



AEROSPACE RECOMMENDED PRACTICE

ARP5825™

REV. B

Issued 2005-07
Revised 2023-02

Superseding ARP5825A

Design Requirements and Test Procedures for Dual Mode Exterior Lights

RATIONALE

The new revision is required to expand the requirements for other exterior lights and to update some of the limits based on current designs in the field.

TABLE OF CONTENTS

1.	SCOPE.....	3
1.1	Purpose.....	3
1.2	Limitations.....	3
1.3	Field of Application.....	3
1.4	Classes of Tests.....	3
2.	REFERENCES.....	3
2.1	Applicable Documents.....	3
2.1.1	SAE Publications.....	3
2.1.2	U.S. Government Publications.....	4
2.1.3	FAA Publications.....	4
2.2	Applicable References.....	4
2.3	Definitions.....	4
3.	TECHNICAL REQUIREMENTS.....	6
3.1	Background Information.....	6
3.2	Basic Visible Requirements for Exterior Lighting.....	6
3.2.1	Requirements for Anti-Collision Lights.....	6
3.2.2	Requirements for Position Lights.....	8
3.2.3	Requirements for Formation Lights.....	10
3.2.4	Requirements for Landing/Taxi Lights.....	11
3.2.5	Requirements for Refueling Lights.....	11
3.2.6	Requirements for Search Lights.....	12
3.3	Overview of Photometric Requirements for NVIS Friendly Portion of Dual Mode Exterior Lighting.....	12
3.3.1	Definition of NVIS Friendly Exterior Lights.....	12
3.3.2	NVIS Friendly Requirements for Anti-Collision Lights.....	15
3.3.3	NVIS Friendly Requirements for Position Lights.....	16
3.3.4	NVIS Friendly Requirements for Formation Lights.....	18
3.3.5	NVIS Friendly Requirements for Landing/Taxi Lights.....	19
3.3.6	NVIS Friendly Requirements for Refueling Lights.....	19
3.3.7	Chromaticity Requirements for NVIS Friendly Refueling Lights.....	20
3.3.8	NVIS Friendly Requirements for Search Lights.....	20

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Documents

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3.4	Covert Requirements	20
3.4.1	Definition of Covert Exterior Lights	20
3.4.2	Design Requirement for Covert Lighting	20
3.4.3	Covert Radiance Limits for Anti-Collision Lights	21
3.4.4	Covert Radiance Limits for Position Lights	22
3.4.5	Covert Radiance Limits for Formation Lights	24
3.4.6	Covert Radiance Limits for Landing/Taxi Lights	25
3.4.7	Covert Radiance Limits for Search Lights	25
3.5	General Guidelines for Linking NRI Values to Distance	26
4.	MEASUREMENT PROCEDURES	26
4.1	Important Measurement Considerations	26
4.1.1	Laboratory Conditions	26
4.1.2	Laboratory Standards	26
4.1.3	Measurement Equipment	27
4.1.4	Positioning Equipment	27
4.2	Units of Measurement	27
4.3	Test Procedures	27
4.3.1	Class 1 Test Procedures for Dual Mode Exterior Lights	27
4.3.2	Class 2 Test Procedures for Dual Mode Exterior Lights	30
4.3.3	Class 3 Test Procedures for Dual Mode Exterior Lights	30
5.	NOTES	30
5.1	Revision Indicator	30
Figure 1	Standard or non-NVIS friendly exterior lights	5
Figure 2	NVIS friendly exterior lights	5
Figure 3	Test set-up for NRI	15
Figure 4	Test set-up for covert lights	28
Figure 5	Test set-up for direct view detectors	29
Table 1	Minimum effective light intensities	8
Table 2	FAA navigation light requirements (must equal or exceed values)	8
Table 3	FAA CFR overlapping requirements	9
Table 4	Military navigation light requirements	9
Table 5	Effective NRI limits for anti-collision lights	16
Table 6	NRI limits for color linked position light	17
Table 7	NRI limits for non-color linked position light	18
Table 8	Minimum NVIS radiance values above the horizontal plane	21
Table 9	NRI limits for covert position light	22
Table 10	Right wingtip NRI values in the horizontal plane	23
Table 11	Minimum NRI values above the horizontal plane	23
Table 12	Left wingtip NRI values in the horizontal plane	23
Table 13	Minimum NRI values above the horizontal plane	24
Table 14	Range calculations for NRI detection with goggles	26

1. SCOPE

This SAE Aerospace Recommended Practice (ARP) contains the general requirements and test procedures for Dual Mode (NVIS Friendly visible and Covert) exterior lighting for most rotorcraft and fixed wing aircraft and could be applicable to ground vehicles that desire a Dual Mode lighting system.

1.1 Purpose

This document is to define both the basic NVIS Friendly limits for visible exterior lights and the radiance limits for the covert energy sources. In addition, this document will define the test methods and equipment necessary in verifying the measurements.

1.2 Limitations

This document includes and updates the traditional requirements that cover normal visible exterior lighting and integrate them with Dual Mode exterior lighting design and testing concepts. This document will not attempt to define the environmental qualification, reliability requirements or any of the other tests required that are normally contained in procurement specifications or readily found in other technical documentation. The primary focus of this document is for rotorcraft and fixed wing aircraft, but ground vehicles can use many of the technical requirements.

1.3 Field of Application

This document defines three classes of tests. Each test is applicable to the different phases of a product's life: for example, engineering development and qualification (Class 1), production/quality assurance (Class 2), and field service maintenance or flight readiness (Class 3). The test requirements for each of these phases differ and hence the test procedures for each test class may differ. Each procedure in this document is Class 1 unless otherwise stated.

1.4 Classes of Tests

Class 1 - Laboratory Tests - The objective of tests in this class is to verify the design of the assembly. Tests in this class are most appropriate in an engineering laboratory environment or as part of a certification program.

Class 2 - Production/Quality Assurance - The objective of this test class is to verify that every assembly has been manufactured or repaired to meet specified requirements. Tests in this class are most appropriate for acceptance and/or end item tests.

Class 3 - Maintenance/Flight Readiness - The objective of tests in this class is to verify that the assembly is within acceptable performance limits. Tests in this class are most appropriate for field service maintenance and flight line inspection.

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 International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

ARP693 Landing and Taxiing Lights - Design Criteria for Installation

ARP694 Aerial Refueling Lights - Design Criteria

ARP6402	LED Landing, Taxiing, Runway Turnoff, and Recognition Lights
AS8017	Minimum Performance Standard for Anticollision Light Systems
AS8037	Minimum Performance Standard for Aircraft Position Light

2.1.2 U.S. Government Publications

Copies of these documents are available online at <https://quicksearch.dla.mil>.

MIL-L-6503	Lighting Equipment, Aircraft, General Specification 25 March 1996 for Installation of Notice 2
MIL-L-85762	Lighting, Aircraft, Interior, Night Vision Imaging System (NVIS) 26 Aug. 1988 Compatible
MIL-L-006730	Lighting Equipment, Exterior, Aircraft (General Requirements for) 9 Oct. 1996 Notice 2 (Cancelled with no superseding document)
MIL-STD-3009	Lighting, Aircraft, Night Vision Imaging System 04 Oct. 2002 Notice 1 (NVIS) Compatible
CFR 23	Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes
CFR 25	Airworthiness Standards: Transport Category Airplanes
CFR 27	Airworthiness Standards: Normal Category Rotorcraft
CFR 29	Airworthiness Standards: Transport Category Rotorcraft

2.1.3 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

AC20-74	Aircraft Position and Anticollision Light Measurements
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2.2 Applicable References

Aerospace Lighting Institute, February 2002 Advanced Seminar Tim Bushell, Oxley Presentation

2.3 Definitions

COVERT: Covert exterior lights cannot be viewed in normal operation by the unaided eye and requires the use of night vision goggles. Covert lighting allows the benefits of exterior lights in mission requirements while in hostile battle area where there is a desire to limit visible detection.

DUAL MODE: Dual Mode exterior lights are comprised of two modes; visible (NVIS Friendly) and covert. The visible mode can be viewed with the unaided eye whereas the covert mode requires additional sensors (i.e., night vision goggles). The visible mode is further defined to add radiance requirements with night vision goggle operation as opposed to Aviation (or standard) which has no radiance limitations (see NVIS Friendly). Dual Mode exterior lights are designed to operate with the use of night vision goggles. Most Standard or Aviation exterior lighting systems do not integrate naturally with night vision goggles. The exception being aviation lights that are naturally NVIS Friendly (this includes aviation green lights in general and selective LEDs that are being used for exterior lights).

IR; Infrared. This applies to radiant energy with wavelengths just beyond the visible spectrum in the Near IR (780 to 930 nm).

NRI: This abbreviation stands for NVIS Radiant Intensity. NRI is the unit used to measure Dual Mode exterior lights. Radiometric energy from a light source is collected and integrated with the response curve of the night vision goggles as defined in MIL-L-85762A. This integration is then multiplied by the distance squared of the energy source to the detector (in accordance with the inverse square rule). The units of NRI are Watts/steradian (W/sr).

NVIS FRIENDLY: NVIS Friendly exterior lights can be viewed by the unaided eye and also with night vision goggles, but without degradation to the operational use of the goggles that are common with Standard or Aviation lighting designs. An NVIS Friendly lighting system reduces (but does not eliminate) the amount of near infra-red energy contained by the light source. When viewed through night vision goggles, the NRI does not cause excessive "blooming" in the goggles. Excessive blooming can be defined as when the aircraft's exterior lights that are being viewed through the goggles merge together and obscure the outline of the aircraft (Figure 1).

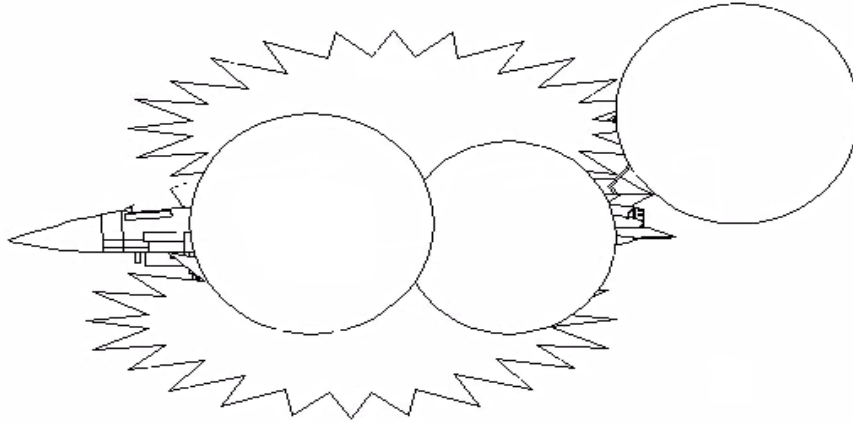


Figure 1 - Standard or non-NVIS friendly exterior lights

A NVIS Friendly exterior light will have some IR content as compared to lights that are completely NVIS compatible (i.e., which would not be seen through night vision goggles). The proper balance of restricting the amount of IR content for various exterior lights is the key to the definition of "NVIS Friendly." With a proper control of IR content, NVIS Friendly exterior lights will be detected when viewed through the night vision goggles but would not overwhelm the aircraft outline (Figure 2).

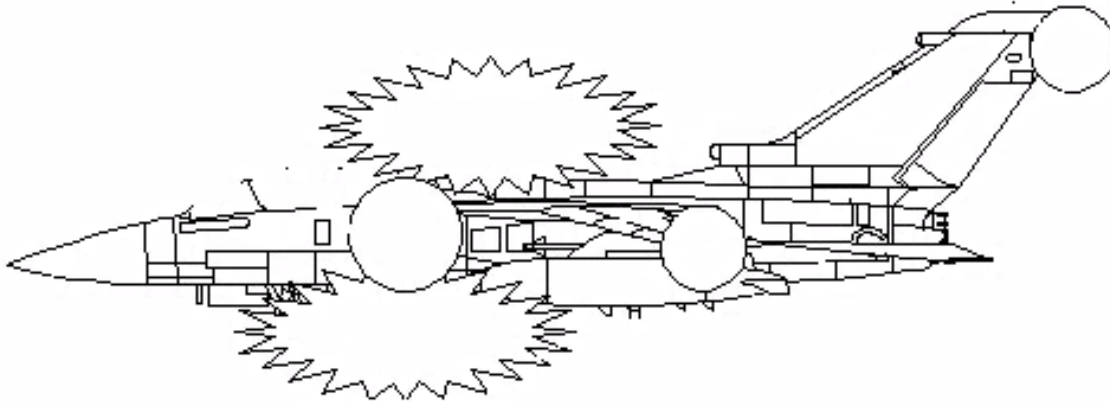


Figure 2 - NVIS friendly exterior lights

3. TECHNICAL REQUIREMENTS

3.1 Background Information

As the use of night vision goggles became increasingly standard in interior cockpit design, technical requirements and specifications were developed to provide a common baseline design for aircraft cockpits and interior lighting systems. Previously for exterior lighting, the NVIS requirements have been limited to defining covert Electroluminescence (EL) strips for formation flying. However, the mission requirements for operational use of night vision goggles have driven the need to have the rest of the exterior lights to be made not only useable with the goggles but designed to be part of nighttime tactics. Existing standard exterior lights are designed primarily to prevent mid-air collisions. The specifications require most of the radiometric energy to be directed in all directions, and with additional energy via the position lights directed forward and aft along with color filters to provide orientation (aviation colors). However, with the use of night vision goggles, these standard visible lights overwhelm the goggles and require IR suppression. The IR suppression must not impact the lights to the extent that they fail the FAA and military specifications, nor prevent the use of night vision goggles. This is the biggest challenge in designing NVIS Friendly exterior lights.

As the operational use of night vision goggles has evolved, so has the mission requirements such that, NVIS Friendly lights alone do not support all the operational mission requirements. The opposing pilots and enemy ground forces also have the use of night vision goggle technology and projecting even NVIS Friendly light impacts the survivability of the mission and the pilot. However, turning off all the visible exterior lights (the first use of the covert mode) makes it very difficult for your fellow pilots to regroup (or rejoin) and increases the possibility of mid-air collisions. This fact created the requirement for what is commonly considered covert lighting. Covert exterior lighting has very different radiometric patterns than visible exterior lighting. This is due to the mission requirements that dictate that no radiometric energy be directed forward for the enemy pilot to detect, and no radiometric energy downward for enemy ground forces to detect. All the covert lighting must be directed upward and aft to assist in rejoins. The major exceptions would be the Anti-Collision lights and any covert Landing/Taxi light systems.

Current civil and military specifications cover the photometric patterns for visible exterior lighting, but they do not detail the requirements for NVIS Friendly or covert designs.

3.2 Basic Visible Requirements for Exterior Lighting

All NVIS Friendly exterior lighting must still meet the standard (aviation) visible requirements with the additional requirement of limiting the amount of IR content the various exterior lights should contain. Exterior lights can be modified or replaced to make the lights NVIS-Friendly while retaining normal unaided eye viewing. The advantages of NVIS-Friendly lights are:

- Military aircraft can safely operate with goggles in civilian airspace and can be seen by other aircraft. This provides greater flexibility when conducting training operations. In a multi-man cockpit, one pilot can be on goggles and one off without affecting the safety of flight.
- Can refuel aircraft while on goggles.
- Operate close to a combat area without being easily detected by goggles on the ground.

This ARP document will supplement the requirements that cover normal visible exterior lighting and include the additional requirements for Dual Mode (NVIS Friendly and Covert) exterior lighting.

3.2.1 Requirements for Anti-Collision Lights

All aircraft are required to have an anti-collision light system in accordance with both the FAA and various military specifications. The lights shall be located as not to be detrimental to the crew's vision and will not detract from the conspicuity of the position lights. Lights that are located on top of the fuselage shall be located as far back from the pilot as practicable in order to reduce to a minimum the possibility of causing vertigo. The use of shielding is acceptable to prevent light beams from being directly or indirectly projected into the cockpit as long as the shielding does not affect the output. For additional information on anti-collision light design requirements for multiple aircraft types, review AS8017.

3.2.1.1 Field of Coverage for Anti-Collision Lights

The system shall consist of one or more light assemblies such that sufficient field of coverage shall extend in all directions within a plane not less than 30 degrees above and 30 degrees below the horizontal plane of flight. Allowed obstructed visibility totaling not more than 0.03 steradian is allowable within a solid angle equal to 0.15 steradian centered about the longitudinal axis in the rearward direction.

3.2.1.2 Flashing Characteristics for Anti-Collision Lights

Flash characteristics for anti-collision lights are determined by the mission requirements for selected military aircraft. In accordance with MIL-L-6503 and MIL-L-006730, a minimum flash pattern frequency is required. This minimum effective flash frequency shall be not less than 40 nor more than 100 cycles per minute except when the anti-collision light system lights overlap due to more than one light source. In cases of overlap, effective flash frequencies shall not exceed 180 cycles per minute. The effective flash frequency is established as that frequency at which the aircraft's complete anti-collision light system is observed from a reasonable distance. Multiple flash patterns are allowed to meet mission requirements. For LED ACL systems, the flash duration shall not exceed 200 ms.

3.2.1.3 Chromaticity for Anti-Collision Lights

The chromaticity for anti-collision lights shall be aviation red, aviation white, or both. Chromaticity selection is determined by customer requirements.

3.2.1.4 Light Intensity Requirements for Anti-Collision Lights

The light intensity requirements for anti-collision lights are not dependent on the technology used for the light assembly. Existing technologies include rotating beacons, flashing incandescent, gas discharge tubes (strokes) and Light Emitting Diodes (LEDs). When a light signal consists of separate flashes, the maximum intensity during the flash must be greater than the intensity of a steady light to have the same apparent intensity. It is, therefore, convenient to evaluate flashing lights in terms of their effective intensity.

3.2.1.4.1 Measurement of Effective Intensity for Anti-Collision Lights

For measuring all Anti-Collision light systems, the minimum light intensity for each light assembly shall be expressed in terms of effective candlepower in accordance with the Blondel-Rey equation. This requirement is based on the assumption that the maximum intensity during the flash must be greater than the intensity of a steady light to have the same apparent intensity.

$$I_E = \frac{\int_{t_1}^{t_2} I(t) dt}{0.2 + (t_2 - t_1)} \quad (\text{Eq. 1})$$

where:

I_E = effective intensity (effective candela)

$I(t)$ = instantaneous intensity as a function of time

$t_2 - t_1$ = flash time interval (seconds)

3.2.1.4.2 Minimum Effective Intensity for Anti-Collision Lights

Both the FAA (CFR Part 23, 25, 27, and 29) and MIL-L-6503 have minimum values for anti-collision light effective intensity requirements along the horizontal plane. These minimum values are detailed in Table 1. The military specification limits their photometric requirements from 0 to 30 degrees above and below the horizontal plane. Where the degree locations are called out twice, the requirement is to be of the higher candela value.

Table 1 - Minimum effective light intensities

Angle Above or Below the Horizontal Plane	Effective Intensity (cd) for CFR 23 & 25	Effective Intensity (cd) for CFR 27 & 29	Effective Intensity (cd) for MIL-L-6503H
0 to 5 degrees	400	150	400
5 to 10 degrees	240	90	240
10 to 20 degrees	80	30	80
20 to 30 degrees	40	15	40
30 to 75 degrees	20	0	N/A

3.2.2 Requirements for Position Lights

The design requirements for position lights are defined into two categories: FAA regulated civilian aircraft and military aircraft. For civilian aircraft, FAA requirements will define the photometric requirements. For most military aircraft, MIL-L-6503H or MIL-L-006730 will define the photometric requirements. AS8037 also provides design guidance. None of these documents contains any information or requirements for NVIS Friendly and Covert lighting. Another design consideration is that all of the military specifications are only concerned with the minimum values. With the incorporation of LEDs, there must be a design consideration with an upper photometric limit. Based on pilot feedback of position lights using LEDs, the general consensus is that the maximum candela value should be below 120 candelas. Furthermore, the peak intensity should be aimed at the most forward longitudinal axis.

3.2.2.1 FAA Position Light Requirements

The major design issue with NVIS-Friendly lights is maintaining the minimum Federal Aviation Administration (FAA) intensity, distribution patterns and color for the Position (Navigation) lights as defined in Tables 2 and 3.

Table 2 - FAA navigation light requirements (must equal or exceed values)

CFR Part 23, 25, 27, and 29

Intensities in any vertical plane

Dihedral Angle (Light Included)	Angle from Right or Left of Longitudinal Axis, Measured From Dead Ahead	Intensity (I) (candelas)
L and R (fwd red and green)	0 to 10 degrees	40
	10 to 20 degrees	30
	20 to 110 degrees	5
A (rear white)	110 to 180 degrees	20

Intensities in the horizontal plane perpendicular to the horizontal plane

Angle Above or Below the Horizontal Plane: Intensity, I	
0 degrees	1.00
0 to 5 degrees	0.90
5 to 10 degrees	0.80
10 to 15 degrees	0.70
15 to 20 degrees	0.50
20 to 30 degrees	0.30
30 to 40 degrees	0.10
40 to 90 degrees	0.05

Table 3 - FAA CFR overlapping requirements

Maximum Intensities in Overlapping Beams of Forward and Rear Position Lights

Overlaps	Maximum Intensity	
	Area A (cd)	Area B (cd)
Green in Dihedral Angle L	10	1.00
Red in Dihedral Angle R	10	1.00
Green in Dihedral Angle A	5	1.00
Red in Dihedral Angle A	5	1.00
Rear White in Dihedral Angle L	5	1.00
Rear White in Dihedral Angle R	5	1.00

Whereas area A includes all directions in the adjacent dihedral angle that passes through the light source and intersects the common boundary plane at more than 10 degrees but less than 20 degrees.

Whereas area B includes all directions in the adjacent dihedral angle that passes through the light source and intersects the common boundary plane at more than 20 degrees.

For intensities >100 cd (10% Area A and 2.5% Area B).

Where the degree locations are called out twice, the requirement is to be of the higher candela value.

3.2.2.2 Military Position Specifications

The photometric requirements for position lights on military aircraft are more demanding than with FAA CFR requirements. The light distribution is defined in Table 4. Where the degree locations are called out twice, the requirement is to be of the higher candela value.

Table 4 - Military navigation light requirements

Intensities in the horizontal plane

Dihedral Angle (Light Included)	Angle from Right or Left of Longitudinal Axis, measured From dead ahead	Intensity (I) (candelas)
L and R (fwd red and green)	0 to 10 degrees	40
	10 to 20 degrees	40
	20 to 30 degrees	30
	30 to 40 degrees	20
	40 to 50 degrees	15
	50 to 70 degrees	10
	70 to 110 degrees	6
	110 to 120 degrees	5 cd Max*
	120 to 130 degrees	
A (rear white)	90 to 100 degrees	5 cd Max*
A (rear white)	100 to 110 degrees	
A (rear white)	110 to 180 degrees	20

Intensities in any vertical panel
perpendicular to the horizontal plane

Angle Above or Below the Horizontal Plane: Intensity, I	
0 degrees	1.00
0 to 5 degrees	0.90
5 to 10 degrees	0.80
10 to 15 degrees	0.70
15 to 20 degrees	0.50
20 to 30 degrees	0.30
30 to 40 degrees	0.10
30 to 90 degrees	4 cd min

* maximum
overlap value
can be greater
if I > 100 cd

The dim values are in accordance with MIL-L-6503H, Table IX, the right and left position lights should have a 10% dim value while the aft position light should have a dim value of 1 to 5%.