The Engineering Society For Advancing Mobility Land Sea Air and Space®
INTERNATIONAL
400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE STANDARD

SAE AS5452

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Night Vision Goggles (NVG) Compatible Lighting for Civil Aircraft

FOREWORD

The purpose of this document is to provide a standard to which civil aircraft can be designed, modified, qualified, and certified to be operated by specially trained pilots using approved night vision goggles (NVGs). This will allow the operators to conduct essential night operations utilizing approved NVGs with minimal degradation of the night vision image caused by the spectrum of the crew station and exterior lighting of their aircraft overlapping the spectral response of the night vision goggles. At the same time the modified aircraft will maintain a visible presence for other aircraft that are being operated by pilots who are not using night vision devices flying in the same vicinity. Safety of flight is the primary concern while conducting flight operations utilizing night vision goggles. Night vision goggles replace normal color vision with a monochromatic image and have a narrower field of view than normal vision. Training must minimize the effect of these limitations. This standard makes no affirmations, positive or negative, about the operational safety of aircraft being operated by pilots using night vision goggles. Operational issues and safety are the responsibility of the certifying organization. Operational approval must be obtained from the Standards District Office of the certifying organization.

1. SCOPE:

This SAE Aerospace Standard (AS) will specify what type night vision goggles are required, minimum requirements for compatible crew station lighting, aircraft exterior lighting such as anticollision lights and position/navigation lights that are "NVG compatible." Also, this document is intended to set standards for NVG utilization for aircraft so that special use aircraft such as the Coast Guard, Border Patrol, Air Rescue, Police Department, Medivacs, etc., will be better equipped to chase drug smugglers and catch illegal immigrants, rescue people in distress, reduce high-speed chases through city streets by police, etc. Test programs and pilot operator programs are required.

2. REFERENCES:

2.1 Applicable Documents:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

ARP4392	Lighting, Aircraft Exterior, Night Vision Imaging System (NVIS) Compatible
AS8017	Minimum Performance Standard for Anticollision Light Systems
AS8037	Minimum Performance Standard for Aircraft Position Lights

2.1.2 U.S. Government Publications: Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-A-49425	GEN III NVGs
MIL-PRF-49425	GEN III NVGs
MIL-L-85762A	Lighting, Aircraft Interior Night Vision Imaging System

Code of Federal Regulations (CFR), Parts 23/25/27 and 29

2.1.3 Other Publications:

U.S. Navy Air Development Center document NAVAIRDEVCEN Code 5013, dated 14 March 1988

AN/AVS-9(V), NVIS-9 Performance Specification

ASC EN 981, Lighting, Aircraft Interior Night Vision Imaging System (NVIS) Compatible

AL/HR-TR-1995-0167 Procedure for Conducting a Field Evaluation of Night Vision Goggle Compatible Cockpit Lighting, Armstrong Laboratory - U.S. Air Force Material Command, Brooks Air Force Base, Texas

Aerospace Lighting Institute Book "Principles of Display Illumination Techniques for Aerospace Vehicle Crew Stations," Author Geo. W. Godfrey

Optical Specification for F-16 Left and Right-Hand Inlet Position Lights, Document No. 01/QS/3397 and Optical Specification for F-16 Tail Position Light Document No. 01/QS/3405, Oxley, Inc., Cumbria, England

2.1.3 (Continued):

Introduction to Radiometry and Photometry - Author, Ross McCluney ISBN 9-89006-678-7 1994, Artech House, Inc.

Handbook of Applied Photometry - Editor Casimer Decusatis ISBN 1-56396-416-3, Sponsored by the Optical Society of America, 1997 American Institute of Physics Press

2.2 Definitions/Abbreviations:

ABC: Automatic Brilliance Control

CFR: Code of Federal Regulations, Federal Aviation Administration

FAA: Federal Aviation Administration

FOV: Field of View

GEN III NVGs: Generation III Night Vision Goggles

NAS: National Airspace

NAVAIRDEVCEN: Naval Air Development Center

NR: NVIS Radiance

NVG: Night Vision Goggles

NVG Friendly Exterior Lighting: NVG friendly exterior lighting is exterior lighting which shall not degrade the performance of the goggles.

NVG Compatible Interior Lighting: NVG compatible interior lighting is lighting which meets the requirements of MIL-L-85762A and ASC EN 981 for Type I Class B.

NVIS: Night Vision Imaging Systems

VA: Visual Acuity

3. GENERAL REQUIREMENTS:

3.1 Night Vision Goggles:

Night vision goggles (NVGs) have been utilized in military aircraft since about 1980. By allowing pilots to fly nighttime missions, the NVGs amplify ambient illumination and produce a highly intensified monochromatic, near day like presentation of the nighttime scene. In order to quantify the interaction between the NVG and a particular light source, it is necessary to know that the spectral characteristics of Generation III (GEN III) NVGs have a spectral response which is greatest in the near infrared; however, this system also has a considerable sensitivity in the visible region.

3.1.1 NVGs provide an intensified image of scenes illuminated by ambient light in the red and near infrared part of the electromagnetic spectrum which exist in the night environment. The intensified imagery is on average at least 2000 times brighter than the original scene. In order to quantify the interaction between the NVG and a particular light source, it is necessary to know the spectral characteristics of both. GEN III NVGs have a spectral response which is greatest in the near IR; however, these systems also have considerable sensitivity in the visible region (Figure 1).

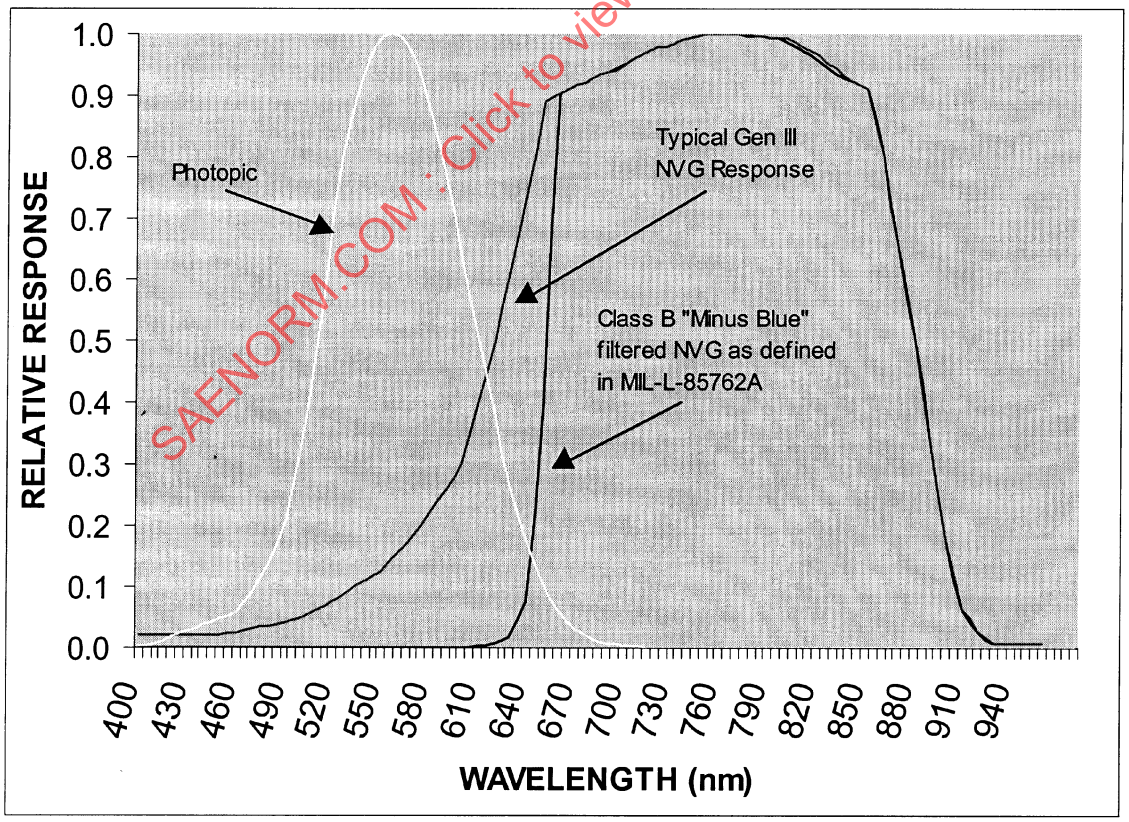

FIGURE 1 - Spectral Response

3.1.2 NVGs employ an automatic brilliance control (ABC) feature which acts to maintain a constant image brightness by decreasing the intensifier gain in response to input light levels exceeding a defined threshold. Proximate lights emitting energy within the range of the spectral response of the NVG are considered incompatible if they activate the ABC, thereby decreasing intensifier gain. With decreased gain, there is a corresponding decrease in image contrast and a loss in NVG-aided visual acuity (VA).

3.1.3 Incompatible light can severely degrade NVG-aided VA if the source is within the field of view (FOV) of the NVG. Incompatible light sources outside the FOV also can degrade NVG-aided VA if enough light is captured and internally reflected by the glass elements of the NVG objective lens structure to cause veiling glare. If the veiling glare is severe, it will activate the ABC and decrease image contrast. Even if the veiling glare is not severe, some contrast loss still may occur. Veiling glare generally is caused by incompatible light reflected by cockpit instruments, canopy, or windscreen.

3.1.4 To achieve compatibility and avoid losses in NVG-aided VA due to ABC, cockpit and exterior lighting should have a spectral distribution containing little or no overlap with the spectral response of the NVG. (For a more detailed explanation see "Principles of Display Illumination Techniques for Aerospace Vehicle Crew Stations.")

3.1.5 NVGs must be affixed in front of the pilot's eyes by attachment to a helmet or head mounted support unit so that both hands are free to operate flight controls. Attachment of the NVGs to the helmet will be accomplished in a manner that meets the requirements of AN/AVS-9(V), NVIS-9 Performance Specification. It is critical that the attachment geometry meets the requirements of this specification so that the NVGs can be adjusted to the maximum field of view.

3.1.6 The night vision goggles (NVGs) necessary to meet the requirements of this SAE standard will as a minimum be GEN III goggles, Type 1, Class B, and must be approved by the FAA at the time the NVG compatible lighting aircraft is certified.

3.2 Crew Station Lighting:

Pilots of aircraft conducting nighttime operations utilizing NVG need reduced levels of night vision imaging system (NVIS) radiance (NR) in order to keep their NVGs from "blooming" which would effectively shut down operation of the goggles.

3.2.1 The crew station lighting in a conventionally lighted civil aircraft must be extensively modified to be NVG compatible. All displays, instruments, indicators, warning caution lights, etc., deemed necessary for safe flight operation must be made compatible with MIL-L-85762A and ASC EN 981 specification requirements, except for the daylight readability requirements (see 3.2.2). This can be accomplished by changing out the unit, putting a filter over it, replacing the cap, etc., but it is imperative that it be NVG compatible. Degradation in outside visual acuity due to exterior or interior cockpit lighting is not allowed. Green light or a green filter does not necessarily mean the lighting in the crew station is NVG compatible. Light must be properly emitted or filtered to exclude

3.2.1 (Continued):

wavelengths in the effective range of the NVGs. Filters and color uniformity may give NVG compatibility, but intensity balance is also a very important factor. Unfiltered light leaks cannot be tolerated, since a cockpit with light leaks does not meet the reference specification. The NVG are so sensitive that unfiltered light in the cockpit of extremely small quantities can saturate or bloom the goggles.

3.2.2 Converting the civil aircraft crew station from conventional lighting to NVG compatible lighting should not degrade daylight readability or nighttime readability when NVGs are not used. Filter use intended to make crew station lighting NVG compatible often results in reduced display contrast and reduced attusity (the ability to attract attention) during daytime. Daylight readability should be assessed utilizing simulated or actual sunlight.

3.2.3 Another aspect of crew station lighting is the use of auxiliary lights or flashlights for map reading, flood lighting or other applications. Lights used in these applications need to be filtered in order to be compatible with NVG. Recommendations for the color and NVG compatibility of NVIS white filters is contained in a U.S. Navy Air Development Center document (NAVAIRDEVCEN Code 5013) dated 14 March 1988. Using a 2100 K source, the u' and v' chromaticity coordinates should lie within a circular boundary defined by a center point u' = 0.180, v' = 0.500 and a radius of 4 = 0.055. The NVIS radiance (Class A) should not exceed 1 x 10^{-9} at a luminance of 0.1 fL, and the filter should have a minimum photopic transmission of 10%.

3.3 Aircraft Exterior Light Systems:

Civil aircraft, both fixed wing and helicopters, have many different configurations. Consequently, the position/navigation light system and the anticollision light system have light emitting fixtures installed in many locations on the exterior of the aircraft. The Federal Aviation Administration (FAA) that is responsible for aircraft that fly in the national airspace (NAS) specifies that each of these systems emit a specific color of light in a specific pattern around the aircraft for the purpose of easy recognition of its location and direction of flight by other aircraft. This is required so that all aircraft can operate in the same airspace with safety.

3.3.1 Therefore, when a civil aircraft is modified so that it can be certified to fly with night vision goggles, it must be ascertained that the exterior lights are NVG compatible. If any of the position/navigation lights or anticollision lights reflect in any way into the crew station, this will cause the NVGs to bloom, creating an unsafe condition. This condition, if it exists, must be remedied. Options for correcting this condition include relocating the light fixture, or by baffles, or by lens/covers with IR filter coatings that prevent the light emission from the offending light from reaching the crew station. NVG friendly lights are not presently approved by the FAA. Each type aircraft must be evaluated and any modifications necessary must be made to correct this unsatisfactory condition (see ARP4392 for general information on NVG aircraft exterior lighting).

3.4 Aircraft Exterior Position/Navigation Lighting System:

The position/navigation light system must comply with Code of Federal Regulations (CFR) Part 23/25/27/29.1387 thru 23/25/27/29.1397. The chromaticities of the light emitted, after NVG compatibility, must meet the requirements of the applicable CFR. When the aircraft was originally certified by the FAA, it met these chromaticity requirements (Reference AS8037).

The optical specification for NVIS compatible exterior navigation/position lighting should consist of four distinct areas of reference. They include signal color (per CFR requirements), minimum/maximum visible intensity (per CFR requirements), minimum/maximum NVIS radiant intensity (NRI), and minimum/maximum NVIS radiance. Except for color, these areas should have distinct maximum and minimum requirements defined per angularity of the signal's distribution. This would characterize the complete energy distribution of the signal and provides a baseline of compliance that ensures compatibility within the night vision user community.

Figure 2 shows the spectral irradiance of a typical red position light and the necessary blocking required to make the signal more compatible with NVG equipment. It is provided as a reference to describe the type of spectral blocking that is required to make the signal usable with night vision goggles. The spectral blocking should be chosen such that there is a minimum impact on the visible content of the signal without reducing it below the minimum FAR requirements but deep enough through the near IR wavelengths to minimize goggle "blooming." This blocking can be represented using NRI calculated integrals as well as NVIS radiance, a measure of the reflected spectral content of the signal at some distance from the light. This value then can be used to determine the amount of reflected IR energy that would be present if it strikes surrounding aircraft structures and is reflected back into the cockpit. NRI values can be used to determine the amount of direct light and its effect on the goggles when directly viewed by the pilot or others wearing goggles.

Currently the specification for night vision compatible exterior navigation/position lights that was developed for the F-16 retrofit program has been the most extensive specification that covers all of these requirements. As a baseline of compatibility, any NVIS compatible position/navigation exterior lighting system should try and meet the intent of this specification. Reference Optical Specification for F-16 Left and Right-Hand Inlet Position Lights, Document No. OI/QS/3397 and Optical Specification for F-16 Tail Position Light, Document No. OI/QS/3405.