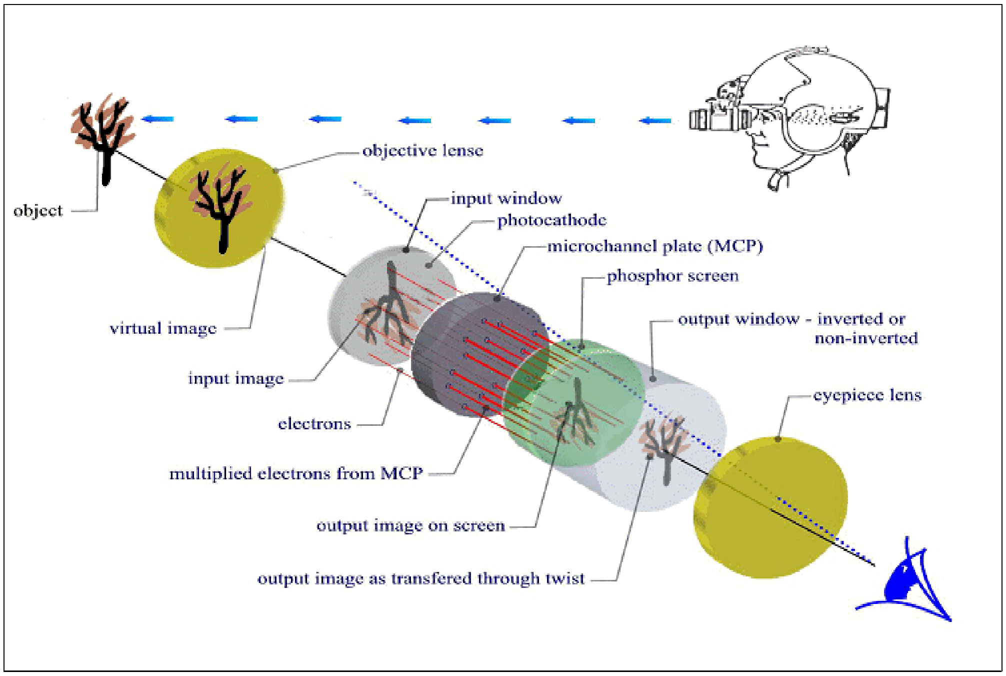


Figure 1-1 Typical Night Vision Imaging Systems Components

1.2.1 Night Vision Goggle

1.2.1.1 Binocular Assembly

The binocular assembly contains two monocular assemblies. It may house the adjustment mechanisms for interpupillary (eyespan) adjustment, eyepiece and objective lens focus, fore and aft adjustment, and tilt adjustment. It may also contain a breakaway feature at its interface with the head or helmet mount.

1.2.1.2 Monocular Assembly

The monocular assemblies contain the electro-optical components that gather the available light, amplify that light and present that light to the human eye. Each monocular assembly contains one or more intensifier channels.

Each channel consists of an objective lens, image intensifier tube, and eyepiece lens. Available light from the night sky and other sources is reflected off scene objects, creating the input to the NVG.

1.2.1.3 Objective Lens Assembly

The objective lens assembly (See Figure 1-1) collects the available energy and focuses it on the photocathode (the first part of the image intensification tube). It is housed in an assembly that is used for distance focusing. A coating is placed on the inside portion of the lens that filters out specific wavelengths, thus allowing the use of properly designed interior lighting without degrading the NVG image of the outside scene.

1.2.1.4 Image Intensifier

An image intensification tube greatly amplifies available energy to provide an imaging capability at night. It consists of a photocathode, microchannel plate, phosphor screen, and fiber optic twist. Embedded circuitry is designed to protect the tube from bright light sources, and to automatically adjust the gain in response to varying light input levels by controlling the electron flow through the microchannel plate.

1.2.1.5 Eyepiece Lens

The eyepiece lens assembly is designed to provide some adjustment for the user that compensates for minor vision deficiencies (i.e., diopter adjustment). However, the assembly does not correct for all eye deficiencies and does not replace the need for wearing prescribed spectacles or contact lens.

1.2.1.6 Power Source Assembly

The power source for each tube can be provided by a variety of methods including for example duplicated battery compartments, individual batteries mounted on each tube, aircraft supplied with automatic switching to battery or aircraft back up power supply, or any other method providing a sufficiently reliable source of power. A suitable means of indicating to the user actual or impending power source problems would normally be provided.

1.2.1.7 Helmet or Head Mount

The mount assembly serves as the mounting point for the binocular assembly. It may be affixed to an assembly that serves as a head mount (e.g., hair net mount), or it may attach to a helmet. The mount may contain a vertical adjustment and a means for connecting the binocular assembly to system power. The design may include a breakaway feature for the binocular assembly and/or the binocular assembly/mount combination. The mounting system shall provide a stable platform for the NVG during all flight conditions, and shall be designed not to interfere with the operator’s ability to look beneath or around the binocular assembly when viewing inside or outside the cockpit using unaided vision.

1.2.2 NVIS Lighting

Properly designed NVIS lighting provides for adequate illumination of cockpit instruments/displays/controls for unaided readability without degrading the NVG image.

1.2.3 Transparencies

Cockpit transparencies include the windshield, windows and other transparencies through which operators view the outside scene with NVGs.

1.2.4 Ancillary Equipment

The aircraft shall be equipped with a radio altimeter (also known as a radar altimeter), vertical speed indicator, and attitude indicator within the pilot’s primary field of view to facilitate cockpit viewing with minimal head movement, thereby minimizing the potential for spatial disorientation (e.g., lack of depth perception). It is recommended that the radio altimeter be equipped with an audio and/or visual warning device at a pilot selectable height, especially if the radio (radar) altimeter provides only a digital display. All cockpit instruments, displays, annunciators, etc. are viewed with unaided vision and not with the NVG.

Also, the aircraft will be equipped with a generator or alternator of adequate capacity, and two-way radio communication equipment. (Reference RTCA/DO-268, *Concept of Operations – Night Vision Imaging System for Civil Operators.*) This equipment is to allow for a safe recovery from inadvertent encounters with below VFR weather conditions, or spatial disorientation.

1.3 Operational Application

This document establishes equipment requirements for the use of NVGs during night VFR operations. The minimum operating performance standards set forth in this document are intended to provide a system that will be compatible with both existing and future airspace operations.

1.4 Intended Function

The fundamental purpose of a NVG is to provide the operator with a means of acquiring an enhanced view of the scene outside the aircraft, thus enhancing situation awareness. If the NVG is to be used for tasks beyond those addressed in this document, additional requirements may apply. The NVG is not designed to be used during daytime or in bright conditions at night (e.g., in a hangar or ramp illuminated with incompatible light sources).

1.5 Operational Goals

Properly designed and integrated, NVIS equipment should increase the effectiveness of operations during night VFR conditions.

1.6 Assumptions and Scope

The following are germane when designing NVIS equipment or when developing operational guidelines:

1.6.1 NVIS Design Assumptions

1. NVG design guidance in this document is intended for head-mounted devices presenting independent imagery to both eyes (i.e., binocular systems).
2. This document provides a baseline for the NVIS, but does not contain an exhaustive or comprehensive list of shared display or imaging considerations (e.g., simultaneously depicting imaging data with symbology).
3. The design guidance in this document provides for NVG incorporating Class B and modified Class B filters.
4. Design guidance in this document does not address forward looking infrared (FLIR) systems, synthetic or enhanced vision systems, fixed head-up displays (HUDs), or NVG HUD systems (attachable to or part of the NVG).
5. All aircraft interior and exterior lighting complies with the applicable regulations.
6. All testing is performed by trained and experienced test personnel.
7. All references to the term “modification” can apply to new designs or installations.

1.6.2 NVIS Operational Assumptions

1. NVG enhanced vision is not equivalent to daytime vision.
2. The pilot can maintain VFR flight in the event NVG imagery is lost or degraded.

3. The operator has 20/20 corrected vision and wears the appropriate corrective lenses while using NVGs.
4. The NVG does not provide adequate imagery under all lighting conditions, scene contrast, and atmospheric conditions.
5. The operator takes advantage of the maximum visual performance available of the NVG, through proper alignment and focus.
6. Viewing imagery provided by a NVG will degrade the operator's depth perception and distance estimation.
7. The operator shall meet the color vision standard that is deemed necessary for safe performance of duties.
8. Acquiring and installing NVIS equipment that meets the standards of this document does not constitute an operational approval. All NVIS operators shall be trained and have proper approval from their regulatory agency/authority to operate NVIS equipment.

1.7 Test Procedures

The test procedures specified in this document are intended to be used as one means of demonstrating compliance with the performance requirements. Although specific test procedures are cited, it is recognized that other methods may be preferred. These alternate procedures may be used if they provide at least equivalent information.

The order of specified tests suggests that the equipment be subjected to a succession of tests as it moves from design, to design qualification, and finally to operational use. For example, compliance with the requirements of Section 2 and 3 shall have been demonstrated as a precondition to satisfactory completion of the installed system test of Section 4.

1.7.1 Environmental Tests

Environmental tests are specified in Section 2.3 and 3.3. The intent of environmental testing is to provide a laboratory means of determining the electrical and mechanical performance of the equipment under environmental conditions that replicate a wide range of aeronautical operations. Unless otherwise specified, the environmental test procedures contained in RTCA/DO-160D, "Environmental Conditions and Test Procedures for Airborne Equipment," will be used to demonstrate equipment compliance.

1.7.2 Bench, Component and/or System Tests

Bench, component and/or system test procedures are specified in Section 2.4 and 3.4. These tests provide a laboratory means of demonstrating compliance with the requirements in Section 2.2 and 3.2. Test results may be used by equipment manufacturers for ensuring compliance and, in certain cases, for obtaining formal approval of equipment design.

1.7.3 Installed Equipment Tests

The installed test procedures are specified in Section 4. The following is applicable to installed system testing:

1. Installed testing will take place only when the entire NVIS installation has been incorporated by the applicant.
2. Installed testing (i.e., integrated NVIS system testing) does not replace the requirement for performing NVIS lighting component testing described in Section 3 unless alternate methods of compliance can be demonstrated.

3. Installed equipment tests may be used in lieu of bench/component testing when test points are impossible to otherwise acquire (e.g., interference from other equipment installed on the aircraft, etc.). The need for this shall be adequately justified.
4. Installed tests are normally performed on the ground and in flight.
5. Test results shall demonstrate functional performance in the intended operational environment.
6. Test results shall demonstrate compliance with the functional performance requirements for daytime operations (e.g., daytime readability of instruments).

1.8 Definition of Terms

This section contains a definition of terms used that may have multiple, special, or unique meanings in this document.

Channel: A channel consists of an objective lens, image intensifier tube, and eyepiece lens.

CIE color coordinate system: The fundamental definitions of color are expressed in terms of the "standard observer" and coordinate system adopted by the International Commission on Illumination (C.I.E.) at Cambridge, England, in 1931 and published in the Journal of the Optical Society of America, Vol. 23, page 359, October 1933. Wherever chromaticity coordinates (x, *y,* z) appear in this document they relate to this system. The CIE 1976 Uniform Color Space (UCS) diagram is the CIE 1931 chromaticity diagram redrawn with the x and y axes subjected to a linear transformation as defined in CIE Publication 15, Supplement 2, 1978. Wherever chromaticity coordinates (u',v') appear in this document, they relate to this last system.

Class A: Refers to a NVG in which a 625nm minus blue objective lens filter has been incorporated. This term also can refer to the NVIS lighting designed for use with NVGs that contain a class A filter.

Class B: Refers to a NVG in which a 665nm minus blue objective lens filter has been incorporated. This term also can refer to the NVIS lighting designed for use with NVGs that contain a class B filter.

Class C: Refers to a NVG in which a 645nm minus blue objective lens filter has been incorporated. These filters are typically incorporated in NVGs produced in Europe.

Contrast (Modulation Contrast): defined by the following equation: $C_m = (B_1 - B_2)/(B_1+B_2)$. B_1= luminance of the background (bright area) and B_2 = luminance of a dark spot.

Contrast ratio: defined by the following equation, B_1/B_2.

Crewstation or compartment: All work stations or compartments within the aircraft in which the operator is required to use a NVG in the performance of their duties.

Cycles Per Milliradian (cy/mrad): A measure of spatial (angular) resolution. A cycle is a white space and an adjacent dark bar, both of equal width. A milliradian is 0.0573 degrees. This measure is used to describe the resolution performance of a NVG.

Direct View Image NVG (Type I): Any NVG in which the intensified image is displayed in the operator's direct line of sight.

Display: A device, which presents visual information to the flight crew. This includes, but is not limited to: multi-function displays, flight instruments, engine instruments, annunciators, etc.

Electronic displays: All displays capable of presenting a variety of different images on a screen through an electronic medium. These displays may present characters, numerals, symbols, graphics, or video. They are based on CRTs, LCD's, electroluminescence, plasma and light emitting diodes (LED's) that can be either multi-color or monochromatic.

Exterior Lighting: All lighting attached to the outside of the aircraft including but not limited to: position lights, anticollision lights, landing lights, search lights, formation lights, etc.

Footcandles (fc)*:* A measure of illuminance; specifically, the illuminance of a surface upon which one lumen is falling per square foot. One footcandle is equal to 10.76391 lumens per meter square or lux (lx).

Footlamberts (fL)*:* A measure of luminance; specifically the luminance of a surface that is receiving an illuminance of one foot-candle. One footlambert is equal to 3.426751 candela per m^2 (cd/m^2) or nits.

Functional Hazard Assessment: A systematic, comprehensive examination of aircraft functions to identify and classify Failure Conditions of those functions according to their severity.

Image Intensifier: An electro-optic device used to detect and intensify optical images in the visible and near infrared region of the electromagnetic spectrum for the purpose of providing visible images. It is composed of the photocathode, microchannel plate, and phosphor screen. It does not include the objective and eyepiece lenses. The component that performs the intensification process in a NVG.

Interior lighting: All lighting within the aircraft including but not restricted to the following lighting systems: instrument (primary & secondary), console (primary & secondary), emergency, warning, caution, and advisory displays and indicators, utility, controls (knobs, handles, push buttons), compartment, work and inspection lights, etc.

Light leaks: Light that is emitted from a location in the crewstation that was not intended to emit light. One form consists of incompatible light sources found after the installation of an NVIS lighting system. The sources could originate from within a modified component but more typically result from inadequate installation. In addition to lights leaks resulting from incompatible sources, there can be light leaks from compatible sources that may interfere with unaided readability (e.g., scratched panels). Light leaks may also develop after prolonged operational use.

Major: Failure Conditions that would reduce the capability of the aircraft or the ability of the crew to cope with adverse operating conditions to the extent that there would be a significant reduction of safety margins or functional capabilities; a significant increase in crew workload or in conditions impairing crew efficiency; some discomfort to occupants.

Modified Class B: Refers to an NVG in which a modified Class B filter has been incorporated. The filter has been modified with a notch or band-pass feature for the purpose of passing a small amount of energy in the green wavelengths. This allows for the operator to view fixed HUD symbology with the NVG.

Monocular: A monocular contains the electro-optical components that gather the available light, amplify that light and present that light to a single eye. Each monocular assembly contains one or more intensifier channels.

Night Vision Goggle (NVG): A head-mounted, lightweight, self-contained binocular system consisting of two independent monocular assemblies.

Night Vision Imaging System (NVIS): The integration of all elements required to successfully and safely use NVGs while operating an aircraft.

Normal Performance: A state where the device or system meets its intended function.

NVG Compatible: Lighting components or systems that comply with applicable NVIS standards and do not adversely affect NVG performance.

NVIS Lighting Component: Any component that emits or transmits light within the flight deck or other crew compartments, or that is attached to the aircraft exterior, and does not degrade NVG performance.

NVIS Lighting System: An aircraft lighting system that has been modified or designed to incorporate NVIS lighting components. It provides adequate illumination of instruments/displays/controls for the unaided eye without degrading NVG performance.

NVIS radiance: NVIS radiance is defined as the integral of the curve generated by multiplying the spectral radiance of a light source by the relative spectral response of the NVG.

NVIS radiant intensity: NVIS radiant intensity is defined as the integral of the curve generated by multiplying the spectral radiant intensity of a light source by the relative spectral response of the NVG.

Optimum Light Conditions: Conditions that provide the intensification process enough energy to maximize system resolution.

Photometer: An electro-optical device used to measure and quantify the luminous intensity of visible light that is emitted from a source or reflected from a surface area.

Projected Image (Indirect View) NVG (Type II): Any NVG in which the intensified image is projected on a see-through medium in the operator’s line of sight. The image intensification tube is located somewhere other than in the operator’s direct line of sight.

Radiometer: An electro-optical device used to measure and quantify the radiant intensity of near-infrared energy that is emitted or reflected from a source or surface area.

Rated drive condition: Rated drive condition(s) are the electrical power state(s) obtained by conformance to the allowable electrical characteristics (voltage, current, pulse width modulation, frequency, etc.) for the various lighting components or systems in meeting specified lighting levels.

Severe Major/Hazardous: Failure Conditions that would reduce the capability of the aircraft or the ability of the crew to cope with adverse operating conditions to the extent that there would be a large reduction of safety margins or functional capabilities; higher workload or physical distress such that the crew could not be relied upon to perform tasks accurately or completely; adverse effects upon occupants.

Shall: In this document, the term “**shall**” is used to indicate requirements. An approved design must comply with every requirement, which can be assured by inspection, test, analysis, or demonstration.

Should: The term “**should**” is used to denote a recommendation or guideline that does not constitute a requirement.

Spectroradiometer: An instrument for measuring the radiant energy from a source at each wavelength throughout the spectrum.

Spot Photometer (or spotmeter): An electro-optical device (typically hand-held) that may be aimed at a surface, much like a camera, to measure the luminance of that surface. The spot photometer typically has a viewfinder, and a circle or square in the viewfinder image defines the area of the surface in which the luminance is measured. Only light within the defining circle or square is measured. With accessory close-up lenses, a suitable spot photometer can measure the luminance of very small areas (such as portions of individual letters or numbers on instruments or displays). A spot photometer is a fundamentally useful instrument for many different types of light measurements.

Stray Light Emissions: Light that is emitted from a location in the crewstation that is intended to emit light, but which is misdirected or reflected in undesirable locations (e.g., light reflected from an aircraft structure or clothing).

Sungun: Typically a 300 watt Halogen lamp and collimator contained in a hand-held enclosure. The sungun is used in conjunction with a luminance meter to perform daylight readability tests.

Transparency: Any transparent screen in front of occupants in an aircraft or vehicle (e.g., side windows, chin bubbles, etc.).

Windshield: A transparent screen in front of the pilot(s) of an aircraft or vehicle usually made of polymers, plastics, or glass.

2 EQUIPMENT PERFORMANCE REQUIREMENTS AND TEST PROCEDURES

2.1 General Requirements

This section lists general equipment requirements. Compliance with these requirements may be shown by demonstration. Specific requirements for which compliance shall be shown by testing are listed in paragraph 2.2 and its sub-paragraphs.

2.1.1 Airworthiness

The manufacturer shall design such equipment, and the installation shall be implemented, such as not to impair the airworthiness of the aircraft.

2.1.2 Intended Function

The equipment shall perform its intended function(s), as defined by the manufacturer, and its proper use shall not create a hazard to other users of the civil airspace.

2.1.3 Federal Communications Commission Rules

All equipment shall comply with the applicable rules of the Federal Communication Commission or the equivalent regulatory body.

2.1.4 Fire Protection

All materials used shall be self-extinguishing except for small parts (such as knobs, fasteners, seals, grommets and small electrical parts) that would not contribute significantly to the propagation of a fire.

2.1.5 Operation of Controls

The equipment shall be designed so that controls intended for proper use during night flight cannot be operated in any position, combination or sequence which would result in a condition detrimental to the reliability of the equipment or operation of the aircraft.

2.1.6 Accessibility of Controls

Controls which do not require adjustment during flight should not be readily accessible to flight personnel.

2.1.7 Effects of Test

The equipment shall be designed so that the application of specified test procedures shall not be detrimental to equipment performance following the application of the tests, except as specifically allowed.

2.1.8 Design Assurance (FHA Assessment)

Complete loss of the Night Vision Goggle or inaccurate information (display of hazardously misleading NVG imagery) from the Night Vision Goggle is classified as severe-major/hazardous, and therefore its design assurance must be extremely remote per SAE ARP-4754.

2.2 Equipment Performance — Standard Conditions

2.2.1 System Optical Performance

2.2.1.1 System Resolution

The system resolution shall be a minimum of 1.0 cycles per milliradian (cy/mrad) on-axis under optimum light conditions using a nominal 100% contrast dark bar on white background resolution target chart. At 14 degrees off-axis, the resolution shall be not less than 0.81 cycles per milliradian. If each monocular has a variable focus objective lens, then it shall focus through infinity, and at the through-infinity mechanical stop shall maintain an on-axis resolution of not less than 0.49 cycles per milliradian. If each monocular has a fixed focus objective lens, then 1.0 cycle per milliradian will be maintained at infinity.

Note: *The numbers mentioned for resolution and system gain were selected to account for all levels of performance in various ambient light conditions. These numbers assure testing reproduceability and less subjective measurement.*

2.2.1.2 System Luminance Gain

At 1 x 10^{-4} footlamberts input light level, the luminance gain shall not be less than 2,500 footlamberts (fL) per footlambert. The output luminance averaged across the full field of view shall not exceed 4 footlamberts. Output brightness uniformity shall be such that the ratio of the maximum to minimum brightness variation over the useful image area shall not exceed 3:1. The ratio of luminance gain between any two channels (See Section 1.2.1.2) shall not exceed 1.5.

2.2.1.3 Field of View

The field of view (FOV) of each monocular (See Section 1.2.1.2) shall be at least 38 degrees horizontal and at least 38 degrees vertical, both horizontal and vertical axes passing through the center optical axis.

2.2.1.4 Magnification

System magnification shall be unity (1X) +/- 2 percent.

2.2.1.5 Distortion

Linear (Radial) Distortion for each monocular shall be no greater than 4 percent across the total field of view. If Trapezoidal (Keystone) Distortion exists, then it shall be no worse than 2 percent.

Gross Distortion and/or shear distortion shall not exist to the extent that they detract from normal performance.

2.2.1.6 Collimation

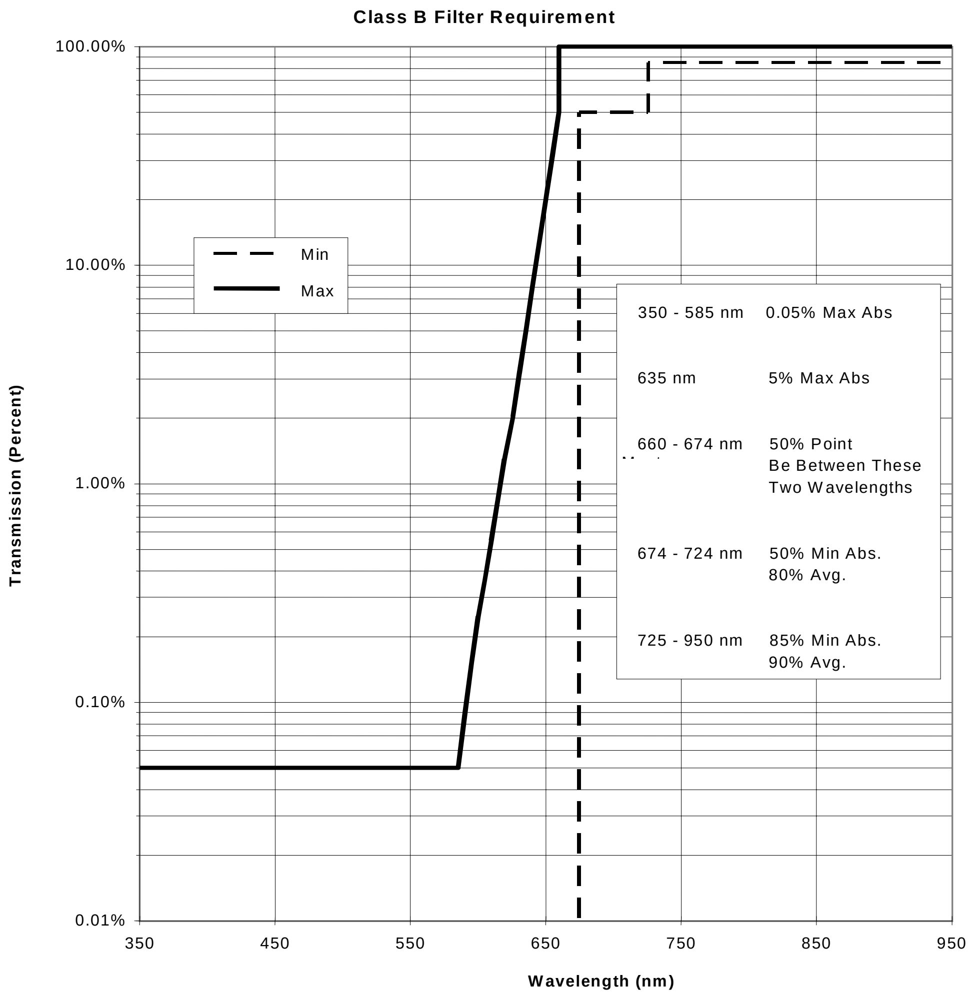
When two parallel beams of collimated light are projected into the objective lenses, the conjugate beams emerging from the two eyepieces shall be parallel to within 1.0 degree eye-convergence and 0.3 degrees eye-divergence and dipvergence. The objectives shall be set at the infinity focus position and both eyepieces (if adjustable) shall be set at zero diopter.

For systems that overlay the intensified image on the unintensified scene, the image of an object point at infinity seen through the center of the intensified channel shall be coincident with the position of the same point seen through the see-through channel within 4 milliradians for each monocular.

2.2.1.7 Objective Lens Characteristics

2.2.1.7.1 Spectral Transmission

The objective lens spectral transmission shall be in accordance with Figure 2-1 (Class B). If a fixed Head-Up Display is intended for use and cannot be seen with the Class B filter, then a filter incorporating a notch component (e.g., Modified Class B) shall be permitted as long as it does not adversely affect performance (See Figure 2-2).



<u>Figure 2-1</u> Class B Objective Lens Transmission

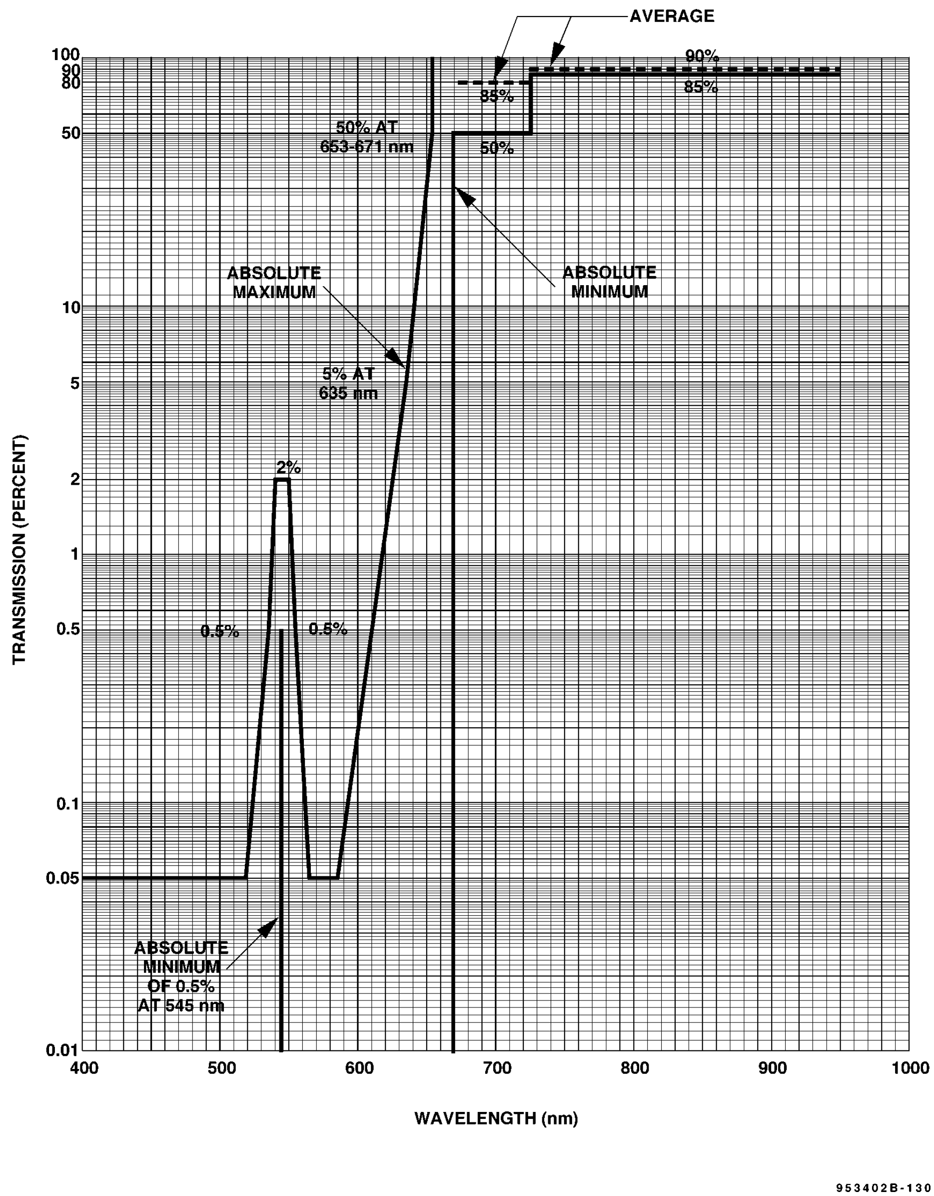


Figure 2-2 Modified Class B Objective Lens Transmission

2.2.1.7.2 Veiling Glare

A high intensity point light source located anywhere between two degrees through 70 degrees outside the field of view shall not cause reflections/glare to be present in the intensified image to the extent that they detract from normal performance.

2.2.1.8 Image Cosmetic Defects

No dark or bright spots shall be discernible within the field of view to the degree that they detract from normal performance. Specifically:

With no light input to the NVG, there shall be no bright spots or discernible field emissions (see Section 2.2.1.8.1) in the image. At low light levels there shall be no bright spots or discernible field emissions brighter or larger than the background scintillations (see Section 2.2.1.8.2) visible in the intensified image. With the light level on the photocathode adjusted to obtain the best contrast, there shall be no bright spots visible in the intensified image.

With the NVG imaging a uniform bright field that fully fills the field of view and adjusted for best spot contrast, dark spots which exceed a contrast (see Section 2.2.1.8.3) of 30 percent of their surrounding areas shall not exceed the sizes and quantities specified in the Table 2-1 below. If the spot is non-circular, the diameter of the circular spot of an equal area shall be used. When the distance between two spots is less than the maximum dimension of either spot, the two spots shall be considered as one circular spot whose diameter is equal to the sum of the maximum dimensions of the two spots plus the amount of separation between them.

With the field of view uniformly illuminated, graininess, channel-to-channel gain variations, or other irregularities (see Section 2.2.1.8.4) shall not be discernible over the useful diameter of the image to the degree that they detract from normal performance.

Table 2-1 Spot Criteria

Size of Spots Milliradians (mR)	Number of spots within 206 mR diameter circle	Number of spots within annulus bounded by two circles 206 to 562mR diameter	Number of spots within annulus bounded by circles 562 mR diameter and total screen diameter
8.5 or larger	0	0	0
5.6 to 8.4	0	1	2
2.8 to 5.5	0	2	3

Note: *The circles on the image screen, defined in the table above, shall be concentric and centered on the optical axis of the assembly. Spots smaller than 2.8 mR shall be ignored.*

2.2.1.8.1 Terms for Image Cosmetic Defects

2.2.1.8.1.1 Field Emission

Discernible field emission is voltage-dependent extraneous emission which appears as bright spots or a pattern that may flicker or appear intermittently on the image screen in one general area. Field emission is voltage dependent and is best observed with a low level of radiation incident on the photocathode.

2.2.1.8.1.2 Scintillations

Scintillations are defined as bright spots that occur on the image screen randomly in space and time.

2.2.1.8.1.3 Contrast

Contrast is defined as $C = \dfrac{B_1 - B_2}{B_1 + B_2}$

where B_1 is the luminance of the background

and B_2 is the luminance of the dark spot.

2.2.1.8.1.4 Image Irregularities

Image irregularities are defined as imperfections in the photocathode or other sources which lead to significantly degraded image quality, including a cosmetic defect manifested as an irregular zone of reduced brightness or contrast in the intensified image, subtending an area larger than that defined in the table above, which reduces or impairs the image definition of the assembly. (Examples of irregularities are: honeycomb, dead optical fibers, shading, and edge glow.)

2.2.1.9 Image Stability

The NVG shall not exhibit any instability in the image such as flickering, flashing or intermittent operation that impacts user performance under all operational conditions. In the event the NVGs are operated in very bright light conditions (i.e., ambient room light and civil twilight), some image resolution degradation is permitted, but the intensifiers shall continue to operate and the NVG shall continue to provide a positive intensified image to the user.

2.2.1.10 Halo Size

Halos shall be no greater than 1.25 mm in diameter at the output of the image intensifier tube.

2.2.1.11 Eyepiece Diopter Range

If adjustable, the minimum diopter focus range shall encompass at least+1.0 to –2.0 diopters. If fixed, the diopter setting shall be between -0.5 and –1.0 diopters.

2.2.1.12 Objective Focus Range

For objective lenses having variable focus, the objective lens focus shall be continuously adjustable from beyond infinity to a close distance no greater than 45 cm. Through-infinity focus capability shall be provided. Fixed focus objective lenses shall be focused at infinity.

2.2.1.13 Eye Relief

2.2.1.13.1 Direct View

Each eyepiece shall have at least a 6.0 mm diameter exit pupil at 25 mm nominal eye relief distance (from the vertex of the rear most optical element to the cornea of the eye at which the full field of view can be seen).

2.2.1.13.2 Projected image

Each eyepiece shall have at least 20 mm nominal eye relief (the distance from the eyepiece to the front of the eye, where the exit pupil is defined as a 1.0 mm point or hole through which the full field of view can be seen).

2.2.2 System Mechanical

2.2.2.1 Mount

The binocular assembly shall attach to and detach from the mount, and shall provide a quick detach mechanism. The binocular assembly or mount/binocular assembly shall be capable of being detached from the helmet or head mount quickly using only one hand. A mounting system shall permit one-handed (either hand with equal facility) operation of adjustments.

2.2.2.2 Automatic Breakaway

Unless crash safety is otherwise demonstrated, an automatic breakaway system shall be incorporated as part of the mount. Automatic breakaway shall not occur during normal flight maneuvers.

2.2.2.3 Mount/binocular Interface

All mount/binocular interfaces shall operate without damage or degradation of performance. If the binocular assembly has both stowed (away from operator's forward field of vision) and operating positions, then the binocular assembly shall lock in place for each position. If the binocular assembly has a stowed position, then the image intensifier tubes shall not be powered when the binocular assembly is in the stowed position, unless it otherwise can be demonstrated that normal performance can be maintained. In addition, when the binocular assembly is restored to its operating position from the stowed position, then the binocular assembly shall maintain its original positional adjustments prior to stowage.

2.2.2.4 Adjustment Capability

Sufficient adjustment capability shall be provided to ensure the exit pupils of the eyepieces can be correctly positioned and the optical axes can be correctly aligned with respect to the user's eyes at all times.

Once properly adjusted, the alignment shall be maintained under all operational conditions.

2.2.2.5 Interpupillary Adjustment

Individual interpupillary adjustment capability shall be provided which allows each monocular to be effectively adjusted independently. In the event there is no interpupillary adjustment mechanism, the size of the exit pupil shall be large enough to accommodate the operator's interpupillary distance. In the event that there is a mechanical adjustment, this shall cover the operator's interpupillary distance, shall be user adjustable without the use of tools, and shall not move inadvertently inflight. A recommended range is 51 to 72 mm.

2.2.2.6 Power Source

The power source shall be designed to provide system integrity commensurate with the failure condition category/classification stated in Section 2.1.8 regarding total loss of external view.

If operator action is required to regain (or switch to) a backup or secondary source in order to avoid total loss of external view, then an annunciation shall be provided to the operator with sufficient time to take the action required without complete loss of power and/or degradation of NVG performance.

2.2.2.7 ON/OFF Switch

It shall be possible for the operator to switch the NVG power supply on and off with the use of one hand. The means provided to switch power on and off shall be located within easy access to the operator, shall not require excessive strength or skill to manipulate, and shall not be prone to inadvertent selection.

2.2.2.8 Finishes

External surfaces shall have a finish to minimize light reflectance and be rust-and corrosion resistant.

2.3 Equipment Performance — Environmental Conditions

The environmental tests and performance requirements described in this subsection are intended to provide a laboratory with a methodology for determining the overall performance characteristics of the NVG under conditions representative of those which may be encountered in actual aeronautical operations.

Unless otherwise specified, the test procedures applicable to a determination of equipment performance under environmental test conditions are contained in RTCA Document DO-160D, *Environmental Conditions and Test Procedures for Airborne Equipment* and Military Standard (MIL-STD) 810(C). General information on the use of DO-160D is contained in Sections 1 through 3 of that document. Also, a method of identifying which environmental tests were conducted and other amplifying information on the conduct of the tests is contained in MIL-STD 810(C) and/or Appendix A of DO-160D. In addition, specific test methods and procedures out of MIL-STD 810(C) that are unique to NVGs are documented throughout this section.

Testing to all the conditions contained in RTCA/DO-160D is not required for each of the performance requirements in Section 2.2. Judgment and experience have indicated that certain of these particular performance parameters are not susceptible to certain environmental conditions and that the level of performance specified in Subsection 2.2 will not be measurably degraded by exposure to these certain environmental conditions.

The specific set of environmental performance requirements identified in this section must be met for all components in the NVG system.

Table 2-2 indicates which of the NVG design requirements specified in DO-160D shall be satisfied under this MOPS in accordance with the environmental test conditions specified in DO-160D. Certain requirements must be met with the system not operating, others with it operating, and others in both the operating and non-operating modes. For each row in Table 2-2, an “X” in the first column specifies that the requirements on the associated row must be met while this system is not operating. An “X” in the second column specifies that the requirements must be met with the system operating.

Table 2-2 Environmental and Test Performance Requirements

System Mode

System Not Operating	System Operating	RTCA DO-160D or equivalent Environmental Conditions
X	X	4.0 Temperature and Altitude
X		5.0 Temperature Variation
X		6.0 Humidity
X		8.0 Vibration
X	X	9.0 Explosion Proofness *(If Required)*
X		12.0 Sand and Dust *(If Required)*
X		13.0 Fungus Resistance *(If Required)*
X		14.0 Salt Spray *(If Required)*
	X	15.0 Magnetic Effect
	X	16.0 Power Input (*If Required)*
	X	20.0 Radio Frequency Susceptibility – Radiated and Conducted
	X	21.0 Emission of Radio Frequency Energy

In addition to the exceptions above, certain environmental tests contained in this subsection are not required for minimum performance equipment unless the manufacturer wishes to qualify the equipment for additional environmental conditions. If the manufacturer wishes to qualify the equipment to these additional conditions, then these tests shall be performed.

The tests listed below are one means to assure proper operation in the aeronautical environments that are envisioned by the committee. Paragraph 1.2 of DO-160D and MIL-STD 810(C) provides additional information on this subject.

2.3.1 Temperature and Altitude Tests (DO-160D, Section 4)

RTCA/DO-160D contains several temperature and altitude test procedures which are specified according to equipment category. These categories are included in paragraph 4.3 of DO-160D. The following subparagraphs contain the applicable test conditions specified in Section 4 of DO-160D.

If the equipment is subjected to the test conditions as specified in MIL-STD 810(C), Method 501, then the following requirements of this standard shall be met.

2.3.1.1 Temperature Variation

The binocular shall not be damaged nor suffer degradation of performance by continuous operation from +52°C to -32°C or after storage from +71°C to -32°C. The binocular, mount and power pack assembly shall not be damaged or suffer degradation of performance by sudden temperature changes from +23°C to +71°C, +71°C to +23°C and from +23°C to -32°C, -32°C to +23°C each transition occurring within five (5) minutes. Soak time at each temperature extreme shall be sufficient to attain temperature stabilization.

2.3.1.2 Temperature and Altitude

The equipment shall be subjected to the test conditions as specified in MIL-STD 810(C), Method 504.1, and the following requirements of this standard shall be met:

The binocular, mount and power pack assembly shall not be damaged nor suffer degradation of performance by continuous operation throughout the operating temperature range at altitudes of sea level to 15,000 feet or the non-operating temperature range at altitudes up to 50,000 feet.

2.3.2 Humidity

The equipment can be subjected to the test conditions as specified in RTCA/DO-160D, Section 6, paragraph 7.2. If the equipment is subjected to the test conditions as specified in MIL-STD 810(C), Method 507.1, then, the following requirements of this standard shall be met:

The binocular, mount and power pack assembly shall not be damaged nor suffer degradation of performance after being subjected to relative humidity greater than 90 percent, with varying temperatures from +21°C to +65°C for exposure up to 120 hours, including conditions wherein condensation takes place in and/or on the equipment during both operating and non-operating conditions. Fogging on the inside of optical elements shall not occur.

2.3.3 Vibration

The equipment can be subjected to the test conditions as specified in RTCA/DO-160D, Section 8. If the equipment is subjected to the test conditions as specified in MIL-STD 810(C), Method 514.2, then, the following requirements of this standard shall be met:

The binocular with mount and power pack assembly shall not be damaged nor suffer degradation of performance when subjected to vibrations within the frequency range and amplitude shown on Figure 2-3 at room temperature (see Section 2.5.5).

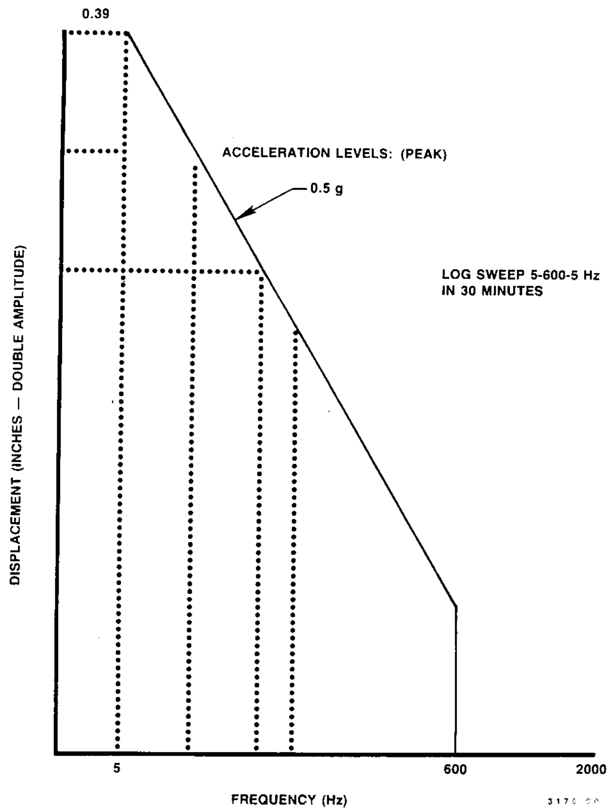


Figure 2-3 Vibration Test

2.3.4 Explosion Test (DO-160D, Section 9)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160D, Section 9. If the equipment is subjected to the test conditions as specified in MIL-STD 810(C), Method 511.1, then, the following requirements of this standard shall be met.

The binocular with mount and power pack assembly shall not cause ignition when operating in an ambient explosive atmosphere environment.

2.3.5 Sand and Dust (DO-160D, Section 12)

The equipment shall be subjected to the test condition as specified in RTCA/DO-160D, Section 12. If the equipment is subjected to the test conditions as specified in MIL-STD 810(C), Method 510.1, then, the following requirements of this standard shall be met.

The NVG with mount and power pack assembly, with objective and eyepiece lenses covered, shall not be damaged and shall operate without degradation after exposure to blowing fine sand and dust particles for 90 minutes on each side.

2.3.6 Fungus (DO-160D, Section 13)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160D, Section 13. If the equipment is subjected to the test conditions as specified in MIL-STD 810(C), Method 508.1, then, the following requirements of this standard shall be met.

The NVG which is free of all salt residue, shall neither support fungus growth, be damaged, nor suffer degradation of performance by the presence of fungus spores or adjacent fungal growth during and after a period of exposure to viable fungal spores for not less than 28 days at a relative humidity of not less than 90 percent and a temperature between +24°C and +31°C.

2.3.7 Salt Spray (DO-160D, Section 14)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160D, Section 14. If the equipment is subjected to the test conditions as specified in MIL-STD 810(C), Method 509.1, then, the following requirements of this standard shall be met.

The binocular with mount and power pack assembly shall not be damaged and shall operate without degradation of performance after a minimum 48 hour exposure to a salt-fog atmosphere of sodium chloride containing (on a dry basis) not more than 0.1 percent sodium iodide and not more than 0.5 percent total impurities, followed by a minimum drying period of 48 hours.

2.3.8 Magnetic Effect Test (DO-160D, Section 15)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160D, Section 15, and the equipment shall meet the requirements of the appropriate instrument or equipment class specified therein.

2.3.9 Emission of Radio Frequency Energy Test (DO-160D, Section 21)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160D, Section 21. If the equipment is subjected to the test conditions as specified in MIL-STD 461, then the following requirements of this standard shall be met.

The NVG with mount and power pack assembly shall not cause interference with other electronic equipment as well as not being affected when operated in proximity to other equipment. The monocular with mount and power pack assembly shall meet the following requirements when operated at light levels from 2 x 10^{-6} fc to 1 x 10^{-2} fc. The light source used for tests need not meet the color temperature requirements, but must provide equivalent night vision radiance as demonstrated by the system's output gain saturation characteristic.

2.3.9.1 Radiated Emissions, Electrical Field

The NVG with mount and power pack assembly shall not radiate E-field emissions in excess of those given in Figure 2-4 Narrowband Emissions Limit and Figure 2-5 Broadband Emissions Limit for the frequency range of 14 kHz to ten times the highest frequency generated within the unit under test. Above 30 MHz, the limits shall be met for both horizontally and vertically polarized waves.

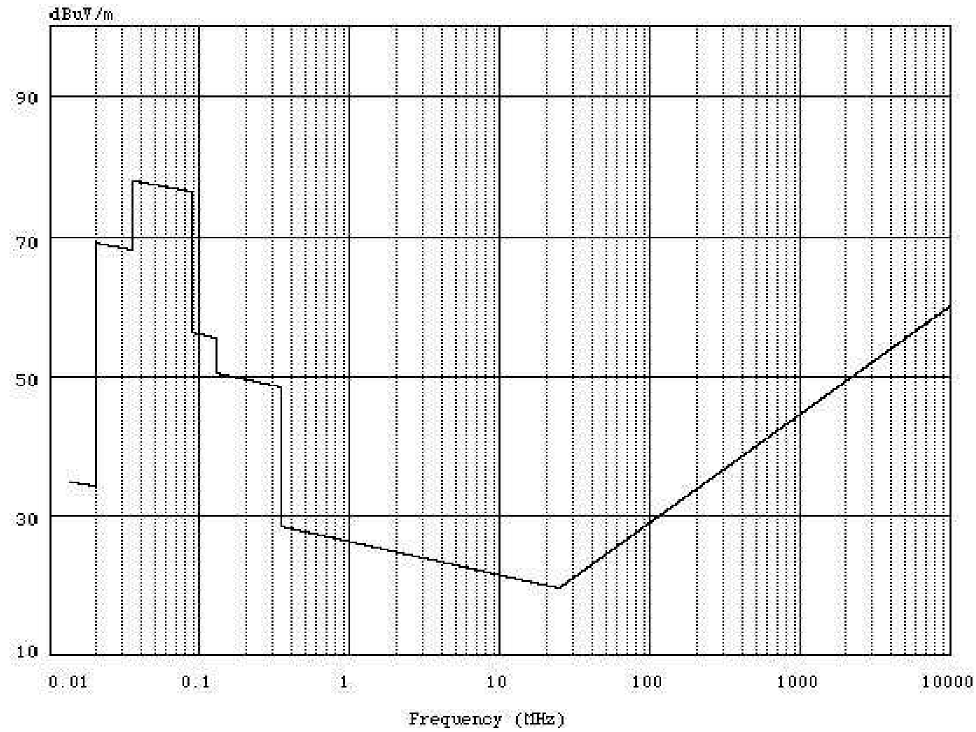


Figure 2-4 Narrowband Emissions Limit

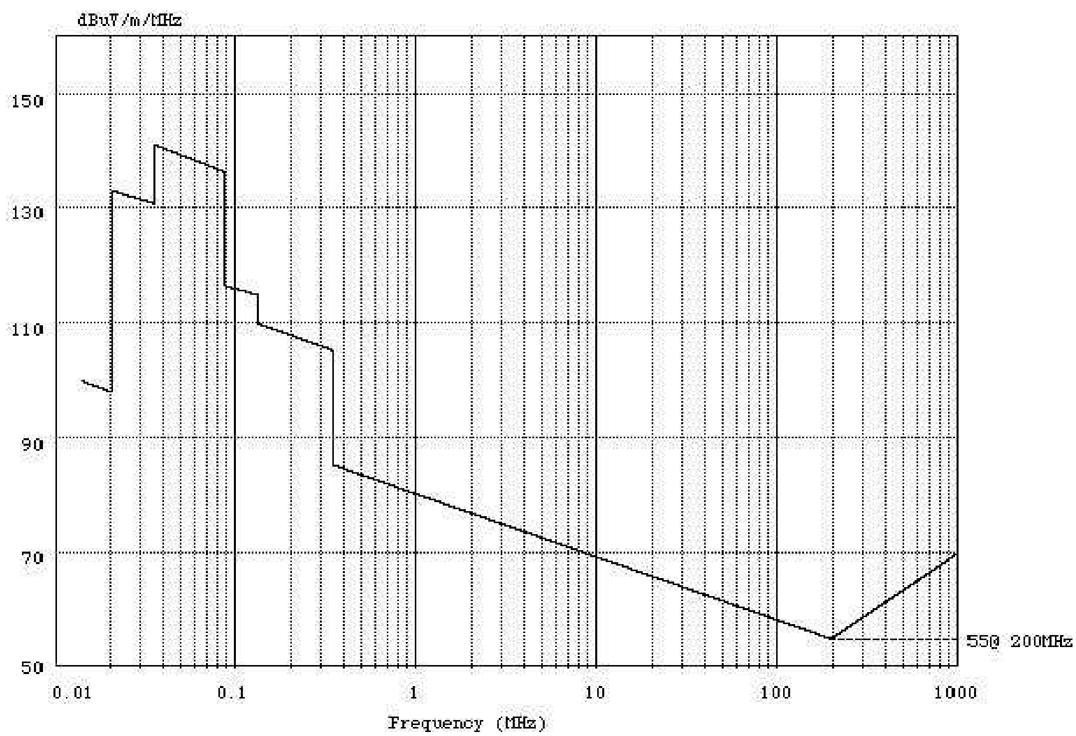


Figure 2-5 Bandpass (Broadband) Emissions Limit

2.3.10 Radio Frequency Susceptibility Test (Radiated & Conducted) (DO-160D, Section 20)

The equipment shall be subjected to the test conditions as specified in RTCA/DO-160D, Section 20. If the equipment is subjected to the test conditions as specified in MIL-STD

461, then the following requirements of this standard shall be met (See Sections 2.3.10.1 and 2.3.10.2).

2.3.10.1 Radiated Susceptibility, Magnetic Field, Spike

The binocular with mount and power pack assembly shall not exhibit damage (see Section 2.5.1), degradation of performance (see Section 2.5.2), or susceptibility (see Section 2.5.3) during or after being subjected to magnetically induced test spikes having the waveform shown in Figure 2-6. The test spikes shall be magnetically induced in both polarizations.

FIGURE 4. Waveform for magnetically induced spike.

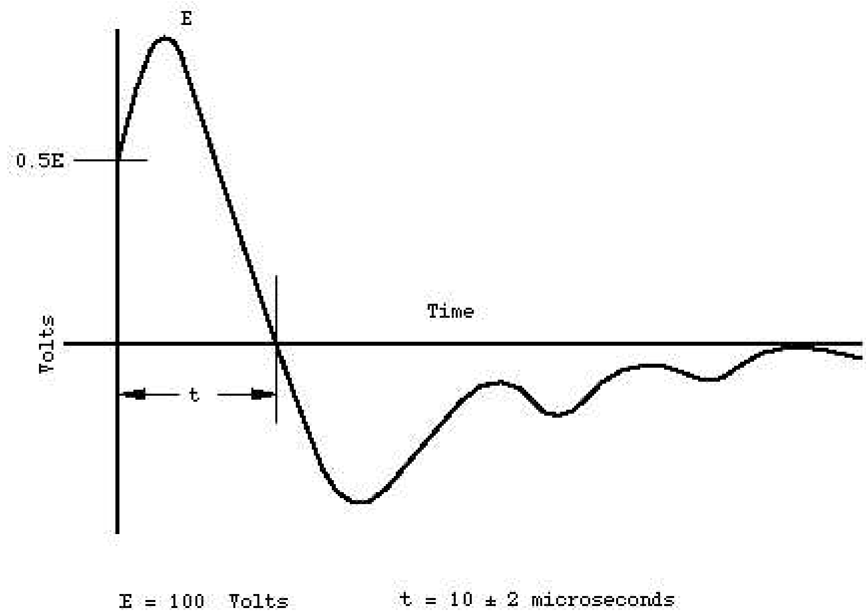


Figure 2-6 Waveform for Magnetically Induced Spike

2.3.10.2 Radiated Susceptibility, Electric Field, 14 kHz to 40 GHz

The NVG with mount and power pack assembly shall not exhibit damage, degradation of performance, or susceptibility during or after being subjected to radiated fields under the conditions listed below. Damage is defined, in this context, as a malfunction to include arcing, corona, flickering, intermittent operation or similar characteristics affecting operation, failure of any hardware, connection or component; or any imperfections that adversely affect the prescribed performance. Degradation of performance is defined as a cumulative change of the measured level of performance which can result in the assembly no longer meeting specified requirements. Cumulative change is that change which occurs either during, or as the result of, any one test or series of tests. Susceptibility is defined as an increase in output brightness greater than 100 percent or a decrease greater than 35 percent from a steady output condition.

a. The radiated field levels shall be 100 V/m through all frequencies from 10 kHz to 40 Ghz or a Government approved lower radiated field which would include an operator in the test field.

b. The radiated fields shall be performed in both vertical and horizontal polarizations. Circular polarized waves are not acceptable.

c. The radiated fields shall be modulated with amplitude modulation (AM) @ 50 percent 1 kHz tone.

d. The unit under test shall be subjected to the radiated fields while positioned in the following orientations:

(1) Horizontal 0° – Objective lens facing source of radiation.

(2) Horizontal 270° – Rotated clockwise around the vertical axis 270° from horizontal 0°.

(3) Vertical 90° – Rotated 90° downward from horizontal 0°.

2.4 Equipment Test Procedures

2.4.1 Definitions of Terms and Conditions of Test

All test equipment used shall be within its calibration period. Unless otherwise specified herein, operational performance requirements shall be verified under the following conditions:

a. The radiation source used shall be a tungsten filament lamp operated at a color temperature of 2856 Kelvin (K) ± 50K or suitable equivalent.

b. The resolution target shall be a nominal 100 percent contrast resolution target having black bars on a clear background

c. Tolerances on specified radiation levels shall be ± 10 percent.

d. Meters used for monitoring lamp current and voltage shall have an accuracy of ± 0.25 percent.

e. Neutral density filters used in test equipment shall have transmission characteristics within 10 percent of the nominal filter transmission for wavelengths from 0.35 to 1.0 micrometer.

f. Tests shall be performed at these room conditions: +23°C, +10°C/-2°C.

g. Test chambers for environmental temperatures tests shall maintain the temperature within ± 2.0°C.

h. Tests shall be performed using each power source that will be qualified for use (i.e., batteries, external power, etc.that will be commonly used with the intended equipment).

2.4.2 Required Test Equipment

a. Photometer – An electro-optical device used to measure and quantify the luminous intensity of visible light that is emitted from a source or reflected from a surface area.

b. Collimator – An optical instrument consisting of a well-corrected objective lens with an illuminated slit or reticle at its focal plane.

c. Diopterscope

d. Traveling telescope – A measuring instrument composed of a telescope and reticle, and mounted on a calibrated slide mechanism.

e. Filar eyepiece – measuring eyepiece with a screw-micrometer-driven crosshair used to measure the size of the image.

f. Vernier scale – a phase-shift scale.

g. Hoffmann ANV-126 test set or equivalent – test set that provides optical and electronic means to test NVG performance at multiple light levels.

h. Resolution target

2.4.3 Detailed Test Procedures

The test procedures set forth below constitute a satisfactory method of determining required performance. Although specific test procedures are cited, it is recognized that other methods may be preferred. Such alternate methods may be used if the manufacturer can show that they provide at least equivalent information. Therefore, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures.

2.4.3.1 Operation During Environmental Tests

When operation during environmental tests is required the assembly shall as a minimum successfully pass the requirements of Section 2.2.2.7, "ON-OFF switch." Should an assembly indicate an operational failure after the last environmental test it shall be the manufacturer's responsibility to determine and prove where (in which environmental test condition) the operational failure occurred.

Table 2-3 defines four (4) environmental test performance categories in terms of the set of parameters to be measured or tested for each category and the associated requirement paragraph number. For example, Category 3 tests consist of testing the Mount IAW Section 2.2.1 and testing the ON-OFF switch IAW Section 2.2.2.7. Category 2 tests consist of both of those tests plus measurement of resolution IAW Section 2.2.1.1 and measurement of eyepiece diopter range IAW Section 2.2.1.10.

Table 2-3 Environmental Performance Test Categories

Parameter	Requirement paragraph	Category			
		1	2	3	4
Resolution (on-axis only)	2.2.1.1	X	X		
Collimation	2.2.1.6	X			
Objective focus range	2.2.1.11	X			
Eyepiece diopter range	2.2.1.10	X	X		
Mount	2.2.1	X	X	X	
Automatic breakaway	2.2.2.2	X			
ON-OFF switch	2.2.2.7	X	X	X	X

2.4.3.2 Operational Tests

For the purpose of operational testing, the NVG shall be defined as the binocular, mount, and power pack unless otherwise stated.

2.4.3.2.1 System Resolution

Place a resolution target in the infinity focal plane of a test collimator. Adjust target luminance to obtain maximum resolution. Look into the collimator with one channel and obtain best focus. Determine smallest, i.e., highest spatial frequency test pattern that can be accurately resolved. Repeat for infinity stop. Determine the linear spatial frequency of test patterns resolved, “RA”, in cy/mm. Calculate NVG resolution in cycles per milliradian (cy/mrad), “R”,as:

R = RA * (EFL) mm/1000.

Where R is resolution in cy/mrad
RA is linear spatial frequency in cy/mm
EFL is collimator effective focal length in mm

Repeat tests for other channels. Rotate channel approximately two-thirds the channel semi-field of view off-axis and read resolution in each monocular. Failure to meet requirements of Section 2.2.1.1 shall constitute failure of this test.

2.4.3.2.2 System Luminance-Gain

Place a 2856K, extended Lambertian light source at least 28cm in front of the NVG objective lens. The extended Lambertian source shall be large enough to cover the field of view of the channel. Using a calibrated photometer, the extended light source shall be set to a luminance of not greater than 1 x 10^{-4} footlambert. Activate the binocular looking at the extended source, and read output through each eyepiece using a photometer calibrated to read with a 5 mm entrance pupil.

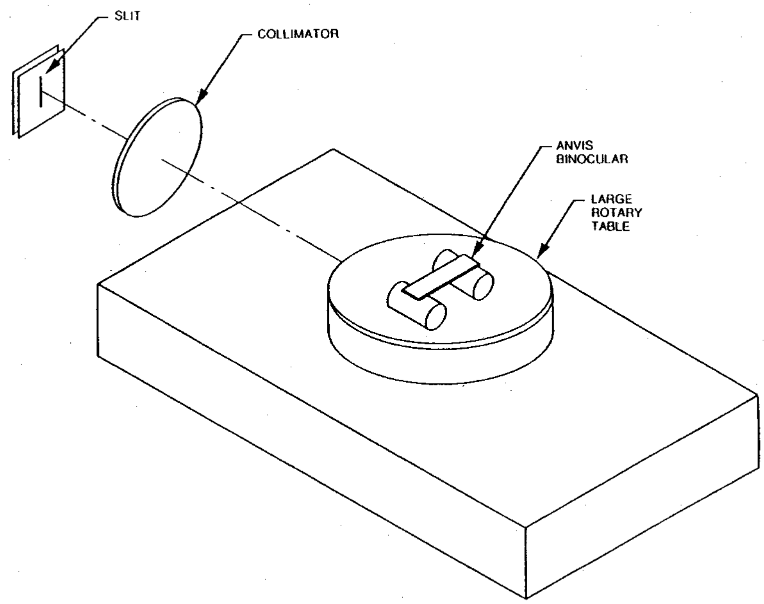
The 5.0 mm entrance pupil shall be placed on the optical axis of the photometer and the optical axis of the monocular under test at the specified eye relief distance**.** Gain is calculated for each monocular as:

$$\text{Gain} = \frac{\text{Output luminance}}{\text{Input luminance}}$$

Failure to meet requirements of Section 2.2.1.2 shall constitute failure of this test.

2.4.3.2.3 Field of View (FOV)

Place the binocular in the setup shown in Figure 2-7. Set the slit target luminance to 1 x 10^{-4} footlambert or less. Looking through a monocular, rotate the table to the left until the edge of the field is located. Record this field angle. Rotate the table right until the slit is at the edge of the field. Record this angle. The difference between the two recorded angles is the FOV. Repeat for the other monocular. Failure to meet requirements of Section 2.2.1.3 shall constitute failure of this test.



Field of view test setup.

Figure 2-7 FOV Test Set-Up

2.4.3.2.4 Magnification (M)

Place the binocular in the test setup shown in Figure 2-8 and place the diopterscope (which is set to infinity) 25 mm behind a monocular eyepiece. Looking through the diopterscope mounted on a small rotary table, superimpose the slit image and the scope crossline by rotating the small table.

Record the reading from the vernier scale of the small rotary table. Rotate the large rotary table to an angle θ, on either side of the optical axis. Measure the amount of small table rotation required to superimpose the image and diopterscope reticle again and record the difference angle α. The difference between the second reading and first reading determines the real angle of image rotation θ_r. Repeat these steps with the image positioned on the opposite side of the optical axis (θ_r', α'). The average tan is used to calculate the magnification M:

$$M = \frac{\overline{\tan\alpha}}{\overline{\tan\theta}}$$

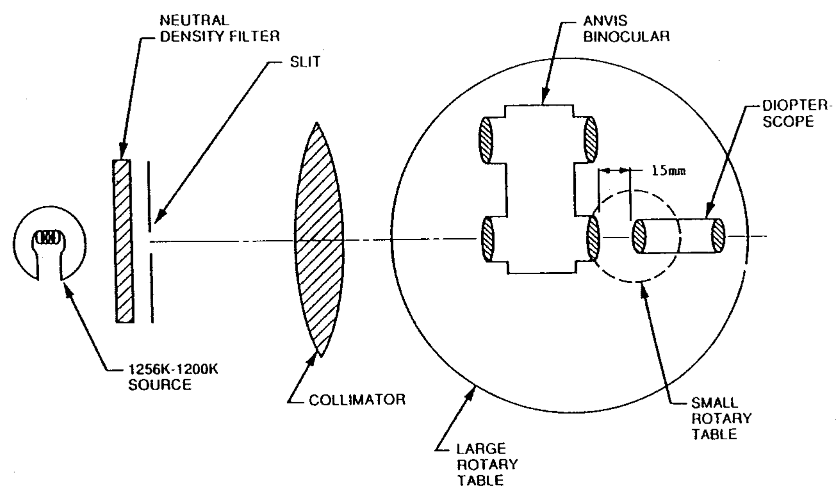
where

$$\overline{\tan\theta} = \frac{(\tan\theta_r + \tan\theta_r')}{2}$$

$$\overline{\tan\alpha} = \frac{(\tan\alpha + \tan\alpha')}{2}$$

θ = semifield angle

Repeat for the other monocular. Failure to meet requirements of Section 2.2.1.4 shall constitute failure of this test.



Magnification test setup.

<u>Figure 2-8</u> Magnification Test Set-Up

2.4.3.2.5 Distortion

Calculate distortion for each monocular using data from Section 2.4.3.2.4. The distortion at any point is calculated as:

$$D = \frac{\left(\tan \phi_n - M \tan \theta_n\right)}{M \tan \theta_n} \times 100$$

where M = magnification of the system. Data shall be recorded for several field angles, including the largest semifield angle. Failure to meet the requirements of Section 2.2.1.5 shall constitute failure of this test.

If trapezoidal distortion is detected, then calculate distortion for each test point using the following formula: $\Delta r/R$,

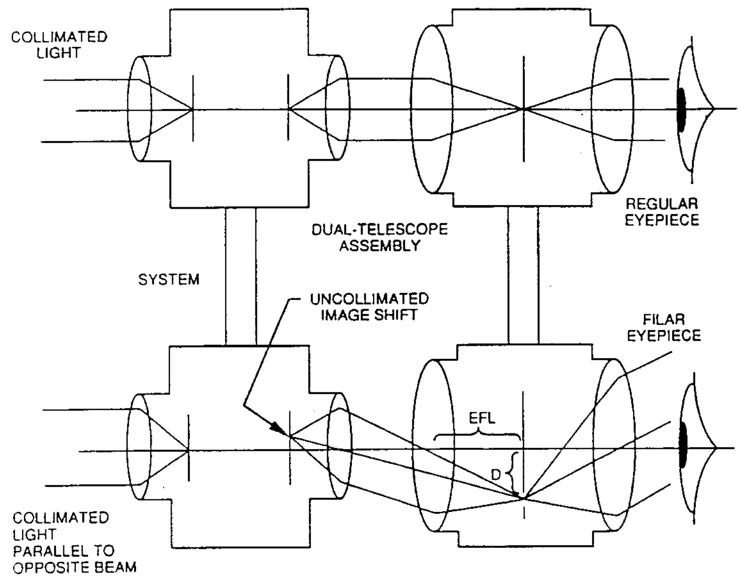
where $\Delta r = (\Delta x^2+\Delta y^2)^{1/2}$ and $R = (X^2+Y^2)^{1/2}$

X = coordinate of the point on the x-axis taken from the center of the display
Y = coordinate of the point on the y-axis taken from the center of the display
$\Delta x = x - X$ and $\Delta y = y - Y$,
x = coordinate of the image on the x-axis and y = coordinate of the image on the y axis

Note: *On-Axis designs should not need to perform trapezoidal distortion calculation.*

2.4.3.2.6 Collimation

With two parallel beams of light entering the binocular objectives (or one beam large enough to fill both objectives) as shown in <u>Figure 2-7</u>, use a traveling telescope fitted with a filar eyepiece to measure the difference between the emergent beams (See <u>Figure 2-9</u>). Failure to meet requirements of Section 2.2.1.6 shall constitute failure of this test.



Collimation test setup.

Figure 2-9 Collimation Test Set-Up

2.4.3.2.7 Objective Lens Characteristics

2.4.3.2.7.1 Spectral Transmission

Inspect the manufacturer's data on the objective lens and ensure it meets Section 2.2.1.7.1.

2.4.3.2.7.2 Veiling Glare

Inspect the manufacturer's data on the objective lens and ensure it meets Section 2.2.1.7.2.

2.4.3.2.8 Image Cosmetic Defects

Spot sizes shall be verified against the chart in the Hoffmann ANV-126 (or equivalent) test set to ensure compliance with Section 2.2.1.8.

2.4.3.2.9 Image Stability

The requirements of Section 2.2.1.9 shall be verified by demonstration in all operational lighting conditions.

2.4.3.2.10 Halo Size

Halos are measured at the output of the image intensifier assembly. The standard test focuses a 0.35 mm diameter light spot (usually produced by projecting light through an aperture) on the photocathode. A 0.625 mm diameter halo would actually be made up of a 0.35 mm diameter spot in the center surrounded by an annulus with an inner circle at 0.175 mm radius and the outer circle at 0.5 mm radius. Zero halo would actually be 0.35 mm diameter under this test. The illumination in the spot shall be not less that 5×10^{-4} fc. The illumination incident on the photocathode in the region outside the 0.350mm spot shall not exceed $5 \text{ X } 10^{-7}$ fc.

2.4.3.2.11 Eyepiece Diopter Range

Place a resolution target in the infinity focal plane of a test collimator. Adjust the target luminance for maximum system resolution. Set each monocular objective focus to infinity. Look into each monocular eyepiece with a diopterscope of at least 3 power and measure the diopter focus range. Verify the diopter focus range meets the requirements of Section 2.2.1.11 or it shall constitute failure of this test.

2.4.3.2.12 Objective Focus Range

2.4.3.2.12.1 Variable Focus Objective Lens

Place a resolution target in the infinity focal plane of a test collimator. Adjust target luminance to obtain maximum resolution. Place a second resolution target, illuminated to the same light level, beside the front aperture of the collimator and 45 cm in front of the binocular objectives. Place the binocular in its holding fixture with one monocular objective looking into the collimator. Using objective focus ring rotation, determine if the infinity focus and the 45 cm focus will achieve the minimum specified resolution in cy/mrad at both focus positions. Repeat for the other monocular. Using objective focus ring rotation, determine if focus through infinity is possible. Repeat for the other monocular. Failure to meet requirements of Section 2.2.1.12 shall constitute failure of this test.

2.4.3.2.12.2 Fixed Focus Objective Lens

Place a resolution target in the infinity focal plane of a test collimator. Adjust target luminance to obtain maximum resolution. Place the binocular in its' holding fixture with one monocular objective looking into the collimator. Determine if the infinity focus achieves the minimum specified resolution in cy/mrad. Repeat for the other monocular. Failure to meet the requirements of Section 2.2.1.12 shall constitute failure of the test.

2.4.3.2.13 Eye Relief

Inspect the manufacturer's data on the objective lens and ensure it meets Section 2.2.1.13.

2.4.4 System Mechanical

2.4.4.1 Mount

Compliance with Section 2.2.2.1 shall be verified by demonstration**.**

2.4.4.2 Automatic Breakaway (If Applicable)

With the mount and binocular mounted on a secured helmet or equivalent, apply a force of 9 times the weight of the binocular in a direction away (straight ahead at zero degrees) from and horizontal (parallel to the helmet's x-axis). The binocular shall not break away from the mount for a period of 15 seconds. Apply a force of 15 times the weight of the binocular in a direction away from and horizontal to the helmet or equivalent. The binocular shall break way from the mount in less than 1 second. Failure to meet these requirements shall constitute failure of this test.

2.4.4.3 Mount/Binocular Interface

The NVG, as defined by paragraph Section 1.2.1-1.2.1.7, shall be tested for compliance to Section 2.2.2.3. If the binocular has a locking mechanism, move the binocular from the operational position to the stowed position using an appropriate force gage six times assuring that the position change can only take place when the lock release button is depressed and the binocular remains in the mount at all times. With the locking mechanism engaged, ensure that the binocular assembly will not move from the operating to the stowed position (and vice versa) for a force less than or equivalent to that required for breakaway to occur, reference Section 2.4.4.2. Then provide power to the image tubes and, if applicable, assure that the image tubes cut off and remain off when in the stowed position and turn on when in the operational position, as appropriate to the requirements of Section 2.2.2.3.

2.4.4.4 Adjustment Capability

Compliance with Section 2.2.2.4 shall be verified by demonstration**.**

2.4.4.5 Interpupillary Adjustment

Compliance with Section 2.2.2.5 shall be verified by demonstration.

2.4.4.6 Power Source

Compliance with Section 2.2.2.6 shall be verified by demonstration.

2.4.4.7 ON/OFF Switch

Compliance with Section 2.2.2.7 shall be verified by demonstration.

2.4.4.8 Finishes

Compliance with Section 2.2.2.8 shall be met through inspection.

2.5 Environmental Tests

The following environmental test procedures reference Military Standard (MIL-STD) 810(C). When RTCA Document DO-160D environmental conditions are met, then the test procedures from that document shall be adhered to. For the purpose of environmental testing, the NVG shall be defined as the binocular, mount, and powerpack unless otherwise stated. Each NVG selected for testing shall, following the last test performed upon it, demonstrate its ability to perform properly after being subjected to all the post-environmental test required for it. For the purpose of post-environmental testing, "perform properly" is defined as the ability to successfully complete the category 1 tests listed in Table 2-3.

2.5.1 Temperature and Altitude Tests

2.5.1.1 Temperature Variation

2.5.1.1.1 High Temperature

The NVG shall be tested in accordance with MIL-STD-810(C), Method 501.1, Procedure 11. When inspections or operational tests are required, it is permissible to open the chamber door to conduct the test provided that the door does not remain open for greater than five (5) minutes per unit. Failure to satisfactorily perform the operation of Table 2-3, category 2, during this test, and upon completion of the test, shall constitute failure of this test.

2.5.1.1.2 Low Temperature

The NVG shall be tested in accordance with MIL-STD-810(C), Method 502.1, Procedure I. When inspections or operational tests are required, it is permissible to open the chamber door to conduct these tests provided that the door does not remain open for greater than five (5) minutes per unit. Failure to satisfactorily perform the operation of Table 2-3, category 2, during this test, and upon completion of this test shall constitute failure of this test.

2.5.1.2 Temperature-Altitude

The NVG shall be tested in accordance with MIL-STD-810(C), Method 504.1, with modified temperature and altitude conditions. Those conditions are: Operating temperature

+52°C and -32°C, non-operating temperature +71°C and -35°C. Operating altitude 15,000 feet, storage altitude 50,000 feet. The following test sequence shall be followed:

MIL-STD-810(C) Equipment Procedure		Altitude (feet)	Temperature (C)	Operating Test
Category	Step			
3	1-b	Site	-32	No
3	3	15,000	-32	Turn ON, check for proper operation
5	3	50,000	-35	No
3	5	Site	Site	No
3	6	Site	+52	No
3	10	15,000	+52	Turn ON, check for proper operation.
				No
				No
6	10	50,000	+71	
6	15	Site	Site	

Table 2-4 Test Sequence

Failure to satisfactorily perform the listed operating test in preset "ON" position during test or the operations of Table 2-3, category 2 after the test shall constitute failure of this test.

2.5.2 Humidity

The NVG shall be tested in accordance with MIL-STD810(C), Method 507.1, Procedure I. Step 5 and 6 shall be followed as modified herein. After the fourth cycle, run the test of Table 2-3, category 3, with chamber door open. Run the tests of Table 2-3, category 3 before and after humidity test. Failure to meet the requirements of Section 2.3.2 or the tests prescribed herein shall constitute failure of this test.

2.5.3 Vibration

The NVG system consisting of the binocular assembly, the mount, and the power source shall be mounted to a test fixture maintaining the same dimensions and geometry as a helmet or equivalent. This assembly shall be rigidly mounted to the vibrator armature and tested as follows and at the vibration levels contained in Figure 2-3. MIL-STD-810(C), Method 514.2, Procedure 1, Category C shall be followed as modified herein. Run the tests of Table 2-3, category 2 after vibration. Failure to meet requirements of Section 2.3.3 or the above tests shall constitute failure of this test.

a. With the NVG mounted on a vibration table such that the axis of vibration is the X-axis, defined as along the pivot adjustment shelf (PAS), stabilize the NVG at ambient temperature. With the NVG operating, vibrate the NVG over the frequency range of 5-600-5 Hz according to Figure 1 in a period of 30 minutes. The NVG shall then be vibrated for 5 minutes at each critical resonant dwell frequency, as defined below.

   The critical resonant dwell frequencies shall be determined by measuring the response of a test system at the center of either monocular housing and any other critical locations. The frequencies at which response amplitudes exceed or equal twice the input shall be critical resonant frequencies and used for each dwell.

b. Repeat with the test item oriented in the Y (fore and aft axis) and then Z (vertical) axis.

2.5.4 Explosion Test

The NVG shall be tested in accordance with MIL-STD-810(C), Method 511.1, Procedure 1. When operation is required, run the tests of Table 2-3, category 4. Failure to meet requirements of MIL-STD-810(C), Method 511.1 and Section 2.3.4 shall constitute failure of this test.

2.5.5 Sand and Dust

The NVG shall be tested in accordance with MIL-STD-810(C), Method 510.1, Procedure I. At the end of the test, before the item is cleaned per Procedure I, run the tests of Table 2-3, category 2. Clean the item of excess dust and run the tests of Table 2-3, category 1. Failure to meet requirements of Section 2.3.5 shall constitute failure of this test.

2.5.6 Fungus

The NVG shall be tested in accordance with MIL-STD-810(C), Method 508.1, Procedure I, non-operating. Failure to meet requirements of MIL-STD-810(C) and Section 2.3.6 shall constitute failure of this test.

2.5.7 Salt Spray

The NVG shall be tested in accordance with MIL-STD-810(C), Method 509.1, Procedure I. After the first 48-hour period, open the chamber door and run the test of Table 2-3, category 2. After the next 48-hour period, run the tests of Table 2-3, category 1. Failure to meet requirements of MIL-STD-810(C), Method 509.1 and Section 2.3.7 shall constitute failure of this test.

2.5.8 Emission of Radio Frequency Energy

The NVG system under test shall consist of a binocular assembly and battery Pack Mounted to a helmet. The system shall be tested for the requirements specified in Section 2.3.9 in conformance with the test method of MIL-STD-461. Failure to meet the requirements of Section 2.3.9 shall constitute a failure of this test.

2.5.8.1 Radiated Emissions

The NVG shall fail the test if the emitted radiation exceeds the limits of Section 2.3.9.

2.5.9 Radio Frequency Susceptibility (In addition, reference MIL-STD 461, RS03) Testing

The RS03 test shall be performed under three (3) different test conditions, with the NVG oriented as follows:

a. Horizontal 0 degrees – Objective lenses facing source of radiation.

b. Horizontal 270 degrees – Rotated clockwise around the vertical axis 270 degrees from horizontal 0 degrees.

c. Vertical 90 degrees – Rotated 90 degrees downward from horizontal 0 degrees.

NVG shall be subjected to E-Field level of 100v/m in both horizontal and vertical polarization, over the frequency range specified in Section 2.3.10. If a failure (as defined in Section 2.3.10) occurs within a given frequency range for a set of test conditions, the test conditions shall be noted. During RS03 testing, the output luminance shall be monitored continuously and recorded for each monocular assembly. The NVG shall be tested in both a linear operating and in an ABC region. In performing RS03 testing, the illumination on the photocathode does not have to be a color temperature of 2856K. However, the illumination levels shall provide the linear and ABC operating modes as referred to above. Failure to meet the requirements of Section 2.3.10 shall constitute a failure of this test.

3 NVIS LIGHTING COMPONENT PERFORMANCE REQUIREMENTS AND TEST PROCEDURES

This section defines the minimum acceptable level of performance for NVIS lighting components. General guidance has also been provided where appropriate. The use of lighting components that meet the requirements defined in this section will reduce the risk that the lighting system will not comply with the requirements defined in Section 4. Lighting components that do not meet requirements defined in this section may still be able to comply with the requirements defined in Section 4. In this case, if an alternate means of compliance to this section is utilized, then it shall be documented and demonstrated. Recommendations made within this section (denoted by the word “should”) are **one acceptable means** of assuring that the component will perform its intended function under any foreseeable operating condition.

3.1 General Requirements

This section lists general component requirements. Compliance with these requirements may be shown by demonstration. Specific requirements, for which compliance shall be shown by testing, are listed in paragraph 3.2 and its sub-paragraphs.

3.1.1 Airworthiness

The manufacturer shall design such components, and the installation shall be implemented, such as not to impair the airworthiness of the aircraft.

3.1.2 Intended Function

The component shall perform its intended function(s), as defined by the manufacturer, and its proper use shall not create a hazard to other users of the civil airspace.

3.1.3 Federal Communications Commission Rules

All components shall comply with the applicable rules of the Federal Communication Commission or the equivalent regulatory body.

3.1.4 Fire Protection

All materials used shall be self-extinguishing except for small parts (such as knobs, fasteners, seals, grommets and small electrical parts) that would not contribute significantly to the propagation of a fire.

3.1.5 Operation of Controls

The component shall be designed so that controls intended for use during night flight cannot be operated in any position, combination or sequence which would result in a condition detrimental to the reliability of the component or operation of the aircraft. Design consideration shall be given to the prevention of inadvertent operation of controls that would cause a hazard to operators during aided or unaided flight.

3.1.6 Accessibility of Controls

Controls, which do not require adjustment during flight, should not be readily accessible to flight personnel.

3.1.7 Effects of Test

The component shall be designed so that the application of specified test procedures shall not be detrimental to component performance following the application of the tests, except as specifically allowed.

3.1.8 Design Assurance (FHA Assessment)

Complete loss of the NVIS lighting system is classified as major, and therefore its loss shall be improbable. Inadvertent/un-commanded actuation of NVG incompatible light sources is classified as severe-major/hazardous, and therefore must be extremely remote. Design consideration shall take into account component failures and system design shall be failsafe.

3.2 Component Performance — Standard Conditions

3.2.1 Installation

All lights shall be oriented and all components shall be so indexed or designed such that the lights are properly aimed when lighting system maintenance is performed.

3.2.2 System Integration

The number of different types of lighting components and power sources should be kept to a minimum in any given aircraft installation. All lighting components on a single lighting control shall track together in luminance over the entire range of adjustment.

3.2.3 Lighting Provisions

The design and location of the lighting components shall optimize visual performance and minimize adverse effects on NVG performance. The components shall not cause objectionable direct or indirect glare and/or reflections, which interfere with the operator’s aided or unaided vision.

3.2.4 Lighting Power

The lighting system shall be designed to operate from aircraft power. The secondary lighting system, if installed, shall be powered by an independent electrical source separate from the primary lighting system in order to maximize system reliability.

3.2.5 Lighting Control Location and Actuation

Lighting controls shall allow control of the intensity of all NVIS lighting subsystems. Continuous intensity controls of any lighting component should allow intensity to be smoothly variable from full bright (maximum rated drive condition for the lighting component) to full dimmed (reduced drive condition resulting in barely perceptible luminance of lighting components) plus “off”. Lighting units related by function or area should have common controls. The design shall preclude inadvertent actuation of non-NVG compatible lighting.

In addition, if a lighting component has a dedicated luminance control (or controls), then the control (or controls) shall provide continuously variable intensity for all anticipated lighting conditions.

3.2.6 Daylight Legibility and Readability

Each lighted component shall be daylight readable to the operator in all probable lighting conditions. When a lighted component has been modified, the daylight readability and attensity (ability to attract attention) shall be maintained.

3.2.7 Nighttime Readability

During night operations, the lighting system shall provide the operators with a capability to rapidly and accurately obtain required crew-station information with unaided vision.

The lighting system shall not have an adverse effect on external unaided night vision or on the operator's capability to obtain required information external to the aircraft while employing NVGs.

3.2.7.1 Luminance and Illuminance

The luminance or illuminance levels of all lighted components, to include multi-function, and alphanumeric displays shall be adjustable to provide adequate attensity (ability to attract attention) and readability for all anticipated night lighting conditions. The luminance or illuminance level between lighted components shall be adequately balanced at operational intensity levels, such that all information on lighted components is easily read with the unaided eye, while at the same time no lighted component constitutes a bright visual distraction. Recommended luminance and illuminance levels for cockpit and cabin lighting are provided in Appendix E, paragraph 7.

3.2.8 Chromaticity and NVIS Radiance Limits

Chromaticity and NVIS radiance of the aircraft lighting shall not adversely affect NVG performance. Suggested radiance limits and associated luminance levels for such lighting are listed in Table 3-1 and Figure 3-1. These limits, if properly employed, should provide color discrimination and perceptibility while not adversely affecting NVG performance. Recommended luminance and/or illuminance levels for installed lighting are provided in Appendix E, "Recommended Design Practices for NVIS lighting". The suggested colors (designated as "NVIS WHITE", "NVIS GREEN A", "NVIS GREEN B", "NVIS YELLOW" and "NVIS RED") of illuminated information (alphanumeric and symbolic) on instruments, controls, control panels and on illuminated areas in designated crew station and compartment areas are listed in Table 3-1. The CIE 1976 chromaticity coordinates and tolerances associated with those colors are shown on Figure 3-1. Radiance and chromaticity measurements shall be performed for all anticipated lighting conditions, to include daylight, dusk, night unaided and NVG aided, as appropriate.

Note: *A limited number of light sources may slightly exceed the NVIS Radiance limits shown in Table 3-1 without adversely affecting the overall NVIS lighting system compatibility (See Section 4 Integrated NVIS Installation Performance). In such an event, careful consideration shall be given to the quantity, location and NVIS radiance of such sources.*

<u>Table 3-1</u> NVIS Lighting Chromaticity, Luminance and NVIS Radiance Requirements for Class B, Type 1 or Type 2 NVG

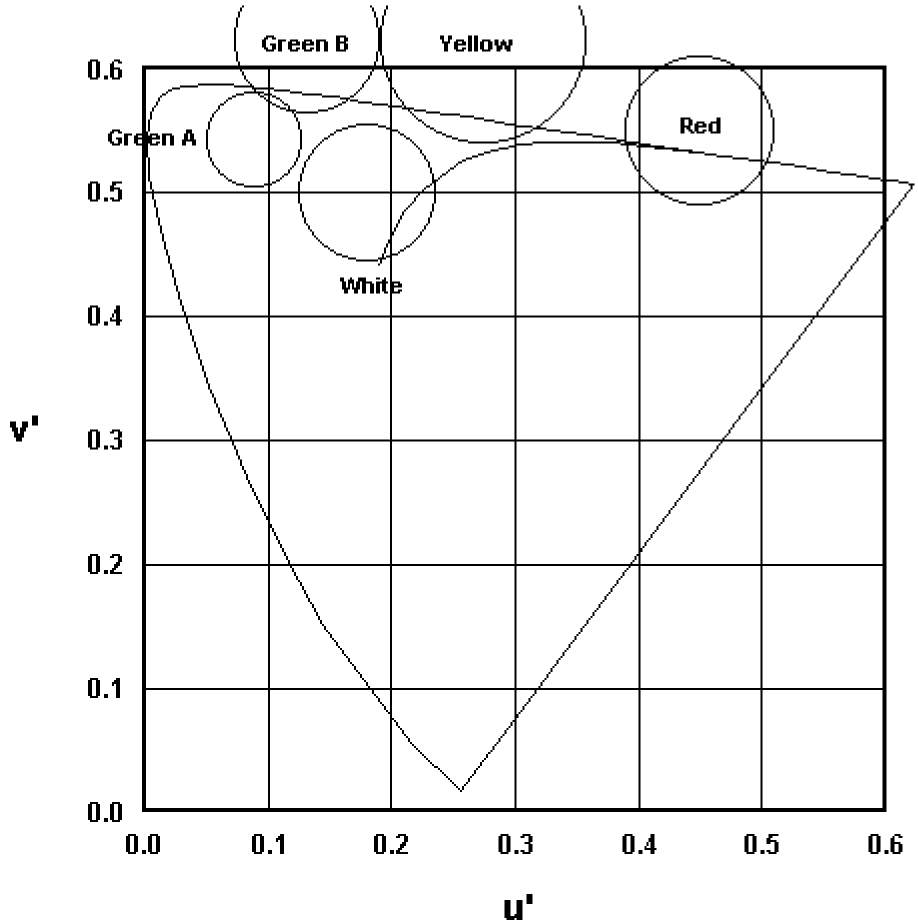
Lighting component(s)				
			NVIS Radiance (Nr_B)	
	NVIS Color (1)	Luminance (fL) Component for Test	Minimum	Maximum
Primary	Green A, Green B, or White (2)	0.1	---	1.7x10E-10
Secondary	Green A, Green B, or White (2)	0.1	---	1.7x10E-10
Cabin Lighting	Green A, Green B, or White (2)	0.1	---	1.7x10E-10
Master Caution Signal	Amber/Yellow	15.0	4.7x10E-8 (3)	1.4x10E-7
Caution Signal	Amber/Yellow	0.1	---	1.7x10E-9
Advisory Signal	Green A, Green B, or White (2)	0.1	---	1.7x10E-10
Master Warning Signal	Red	15.0	4.7x10E-8 (3)	1.4x10E-7
Warning Signal	Red	15.0	4.7x10E-8 (3)	1.4x10E-7
Emergency Exit Lighting	---	15.0	4.7x10E-8 (3)	1.4x10E-7
Electronic and electro-optical displays (Monochromatic)	---	0.5	---	1.6x10E-10
Electronic and electro-optical displays (multi-color) - White	---	0.5	---	2.2x10E-9
Electronic and electro-optical displays (multi-color) – Maximum		0.5	---	1.1x10E-8

Where:fL= footlamberts

Notes:

1. *The CIE Chromaticity coordinates for the NVIS colors are defined in <u>Figure 3-1</u>.*
2. *The lighting components may be chosen to be NVIS Green A, NVIS Green B, or NVIS White, but the choice of colors shall constitute a homogenous, uniform lighting scheme throughout each crew station.*
3. *The minimum NVIS Radiance NR_B does not apply when a Type 2 NVG is utilized.*

CIE 1976 UCS Chromaticity Diagram



NVIS Green A	NVIS Green B	NVIS Yellow/Amber
u’ = .088	u’ = .131	u’ = .274
v’ = .543	v’ = .623	v’ = .622
r = .037	r = .057	r = .083

NVIS Red	NVIS White
u’ = .450	u’ = .180
v’ = .550	v’ = .500
r = .060	r = .055

Where: u’ and v’ = 1976 UCS chromaticity coordinates of the test article.
r = radius of the allowable circular area on the 1976 UCS chromaticity diagram for the specified color.

Figure 3-1 NVIS Lighting Color Limits

3.2.8.1 Primary Lighting

The NVIS radiance and chromaticity of instruments, displays, and consoles illuminated by the primary lighting system should be as specified in Table 3-1 and Figure 3-1.

3.2.8.2 Secondary Lighting

The secondary lighting system (backup lighting) shall provide area illumination of the crew station controls and displays. The chromaticity and NVIS radiance of instruments, displays, and consoles illuminated by the secondary lighting system should be as specified in Table 3-1.

3.2.8.3 Cabin Lighting

The cabin lighting system shall provide area illumination of the cabin interior areas other than crew station controls and displays. The chromaticity and NVIS radiance of such areas illuminated by the cabin lighting system should be as specified in Table 3-1. This lighting should allow the crew and passengers normal ingress to, normal and emergency egress from the aircraft interior. The lights shall not be a source of objectionable direct or indirect glare and/or reflections to operators. Cabin lighting shall be NVG compatible if intrusion of non-compatible light cannot be prevented from entering the cockpit.

3.2.8.4 Warning, Caution and Advisory Messages/Annunciators

The color scheme chosen for the Warning, Caution and Advisory messages/annunciators shall comply with the applicable airworthiness standards. The Warning, Caution and Advisory messages/annunciators shall be readable and draw the pilot's attention under all anticipated lighting conditions. If an aircraft is modified, then the original equipment manufacturer's previously approved color philosophy should be maintained. Optimally, the radiance and chromaticity of the Master Warning, Warning, Master Caution, Caution, and Advisory messages/annunciators should be as specified in Table 3-1 and Figure 3-1. It is important to emphasize that the colors (specifically, red and amber/yellow) appear to the human eye readily identifiable and distinguishable qualitatively during day and night conditions, as well as not adversely affect NVG performance. The true radiance and chromaticity of the message/annunciator may need to be a compromise with the applicant and regulatory body in order to fulfill the requirements above.

3.2.8.5 Emergency Exit Lighting

Emergency exit placards/signs/annunciators shall comply with the applicable airworthiness standards and shall be illuminated with NVIS compatible light. All lighting shall provide acceptable attensity and readability of placards.

3.2.8.6 Monochromatic and Multi-Color Electronic Display Radiance

Electronic displays shall be readable in all ambient lighting conditions. Electronic displays should meet the radiance and chromaticity requirements specified in Table 3-1.

3.2.9 Light Leaks

Lighting components shall not exhibit light leakage. (Reference Section 1.8 definition of light leaks.)

3.2.10 Luminance Uniformity

The luminance of similar indicia across panels, displays, and indicators shall be uniform to the maximum extent possible. Non-uniformity should not exceed 3:1.

3.2.11 Stray Light Emissions

Component stray light emissions shall be minimized to the maximum extent possible. Stray light emissions shall not adversely affect the aided and unaided vision or performance of operators wearing NVGs.

3.3 Equipment Performance — Environmental Conditions and Procedures

New lighting sources need to be qualified in accordance with RTCA DO-160D, *Environmental Conditions and Test Procedures for Airborne Equipment* based on the intended operating environment. Modified NVIS lighted equipment (e.g., replacing the lighting source in an appliance) will not normally require additional environmental testing if the equipment was previously tested. Environmental testing conditions may be proven through similarity. However, certain NVIS lighting components may need to be qualified to the applicable environmental test conditions and procedures of RTCA DO-160D, *Environmental Conditions and Test Procedures for Airborne Equipment* based on the intended operating environment.

Note: *Modified NVIS lighted equipment shall meet the original manufacturer functional requirements.*

3.4 Equipment Test Procedures

3.4.1 Definitions of Terms and Conditions of Test

3.4.1.1 Lighting Conditions

Luminance, chromaticity and radiance measurements shall be made in a dark room where the ambient spectral radiant energy over the spectral range of 380 through 930 nanometers is either immeasurable (equivalent to measurement instrument system noise) or no greater than 1% of the value of radiant energy from the test sample being measured.

3.4.1.2 Test Set-Up Verification

Prior to performing tests, all set-ups and test equipment calibration shall be verified per manufacturer instructions and be within its calibration period. Ensure ambient light has no effect on the test.

3.4.1.3 Test Set-Up

Stray light from the test equipment shall be controlled so that it is not reflected, refracted, or scattered into the field of measurement.

3.4.2 Required Test Equipment

1. Photometer or equivalent – An electro-optical device used to measure and quantify the luminous intensity of visible light that is emitted from a source or reflected from a surface area. Provides a means of defining the area in which the luminance is measured, such as a viewfinder, and a circle or square within the viewfinder image defining the measurement field. The device is to be capable of providing luminance intensity in units of foot-lamberts (fl) or candelas/m^2.
2. Radiometer, Spectroradiometer or equivalent – a device used to measure the intensity of radiant energy, or in the case of a spectroradiometer to measure radiance per unit wavelength interval at a given wavelength. Either device to be capable of providing the integral of radiant energy expressed in watts per steradian per unit area per wavelength interval (W/cm^2 sr nm) between the wavelengths of 450nm and 930nm.
3. Reflectance Standard – A perfectly diffuse white (Lambertian) reflecting surface having reflectivity greater than 90 percent from 380nm to 930 nm.
4. Sungun – Typically a 300 watt Halogen lamp and collimator contained in a handheld enclosure. The sungun is used in conjunction with an illuminance meter to perform daylight readability tests. The sungun must be capable of providing at least 10,000 foot candles (fc) of illuminance.
5. Illuminance meter – A device used to ascertain actual or simulated sunlight levels during daylight readability tests. The device shall be capable of illuminance measurements to at least 10,000 fc.

6. Colorimeter – A device utilizing three filters with broad spectral bands (tristimulus values) used to measure color. The device shall be capable of providing color coordinates expressed in u' and v' as specified in the CIE 1976 Uniform Color Space (UCS).
7. NVGs or imaging devices equivalent to those used by an operator and IAW standards in Section 2 of this document
8. Interference Filter (Optional) – Optical filter that passes near infrared (approx. 700-900 nanometers) but no visible light to be used in conjunction with the NVG to determine light leakage.

3.4.3 Detailed Test Procedures

The test procedures set forth below constitute a satisfactory method of determining required performance. Although specific test procedures are cited, other methods may be preferred. Such alternate methods may be used if the manufacturer can satisfactorily show that they provide at least equivalent information. Therefore, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures.

3.4.3.1 Visual Examination

Each lighting system, subsystem, or component shall be examined for evidence of foreign matter, cracks, scratches, bubbles, delamination, warps or stray light.

3.4.3.2 Operation

Each lighting system, subsystem, or component shall be verified for proper operation.

3.4.3.3 Luminance and Illuminance Measurements

Verify requirement 3.2.7.1 by inspection. Luminance and illuminance measurements shall be performed by using either a spectroradiometer, photometer, or illuminance meter as appropriate.

3.4.3.4 Chromaticity Measurements

3.4.3.4.1 Primary Lighting Chromaticity Measurements

Chromaticity measurements shall be made in a dark room. The drive condition shall be appropriate for the type of lighting component being evaluated, as required to achieve the luminance level of Table 3-1. The luminance shall be measured using either a spectroradiometer or photometer. At the specified luminance, the spectral output of the lighting component shall be measured with a spectroradiometer and the chromaticity calculated using appropriate formulas applied to the corrected spectral radiance data.

3.4.3.4.2 Secondary Lighting Chromaticity Measurements

This paragraph assumes secondary lighting to be flood lighting. If flood lighting is not used, then refer to Section 3.4.3.4.1. For chromaticity measurements the appropriate drive condition shall be applied to the light being tested (test light) to illuminate a reflectance standard (see 3.2.8.2), to a luminance level of 0.1 fL at a distance of 12 inches. The test light shall be oriented perpendicular to the reflectance standard. The spectroradiometer shall be set up such that the reflectance standard is at a 45° angle with the line of sight of the spectroradiometer. The spectral radiance of the reflectance standard shall be measured using an aperture that is as large as possible within the projected area of the reflectance standard. Chromaticity shall be calculated using appropriate formulas applied to the correct spectral radiance data.

3.4.3.4.3 Cabin Lighting Chromaticity Measurements

The chromaticity inspection for compartment lighting shall be the same as for secondary lighting (3.4.3.4.2).

3.4.3.4.4 Warning, Caution and Advisory Light Chromaticity Measurements.

Warning, caution and advisory lights shall be verified by inspection. A suggested means of verification should be in accordance with 3.4.3.4.1.

3.4.3.4.5 Emergency Exit Lighting

Emergency exit lighting shall be verified by inspection to meet 3.2.8.5. The method described in 3.4.3.4.1 or 3.4.3.4.2 as appropriate may be used to ensure this requirement is met.

3.4.3.5 Spectral Radiance Measurements

3.4.3.5.1 Primary Lighting Spectral Radiance Measurements

NVIS radiance measurements shall be made in a dark room. The drive condition shall be appropriate for the type of lighting component being evaluated, as required to achieve the luminance level cited in Table 3-1. The luminance shall be measured using either a spectroradiometer or photometer. At the specified luminance, the spectral output of the lighting component shall be measured with a spectroradiometer, and the NVIS radiance calculated using appropriate formulas applied to the corrected spectral radiance data.

3.4.3.5.2 Secondary Lighting Radiance Measurements

This paragraph assumes secondary lighting to be flood lighting. If flood lighting is not used, then refer to Section 3.4.3.5.1. The test light shall illuminate the reflectance standard at a distance of 12 inches, and shall be driven such that the standard exhibits proper luminance value as cited in Table 3-1. The test light shall be oriented perpendicular to the reflectance standard. The spectroradiometer shall be set up such that the reflectance standard is at a 45° angle with the line of sight of the equipment. The spectral radiance of the reflectance standard shall be measured, and the NVIS radiance calculated using appropriate formulas applied to the corrected spectral radiance values.

3.4.3.5.3 Cabin Lighting Radiance Measurements

The NVIS radiance inspection for cabin lighting shall be in the same manner described in Section 3.4.3.5.2.

3.4.3.5.4 Warning, Caution and Advisory Message/Annunciator Radiance Measurements

Inspection shall be in accordance with 3.4.3.5.1.

3.4.3.5.5 Emergency Exit Lighting Radiance Measurements

Inspection for emergency exit lighting shall be in accordance with 3.4.3.5.1 or 3.4.3.5.2.

3.4.3.5.6 Monochromatic and Multi-Color Electronic Display Radiance Measurements

Inspection shall be in accordance with 3.4.3.5.1.

3.4.3.6 Light Leak Inspection

The lighting component, system, or subsystem shall be illuminated as specified and examined through the NVGs in conjunction with an optional interference filter for evidence of light leakage. In addition, the lighting component, system, or subsystem shall be inspected by the unaided eye for light leaks due to scratches, damage, or imperfections that degrade the readability of that component or system. Light leaks shall be corrected.

3.4.3.7 Luminance Uniformity

Verify conformance to the requirement of 3.2.10 by visual inspection. If non-uniform luminance is observed, the luminance of appropriate indicia across the area(s) of interest should be measured and documented using a spot photometer having a measuring field of appropriate size.

3.4.3.8 Stray Light Inspection

Verify conformance to the requirement of 3.2.11 by visual inspection of the entire aircraft interior.

3.4.3.9 Daylight Legibility and Readability Inspection

Verify requirement 3.2.6 by inspection.

4 INTEGRATED NIGHT VISION IMAGING SYSTEM (NVIS) INSTALLATION PERFORMANCE

This section states the minimum acceptable level of performance for the equipment when installed in the aircraft. The performance of the NVG and the NVIS lighting components were verified to meet the applicable requirements using the test procedures described in Sections 2 and 3. However, the installed performance of the integrated NVIS shall be verified using the tests described in this section. This is done to evaluate the effects secondary to the physical installation of NVIS lighting components (e.g., cockpit reflections, control locations, etc.) and the effects of cockpit design on the use of NVGs, during both ground and flight evaluations.

4.1 Equipment Installation

The installed equipment shall meet the performance requirements stated in Sections 2, 3 and 4.

4.1.1 Accessibility

4.1.1.1 Accessibility of NVG Controls

In-flight manipulation of controls and operation of the NVG shall be possible with one hand only, and the controls shall be readily identifiable.

4.1.1.2 Accessibility of NVIS Lighting System Controls

Lighting controls provided for in-flight operation shall be readily accessible from the pilot's normal seated position and shall be readily identifiable. In-flight manipulation and operation of the lighting controls shall be possible with one hand only.

4.1.2 Aircraft Environment

The NVG and NVIS lighting system shall be compatible with the environmental conditions present in the specific location in the aircraft where they are installed.

4.1.3 Display Visibility

4.1.3.1 Effect of NVG on Display Visibility

The effect of the NVG hardware on display visibility should be minimized. The pilot, when seated in the normal flight position, shall have an unobstructed view of the primary flight instruments. All operators should have unobstructed views of displays when in the seated position.

4.1.3.2 Effect of NVIS Lighting System on Display Visibility

Components of the NVIS lighting system shall not cause unacceptable obstruction of data displayed in the cockpit.

4.1.4 Dynamic Response (Operation in Intended Environment)

Operation of the NVG and NVIS lighting system shall not be adversely affected by required crew movements, aircraft maneuvering, or changes in aircraft attitude within the aircraft's approved flight envelope.

4.1.5 Failure Protection

Any failure of the NVG and NVIS lighting system shall not degrade the normal operation of equipment or associated systems. Likewise, the failure of interfaced equipment or associated systems shall not degrade normal operation of the NVG or NVIS lighting. Additionally, the applicable regulations or design requirements for the aircraft shall be met.

4.1.6 Interference Effects

The conducted or radiated emissions from the NVG and NVIS lighting system shall not adversely affect aircraft systems, nor be adversely affected by conducted or radiated interference from other equipment or systems installed in the aircraft.

Note: *Electromagnetic compatibility problems noted after installation of this equipment may result from such factors as the design characteristics of previously installed system or equipment and the physical installation itself. It is not intended that the equipment manufacturer design for all installation environments. The installing facility will be responsible for resolving any incompatibility between this equipment and previously installed equipment in the aircraft. The various factors contributing to the incompatibility shall be considered.*

4.1.7 Inadvertent Actuation of Controls

Appropriate protection shall be provided to minimize the possibility of the inadvertent actuation of NVG controls and non-NVIS light sources.

4.1.8 Aircraft Power Source

The primary and secondary NVIS lighting systems shall be powered by independent power sources.

4.2 Installed Equipment Performance Requirements

The NVG and NVIS lighting system shall meet the requirements of Sections 2.1, 2.2, 3.1 and 3.2 in addition to, or as modified by, the requirements stated in Section 4.

4.2.1 Installed Performance Degradation

A limited amount of degradation in NVG performance, as measured by the tests described in this section, may be acceptable. The following describes the acceptable levels of degradation in NVG-aided visual acuity (VA):

1. The design and/or composition of transparencies (e.g., windshields, windows, etc.) may result in the loss of energy to which the NVG is sensitive, which can result in image degradation. A loss of one resolution element (approximately 12%) is acceptable.

Note 1: *Windshield anti-ice systems may cause distortion in the area being heated. The distortion may in turn cause some degradation of the outside scene when viewing through the affected area during daytime or when using NVGs. The effect should be evaluated during flight test to determine the impact to operations, and, if necessary, relevant procedures should be developed and incorporated into applicable aircraft manuals. No added degradation to resolution due to this distortion is acceptable.*

CAUTION: When testing the anti-ice system, be sure to review operating limitations for the system. Damage to the windshield can occur if the system is actuated inappropriately.

2. A maximum loss of one resolution element (approximately 12%) is acceptable when attributed to warning, master caution and/or master warning messages/annunciators.

Note 2: *All other interior aircraft lighting shall not degrade NVG-aided VA. The combination of all degrading effects shall cause a maximum loss of no more than one resolution element.*

4.2.2 Additional Equipment

Any additional equipment required for NVG operations must perform its intended function under all foreseeable operating conditions.

4.3 Conditions of Test

A detailed description of test conditions is included in Section 4.4.

4.3.1 Safety Precautions

Personnel and/or equipment safety precautions due to any unique characteristics of the equipment or installation shall be observed.

The flight test procedures described in Section 4.4 will result in the aircraft being flown in poor illumination conditions at night, possibly in close proximity to terrain and obstacles. The following are proposed as means to mitigate the risk inherent to this type of flight test:

1. All maneuvers planned for the in-flight evaluation must be briefed during the pre-flight briefing, including criteria for terminating maneuvers if a potentially unsafe condition should occur.
2. The maneuvers planned for the in-flight evaluation should be performed during the day prior to performing them at night. A build-up approach should be adhered to, progressing from more benign conditions to more severe conditions.
3. The evaluation crew must familiarize themselves with the area that will be used to evaluate the aircraft at night under daylight conditions prior to its use at night. Particular attention must be focused on the terrain, obstacles, and off-site landing area suitability. Emergency landing areas should be identified.
4. Spatial awareness must be maintained at all times. In multi-crewed aircraft if any crewmember has any doubts about the safety of the aircraft then the aircraft must be placed at a suitable altitude, in non-maneuvering flight until the flight crew is comfortable continuing with the test program.
5. Prior to commencing the test ensure that all the barometric altimeters are set to the current altimeter setting, and that the radar altimeter is serviceable. Set the low set index to an appropriate altitude in the radar altimeter.
6. Maintain awareness of other air traffic.
7. Maneuvers should be immediately abandoned if visual contact is lost with any obstacles or terrain during a test sequence.
8. Control and display lighting should be adjusted to a level allowing readability with minimal delay when transitioning from a bright, intensified image.

4.3.2 Power Input

Unless otherwise specified, all aircraft electrically operated equipment and systems shall be turned on before conducting interference tests (See Section 4.4.1.1). The power supply used for ground tests, with the aircraft electrical generating system not operating, should provide power at the appropriate voltage (e.g., using a 24 volt aircraft battery or battery cart will not power aircraft electrical busses at the normal 28 volts).

4.3.3 Environment

During test, the equipment shall not be subjected to environmental conditions that exceed those specified by the equipment manufacturer.

4.3.4 Adjustment of Equipment

Circuits of the equipment under test shall be properly aligned and otherwise adjusted in accordance with the manufacturer's recommended practices prior to application of the specified tests.

4.3.5 Warm-up Period

Unless otherwise specified, tests shall be conducted after an appropriate warm-up (stabilization) period.

4.4 Post Installation Test Procedures

The following test procedures provide one means of determining the performance of an integrated night vision imaging system after installation. Although specific test procedures are cited, it is recognized that the applicant may prefer other methods. These alternate procedures may be used if they provide at least equivalent information. In such cases, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures. The equipment shall be tested to demonstrate compliance with the minimum requirements stated in Sections 2.2 and 3.2. It is important to test the complete system. Partial system testing could lead to potential erroneous results and will lengthen the evaluation process.

The procedures are designed to capture all components of the NVIS: the NVG (e.g., binocular assembly, mount, and helmet), the aircraft (e.g., NVIS lighting, transparencies, and crewstation ergonomics), and the operator (e.g., personal equipment). There will be concurrent testing in some cases (e.g., NVIS lighting and transparency transmissivity), but the various subcomponents of the system will be discussed individually to ensure each is adequately addressed. The procedures will be divided into those performed on the ground and those performed in flight.

4.4.1 Ground Test Procedures

The following represents a recommended approach for planning and conducting ground testing (A Testing Guide that summarizes the procedures in this section is provided as Appendix H):

1. Coordinate with the applicant well in advance with respect to the test plan and the support required for the conduct of testing. The following are some of the things to consider:
   a. Operator availability for test support (e.g., familiarity with aircraft and flight operations, availability of test subjects, etc.).
   b. Availability of a test area: Typically this will require the use of a hanger or other building (e.g., paint barn) that can be closed in order to control the interior light level. The test facility shall be sufficiently dark, such that when the NVGs are activated, nothing is visible through the NVGs except scintillation. This may require temporarily sealing windows, disconnecting vending machines, covering exit signs and other actions to eliminate excess light in the space. In extreme situations, this may require flying the aircraft to another site in order to have access to an acceptable test location.
   c. Equipment availability: This includes such things as electrical supply for test equipment, stands for holding resolution charts, extension cords, coverings for windows, tape, and other things as required by the evaluator.
   d. Test plan development: It is advantageous to have the applicant supply in advance a list of NVG equipment that will be used, and a layout of the NVIS lighting modification/installation that includes: each component that will be

modified/installed; the method used for the modification/installation (e.g., post light, bezel, floodlight, etc.); and a layout of the cockpit and cabin showing the location of all panels, displays, instruments, controls, annunciators, etc. From this information the evaluator can develop data sheets on which to document test results. This helps reduce the chance of missing items and also provides for a good record of the test.

2. Ensure the aircraft is ready for testing prior to traveling to the test site. The entire system (NVG selected for use, NVIS lighting, etc.) should be available/installed prior to the start of testing.

3. Upon arrival, review the test plan with the applicant, examine the testing area to ensure it is acceptable (e.g., space is adequate, unwanted light sources have been covered or disconnected, etc.), inventory the test and support equipment to ensure everything is available that is needed, and set-up the test equipment. Setting up the test equipment includes such things as placing the resolution chart(s) at the appropriate location(s), measuring the distance from the chart(s) to the relevant eye position(s), placing the illumination source in a location that will not interfere with NVG-aided acuity testing, etc.

4. NVG and NVIS lighting testing can be accomplished during daytime or nighttime, but in either case the facility shall be able to be completely darkened (See 4.1.1 b). Testing at nighttime can be conducted in the same space provided for NVIS lighting testing. Ensure that all components are available for testing (e.g., NVG, mount, helmet or other head-mounting device, power supply, etc.).

5. Some aircraft test procedures can be accomplished during daytime, but most testing of NVIS lighting should be conducted at night, even if there is a space available that can be made dark. Even in the best testing area some light will intrude during daytime making it difficult to control the light levels required for testing. The order of testing (testing flow) for NVIS lighting may vary depending on the space available (e.g., how well the lighting can be controlled in the hanger, availability of a hanger, etc.) and the availability of test support. However, the following is a typical flow given that the space is adequate and that support is available:

   a. Conformity Inspection

   b. Daylight Readability Evaluation

   c. Crewstation Ergonomics

   d. Light Leak Evaluation (Shall be accomplished under dark conditions.)

   e. Nighttime Readability Evaluation (Shall be accomplished under dark conditions)

   f. NVG-Aided Visual Acuity Evaluation (Shall be accomplished under dark conditions)

4.4.1.1 Interference Effects Tests

Applicant is responsible for determining the emission characteristics for the NVIS installed component and how they can affect essential aircraft systems and NVG (if powered by aircraft). With the NVG and NVIS lighting system energized, individually operate each of the other electrically operated aircraft equipment and systems to determine that any detectable conducted or radiated interference do not exist. Evaluate all foreseeable combinations of control settings and operating modes. Make note of system states or modes of operation that should also be evaluated during flight. If appropriate, repeat tests using emergency power with the aircraft's batteries alone and the inverters operating. If detectable interference is noted during ground test, then the applicant shall determine if the worst case has been detected. After worst case is defined, the interference shall be eliminated at the source or the interference shall be evaluated to assure that the NVG or NVIS lighting system functions do not result in an unsafe condition.

4.4.1.2 Night Vision Goggle Test Procedures

In addition to the following test procedures, the applicant should review bench test results conducted by the manufacturer, and should refer to the manufacturer instructions for NVG controls and adjustment procedures. Appendix G has a generic sample of NVG adjustment procedures.

4.4.1.2.1 Conformity Inspection

Visually inspect the NVG to determine the use of acceptable workmanship and engineering practices. Verify, through review of manufacturer's system description that the NVG is in fact representative of that described and that all components (e.g., binocular assembly, mount, helmet, etc.) are included.

4.4.1.2.2 Equipment Function

Testing of the NVG will include an evaluation of the following: visual performance, operator controls, mount assembly, head mounting device, and power supply. Though these will invariably be tested concurrently, it is important to assess each independently for functionality and human factor acceptability.

4.4.1.2.2.1 Operator Controls

The purpose of this evaluation is to ensure that controls provided on the NVG perform their intended function during flight. In general, the controls: should allow the operator to properly locate an image directly in front of each eye, should be easily assessable, should move easily, and should not slip once the position is selected. The result should be an image that is properly fused by the brain and does not cause eyestrain after prolonged use. Typical operator controls include the following: fore and aft (to and from the eye), vertical (up and down), interpupillary (eye span), tilt (allows for proper alignment with the visual axis), and power on/off. For most operator's, the final position of all adjustments should be somewhere other than at the end of the adjustment range, thus allowing for maximum use over a wide range of facial types. The controls may be located on different components of the NVG system (e.g., binocular assembly and mount assembly).

4.4.1.2.2.2 Mount Assembly

The mount assembly is that part of the NVG system that allows for attaching the binocular assembly (or equivalent) to the helmet (or other method used for head mounting). The mount usually provides access to the power necessary for the NVG to function. In some cases the design may incorporate the mount into the head-mounting device (e.g., helmet with integrated mount). In other cases, the mount assembly may be separate from the head-mounting device. The following are important to assess relative to the mounting system: ease of attaching and removing the binocular assembly (or equivalent), stability of the system when in the operating position (image in the line of sight), and stability of the system when in the stowed position (if available).

4.4.1.2.2.3 Head-Mounting Device

The head-mounting device provides a platform on which the binocular assembly (or equivalent) can be attached for operator use. Depending on the system design, the head-mounting device may also be the attachment point for the power supply. Typically this will be a helmet but there are other methods that could be used (e.g., hair net mount). The helmet or other device should be evaluated for functionality relative to the use of NVGs. The following are of importance: stability during scanning, comfort during long periods of NVG use (e.g., acceptable weight and center of gravity), and compatibility with the crew station compartment (e.g., remains clear of overhead obstructions, etc.). If a helmet is not used, in addition to the issues previously discussed, it is important to consider the compatibility of the selected head-mounting device with other required flight equipment (e.g., ear phones).

4.4.1.2.2.4 Power Supply and Controls

The power supply may be contained in a separate device attached to the helmet, may be integral to the mount, or may be of some other design. Evaluation of the power supply should include the following: ease of access to controls, ease of manipulation of controls, avoidance of inadvertent activation, ease of changing power supply or batteries in-flight, provision of a back-up power supply, stability of the power supply when attached (if designed as a separate component), and the security of wiring leading from the power supply to the mount.

4.4.1.2.2.5 NVG Visual Performance

The visual performance of the NVG must be assessed in order to determine that it meets the intended function. Although this is accomplished mostly during flight testing, ground testing will ensure that the NVG can be safely and effectively tested in flight, and is better suited for determining compliance with minimum standards.

If a test set is available that is compatible with the NVG, follow the recommended procedures for that test set and conduct an evaluation of the NVG. Typically this will include: gain, distortion, optical performance, cosmetic defects, collimation, etc.

If a test set is not available, a qualitative evaluation may be performed using a chart designed for NVG evaluations that is illuminated by a controlled photopic light source. The following is a recommended procedure:

1. Locate a space at least 30 feet long that can be made light tight (absence of light).
2. Place a 1951 USAF Medium or High Contrast Tri-Bar Chart (or equivalent (e.g., other tri-bar, sine-wave, square-wave) chart having element intervals of the sixth root of two) at one end of the space. The chart should contain vertical and horizontal resolution elements, and should be designed to be read at twenty feet.
3. Illuminate the chart with a light source that is capable of producing selectable illumination that is reasonably equivalent to either full moon or starlight conditions. This can be a simple source and does not need to accurately represent the color content of the night sky. Refer to Appendix I for more information concerning a recommended light source setup and adjustment.
4. Stand twenty feet from the chart. After correctly aligning and adjusting the NVG, determine the smallest set of elements in which both horizontal and vertical lines can be discerned. It is not unusual to be able to more easily discern the vertical lines, but in order to be consistent, pick the smallest set in which both are discernable. Discernable means it is clear that the lines are horizontal and/or vertical, but it does not necessarily mean that every individual line in the set can be seen.

Note: *Varying the illumination level and using charts with varying contrast levels will allow for more definitive testing of an NVG, and will help provide a better method of comparing the performance of two different NVGs.*

5. Note the findings and compare to the manufacturer's results for similar conditions (specification sheet). The purpose is to determine qualitatively if the NVG meets the

minimum standards for resolution. See Appendix F for formulas that can be used to change resolution specifications into Snellen acuity figures.

6. In addition to resolution, other image characteristics should be assessed during this procedure. Be attentive to the presence of any of the following: dark spots, bright spots, honeycombing, edge glow, shading, and distortion. Should any of these be obvious and/or distracting, then compare to the minimum standards (Section 2.2.1.8) for compliance.

4.4.1.3 Aircraft Test Procedures

These procedures include guidance for conducting tests of the various NVIS components that are incorporated in the aircraft or with which the NVIS components interoperate (e.g., NVIS lighting, transparencies, and crew station ergonomics.

4.4.1.3.1 Conformity Inspection

Visually inspect the installed NVIS lighting system to determine the use of acceptable workmanship and engineering practices. Verify, through review of installation drawings, wiring diagrams, and descriptive wiring routing that all mechanical and electrical connections have been made properly and without creating an unsafe electrical and mechanical environment. If primary and secondary NVIS lighting systems are installed, then confirm that they are powered by independent sources. Verify that the equipment has been located and installed in accordance with the manufacturer's recommendations, approved equipment list, and master drawing list (MDL).

4.4.1.3.2 Daylight Readability Evaluation

Filters or other methods (e.g., LEDs) employed to make cockpit lighting NVG compatible may degrade the daylight readability of displays and/or annunciators. Consequently, it is necessary to evaluate a NVIS modification to determine if daylight readability has been adversely impacted. Two different assessment procedures will be described. The first consists of a qualitative assessment conducted under natural daylight conditions, and the second consists of qualitative assessment using test equipment to replicate daylight conditions. The following is applicable to the evaluation regardless of the method used:

1. Only those modified (or filtered) items that provide information to be read (e.g., displays) or those items that provide status information (e.g., warning, caution or advisory annunciators) need to be evaluated.
2. In some cases, daylight readability of an item may already be degraded due to poor design or some other factor prior to the modification. It is highly likely that the modification will worsen the problem. It is the applicant's responsibility to identify items that relate to safety of flight (i.e., caution and warning indicators, primary flight displays, etc) that are to be modified for NVIS compatibility and assess possible daylight readability issues. In these special cases, it shall be necessary for the applicant/ authority to determine compliance with the appropriate regulations. It is highly recommended that these issues be discussed prior to aircraft installation.
3. The attensity (ability to attract attention) of some annunciators (e.g., fire warning, master caution, etc.) is critical to flight safety. Modifications to these annunciators must be evaluated to ensure attensity is acceptable.
4. Modified displays with brightness and/or contrast controls should be evaluated at various settings to fully assess daylight readability.
5. The evaluator should document all findings.
6. It is important to compare the results of ground tests with the results of flight test when making final decisions.

7. These tests should be conducted with lighting power at the maximum available drive level applicable for that component. The power supply used for the ground tests, with the aircraft electrical generating system not operating, should provide power at the appropriate voltage (e.g., using a 24 volt aircraft battery or battery cart will not power aircraft electrical busses at the normal 28 volts).

4.4.1.3.2.1 Qualitative Assessment Using Ambient Illumination

The intent of this method is to simplify the process by using ambient daylight as the illumination source for evaluating daylight readability. The aircraft shall be positioned outside in an area where it can be easily repositioned. Repositioning is important in order for assessments to be conducted with the sun at various angles relative to the modified components (thus replicating flight in varying directions). The evaluator shall sit in the aircraft at all relevant stations and make subjective assessments of the daylight readability of the modified components. This shall be repeated with the aircraft facing in varying directions in order to ensure the modified instruments are exposed to bright daylight at relevant aspects. The critical case for instrument panel mounted displays is generally when the sun is at a low elevation angle. Therefore, ensure the test is performed when the sun is at low angles, and the light from the sun is unattenuated by any clouds.

4.4.1.3.2.2 Qualitative Assessment Using Artificial Illumination

Performing daylight readability assessments while using an artificial source of illumination allows the evaluations to be performed regardless of the time of day or cloud condition, can be performed at any time during the NVIS evaluation process, and provides for a more consistent and reproducible test environment.

Daylight readability is evaluated using a sunlight simulation device (sun gun). The sun gun is used in conjunction with an illuminance meter. The illuminance meter is placed immediately adjacent to the component being evaluated, and the sun gun is directed at the meter. The sun gun’s distance from the meter is varied until an illuminance of 10,000 foot candles (fc) is indicated on the meter display. The distance is noted in case the illuminance meter cannot be easily placed next to the modified item due to access difficulties. In this case, the sun gun is positioned at the approximate distance from the modified item. The evaluator assesses daylight readability while the sun gun is positioned at the appropriate distance and at various angles relative to the item (thus replicating flight in varying directions). An attempt should be made to note those items that may not be fully subjected to bright sky conditions (e.g., shielded by a glareshield, located on a console well away from windows or a canopy, etc.). In those cases, judgment is required to evaluate daylight readability under realistic operating conditions.

4.4.1.3.3 Crewstation Ergonomics Evaluation

In addition to testing the equipment that constitutes the NVIS, it is important to determine if the operators can safely and effectively use NVGs when occupying the crewstation. The following are recommended procedures:

1. When seated in the various crew positions, evaluate the proximity of obstructions relative to their interference with NVG scanning procedures (e.g., window, overhead consoles, overhead throttles, etc.). In addition the potential for limiting the scan volume (and therefore the NVG field of regard), striking the obstructions may dislodge the NVG from the mount or may cause damage to the object (e.g., scratched window).
2. Cross-cockpit viewing of instruments may be required for some aircraft, and if so should be evaluated during the nighttime readability evaluation.

3. Accessible stowage locations for the NVGs may be necessary. In this case the stowage locations should be evaluated for ease of access (e.g., reduce heads-down time, require crew coordination technique, etc.), and for security (e.g., protection of NVG and avoidance of loose objects in the cockpit).
4. If the aircraft has a compartment in which incompatible light sources will be used during NVG flight, an evaluation should be performed to ensure the incompatible light sources are effectively shielded from the crewstation environment.
5. Efforts should be made to identify crewstation design features that may increase operator workload while using NVGs (e.g., primary flight instrument layout, location of controls that are frequently used during flight, etc.).

If the applicant has a fleet of aircraft of the same type that are being modified, efforts should be made to identify significant differences among these aircraft relative to crewstation design considerations. This is especially true for the primary flight instrument layout or the positioning of frequently used controls, displays, etc. These differences may lead to an increase in operator workload when using NVGs in the various aircraft (particularly if different aircraft are flown on the same night).

4.4.1.3.4 NVIS Lighting Test Procedures

The following paragraphs provide guidance for performing an evaluation of the interior NVIS lighting modification. If the exterior lighting has been modified (e.g., strobe light repositioned, position lights filtered to reduce infrared emissions, etc.), the only testing that can be effectively accomplished during ground test is functionality (e.g., the correct lights illuminate when selected, the strobe light flashes, etc.). The effectiveness of the exterior lighting is more accurately evaluated during flight test.

4.4.1.3.4.1 Light Leak Evaluation

Light leaks usually result from improper installation procedures (e.g., leaks at the base of a floodlight) or manufacturing problems (e.g., loose filter in an annunciator). If present during the formal evaluation, test results can be invalidated, in particular the NVG-aided visual acuity measurements. Before beginning the formal evaluation, conduct a brief survey of the installed lighting system to determine if light leaks are present. While seated at the crew station and using the NVG that the operator will employ, focus the NVG on the instrument panel. Using the NVG, scan the cockpit (e.g., instrument panels, consoles, overheads, etc.) and look for halos or blooming of the image. Note and record light leaks that are visible to the unaided eye and those that are seen in the NVG image. If the NVIS lighting components have been properly manufactured and installed there should be no halos or blooming. If a halo or if blooming is noted, attempt to identify the offending component or installation defect. This may require refocusing the NVG to the specific area of interest. In multiplace aircraft, or when performing evaluations in areas away from the cockpit (e.g., cabin), perform the same procedure at a location from which the evaluation can be adequately accomplished. It is recommended that significant light leaks be repaired prior to performing further ground tests.

Note: *Some lighting may cause slight haloing in the image that is normal and acceptable (e.g., NVIS red or yellow annunciators). Fluorescence of red flags within some instruments (e.g., ADI) may also cause slight haloing, but these are normally "off" flags that will not be present during flight. It is important to learn how to differentiate these effects from those caused by true light leaks.*

4.4.1.3.4.2 Nighttime Readability Evaluation

This is a subjective determination of the unaided readability of displays, instruments and annunciators during nighttime operational conditions. The intent of this test is to verify that unaided nighttime flight has not been degraded by the modifications required to make the aircraft lighting NVIS compatible. Of particular importance is the readability of primary flight instruments, and the readability and attensity of the warning and caution annunciators. The following are recommended procedures/guidelines:

1. The evaluator should dark-adapt for approximately fifteen minutes prior to the start of the evaluation. This is normally accomplished during the test set-up or during other evaluations that have been conducted under darkened conditions (e.g., light leak evaluation, etc.).
2. Adjust each lighting control independently to evaluate its function, to ensure the range of brightness is adequate, and to ensure that all components whose illumination is dependent on that control are evenly illuminated (balanced) throughout the brightness range.

Note: *This applies to components that are individually illuminated (e.g., bezels or post lights) and to components that are illuminated by flood lighting. If the exterior lighting has been modified, test the lighting controls to ensure they function as required. Recommend testing exterior lighting controls at the end of the night readability evaluation to ensure dark adaptation. The remainder of exterior lighting evaluation will be conducted during flight test.*

3. Adjust all lighting controls to ensure the entire lighting system (i.e., all illuminated components) can be balanced at operationally relevant brightness levels.
4. In addition to the illumination balance on each control and the system illumination balance, evaluate each display for illumination balance across the display face. This is particularly important for the primary flight instruments (e.g., ADI, HSI, altimeter, etc.).
5. Before beginning the readability evaluation, the lighting intensity should be set at a level representative of that normally used during flight.
6. Each display, instrument and annunciator should be evaluated for readability. This could include such things as: loss of individual color markings in a instrument/display due to filtering effects, shading of information on an instrument due to the edge of a bezel or the presence of a post light, lack of attensity of a warning light due to filtering effects or location (e.g., it was never in the unaided field of view and was not noticeable in the NVG image), readability of numerals found in small windows (e.g., course selection in the HSI), etc.
7. Evaluate the legibility and/or positioning of switches and other controls (e.g., can the characters on the panel be read, can it be determined if the switch is on or off, etc).
8. Evaluate floodlight positioning to ensure stray light is reduced and that light does not shine directly in the operator's eyes. This includes any component that shines light onto the surface of an instrument (e.g., post light, bezel edge, console floodlight, etc.).
9. Evaluate failure modes. The evaluator shall simulate failures of various controls, electrical sources, electrical distribution system etc to account for all significant failures. The evaluator shall make an initial assessment whether a safe transition to instrument flight could be made if there was a loss of outside visual cues. If the aircraft has a secondary NVIS lighting system, it should be evaluated independently from the primary system and should be powered by the relevant source (e.g., battery). The comprehensiveness of the evaluation should depend on the purpose of the secondary system (e.g., good enough to continue the mission or just to allow return home). Regardless, at a minimum, readability of the primary flight instruments should be assessed using only the secondary system.

10. Evaluate all reflections noted on transparencies. Document the location of the reflection and the source. Light leaks are the most common source of reflections and if present may adversely affect NVG performance. Other contributors to reflections include displays (especially large color displays) and floodlights. These sources may contain energy incompatible with NVGs in addition to visible energy that degrades unaided outside viewing. A more detailed evaluation of noted reflections will take place during NVG-aided visual acuity testing.
11. Conduct an evaluation with the NVG in place and turned on. Let the eyes adapt to the NVG image for a few minutes, then adjust the lighting to a brightness level that will allow adequate readability of all required instruments with no lag in adaptation time (i.e., information on the instruments can be immediately read). Check to see that the brightness can be increased above this level. This will help ensure that the range of brightness is adequate for NVG operations.
12. With the NVG in the operating position, scan the outside scene while noting if the NVG hardware (e.g., binocular assembly, etc.) obstructs unaided viewability of any displays, instruments, or annunciators. This is particularly important to know regarding warning annunciators (e.g., fire lights) that may be located towards the top of the instrument panel or just beneath the glareshield. If the annunciator is not in the unaided field of view, it is important that it be visible in the NVG image, but without adversely affecting performance (i.e., no change in gain, no large halo, etc.). Refer to Appendix E, last paragraph of 6 for recommendations.

4.4.1.3.4.3 NVG-Aided Visual Acuity Evaluation

NVG-aided visual acuity (VA) measurements are obtained with the evaluator seated in the cockpit and with the cockpit lighting adjusted to an operationally representative level. No detectable degradation in VA due to the NVIS lighting should be observed. If degradation exists, the incompatible light source(s) should be identified, except as noted in Section 4.2.1. The NVG used during the evaluation should be representative of the NVG planned for use in the aircraft. If the NVGs intended for operational use have fixed focus objective lenses, then for the purpose of this evaluation NVGs having variable focus objective lenses and overall performance (e.g., resolution, gain) otherwise equivalent to the fixed focus NVG can be employed. Another means is use of (+) 1/8 diopter ophthalmic lenses in front of the fixed focus objective lenses. The assessment shall be conducted in a facility where absence of light can be easily obtained (See Section 4.4.1.2.2.5 Subparagraph 1).

NVG-aided VA measurements are obtained using a USAF 1951 Medium (or High) Contrast Resolution Resolving Power Target (USAF Tri-bar Chart) (or equivalent chart (e.g., other tri-bar, sine-wave, square-wave) having element intervals of the sixth root of two). The chart consists of a large number of target elements, encompassing a wide range of sizes, divided into groups of six. The elements progressively decrease in size (increasing in spatial frequency) at relative intervals of approximately 12%. Each element contains two patterns, each composed of three dark lines and separating white spaces all of equal width; one pattern is horizontal and the other vertical. Each group is identified by a different number, while the elements in each group are numbered 1 through 6. For a given viewing distance, the group/pattern numbers correspond to Snellen visual acuity values varying at fixed intervals of approximately 12%.

At least two experienced evaluators should be used for the evaluation. The chart is placed twenty feet from the eyepoint of the evaluator seated in the cockpit. If it is not possible to locate the chart at twenty feet (e.g., multiplace aircraft with various eye positions), the chart is placed at a position where it can be viewed while seated at all crew stations (mathematical adjustments can be made for the varied distances). More than one chart could be used if measurements are to be taken through different transparencies (e.g., windscreen, windows, canopy, etc.), through transparency reflections, or for other purposes. The illumination level on the chart should be adjusted so that NVIS radiance measured from the white portion of the target is equivalent to 1.6×10^{-10} NR_B.

Prior to the assessment of NVG-aided VA, the evaluators will adjust the NVG to obtain maximum VA for the distance to the chart(s). If charts are located at different distances, it may be necessary to make small adjustments of the NVG objective lens focus for each chart. If the NVG has a diopter adjustment, care should be taken not to readjust the diopter setting when making these small adjustments for distance. While measurement conditions will be specific to the aircraft type, test procedures are usually performed in the following order:

1. Unobstructed (over or around all transparencies)
2. Baseline condition: View the chart through the appropriate transparency with all cockpit lighting extinguished, and note the smallest discernable element. Some transparencies may block near-IR energy, thus reducing the amount of energy to which the NVG is most sensitive. Any loss of VA noted when going from the Unobstructed Condition to the Baseline Condition is a result of this effect. In this event, the loss of NVG-aided VA should be assessed for potential adverse effects on flight operations. The NVG-aided VA noted during the Baseline Condition will be the comparison point for determining if the modified lighting has an adverse effect on NVG performance.
3. Trial condition 1: View the chart through the appropriate transparency with the cockpit lighting at an operational brightness level and note the smallest discernable element
4. Trial condition 2: View the chart through the appropriate transparency with the cockpit lighting at an operational brightness level and all warning, caution and advisory lights illuminated, and note the smallest discernable element.
5. If any VA degradation is noted between the Baseline Condition and either of the Trial Conditions, then additional measurements should be made with individual lighting components or combinations of components illuminated to identify the offending source(s).
6. Using the reflection information gathered during the nighttime readability assessment, view through adverse reflections with the NVG to determine the impact on NVG-aided VA. This may require the relocation of existing charts or the placement of additional charts. If a chart location is modified or if new charts are added, be sure to measure the viewing distance to the NVG. In addition to the reflections that are incompatible to the NVGs, evaluate the impact of reflections on unaided viewing. This may be difficult to adequately assess given the testing conditions. In that case, further evaluations should be conducted during flight tests.
7. If the aircraft is equipped with a windshield anti-ice system, it should be evaluated (if possible) to determine the impact on NVG use. Typically the problem will be distortion of the area being heated, which may cause some degradation of the outside scene when viewing through the affected area unaided or when using NVGs. The resolution chart should be viewed through the affected area to determine if there is any NVG-aided VA loss in addition to the distortion. The effects should also be evaluated during flight test to determine the impact to operations, and, if necessary, relevant procedures should be developed and incorporated into applicable aircraft manuals.

   CAUTION: When testing the anti-ice system, be sure to review operating limitations for the system. Damage to the windshield can occur if the system is actuated inappropriately.

4.4.1.3.5 Operator Equipment

Operator equipment refers to anything the operator may carry aboard the aircraft and use during NVG flight. The following may be included: flashlights, finger lights, lip lights, lighted kneeboards, computers, etc. Anything that will be used at the crewstation during NVG flight should be evaluated for NVG compatibility. Procedures should be developed that will mitigate the risk associated with inadvertent activation of light sources that will adversely affect the NVG image.

4.4.2 Flight Test Procedures

As with ground testing, early planning and coordination are important. Ground testing shall be completed and the modification deemed acceptable prior to the start of flight test. The following represents a recommended approach for planning and conducting flight test:

1. Coordinate with the applicant well in advance with respect to the test plan and the support required for the conduct of testing. The following are things to consider:
    a. Operator availability for test support (e.g., familiarity with aircraft and flight operations, availability of test subjects, etc.).
    b. Availability of a flight test area: Ideally this will be the area where flight operations will be conducted, which will allow for a more relevant evaluation regarding the effect that the NVIS system will have on flight operations.
    c. Test plan development: The test plan should be developed jointly with the applicant to ensure it includes test points relevant to the operation. The following test points should be included at a minimum:
        i. Flight maneuvers representative of those performed during normal operations.
        ii. Flight over and around terrain and cultural areas representative of those encountered during normal operations (e.g., mountainous areas, urban areas, reflective surfaces, etc.).
        iii. Flight during various illumination and weather conditions. As a minimum this test must be performed during a moonless night and in an area with minimum cultural lighting.
2. Ensure the aircraft is ready for testing prior to traveling to the test site. The entire system (NVG selected for use, NVIS lighting, etc.) shall be available/installed prior to the start of testing, and the interior NVIS lighting shall have successfully passed ground testing.
3. Prior to scheduling the test, review the test plan (to include illumination levels and weather patterns) with the applicant to ensure it is acceptable.

4.4.2.1 Interference Effects Tests

Applicant will complete this test for those systems that need to be evaluated in flight due to the emission characteristics for the NVG or NVIS installed component. Refer to Section 4.4.1.1 for procedures and acceptability criteria.

4.4.2.2 Daylight Readability Evaluation

Readability of modified displays and annunciators shall be accomplished during a daytime test flight. The test conditions should be worse case (i.e., bright sunlight) to ensure components that have been modified comply with the appropriate regulations for readability. This is particularly important for those components that have been filtered in order to make them NVIS compatible. Fly the aircraft at headings that will place the sun at various angles relative to the cockpit (e.g., in front of, behind, to the right side, to the left side, etc.). The flight should be scheduled when the sun is lower towards the horizon rather than when it is high. This will increase the opportunity for evaluating worse case sun angles. Pay particular attention to the readability and attensity of warning and caution indicators.

4.4.2.3 Crewstation Ergonomics Evaluation

This is accomplished to verify the findings during ground testing and to perform evaluations that could not be adequately conducted at that time. Structures and other obstacles in the cockpit that may limit outside viewability or that may hinder the user from conducting an adequate NVG scan should be evaluated for flight safety. Since part of the evaluation is to determine if there are adverse impacts on the NVG field of regard, this evaluation shall be conducted at nighttime.

4.4.2.4 Nighttime Readability Evaluation

This is a subjective determination of the unaided readability of the modified components during nighttime operational conditions. The purpose is to verify findings during ground test and to ensure that night unaided flight has not been degraded by modifications required to make the interior lighting NVIS compatible. The cockpit area (e.g., all instruments and controls) is viewed with unaided vision by looking beneath or around the NVG. Although unaided readability could be performed without wearing the NVG, some of the test points require the NVG to be worn. The lighting should be adjusted to a brightness level consistent with normal flight operations. The following are recommended test points:

1. Evaluate all modified displays, annunciators, instruments and panels for readability, balance of illumination across the instrument and panel face, and attensity.
2. Evaluate the functionality of interior lighting controls.
3. Evaluate the illumination balance of all components on each dimming control, and the illumination balance of the entire NVIS lighting system when set by all dimming controls.
4. Verify that cockpit controls are easily seen and that their selected positions are easily discernable.
5. Determine if wearing the NVG has any adverse effects on unaided viewability of components within the cockpit. For example, when conducting a normal scan of the outside scene with the NVG, are there any warning or caution lights that cannot be seen unaided due to the NVG hardware.
6. Evaluate the effect of reflections. If new reflections are noted, attempt to determine the cause (e.g., aircraft exterior light reflection, moon reflection from smooth surface in the cockpit, etc.) and the impact to flight operations. Due to the potential adverse effects secondary to reflections from exterior lighting, that subject will be addressed in the following paragraph.

4.4.2.4.1 Aircraft Exterior Lighting Evaluation

All the aircraft’s external light sources must be assessed for objectionable glare and reflections from all crew stations under both NVG-aided and unaided night flight conditions. The aircraft should be flown at operationally representative altitudes, over the expected terrain to assess the effects of aircraft light sources reflecting off the terrain/obstacles. If components of the aircraft, such as FLIR, landing gear, or directable spotlights, can change the external configuration of the aircraft then they should be assessed in their worst possible configuration. The following is a partial list of external aircraft mounted light sources:

1. Position lights
2. Anticollision lights
3. Landing lights
4. Search lights

If the exterior lighting has been relocated due to previous NVIS testing deficiencies, a comparison with previous test results shall be accomplished to ensure the deficiencies have been satisfactorily addressed

If there are objectionable reflections/glare, they shall be eliminated. (See Appendix E, concerning recommended design practices). At least one separate switch must be provided as applicable:

1. For each separately installed landing light
2. For each group of landing lights installed at a common location

These lights shall function in order to provide enough light for night operations, including hovering and landing under NVG-aided and unaided conditions.

4.4.2.5 Failure Modes

The pilot shall simulate failures of various controls, electrical sources, electrical distribution system etc to account for all significant failures.

The pilot shall verify that a safe recovery can be made following an NVG failure in any phase of flight. The pilot shall verify that a safe transition to instrument flight can be made after encountering inadvertent IMC.

4.4.2.6 NVG Evaluation

A flight evaluation of the NVG should be an extension of the ground test. Some of the test points are more applicable if comparing two NVGs in order to down select to one, but they can be applied to the evaluation of a single NVG. An evaluation of the NVG with respect to crewstation ergonomics was described previously (see Section 4.4.2.3).

4.4.2.6.1 NVIS Lighting Compatibility Verification

This is a subjective evaluation to ensure that the NVIS lighting modification does not adversely affect the NVG image. The evaluator shall determine that there is no perceptible difference in NVG image quality when viewing the outside scene with the modified lighting on or off. Afterwards, the aircraft should be flown at operationally representative altitudes, over the expected terrain to assess the adequacy of the visual cues provided to the pilot with the NVIS lighting set at operational representative brightness levels.

4.4.2.6.2 Functionality

This evaluation relates to the tests described for Operator Controls, Mount Assembly, Head-Mounting Device, and Power Supply and Controls (Sections 4.4.1.2.2.1 through 4.4.1.2.2.4). Confirm that the findings during ground test are applicable to the relevant flight envelope. The following are examples of possible test points:

1. Ensure that the NVG image remains in the preset position during normal maneuvering.
2. Ensure that the weight and center-of-gravity are adequate (i.e., comfortable) during maneuvering and extended use.

3. Evaluate ease of donning and doffing while at the controls.
4. Evaluate the stowed position (if available) for utility and clearance from cockpit structures (e.g., overhead panels, etc.).
5. Evaluate the functionality of NVG controls (including power controls).
6. Evaluate the interoperability of the head-mounting device with other equipment (e.g., audio head set). Ensure that using the NVG does not degrade the use of other necessary equipment (e.g., makes the head set fit loosely thus reducing clarity of audio).

4.4.2.6.3 Visual Performance

The performance of the NVG should be evaluated during conditions that are representative of the expected operational envelope. This includes but is not limited to the following considerations: terrain, proximity of urban areas, operational maneuvers and/or procedures, weather patterns, variation in ambient illumination, time of night, etc. The main purpose is to determine if the NVG provides an image that can be safely and effectively used for the intended missions. If the goal of testing is to evaluate a new NVG or to compare various NVGs for down select, it is strongly recommended that several test flights be scheduled in order to capture as many of the variables as previously listed. To effectively evaluate the performance, it is important to be very familiar with these variables (e.g., know the terrain very well, know the distances to cultural objects, etc.). At a minimum, test flights should incorporate the worse case scenarios (e.g., low illumination and low contrast terrain, most demanding maneuvers, etc.). The following are some examples of possible test points (as previously stated, some of these are more conducive for comparing the performance of two or more NVGs):

1. Evaluate the effectiveness in detecting subtle terrain variations during high and low illumination conditions.
2. Evaluate the effects of cultural light sources (e.g., size and density of halos).
3. Evaluate the effects of large urban areas (e.g., blooming, de-gaining, etc.).
4. Evaluate the capability for estimating distances to known cultural or terrain features.
5. Evaluate the effects of ambient illumination shortly after sunset or shortly before sunrise.
6. Evaluate the effects of weather and other airborne obscurants (e.g., smoke, haze, etc.).
7. Evaluate the suitability of the field of view and the field of regard (partially addressed in crewstation ergonomics).
8. Evaluate the ability to effectively control the aircraft while using NVGs (e.g., maintain predetermined altitude and airspeed control over a specified course while conducting NVG visual tasks, etc.).
9. Evaluate the impact of image characteristics (e.g., dark spots, veiling glare, distortion, phosphor tailing to include undesirable persistence, etc.).

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5 CONTINUED AIRWORTHINESS

This section describes the requirements for the continued airworthiness of NVIS. In addition, this section sets forth the minimum requirements for records, personnel (who are authorized) to perform preventative maintenance, maintenance and inspection, and the guidance necessary to ensure continued airworthiness of the NVIS.

Note: *An aircraft that does not meet the airworthiness standards for NVIS operations may still be airworthy to conduct other flight operations.*

5.1 Terminology

1. Appliance – Any instrument, mechanism, equipment, part, apparatus, appurtenance, or accessory, including communications equipment, that is used or intended to be used in operating or controlling an aircraft in flight and is not part of an airframe, engine, or propeller. (e.g., NVGs are an appliance)
2. Check – A functional test or other procedure specified within the NVG appliance approved Aircraft (or Rotorcraft) Flight Manual Supplement that is accomplished by the person using the appliance. This type of check or procedure would be considered preventative maintenance. An entry into the appropriate record by that person conducting the check or procedure must be accomplished.
3. Conditional Inspection – An inspection that is required as a result of unusual events, such as dropping the NVG appliance on a hard surface, hard impact, immersion into water, etc.
4. Inspection – A method of qualifying the condition or status of the appliance, its systems, and/or accessories to specific standards and requirements.
5. Maintenance – Inspection, overhaul, repair, preservation, and the replacement of parts, but excludes preventative maintenance.
6. Preventative Maintenance – Simple or minor preservation operations and the replacement of small standard parts not involving complex assembly operations.
7. Overhaul – Using methods, techniques, and practices acceptable to the FAA, or other regulatory agency/authority, the appliance has been disassembled, cleaned, inspected, repaired as necessary and reassembled; and it has been tested in accordance with (IAW) approved standards and technical data.

   Note: *For US operators, refer to Title 14 CFR, Chapter 1, Part 21, Section 21.305 for more information. In addition, for foreign operators, refer to the respective JAR or other civil regulatory equivalent.*

8. Rebuilt – The appliance has been completely disassembled, inspected, repaired as necessary, reassembled, tested, and approved in the same manner and to the same tolerances and limits as a new appliance with either new or used parts. However, all parts used in it must conform to the production drawing tolerances and limits for new parts or be of approved oversized or undersized dimensions for a new appliance.
9. Return to Service – An entry made in the appropriate record by a qualified individual certifying that the appliance, system or accessory is airworthy after accomplishing the required inspection, test, preventative maintenance or maintenance IAW manufacturer’s maintenance instructions or instructions for continued airworthiness.
10. Scheduled Inspection – An inspection performed on a calendar, cycle, or hourly basis or a combination of calendar/hourly/cycle basis.
11. Special Inspection – An inspection that is performed after completing other maintenance, such as installation of a major component (e.g., replacement of binocular assembly, monocular assembly, intensifier tube, etc.)

5.2 Records

Records described in the following sub-sections are required to assure to the operator the product meets the conformity and airworthiness standards established in Sections 2 and 3 of this document, manufacturer's maintenance manual or instructions for continued airworthiness, and for the purposes of tracing the product's history of operational use, repairs, alterations, serviceability and maintenance.

5.2.1 Description of Maintenance Performed

Each owner or operator shall keep the following records for the periods specified in Section 5.2.4 for each NVG appliance (as an assembly) and major components.

Records of the maintenance, preventative maintenance, and alteration and records of the required or approved inspections, as appropriate, for each appliance. The records shall include:

1. A description of the work performed.
2. The date of completion of the work performed.
3. The signature and authorization number for the person approving the aircraft or appliance for return to service.

5.2.2 Component Description

Records shall contain the following information:

1. The nomenclatures, make, and model of the component, assembly, or part.
2. The serial number of each component, assembly or part, if applicable.
3. The total time in service of the appliance.
4. The current status of life limited parts of the appliance, if applicable.
5. The time since last overhaul of all items installed in the appliance which are required to be overhauled on a specific time basis.
6. The current inspection status of the appliance, including the time since the last inspection required by the manufacturer's inspection program under which the appliance is maintained.
7. The current status of applicable airworthiness directives (AD) including, for each, the method of compliance, the AD number, and the revision date. If the AD involves the re-occurring action, the time and date when the next action is required.
8. Copies of the forms for each major alteration to the appliance. For US operators, refer to Title 14 CFR, chapter 1, Part 43, Section 43.9(a) for further information.

5.2.3 Retention of Records

The owner or operator shall retain the following records for the periods prescribed:

1. The records specified in Sections 5.2.1 & 5.2.2 shall be retained until the work is repeated or superceded by other work or for one year after work is performed.
2. The records specified in Sections 5.2.1 & 5.2.2 shall be retained and transferred with the appliance at the time the appliance is sold.
3. A list of defects furnished to a registered owner or operator shall be retained until the defects are repaired and the appliance is approved for return to service.
4. The owner or operator shall make all maintenance records required to be kept by this section available for the inspection by their authorized regulatory representative or the representative of an authorized safety and investigative agency/authority.

5.2.4 Records of Overhaul and Rebuilding

5.2.4.1 Overhaul

No person may describe in any required maintenance entry or form, an appliance or component part as being overhauled unless methods, techniques, and practices acceptable to an authorized regulatory agency/authority were used. And, it has been disassembled, cleaned, inspected, repaired as necessary, reassembled and it has been tested IAW the standards and technical data of Section 2 and 3 of this document.

Note: *Other standards and technical data may be acceptable but this data must be mutually accepted by one's regulatory agency/authority IAW their type certificate, process, or appliance approval. For US operators, refer to Title 14, Chapter 1, Part 21, Section 21.305.*

5.2.4.2 Rebuilt

No person may describe in any required maintenance entry or form an appliance or component part as being rebuilt unless it has been disassembled, cleaned, inspected, repaired as necessary, reassembled, and tested to the same tolerances and limits as a new item, using either new parts or used parts that either conform to new part tolerances and limits or to approved oversized or undersized dimensions.

5.2.5 Assemblies, Components or Parts Requiring Records

Records described in Sections 5.2.1 and 5.2.2 shall be kept for each of the three main NVG appliance assemblies as described below:

1. Helmet/headband mount which may include:

   Low power indicator, wiring harness, and associated hardware.

2. Binocular assembly(s) which may include the following:

   Pivot adjustment shelf or frame, monocular housings, intensifier tubes, eye pieces, objective lenses, and associated hardware and seals.

3. Power source assembly which may include:

   Battery(s), airframe supplied power provisions, battery trays, case, and/or wiring harness and end plug.

5.3 Airworthiness Limitations

Each person performing an inspection or other maintenance specified in an Airworthiness Limitations section of a NVIS manufacturer's maintenance manual or Instructions for Continued Airworthiness shall perform the inspection or other maintenance in accordance with that section, or in accordance with an approved operations specification.

Note: *For US operators, reference Title 14 CFR, Chapter 1, Parts 121, 123, 127, or 135, or an inspection program approved under Part 91, Sec. 91.409(e). In addition, for foreign operators, refer to the respective JAR or other civil regulatory equivalent.*

5.4 Persons Authorized to Perform Aviation NVIS maintenance, Preventive Maintenance, Rebuilding, and Alterations (Refer to Table 5-1)

1. The holder of an airframe mechanic certificate may perform NVIS maintenance, preventive maintenance, and alterations provided the following are met:
   a. The mechanic has been trained by the manufacturer or received other authorized training
   b. The mechanic has the required tools, fixtures, facilities and test equipment specified by the manufacturer for the maintenance being performed
   c. The test equipment is calibrated and the facilities meet the requirements specified by the manufacturer.
2. The holder of a repairman certificate may perform maintenance and preventive maintenance provided:

   The repair facility meets the proper certification requirements of the FAA, or regulatory equivalent, to perform the maintenance and preventive maintenance described in the certificate holders specifications.
3. A person working under the supervision of a holder of a mechanic or repairman certificate may perform the maintenance, preventive maintenance, and alterations that his supervisor is authorized to perform, if the supervisor personally observes the work being done to the extent necessary to ensure that it is being done properly and if the supervisor is readily available, in person, for consultation.
4. The holder of an authorized repair station certificate may perform maintenance, preventive maintenance, and alterations.

   Note: *For US operators, refer to Title 14 CFR, Chapter 1, Part 145. In addition, for foreign operators, refer to the respective JAR 145 or other civil regulatory equivalent.*
5. The holder of an authorized operating certificate may perform maintenance, preventive maintenance, and alterations.

   Note: *For US operators, refer to Title 14 CFR, Chapter1, Parts 121, 127, or 135, operating certificates. In addition, for foreign operators, refer to the respective JAR or other civil regulatory equivalent.*
6. The holder of an authorized pilot certificate, who holds either a NVIS logbook endorsement or operates in a NVIS operation approved by the appropriate regulatory agency/authority may perform functional checks and preventative maintenance as described in Table 5-1 of this section.

   Note: *For US operators, refer to Title 14 CFR, Chapter 1, Part 43, Section 43.3(h), for special allowances for a pilot to perform specific preventive maintenance, if operating rotorcraft in a remote area. In addition, for foreign operators, refer to the respective JAR or other civil regulatory equivalent.*

7. A manufacturer may:
   a. Rebuild or alter any appliance or part of appliances manufactured by him under a Technical Standard Order Authorization, a Parts Manufacturer Approval, or an authorized Product and Process Specification.
   b. Perform any inspection required by this section on appliances it manufacturers, while currently operating under a production certificate or under a currently approved production inspection system for such appliance.

Table 5-1 Authorized Preventative Maintenance Allocations

TYPE	Preventative Maintenance	Preventative Maintenance	Preventative Maintenance	Preventative Maintenance	Preventative Maintenance	Preventative Maintenance	Preventative Maintenance
	Functional/ Preflight Check	Battery Replacement	Cleaning with no disassem-bly required	Cleaning of Power Source Battery Con-tacts	Removing and Installing Helmet or Headband mounting assembly	Inspecting or Cleaning of Windshield	Minor Adjustments for fit, focus, or other adjustments required to complete functional check
Pilot	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Airframe Mechanic	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Repair Station	Yes	Yes	Yes	Yes	Yes	Yes	Yes

5.4.1 Persons Authorized to Approve NVIS Appliances or Component Parts for Return to Service after Maintenance, Preventive Maintenance, Rebuilding, or Alteration (Refer to Table 5-2)

1. The holder of an airframe mechanic certificate or an inspection authorization may approve a NVIS appliance or component part for return to service in accordance with the following:
   a. The mechanic or inspector has been trained by the manufacturer or received other training acceptable to the regulatory agency/authority.
   b. The mechanic or inspector has the required tools, fixtures, facilities, and test equipment specified by the manufacturer for the maintenance being performed.
2. The holder of a repair station certificate may approve a NVIS appliance or component part for return to service.

   Note: *For US operators, refer to Title 14 CFR, Chapter1, Part 145. In addition, for foreign operators, refer to the respective JAR 145 or other civil regulatory equivalent.*

3. A manufacturer may approve for return to service any appliance or component part which that manufacturer has performed work. However, except for minor alterations, the work must have been done in accordance with the approved technical data.

   Note: *For US operators, refer to Title 14 CFR, Chapter 1, Part 43, Sec. 43.3(j). In addition, for foreign operators, refer to the respective JAR or other civil regulatory equivalent.*

4. The holder of an authorized operating certificate may approve a NVIS appliance or component part for return to service.

Note: *For US operators, refer to Title 14 CFR, Chapter 1, Parts 121, 127, or 135. In addition, for foreign operators, refer to the respective JAR or other civil regulatory equivalent.*

5. After performing preventive maintenance as defined in Sections 5.1 and 5.4, a person who holds an approved pilot certificate with an NVIS logbook endorsement or operating in an approved NVIS operation may approve a NVIS appliance for return to service after functionally testing the NVIS.

Table 5-2 Additional Maintenance Allocations

TYPE	Maintenance	Maintenance	Maintenance	Maintenance	Maintenance	Maintenance	Maintenance
	Tightening or replacing associated hardware installed in NVG assembly	Removal or Installation of Pivot Adjustment Shelf or Frame from the Binocular Assembly	Cleaning of NVG assembly that requires disassembly of a Binocular Assembly or Monocular Housing	Removal or installation of Intensifier Tube	Removal or installation of eye piece or Objective Lens	180-Day Inspection	Any repair or action related to wiring harnesses, soldering, etc.
Pilot	No	No	No	No	No	No	No
Airframe Mechanic*	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Repair Station	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Manufacturer	Yes	Yes	Yes	Yes	Yes	Yes	Yes

*Airframe Mechanic that is properly trained, that has the required tools, test equipment, and facilities required by the manufacturer.

5.5 Instructions for Continued Airworthiness (ICA)

The three main components of aviation NVIS that are required checks, inspections, and maintenance are:

1. Aircraft windshield
2. Installed compatible NVIS lighting
3. NVG appliance assembly which consists of:
   a. Helmet/headband mount which may include:
      i. Low power indicator (if applicable), wiring harness, and associated hardware
   b. Binocular assembly(s) which may include the:
      i. Pivot adjustment shelf or frame
      ii. Monocular housings
      iii. Intensifier Tubes
      iv. Eye Pieces
      v. Objective lenses
      vi. Associated hardware and seals
   c. Power source assembly which may include the:
      i. Battery(ies)
      ii. Battery trays

iii. Airframe supplied power provisions

iv. Case

v. Wiring harness and end plug

5.5.1 ICA Preparation

The information provided in this section and paragraphs are provided as a guide for the preparation of the Instructions for Continued Airworthiness (ICA) as required by regulation. However, the applicant should consult with the appropriate regulatory authority for specific requirements in the development of an ICA.

The Instructions for Continued Airworthiness for each appliance, system or accessory shall include:

1. The Instructions for Continued Airworthiness for each NVIS appliance, system or accessory and any required information relating to the interface of the appliance, system or accessory with an aircraft.
2. If Instructions for Continued Airworthiness are not supplied by the applicant or the manufacturer of the appliance, system or accessory installed in the aircraft, the Instructions for Continued Airworthiness for the aircraft shall include the information essential to the continued airworthiness of the installed appliance, system or accessory.

5.5.2 ICA Program

The applicant shall submit to the FAA or other regulatory authority a program to show how changes to the Instructions for Continued Airworthiness made by the applicant or by the manufacturers of appliance, system or accessory installed in an aircraft will be distributed.

5.5.2.1 Format

1. The Instructions for Continued Airworthiness shall be in the form of a manual or manuals as appropriate for the quantity of data to be provided.
2. The format of the manual or manuals shall provide for a practical arrangement.

5.5.2.2 Content

The contents of the manual or manuals shall be prepared in the English language. The Instructions for Continued Airworthiness shall contain the following manuals or sections, as per Sections 5.5.2.2.1 through 5.5.2.2.4.

5.5.2.2.1 Appliance, System or Accessory Maintenance Manual or Section

1. Introduction information that includes an explanation of the appliances', systems' or accessories' features and data to the extent necessary for maintenance or preventative maintenance.
2. A description of the appliance, system or accessory and installations including its components, parts, and accessories.
3. Basic control and operation information describing how the appliance, system or accessories are controlled and how they operate, including any special procedures and limitations that apply.
4. Servicing information that covers details regarding servicing points, location of parts for inspection and servicing, and equipment required for servicing.

5.5.2.2.2 Maintenance Instructions

1. Scheduling information for each part of the appliance, system or accessory, power units and equipment that provides the recommended periods at which they should be cleaned, inspected, adjusted, tested, and the degree of inspection, the applicable wear tolerances, and work recommended at these periods. However, the applicant may refer to an appliance, system or accessory or equipment manufacturer as the source of this information if the applicant shows that the item has an exceptionally high degree of complexity requiring specialized maintenance techniques, test equipment, or expertise. As a minimum the schedule shall include a 180 day inspection of the NVG appliance and a 24 month NVIS validation test.
2. The recommended overhaul period shall cross reference the Airworthiness Limitations section of the manual.
3. In addition, the applicant shall include an inspection program that includes the frequency and extent of the inspections necessary to provide for the continued airworthiness of the appliance, system or accessory. As a minimum the 180 Day Inspection and 24 Month Validation test shall include the items listed below:
   a. Inspect NVG appliance for condition and clean.
   b. Inspect hardware for condition and security, repair as necessary.
   c. Conduct continuity check of power supply and electrical harness, repair or replace as necessary.
   d. Check warning indicators for operation, repair or replace as needed.
   e. Conduct Collimation check, make adjustments as required.
   f. Conduct image quality test in accordance with manufacturer’s procedures, repair or adjust as necessary.
   g. Conduct resolution and gain check in accordance with manufacturer’s or other approved procedures and replace tubes, if necessary.
   h. Purge nitrogen in accordance with the manufacturer’s procedures (if required).
   i. Perform functional check.

   Extent of 24 month validation test:

   Refer to Sections 3 and 4 of this document for the test required to verify the NVIS installation meets the standards required for certification.
4. Troubleshooting information describing probable malfunctions, how to recognize those malfunctions, and the remedial action for those malfunctions.
5. Information describing the order and method of removing and replacing components and parts of the appliance, system or accessory with any necessary precautions to be taken. In addition, identify any special inspection(s) that may be required after other maintenance such as replacement of an Intensifer Tube within a monocular assembly that shall require the completion of a 180 Day Inspection or replacement of a windshield requiring a 24 Month Test.
6. Other general procedural instructions including procedures for system testing, storage limitations and identity of events such as dropped NVG appliance, immersion into water, exposure to sunlight, etc., that shall require the accomplishment of any conditional inspection(s). The scope and detail of the conditional inspection to be performed shall be described.
7. Diagrams of component or parts of the appliance, system or accessory and information needed to gain access to components for inspections, if applicable.

8. Details for the application of special inspection techniques including radiographic and ultrasonic testing where such processes are specified and the qualifications of individuals authorized to perform any Non-Destructive Testing procedure.
9. Information needed to apply protective treatments to the appliance, components or parts after inspection.
10. All data relative to fasteners such as identification, discard recommendations, and torque values.
11. A list of special tools needed.
12. Electrical loads applicable to the systems.
13. Special repair methods applicable to the appliance.
14. Instructions for integrating servicable replacement components or parts of an appliance, system or accessory into the appliance, system or accessories' inspection program.

5.5.2.2.3 Airworthiness Limitations Section

This section must set forth each mandatory replacement time, inspection interval, and related inspection procedure required for certification. If the Instructions for Continued Airworthiness consist of multiple documents, the section required by this paragraph shall be included in the principal manual. As a minimum the Airworthiness Limitations section shall establish the replacement interval for the battery or batteries used in a NVG appliance as the primary power or back-up power source to ensure adequate battery endurance for the intended flight.

5.5.2.2.4 Illustrated Parts Breakdown

1. An illustration of each component or part and their orientation to the assembly being displayed.
2. Each part shall be identified by a part number.
3. For each part that is interchangeable with similar appliances, systems or accessories that may effect the conformity to design specifications, that part shall be identified and have an applicability statement to the next higher assembly to ensure the integrity of the appliance, system or accessory, if applicable.
4. The quantity required of each part to complete the assembly.
5. Common hardware, seals, and o-rings shall be displayed with the part number and quantity required to complete the assembly.

5.6 Training Programs

Each person performing maintenance, inspection, preventive maintenance or alteration on a NVIS appliance, system or accessory shall be trained and qualified in the manufacturer's or applicant's holders methods, techniques, and practices prescribed in the current maunfacturer's maintenance manual or instructions for continued airworthiness, and acceptable to the regulatory authority.

The training should include, but is not limited to the following:

1. The operation of the test equipment, special tools or other equipment required to maintain or test a NVIS appliance, system or accessory.
2. The procedures and requirements for conducting the performance test as described in Section 4 of this document.
3. Validation of windshield transmisstivity.

4. Inspection and maintenance of a NVIS compatible lighting system to include any precautions in the care and cleaning of filters or lenses.
5. NVIS Installation description and operation.
6. NVG mount installation, test and repair.
7. Binocular assembly adjustments, tests, functional checks, and component replacement.

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Night Vision Goggle (NVG) Appliances and Equipment

Minimum Operational Performance Standards for Integrated Night Vision Imaging System Equipment

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Appendix A

ABBREVIATIONS AND ACRONYMS

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Appendix A—ABBREVIATIONS AND ACRONYMS

AC	Advisory Circular
AD	Airworthiness Directive
AM	Amplitude Modulation
ARP	Aerospace Recommended Practice
C	Centigrade
Cm	Modulation Contrast
CFR	Code of Federal Regulations
CG	Center of Gravity
CIE	Commission Internationale de l'Eclairage (International Commission on Illumination)
CM	Centimeters
CONOPS	Concept of Operations
CRT	Cathode Ray Tube
CY/MRAD	Cycles Per Milliradian
DOD	Department of Defense
DOT	Department of Transportation
EFIS	Electronic Flight Instrument Systems
FAA	Federal Aviation Administration
FC	Foot-Candles
FHA	Functional Hazard Assessment
FL	Foot-Lamberts
FLIR	Forward Looking Infrared Radar
FOR	Field of Regard
FOV	Field of View
G	Gravity
GEN	Generation
HUD	Head Up Display
ICA	Instructions for Continued Airworthiness
IFR	Instrument Flight Rules
IPD	Interpupillary Distance
JAA	Joint Aviation Authorities
K	Kelvin
LCD	Liquid Crystal Displays
LED	Light Emitting Diode
MDL	Master Drawing List
MOPS	Minimum Operational Performance Standard
MM	Millimeters
NRI	NVIS Radiant Intensity
NIR	Near Infrared

NM	Nanometers
NRb	NVIS Radiance for Class B lighting
NVD	Night Vision Device
NVG	Night Vision Goggle
NVIS	Night Vision Imaging System
RTCA	Formerly known as Radio Technical Commission for Aeronautics
SAE	Society of Automotive Engineers
SC	Special Committee
UCS	Uniform Color Space
VA	Visual Acuity
VFR	Visual Flight Rules

Appendix B

BIBLIOGRAPHY AND REFERENCE MATERIAL

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Appendix B—BIBLIOGRAPHY AND REFERENCE MATERIAL

1. Air Force Manual 11-217 Volume 2, Chapter 3, *Night Vision Devices*, August 6, 1998.
2. Crowley, John Dr., *Human Factors of Night Vision Devices: Anecdotes from the Field Concerning Visual Illusions and Other Effects,* AAMRL Report No. 91-15, Fort Rucker, Alabama, 1991.
3. Delucia, Patricia R., and Task H.Lee, *Depth and Collision Judgment Using Night Vision Goggles*, Armstong Laboratory, Wright-Patterson Air Force Base, Ohio, 1995.
4. Department of Army, *Training Circular 1-204, Night Flight: Techniques and Procedures,* 1988.
5. DOT/FAA, *Report no DOT/FAA/RD-94/21– Night Vision Goggles in Emergency Medical Services (EMS) Helicopters,* March 1994.
6. FAA Advisory Circular 27-1B, Certification of Normal Category Rotocraft, September 30, 1999.
7. FAA Advisory Circular 29-2C, Certification of Transport Category Rotocraft, September 30, 1999.
8. FAA, *Guide for Aviation Medical Examiners,* November 1996.
9. FAA, *Notice for Proposed Rulemaking Statement- Night Vision Goggles, Draft*, September 7, 1999.
10. FAA Handbook 8083-21, *Rotorcraft Flying Handbook,* 2000.
11. FAA Operation Specification, *Rocky Mountain Helicopters Night Vision Goggle Operations,* February 4,1999.
12. FAA Supplemental Type Certificate Number SR09208RC, *Rocky Mountain Holdings, BO-105,* January 19,1999.
13. FAA, *Aeronautical Information Manual (AIM)*, February 24, 2000.
14. Howard, Celeste, M., Tregear, Stephen J., and Werner, John S., *Time Course of Early Mesopic Adaptation to Luminance Decrements and Recovery of Spatial Resolution,* Link Simulation and Training Division, L-3 Communications, May 2000.
15. ITT Industries, *Operator's Manual-Image Intensifier Set, Night Vision AV4949UL,* June 21,1999.
16. JAA, *JAR-OPS Night Vision Goggle Operations, Draft,* 1999.
17. Leger, A., Roumes, C., Bergeaud, J.M., Dareoux, P., Gardelle, C., *Flight Testing of a Binocular, Bisensor HMD for Helicopter: Some Human Factors Aspects,* 1998 <u>SPIE Proceedings, 1998.</u>
18. Lit, A., *The Magnitude of the Pulfrich Stereophenomenon as a Function of Binocular Differences of Intensity at Various Levels of Illumination,* <u>American Journal of Psychology</u>, No. 62, pp 158-181, 1949.
19. McLean, William Dr., *An Assessment of Luminance Imbalance with ANVIS at an Army Helicopter Training Airfield,*USAARL Report No. 97-21, Fort Rucker, Alabama, May 1997.
20. McLean, William Dr., Shannon, Samuel, McEntire, Joseph, and Armstrong, Scott, *Counterweights Used with ANVIS,* USAARL Report No. 96-30, Fort Rucker, Alabama, July 1996.
21. Military Specification 85762A, *Lighting, Aircraft, Interior, Night Vision Imaging System Compatible,* Attachment 7, Department of Defense, August 1988.
22. Mobility Air Forces, *Concept of Operations-Aircrew Night Vision Goggles,* September 8, 1998.
23. Perfetto, Nicholas J., Embry-Riddle Aeronautical University, *The Feasibility of Metropolitan Police Department Helicopter Pilots Using Night Vision Goggles,* May 2000.
24. Reising, Jack D., Antonio, Joseph C, and Field, Bruce, *Procedures for Conducting a Field Evaluation of Night Vision Goggle-Compatible Cockpit Lighting,* Human Resources Directorate, Aircrew Training Research Division, Armstrong Laboratory, March 1996.
25. RTCA, Inc. – *Basic Document Style Guide,* July 1999.
26. RTCA, Inc – *Minimum Operational Performance Standards Drafting Guide,* September 1994.
27. RTCA/DO-160D, *Environmental Conditions and Test Procedures for Airborne Equipment,* Special Committee 135, July 1997.
28. Simpson, Carol Dr., Williams, Douglas Dr., Gardner, Donald., and Haworth, Loran., *Analysis of Response to Survey of Issues in the Application of Night Vision Goggles to Civil Rotorcraft Flight Operations, Draft,* July 12, 1999.
29. Society of Automotive Engineers, *Certification Considerations for Highly-Integrated or Complex Aircraft Systems,* Aerospace Recommended Practice 4754, November 1996.

30. United States Marine Corps, Marine Aviation Weapons and Tactics Squadron One, *Helicopter Night Vision Device Manual,* Summer 1995.
31. Merriam-Webster Incorporated, *Webster's Ninth New Collegiate Dictionary*, 1983.
32. Laurin Publishing, *The Photonics Dictionary Book 4*, 2000.

Appendix C

GLOSSARY

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Appendix C—GLOSSARY

1. ABSORPTANCE. The ratio of the radiant energy absorbed by a body to that incident upon it.
2. AIDED. A term used to describe those times when NVGs are being used as an aid to night vision.
3. ALBEDO. The ratio of the amount of light reflected from a surface to the amount of incident light.
4. AUTOMATIC BRIGHTNESS CONTROL (ABC). One of the automatic gain control circuits found in second and third generation NVG devices. It attempts to provide consistent image output brightness by automatic control of the microchannel plate voltage.
5. AUTOMATIC GAIN CONTROL (AGC). Comprised of the automatic brightness control and bright source protection circuits. It is designed to maintain image brightness and protect the user and the image tube from excessive light levels. This is accomplished by controlling the gain of the intensifier tube.
6. BLACKBODY. An ideal body of surface that reflects or radiates essentially no energy in the spectral band to which NVGs are sensitive. .
7. BLOOMING. Common term used to denote the “washing out” of all or part of the NVG image due to de-gaining of the image intensifier tube when a bright light source is in or near the NVG field of view.
8. BRIGHT SOURCE PROTECTION (BSP). Protective feature associated with second and third generation NVGs that protects the intensifier tube and the user by controlling the voltage at the photocathode.
9. BROWNOUT. Condition created by blowing sand, dust, etc., which can cause the operators to lose sight of the ground. This is most commonly associated with landings in the desert or in dusty LZs.
10. CIVIL TWILIGHT. The time when the true altitude of the center of the sun is six degrees below the horizon. The illuminance level is approximately 3.40 lux and is above the usable level for NVG operations.
11. DIOPTER. A measure of the refractive (light bending) power of a lens equal to one over the focal length of the lens in meters. Also, used to indicate the eyepiece focus setting needed to adjust the NVG image to compensate for people that require corrective lenses.
12. DIRECT VIEW IMAGE NVG (TYPE I). Any NVG which displays the intensified image on a phosphor screen in the user’s direct line of sight.
13. DISTORTION. The difference between the original image and the intensified (direct or projected image) after correction made by magnification
14. ELECTRO-OPTICS (EO). The term used to describe the interaction between optics and electronics, leading to transformation of electrical energy into light or vice versa.
15. ELECTROLUMINESCENT (EL). Referring to light emission that occurs from application of an alternating current to a layer of phosphor.
16. FOOTCANDLE. A measure of illuminance; specifically, the illuminance of a surface upon which one lumen is falling per square foot.
17. FOOTLAMBERT. A measure of luminance; specifically the luminance of a surface that is receiving an illuminance of one foot-candle. Also, equal to $1/\pi$ candela per square foot.
18. GAIN. When referring to an image intensification tube, the ratio of the brightness of the output in units of footlambert, compared to the illumination of the input in footcandles. A typical value for a GEN III tube is 25,000 to 30,000 fl/fc. A “tube gain” of 30,000 fl/fc provides an approximate “system gain” of 3,000. This means that the intensified NVG image is 3,000 times brighter to the aided eye than that of the unaided eye.

19. HALO. A bright circular "ring" surrounding a point light source that is caused by electron scattering in the intensification process. The intensity and size of the halo will vary depending on the ambient illumination, the intensity of the light source, the wavelengths being generated by the light source, the design of the image intensifier, and other factors. The halos from several light sources may coalesce to form larger appearing halos and may result in blooming of the image.

20. HEAD-UP DISPLAY. An electro-optical system that displays flight data to the pilot while maintaining external view and without requiring direct observation of the cockpit instruments. There are two common types of head-up displays (HUD): fixed (aircraft mounted) and NVG-mounted. Fixed HUDs are mounted in front of the pilot, immediately behind the windshield and are viewed directly by NVGs. NVG-mounted HUDs are physically mounted on the NVG, and the imagery is viewed through the NVG optics.

21. ILLUMINANCE. Also referred to as illumination. The area density of luminous flux (visible light power) on a surface at any given point. Foot-candles (lumens/square foot) and lux (lumens/square meter) are common units to measure illuminance.

22. IMAGE INTENSIFIER. An electro-optic device used to detect and intensify optical images in the visible and near infrared region of the electromagnetic spectrum for the purpose of providing visible images. The component that actually performs the intensification process in a NVG. This component is composed of the photocathode, MCP, screen optic, and power supply. It does not include the objective and eyepiece lenses.

23. INCANDESCENT. Refers to a source such as a filament that emits light due to thermal excitation, i.e., heating by an electrical current, resulting in a very broad spectrum of energy that is dependent primarily on the temperature of the filament.

24. INFRARED. That portion of the electromagnetic spectrum in which wavelengths range from 0.7 microns to 1 millimeter. This segment is further divided into near infrared (0.7-3.0 microns), mid infrared (3.0-6.0 microns), far infrared (6.0-15 microns), and extreme infrared (15 microns-1 millimeter). A NVG is sensitive to near-infrared wavelengths approaching 0.9 microns.

25. IRRADIANCE. The radiant flux density incident on a surface usually measured in watts per square centimeter or watts per square meter. This is similar to illuminance except that it includes all wavelengths of light whereas illuminance includes only visible wavelengths as weighted by the human visual sensitivity curve (photopic curve).

26. LIP LIGHT. A NVG compatible light that can be switched ON and OFF without the use of the hands.

27. LUMEN. A measurement of luminous flux equal to the light emitted in a unit solid angle by a uniform point source of one candle intensity.

28. LUMINANCE. The luminous intensity of a surface in a given direction per unit of projected area. This measure of light most closely approximates the human visual sensation of brightness. It is typically measured in units of foot-lamberts or candela per square meter (nits).

29. LUX. A unit of illumination measurement. The illuminance produced on a surface that is one-meter square, from a uniform point source of one-candle intensity, or one lumen per square meter.

30. MESOPIC VISION. Vision at reduced levels of retinal illumination where both retinal cones and retinal rods are stimulated, but cone function and color vision is limited.

31. MICROCHANNEL PLATE. A wafer containing between 3 and 10 million specially treated microscopic glass tubes designed to multiply electrons passing from the photocathode to the phosphor screen in second and third generation intensifier tubes.

32. MICRON. A unit of measure commonly used to express wavelength in the infrared region; equal to one millionth of a meter.

33. NANOMETER (nm). A unit of measure commonly used to express wavelength in the visible and near infrared region; equal to one billionth of a meter.

34. NIGHT. The time between the end of evening civil twilight and the beginning of morning civil twilight as published in the American Air Almanac.

35. NIGHT VISION DEVICE (NVD). An electro-optical device used to provide a visible image using the electromagnetic energy available at night.

36. NIGHT VISION GOGGLE (NVG). When referring to NVGs used for aviation purposes; a head-mounted, lightweight, self-contained binocular system consisting of two independent monocular intensifier tube assemblies.

37. PERSISTENCE. The time required for the light emission from the phosphor to decay to 10 percent from its steady state value after removal of excitation.

38. PHOTON. A quantum (basic unit) of radiant energy (light).

39. PHOTOPIC VISION. Vision by means of retinal cones; full color vision. Relatively high levels of luminance are required for photopic vision.

40. PROJECTED IMAGE NVG (TYPE II). Any NVG which projects the intensified image on a see-through medium in the user's line of sight.

41. RADIANCE. The flux density of radiant energy per unit solid angle per unit-projected area usually measured in watts per steradian per square centimeter or watts per steradian per square meter. This is similar to luminance except that it includes all wavelengths of light (ultra-violet through infra-read) whereas luminance includes only those wavelengths that are visible to the human eye. Radiance and luminance are not interchangeable terms.

42. REFLECTIVITY. The fraction of energy reflected from a surface.

43. SCINTILLATION. Noise in the NVG image that appears as a sparkling or snow-like effect that typically appears when the NVG is operated in an area of low illumination.

44. SCOTOPIC VISION. Vision by means of retinal rods; vision of the dark-adapted eye. In scotopic vision, the level of luminance is so low that the retinal cones are not stimulated, and there is no color vision.

45. SITUATIONAL AWARENESS (SA). Degree of perceptual accuracy achieved in the comprehension of all factors affecting an aircraft and crew at a given time.

46. STARLIGHT. The illuminance provided by the available (observable) stars in a subject hemisphere. The stars provide approximately 0.00022 lux ground illuminance on a clear night. This illuminance is equivalent to about one-quarter of the actual light from the night sky with no moon.

47. STEREOPSIS. Visual system binocular cues that are used for distance estimation and depth perception. Three dimensional visual perceptions of objects. The use of NVGs seriously degrades this aspect of near-depth perception.

48. TRANSMITTANCE. The fraction of radiant energy that is transmitted through a layer of absorbing material placed in its path.

49. ULTRAVIOLET. That portion of the electromagnetic spectrum in which wavelengths range between 0.1 and 0.4 microns.

50. UNAIDED. Term used to describe those times when NVGs are not being used (i.e., normal night vision is not being aided).

51. VEILING GLARE. Ghost image(s), crescents, or other geometrically shaped images appearing in the system's field of view when a bright source point of light is outside the field of view illuminating the entrance pupil of the objective lens.

52. WAVELENGTH. The distance in the line of advance of a wave from any one point to the next point of corresponding phase; is used to express electromagnetic energy including IR and visible light.

53. WHITEOUT. Whiteout occurs over an unbroken snow cover, with or without blowing snow, and beneath a uniformly overcast sky. The observer is unable to discern shadows, horizon, or clouds, and a sense of depth and orientation is lost.

Appendix D

RELATIVE SPECTRAL RESPONSE OF CLASS B NVG ($G_B(\lambda)$)

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Appendix D—RELATIVE SPECTRAL RESPONSE OF CLASS B NVG ($G_B(\lambda)$)

Wavelength (nm)	Relative Response	Wavelength (nm)	Relative Response
450	1.0000E-05	690	9.3790E-01
455	1.1250E-05	695	9.4480E-01
460	1.2500E-05	700	9.5170E-01
465	1.3750E-05	705	9.5860E-01
470	1.5000E-05	710	9.6550E-01
475	1.6172E-05	715	9.7304E-01
480	1.7500E-05	720	9.7300E-01
485	1.9375E-05	725	9.8020E-01
490	2.1250E-05	730	9.8280E-01
495	2.2266E-05	735	9.8838E-01
500	2.3750E-05	740	9.9310E-01
505	2.7657E-05	745	9.9719E-01
510	3.1250E-05	750	1.0000E+00
515	3.4297E-05	755	1.0000E+00
520	3.7500E-05	760	1.0000E+00
525	4.1875E-05	765	1.0000E+00
530	4.6250E-05	770	1.0000E+00
535	5.0703E-05	775	9.9814E-01
540	5.5000E-05	780	9.9660E-01
545	5.8359E-05	785	9.5430E-01
550	6.2500E-05	790	9.9450E-01
555	7.0000E-05	795	9.9830E-01
560	7.7500E-05	800	9.9310E-01
565	8.5000E-05	805	9.8620E-01
570	9.2500E-05	810	9.7930E-01
575	9.7688E-05	815	9.7283E-01
580	1.1000E-04	820	9.6550E-01
585	1.2566E-04	825	9.5515E-01
590	1.8200E-04	830	9.4480E-01
595	2.6581E-04	835	9.3402E-01
600	5.2500E-04	840	9.2410E-01
605	1.0183E-03	845	9.1720E-01
610	2.0000E-03	850	9.1030E-01
615	3.4569E-03	855	8.6334E-01
620	6.2500E-03	860	8.0000E-01
625	9.0935E-03	865	7.2848E-01
630	1.8414E-02	870	6.5520E-01
635	4.6447E-02	875	5.8016E-01
640	7.4480E-02	880	5.0340E-01
645	2.0949E-01	885	4.2523E-01
650	4.0037E-01	890	3.4480E-01
655	6.7139E-01	895	2.5704E-01
660	9.0340E-01	900	1.7500E-01
665	9.1073E-01	905	1.1009E-01
670	9.1720E-01	910	6.2100E-02
675	9.2741E-01	915	4.3125E-02
680	9.2760E-01	920	2.7600E-02
685	9.3254E-01	925	1.5525E-02
		930	6.9000E-03

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Appendix E

AIRCRAFT LIGHTING — RECOMMENDED DESIGN PRACTICES

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Appendix E—AIRCRAFT LIGHTING — RECOMMENDED DESIGN PRACTICES

Over many years of designing, producing and installing NVIS lighting modifications there have been many lessons learned. The following is a list of things to be cognizant of during the modification process. The list is not all-inclusive and there may be other acceptable solutions.

E.1 General Guidelines

When developing and incorporating a NVIS lighting system it is always important to keep in mind the main goals: instrument readability shall not be degraded, and NVG compatibility shall be maintained. This is particularly applicable to primary flight instruments.

Modifying a lighting system for NVG compatibility does not reduce or eliminate the need to use sound cockpit lighting design principles. If anything, cockpit lighting should be better when using NVGs than when not using them in order to ensure instruments can be read easily when quickly scanned and to help reduce the added workload created by the use of NVGs.

The lighting modification should include instrument panels, overhead panels, consoles, switches, circuit breakers, magnetic compass, secondary (emergency) lighting, cabin lighting, etc.

E.2 Eliminating or Reducing Glare and Reflections Secondary to Interior Light Sources

Minimize use of floodlights (excessive stray light can cause reflections from such things as clothing, seat belts, knee-boards, and floorboards that interfere with unaided viewing of the outside scene).

If flood lighting is used, ensure correct positioning to eliminate stray light and to provide best instrument readability.

Use of non-reflective near-IR paint in the cockpit may help reduce reflections that adversely affect NVG performance (remember – NVGs are mostly sensitive to near-IR energy). It is important to test the paint for near-IR reflectivity before applying. Even some black paints may contain substances that do not reflect visible light but may be good near-IR reflectors.

Use of non-reflective mats/covers may help reduce unwanted reflections.

Note: *Flammability regulatory requirements shall be met.*

Use of louver film or filters may help reduce unwanted reflections by directing the light in desirable directions, while reducing stray radiation.

Glare shields may be used to block stray energy from light sources within the cockpit, thus reducing potential unwanted reflections.

Replacing crazed/scratched windscreens may help minimize the effects of reflections. Crazing and scratches can cause what would normally be a small area of reflected energy to spread (diffuse) over a much larger area.

E.3 Eliminating or Reducing Glare and Reflections Caused by Exterior Light Sources

Consider an exterior light design that is less offensive to NVG performance. Normally this means designing and producing exterior lighting that continue to meet the FARs for unaided viewing while reducing the adverse effect on NVGs. One way this can be accomplished is by filtering out the IR energy being emitted by the light source, while allowing the visible wavelengths to pass.

Consider blanking/blocking the portion of external light source that introduces light into cockpit area.

Consider repositioning of the offending exterior light source.

Glare shields may be used to block energy from light sources outside the cockpit, thus reducing potential unwanted reflections.

Consider limiting operational use of the offending exterior light source.

Consider limiting the flight envelope of the aircraft so there are no effects from the light source (e.g., keep well away from clouds, remove NVGs prior to landing, etc.).

Notes: **1.** *The regulatory requirements for the design of exterior lights (e.g., intensity, angle coverage, and color) shall be followed.*

2. *The regulatory requirements for the use of exterior lighting shall be followed.*

E.4 Eliminating Light Leaks

Proper use of potting material, gaskets, etc. may help eliminate light leaks.

Consider an alternate source of illumination when a light leak cannot be eliminated.

Notes: **1.** *NVGs can be used to identify the source and location of light leaks.*

2. *It is a good operating practice to scan the cockpit area with NVGs prior to taking off to identify light leaks. It is possible that light leaks that are not noticeable to the unaided eye can still adversely affect NVG performance.*

E.5 Improving Daylight Readability of Instruments and Annunciators

Increasing the power to existing light sources, adding additional lamps, or changing to new light sources (e.g., LEDs, etc.) may help improve daylight readability.

Consider trying different types of filters.

Reducing the use of color will help avoid the potential problems associated with daylight readability.

Notes: **1.** *Only those components modified for NVIS compatibility should be assessed for daylight readability.*

2. *Components with pre-existing daylight readability problems will likely be made worse when filtering for NVIS compatibility.*

3. *The regulatory requirements for the use of color shall be followed.*

E.6 Modification of Warning, Caution and Advisory Lights

Use of NVIS red, yellow, green and white filter material is recommended for warning, caution and advisory lights.

Colors must be distinguishable from each other (e.g., red versus amber).

If any of the warning or caution lights are blocked from the unaided field of view when scanning the outside scene with the NVG (i.e., blocked by the physical presence of the goggle), consider moving the lights or ensuring that, when illuminated, the warning/caution lights are visible in the NVG image, but without adversely affecting performance.

E.7 Illuminance and Luminance Levels for Cockpit and Cabin

The following tables provide general guidance for illuminance and luminance levels for the cockpit and cabin. Cabin levels for emergency medical service modifications or other special operations may need to be higher.

Table E-1 Illuminance Levels

AREA/COMPONENT	ILLUMINATED LEVEL IN FOOTCANDLES (at rated drive condition)	
	MIN.	MAX.
Cockpit Area, General Illumination	1 (aisle floor)	20 (crew lap level)
Control Panels Not Illuminated (requiring in-flight adjustment and operation)	5	10
Instrument Panel and Consoles	2	10
Passageways and Aisles (measurement on floor)	0.2	5
Cargo Compartment (measurement on floor)	0.2	5
Loading and Ramp Areas (measurement on floor)	2	10
Crewstation Locations for Navigation and Systems Computations Tasks (light on work area)	30	60
Auxiliary Power Plant, Electrical and Electronic Compartments (light on work area)	5	10

Table E-2 Luminance Levels

Nomenclature	Luminance	
	Day Mode	Night Mode
Primary instrument lighting		0.01 to 1.3fL
Secondary instrument lighting		0.01 to 1.3fL
Primary console lighting		0.01 to 1.3fL
Secondary console lighting		0.01 to 1.3fL
Electronic and electro-optical displays		0.05 to 1.7fL
Master warnings, master cautions and warnings	$\geq$ 150 fL	15 $\pm$ 3 fL
Caution and advisory lights	$\geq$ 150 fL	1 $\pm$ 0.5 fL
Emergency exit lighting		15 $\pm$ 3 fL

Note: *If the warning signal also triggers a master warning or master caution signal, then the warning signal luminance should be 1.0 $\pm$ 0.5 fL.*

E.8 Aircraft Exterior Lighting

Conventional exterior aircraft lighting emits, in addition to the visible light required to meet existing regulations (FAR 27 and 29); near infrared (NIR) energy that, if directed into the NVG may cause NVG aided VA to be degraded. Existing regulations require that the output from exterior light does not cause objectionable glare to the pilot. Note that the

NVG is much more sensitive than the eye, therefore, glare that is not objectionable to the naked eye may be objectionable to the pilot using NVG.

One means to reduce the NIR energy is to introduce visible pass NIR blocking filters in front of the incandescent light sources; however, the lights must still meet existing regulations. An alternative is to replace the lights with new lights fitted with filters or lights using LEDs as the light source.

The performance of lights with filters is best evaluated by measuring NVIS Radiant Intensity (NRI) as this provides (by comparison) information regarding the range from which modified lights can be seen by the NVG.

E.9 Incandescent Position Lights

Measurement of existing filter and LED light systems has shown that the NRI values shown in the Table E-3 below can be achieved with either filtered incandescent or LED lighting systems.

Note: *The lower limits are determined by the existing performance of green lights with glass covers.*

Table E-3 NVIS Radiant Intensity Values

Angle from left or right of longitudinal axis, measured from dead ahead	Maximum NVIS Radiant intensity (mW/sr), NRI_b	Minimum NVIS Radiant Intensity (mW/sr) NRI_b
Forward Lights		
0° to 10°	150	0.25
10° to 20°	75	0.1
20° to 110°	50	0.01
Rear Lights		
110° to 180°	50	0.25

At angles above or below the horizontal plane, the NRI of each position light should meet the following table:

Table E-4 NVIS Radiant Intensity Values Position Lights

Angle above or below the horizontal plane	Maximum NVIS radiant Intensity (mW/sr) NRI_b as a function of the horizontal intensity
0°	100%
0° to 5°	90%
5° to 10°	80%
10° to 15°	70%
15° to 20°	50%
20° to 30°	30%
30° to 40°	10%
40° to 90°	5%

Appendix F

CONVERSION TABLE TO CHANGE BETWEEN SNELLEN ACUITY AND VISUAL ANGULAR RESOLUTION STATED IN EITHER CYCLES PER MILLIRADIAN (c mrad^{-1}) OR CYCLES PER DEGREE (c deg^{-1})

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Appendix F—CONVERSION TABLE TO CHANGE BETWEEN SNELLEN ACUITY AND VISUAL ANGULAR RESOLUTION STATED IN EITHER CYCLES PER MILLIRADIAN (c mrad^{-1}) OR CYCLES PER DEGREE (c deg^{-1})

V_{res} (c mrad^{-1})	V_{res} (c deg^{-1})	Snellen 20/xx	Snellen 20/xx	V_{res} (c mrad^{-1})	V_{res} (c deg^{-1})	V_{res} (c deg^{-1})	Snellen 20/xx	V_{res} (c mrad^{-1})
0.50	8.70	69	60	0.57	10.00	10.00	60	0.57
0.52	9.10	66	59	0.58	10.20	10.50	57	0.60
0.54	9.40	64	58	0.59	10.30	11.00	55	0.63
0.56	9.80	61	57	0.60	10.50	11.50	52	0.66
0.58	10.10	59	56	0.61	10.70	12.00	50	0.69
0.60	10.50	57	55	0.63	10.90	12.50	48	0.72
0.62	10.80	55	54	0.64	11.10	13.00	46	0.74
0.64	11.20	54	53	0.65	11.30	13.50	44	0.77
0.66	11.50	52	52	0.66	11.50	14.00	43	0.80
0.68	11.90	51	51	0.67	11.80	14.50	41	0.83
0.70	12.20	49	50	0.69	12.00	15.00	40	0.86
0.72	12.60	48	49	0.70	12.20	15.50	39	0.89
0.74	12.90	46	48	0.72	12.50	16.00	38	0.92
0.76	13.30	45	47	0.73	12.80	16.50	36	0.95
0.78	13.60	44	46	0.75	13.00	17.00	35	0.97
0.80	14.00	43	45	0.76	13.30	17.50	34	1.00
0.82	14.30	42	44	0.78	13.60	18.00	33	1.03
0.84	14.70	41	43	0.80	14.00	18.50	32	1.06
0.86	15.00	40	42	0.82	14.30	19.00	31	1.09
0.88	15.40	39	41	0.84	14.60	19.50	31	1.12
0.90	15.70	38	40	0.86	15.00	20.00	30	1.15
0.92	16.10	37	39	0.88	15.40	20.50	29	1.17
0.94	16.40	37	38	0.90	15.80	21.00	29	1.20
0.96	16.80	36	37	0.93	16.20	21.50	28	1.23
0.98	17.10	35	36	0.95	16.70	22.00	27	1.26
1.00	17.40	34	35	0.98	17.10	22.50	27	1.29
1.02	17.80	34	34	1.01	17.60	23.00	26	1.32
1.04	18.20	33	33	1.04	18.20	23.50	26	1.35
1.06	18.50	32	32	1.07	18.80	24.00	25	1.38
1.08	18.80	32	31	1.11	19.40	24.50	24	1.40
1.10	19.20	31	30	1.15	20.00	25.00	24	1.43
1.12	19.50	31	29	1.19	20.70	25.50	24	1.46
1.14	19.90	30	28	1.23	21.40	26.00	23	1.49
1.16	20.20	30	27	1.27	22.20	26.50	23	1.52
1.18	20.60	29	26	1.32	23.10	27.00	22	1.55
1.20	20.90	29	25	1.38	24.00	27.50	22	1.58
1.22	21.30	28	24	1.43	25.00	28.00	21	1.60
1.24	21.60	28	23	1.49	26.10	28.50	21	1.63
1.26	22.00	27	22	1.56	27.30	29.00	21	1.66
1.28	22.30	27	21	1.64	28.60	29.50	20	1.69
1.30	22.70	26	20	1.72	30.00	30.00	20	1.72

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Appendix G

SUGGESTED NVG PREFLIGHT AND ADJUSTMENT PROCEDURES

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Appendix G—SUGGESTED NVG PREFLIGHT AND ADJUSTMENT PROCEDURES

G.1 NVG Preflight Effectiveness

A correctly adjusted NVG that has been properly assessed will result in maximized performance. Optimizing performance will enhance operational effectiveness and safety. Until very experienced with focusing procedures and the effects caused by various goggle control adjustments, the use of an NVG eye lane or an adjustment tool such as the ANV-20/20 is the only sure method of optimizing performance.

G.2 NVG Preflight Procedures

NVG preflight procedures fall into three parts: initial inspection, alignment, focusing, and image assessment. These must be accomplished in this sequence in order to ensure the NVG is in good condition and to ensure the best performance is attained prior to flight.

G.2.1 Initial Inspection Procedures

Inspection procedures for the NVG are similar to the preflight procedures used for other aircrew or aircraft systems in that the purpose is to determine if all parts are in working order and if the system is functional. The initial adjustments performed during this time will place the binocular assembly in a favorable location in front of the eyes once inserted in the mount and rotated to the operating position, thus facilitating the alignment procedures.

Before donning the helmet and the NVG, examine all components and manipulate the controls to ensure all are in proper working order. The following are recommended procedures:

1. Inspect Helmet. Inspection of the helmet should be the same as for unaided flight. However, particular attention should be paid to helmet fit due to the extra weight and forward center of gravity caused by the mount, goggle and battery pack.
2. Inspect Mount. Ensure the mount is not cracked and that all contacts are clear and clean, and check wiring for integrity. Test all controls for smooth operation.
3. Load Battery Compartment. Prior to inserting the batteries, make certain that the NVG is turned off. Ensure the batteries are correctly inserted.
4. Inspect Binocular Assembly. Ensure there is no obvious damage to either monocular housing. Each housing is attached to the binocular assembly bridge, which is constructed of lightweight plastic material. Consequently, each monocular may move slightly when gently moved, but the movement should not be excessive. Rotate the objective and diopter controls to ensure freedom of movement. The diopter controls are naturally “sticky” in their travel due to a plastic-on-plastic design. However, if the controls are very difficult to turn, the NVG should not be used. Test all other controls for smooth operation.
5. Inspect and Clean Lenses. Inspect the objective and eyepiece lenses for scratches or other damage. Clean the lenses with lens paper or equivalent material and not with a flight suit or a tee shirt. A single thumbprint on one of the lenses may degrade visual acuity by as much as thirty percent.
6. Set Diopter. Set the diopter on each monocular to zero. Doing so will help ensure the resolution chart will be initially viewable when beginning the focusing procedures.
7. Adjust Eye Relief. Eye relief is the distance between the eyes and the surface of the eyepiece lens. Position the binocular assembly as far forward (away from the eyes) as possible. This will avoid damage to spectacles and placement of oil on the lens from

eyebrows or eyelashes when the NVG is attached to the mount and rotated to the operating position.

Note: *The operational eye relief position varies person to person and is dependent on a number of factors. Essentially, the selected position should allow the user to easily view the cockpit area when looking around or below the goggle without sacrificing the full field of view.*

8. Center Tilt. Set the tilt adjustment to the centered position (determined by aligning the tilt lever with bottom portion of the bridge). Ensure the IPD adjustments do not move when manipulating the tilt lever.
9. Set IPD. Actuate the IPD controls to ensure the mechanisms move freely and that the tilt lever does not move as the monoculars track along the bridge.
10. Adjust Vertical. Ensure the mechanism tracks smoothly to the upper and lower limits of movement, and ensure the thumb wheel moves freely. Leave the adjustment in the centered position.
11. Don Helmet. The helmet should be donned in order to check for proper fit and to prepare for attaching the NVG. Fasten and adjust the chinstrap. The chinstrap will help stabilize the helmet when the NVG is attached.
12. Attach and Remove Binocular Assembly. Attach the binocular assembly to the mount by holding the binocular assembly in a vertical position (i.e., parallel to the body), aligning the spring loaded bearings in the binocular assembly with the grooves in the mount, and pushing gently until the assembly snaps into place. Do not exert excessive force. If too much force is required, it is an indication that the bearings are not properly aligned and the binocular assembly may fail to seat properly or become jammed in the mount.

Do not release the binocular assembly until confirming that it will lock securely in the stowed position. This action confirms two important points: it indicates that the binocular assembly is properly seated in the mount, and that the assembly has not been mounted backwards. If the assembly will not lock in the stowed position, remove it, turn it 180 degrees, and try again. Once the binocular assembly has been properly seated, press the lock release button and rotate the assembly to the operating position. The eyepiece lens (diopter adjustment) should now be closest to the eyes.

Begin removing the binocular assembly by pressing the lock release button and turning the binocular assembly to a vertical position. Once out of the locked position, the lock release button can be released. Pull the binocular assembly straight forward out of the mount, preferably using both hands. Easy removal may be facilitated by first pulling one side slightly out of the detent, and then pulling forward on the assembly. Practice mounting and removing the binocular assembly until comfortable with the procedures.

G.2.2 Alignment Procedures

Proper alignment is important because the best visual performance is possible only when the optical axis of the binocular assembly is perfectly aligned with the visual axis of the eye. For this reason, precise focus is not possible until proper alignment has been accomplished. Rough alignment procedures can be accomplished prior to turning off the lights. This can be beneficial in an operational setting when other aircrew may be in various stages of inspection and initial adjustment. It will, in addition, expedite the alignment procedures once the lights are turned off.

Note: *Never turn on the NVGs in brightly lighted areas. Repeated exposure to bright light will result in a reduction in the life of an intensification tube.*

The following is a recommended order of procedures for obtaining a proper alignment. Using the same procedures in the same order will, over time, help ensure that none of the steps are inadvertently omitted. The procedures are conducted with the helmet on, and the NVG attached and in the operating position.

1. Vertical Adjustment. Adjust the vertical position of the binocular assembly using the vertical adjustment control. The binocular assembly should be located directly in front of the eyes.
2. Tilt Alignment. Adjust the tilt so the optical axis of the binocular assembly is perfectly aligned with the visual axis of the eyes. Changes in tilt usually require a correction in the vertical adjustment, and vice versa.
3. Eye Relief Adjustment. If necessary, move the binocular assembly closer to the eyes. As discussed earlier, eye relief should be positioned to maximize the field of view without unnecessarily reducing the ability to see around the NVG to view cockpit displays or perform other tasks. It is especially important that the goggle never be positioned so close to the face that the eyepiece lens contact spectacles or eyelashes.
4. IPD Adjustment. Close one eye and center the image in front of the opposite eye (e.g., close the left eye and, using the right IPD control, center the image in front of the right eye). Repeat for the opposite eye. With both eyes open, the two images should overlap to form a single image. Small adjustments may be necessary to form a single image.
5. Evaluate Image. When the goggles are correctly aligned, there should be no shading of any part of the image. If shading is present, attempt to eliminate it by making adjustments in the direction of the shading. If there is insufficient travel in the goggle adjustments, move the entire helmet in the direction of shading. If proper alignment can only be made by moving the helmet, it is an indication that the mount assembly is not properly positioned on the helmet. In this case an attempt should be made to reposition the mount.

G.2.3 Focus Procedures (For NVGs having variable focus objective lenses)

These procedures are performed with the lights off. Stand at the appropriate distance from the resolution chart and turn on the NVG. The objective is to be able to see the grids well enough to determine whether the lines are horizontal or vertical. Every line in the grid may not be perfectly clear, but the direction of the lines should be readily apparent. Start by using the coarser grids, and then move to the finer grids as the adjustment process continues.

1. Objective Focus. With one eye closed or one tube covered, turn the objective lens (outer ring) of the opposite tube while viewing one of the coarser grids. Attempt to bring the lines into sharp focus. Do not spend a great amount of time with this initial focus, as the purpose is to obtain an image that is adequate for permitting a suitable diopter adjustment.
2. Diopter Focus. Next, turn the diopter focus adjustment (inner ring) counterclockwise (to the left) until the image is blurred. Pause for one to two seconds to allow the eye muscles to relax, and then turn the diopter adjustment clockwise until the image first becomes quite sharp. It may be necessary to continue to move the adjustment clockwise in order to correctly locate the point where the image first becomes sharpest. In this case, begin the process again by rotating the adjustment counterclockwise until the image blurs, then clockwise to the predetermined point of first image sharpness. Two or more of these exercises may be necessary in order to correctly set the diopter.

Performed correctly, this procedure focuses the image on the retina of the eye without accommodative effort by the eye muscles. Rotating the diopter adjustment beyond the point of first sharpness forces the eye muscles to actively work to keep the image focused. Over time, the eye muscles will become fatigued and unable to maintain focus. This results in a gradual loss of visual acuity and depth perception and often causes severe eyestrain and/or headache.

Note: *The diopter adjustment is the one most misunderstood, and if maladjusted can result in degraded visual acuity. It is essential to understand what the adjustment accomplishes and how to properly perform the procedure.*

3. Readjustment of Objective Focus. Once the diopter has been adjusted, fine-tune the focus by readjusting with the objective adjustment to bring into focus as many of the grids as possible. This accomplishes two things. First, it assures the user that the diopter adjustment has been satisfactorily performed. Second, it allows for an accurate assessment of NVG performance.

   At first it may take several attempts going back and forth between the diopter and objective adjustments to obtain the best focus. However, *once comfortable with the procedure and when familiar with the visual picture*, focusing can be accomplished accurately and consistently with ease.

4. Focus of Opposite Monocular. After focus of the first monocular is accomplished, the same procedures are employed to focus and evaluate the remaining monocular. Do not be concerned if one side is slightly beter than the other. Slight differences in the performance of individual intensification tubes are common.

G.2.4 Assessment of NVG Image

When focusing is complete, assess the NVG image. With experience, some of these things will be noted when performing alignment and focusing procedures.

1. Evaluate Visual Acuity. Visual acuity obtained with both eyes should always be at least as good as that obtained by either side. If this is not the case, the goggles should be returned and another pair obtained. The minimum acceptable visual acuity will be established by the operator, but is always best to maximize NVG performance.
2. Evaluate Image Quality. A number of image peculiarities and defects exist, some acceptable and others not acceptable. The most common include the following:
   a. Shading. Appears as a shaded or indistinct area along the edge of the image. If it cannot be eliminated by adjusting the IPD or by moving the goggle toward the shading, the defect is likely within the optics and the NVG should not be used.
   b. Edge glow. Appearing as a bright area along the outer edge of the image, edge glow is most often the result of a bright light source somewhere just outside the image field of view. If noted, turn away from any bright lights or hold one hand over the objective lens. If the edge glow persists, it is an indication of damage to the intensification tube and the goggle should not be used.
   c. Bright spots. Constant or flickering bright spots may appear anywhere in the image. Hold one hand in front of the objective lens. If bright spots are still present and they degrade the image and/or are distracting, do not use the NVG.
   d. Dark spots. Dark or black spots in the image. If large, numerous, or located near the center of the image, the goggle should not be used.
   e. Honeycomb. A honeycomb-like pattern in the image, which is most often seen in high light-level conditions. If it is obvious or distracting, the NVG should not be used.

f. Distortion. The most common types of distortion noted in the NVG image are "bending" distortion and "shear" distortion. Bending distortion results in the image having a wavy appearance, usually in the horizontal or vertical directions. Shear distortion results in a choppy appearance somewhere in the image. If distortion is present and it is deemed likely to interfere with normal operations, do not use the NVG.

g. Flicker. The NVG image from one or both tubes may flicker. The effect may occur only at a particular illumination level. If noted, do not use the NVG.

h. Veiling glare. Appears as a light haze across the entire image. It can be caused by dirty, chipped, or scratched lenses. If it is obvious during the adjustment procedures, do not use the NVG.

i. Scintillation. A normal finding at low light levels. It is seen as a sparkling effect over the image and represents electronic noise created at the high gain levels that occur during low illumination conditions. In flight, it can be an indication of decreasing illumination caused by such things as worsening weather conditions or flight into shadowed areas.

Note: *Newer intensification tubes have improved signal to noise capability. Consequently, scintillation may be subtler and may not occur until darker conditions. If used to a certain level of scintillation under specific conditions, the use of an NVG with newer tubes may lead to an assumption that conditions are better than actual.*

G.3 Procedures at the Aircraft

Perform the following procedures prior to takeoff:

1. Focus the NVG at Optical Infinity. If the NVG was focused to 20 feet in the eye lane, it will be necessary to refocus at infinity before flight using only the objective lens (unless the diopter setting has been inadvertently moved). This can be accomplished by focusing on an object at least 150 feet distant, preferably one with well developed vertical or horizontal features. It must be illuminated well enough to be easily seen with NVGs but not so brightly lit that the image blooms or washes out. Avoid focusing on incompatible lights because the halo effect they create makes it difficult to discern when the image is in precise focus. Stars are excellent point light sources that do not cause halos and provide for a good endpoint for focusing.

   Note: *If unable to perform this procedure prior to launch (e.g., takeoff during daylight), use the same guidelines in finding something to use for focusing to infinity while airborne.*

2. Set Aircraft Lighting and Display Intensity. Set lighting and display intensity so information can be easily interpreted when looking around or below the NVG. When the NVG is turned on, the brightness of the image will cause unaided night vision to be adversely affected. This will require cockpit lighting and display intensity to be increased in order to be able to immediately interpret information they present. If the lighting is set at a dimmer level, more heads-down time will be required to interpret the information, which may result in loss of situational awareness or, at worse, may result in spatial disorientation.

3. Practice NVG Donning and Removal. Practice donning and emergency removal of the NVG in the aircraft prior to flight. This will become less necessary as more experience is gained with donning and removal of goggles.

G.4 Procedures while Airborne

Make the following minor adjustments during flight as required:

1. Vertical. As the helmet settles and/or rotates during flight, it may be necessary to make minor vertical adjustments as needed to keep the image in the proper position in front of the eyes.
2. Tilt. Any vertical adjustment will likely require a readjustment in tilt.
3. Eye Relief. Eye relief may need readjusting to allow better viewing of cockpit instruments or displays, or in some cases, to maintain the full field of view.
4. IPD. Make small adjustments to IPD as required.

Note: *Limit changes to diopter settings. Once adjusted correctly in the eye lane or with the ANV-20/20, the diopter should never need to be reset in flight. If the diopter was not adjusted prior to flight or if the setting was inadvertently moved, both objective focus and diopter should be readjusted using the standard procedures and an appropriate target (e.g., stars, etc.).*

Appendix H

NIGHT VISION GOGGLE (NVG) GROUND TEST CHECKLIST

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Appendix H—NIGHT VISION GOGGLE (NVG) GROUND TEST CHECKLIST

H.1 NVG

1. Verify NVGs are functioning properly and have no defects that would affect test results.
2. Test should be conducted in a darkened room with a resolution chart at ~ 20 ft. A similar facility should be available for NVG training and pilot pre-flight of NVGs.

H.2 Daylight Readability

1. Normally low sun angle is worse case.
2. Look at various aircraft azimuths.
3. Pay particular attention to filtered displays.
4. Amber/Red/Green colors shall be distinguishable
5. Will illumination of caution/warning get the pilot's attention immediately?

H.3 Setup Requirement for Night Ground Evaluation

1. Aircraft must be in a facility that can be sealed from all light sources.
2. A resolution chart (preferably a tri-bar or equivalent chart) is positioned ~ 20 ft in front of the pilot's eye position.
3. An appropriate NVIS light source is used to illuminate the resolution chart (See Appendix J).
4. Aircraft ground power should be available since the test may last several hours. In addition, an AC power source should also be available and within close proximity to the aircraft.
5. Window/doors and interior shall represent the operation configuration.
6. Windshield and windows are clean prior to evaluation.
7. Evaluator must be familiar with A/C switch positions and be able to activate correct switches during a darkened condition (BAT, NAV, COMM, lights, operating equipment, etc.).
8. Evaluator must assure proper adjustment of NVG (focus on target at higher ambient light condition).

H.4 Test Sequence

Note: *This is accomplished in a darkened test facility, properly illuminated resolution chart, with the evaluator adapted to NVG light level or image brightness level.*

1. Outside A/C
   a. Evaluator will be positioned abeam crew position (outside A/C maintaining 20 feet from the chart) and determine the smallest element on the chart where the white between the black line is clearly discernible.
   b. Note the line number or identify this chart position\ if a different resolution chart is being used for the tests.
2. At each pilot and/or operator's seat position
   a. Normal operation position with aircraft doors/windows closed.
   b. All A/C lights OFF.
   c. Note smallest element with acceptable resolution.

d. Determine if there has been any degradation in the NVG VA due to windshield by comparing the results of test 1 with the results of test 2. The maximum permissible NVG VA degradation due to the windshield is 12%.

3. Light leakage check

a. Turn on all NVIS lighting systems and check for hot spots (non-compatible light sources).

b. Turn on all COMM/NAV and mission systems and again check for hot spots (light leaks around filters).

c. All light leaks shall be fixed.

d. Determine if the evaluation can be continued without jeopardizing test results using "work around" solutions.

4. NVIS lighting tests

a. Start with all A/C lights OFF (including BAT) and reestablish smallest element on chart that can be resolved.

b. Evaluate each NVIS lighting system through the full range of intensity (in night mode only, if applicable) and determine if there is any degradation in the NVG VA obtained from Step a., due to the aircraft lighting system.

c. Evaluate combination of NVIS lighting system to represent operational condition (intensity level) and determine if there is any degradation in the NVG VA obtained during Step a., due to the aircraft lighting system. Also ensure lighting is uniform across cockpit instruments, gauges, displays, etc.

d. Activate COMM, NAV and any other lighted systems individually and in combination and determine if there is any degradation in the NVG VA obtained from Step a., due to various aircraft systems or displays.

Note: *These tests should include all potential light sources that could be used during an operational situation. Ensure all equipment/instrument and cabin lighting has been modified (i.e., magnetic compass, OAT gauge, circuit breaker/switch panels). The effect on NVG VA due to Caution/Warning/Advisory lights or annunciators shall be evaluated.*

e. Degradation of NVG VA due to NVIS lighting is not permitted except as noted Section 4.2.1.

5. Cockpit glare/reflections

a. These tests should include an evaluation in all aircraft positions that flight crew or other individuals will occupy during NVG operations. Additionally, the evaluator should attempt to position themselves to insure a full range of operational eye positions are assessed.

b. During (c) and (d), evaluate all external viewing areas for objectionable glare and reflections.

c. All sources of glare and reflections shall be identified. Objectionable glare and reflections shall be corrected.

d. Effects from illumination of caution/warning or advisory lights must be evaluated. These tests will be repeated during the flight evaluation phase also.

Note: *The evaluations should be repeated by another evaluator that uses a different sitting position, or the evaluator must reposition to a "non-normal" position to insure the required extremes of evaluator eye position has been tested.*

6. Interference

   During the ground tests, note any anomaly that appears to be interference between NVG and other installed equipment. A more comprehensive EMI test shall be conducted during flight phase.

7. Failure

   The effects of NVG/NVIS and A/C system failure should be simulated during the ground test to assess the impact that system failures may have on NVG operations. Some failure modes must be evaluated during the flight phase.

8. Head movement

   a. During these tests, with the evaluator in normal seated position, anticipate head/body movement to simulate operational scenarios. Determine if interference between NVG and A/C structure (or other installed appliances) exists.

   b. During the ground tests normal inflight scan patterns should be evaluated for obstructions to clear field of view. The effects of any blockage to field of view must be evaluated during the flight phase.

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Appendix I

NVG PREFLIGHT ILLUMINATION SOURCE ASSEMBLY INSTRUCTIONS

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Appendix I—NVG PREFLIGHT ILLUMINATION SOURCE ASSEMBLY INSTRUCTIONS

Necessary Materials

Light fixture (recommend the "Spot Clip Light" from Brilliant Light Inc.)
One 7 ½ watt (night light type) bulb
Electrical tape
Black cardboard or matting material
Five millimeter hole punch
Millimeter ruler
Scissors

1. Obtain a standard light fixture that accepts a 7 ½ watt bulb and has a 40mm distance from the bulb to the edge of the enclosure. (See Figure I-1) The 40mm distance is critical for proper chart illumination.
2. Carefully cut disk of black cardboard or matting material to fit the opening of the light fixture. Make a hole in the exact center of the disk using the 5 millimeter punch. (See Figure I-2) From the 10' placement distance, this hole will allow the 7 ½ watt bulb to illuminate the resolution chart with the equivalent of full moonlight. In order to get starlight conditions, one may add a rheostat to allow dimming capability of the bulb.
3. Using rubbing alcohol, remove the manufacturer's logo from the light bulb. Install the light bulb in the fixture.
4. Tape the disk over the front of the light fixture using the electrical tape. Secure all edges to prevent light leaks.
5. Cover the vent holes in the back of the light fixture with electrical tape. This prevents excessive light leaks. If overheating occurs, try leaving the holes partially covered and determine if the light leakage is excessive. If it is desirable to completely cover the vent holes, reducing the amount of time the light is left on will help lessen overheating of the assembly.

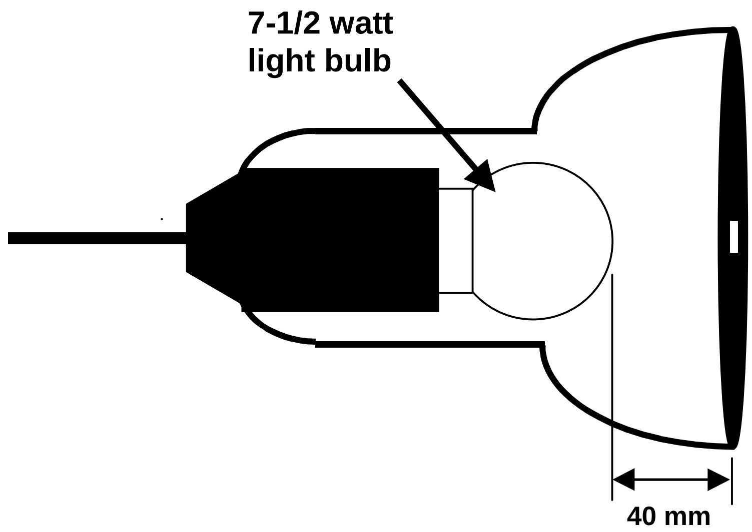

Figure I-1 Standard Light Fixture

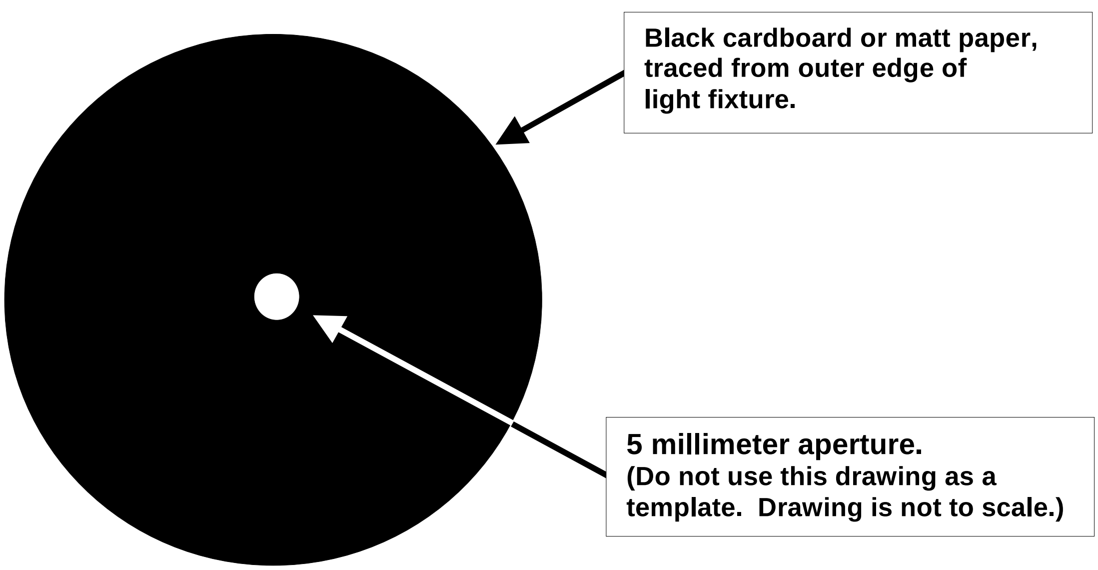

Figure I-2 Disk of Black Cardboard