AEROSPACE RECOMMENDED PRACTICE

ARP694™ REV. D

Issued 1963-01
Revised 2021-12

Superseding ARP694C

Aerial Refueling Lights - Design Criteria

RATIONALE

This SAE Aerospace Recommended Practice (ARP) is revised to include more document references, and to include more illuminance and radiant intensity recommendations.

1. SCOPE

This SAE Aerospace Recommended Practice (ARP) is intended to cover all external lights on the tanker and fixed wing receiver airplanes used to accomplish aerial refueling.

This ARP describes lights used for two basic types of aerial refueling: the probe and drogue, and the boom/receptacle method.

1.1 Purpose

The purpose of this ARP is to set forth the basic considerations and criteria which the design engineer should observe when designing an aerial refueling lighting system. In case of conflict between this ARP and existing military specifications, the military specification will take precedence, unless a waiver is obtained.

2. 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 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.

ARP4087	Wing Inspection Lights - Design Criteria
ARP5825	Design Requirements and Test Procedures for Dual Mode Exterior Lights
AS25050	Colors, Aeronautical Lights and Lighting Equipment, General Requirements for

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SAE WEB ADDRESS: **http://www.sae.org**

For more information on this standard, visit
https://www.sae.org/standards/content/ARP694D

2.2 FAA Publications

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

Code of Federal Regulations Title 14, Part 23

2.3 Military Publications

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

MIL-A-19736A Air Refueling systems, General Specification for

MIL-L-6503 Lighting Equipment, Aircraft, General Specification for Installation of

MIL-L-006730 Lighting Equipment; Exterior, Installation of Aircraft (General Specification)

MIL-STD-3009 Lighting, Aircraft, Night Vision Imaging System (NVIS) Compatible

STANAG ATP-56(B) Air-to-Air Refuelling General Requirements

3. TYPES OF LIGHTS FOR AERIAL REFUELING

The type of lights required by the airplanes depends on the method of aerial refueling as indicated in Table 1. The “type of light” should not be confused with the “number of light fixtures.” A light fixture may be designed to perform the function of two or more types of lights or several fixtures may be required to perform the functions of one type of light. The designer should evaluate the aerial refueling lighting system in a manner that ensures that all required functions are performed.

Table 1 - Types of lights for aerial refueling

Light Type		Use with Probe and Drogue		Use with Boom/Receptacle		Document References
		Receiver	Tanker	Receiver	Tanker	
Rendezvous lighting (4.1)			X		X	MIL-L-6503 Sec. 3.3.8.3 ARP5825 Sec. 3.3.2.1
Tanker illumination (4.2)			X		X	MIL-L-6503 Sec. 3.3.8.1 ARP5825 Sec. 3.3.6.1
Receiver illumination (4.3)		X		X		
Tanker mounted receiver illumination (4.4)					X	
Probe lighting (4.5)		X				MIL-L-6503 Sec. 3.3.8.4 MIL-L-006730 Sec. 3.2.9.1 MIL-A-19736 Sec. 3.15.6
Boom nozzle lighting (4.6)					X	MIL-STD-3009 Secs. 4.5.3 & 5.8.3
Slipway/receptacle and area lighting (4.7)				X		ARP5825 Secs. 3.2.5.1 & 3.3.6.1
Drogue lighting (4.8)		X	X			ARP5825 Secs. 3.2.5.2 & 3.3.6.1
Hose illumination lighting (4.9)			X			
Boom illumination lighting (4.10)					X	MIL-STD-3009 Secs. 4.5.3 & 5.8.3
Pilot director light (4.11)					X	
Signal lights (4.12)	Equipment malfunction		X			MIL-L-6503 Sec. 3.3.8.2 MIL-L-006730 Sec. 3.2.9.3 MIL-A-19736 Sec. 3.7.5.1
	Breakaway		X		X	
	Equipment is ready		X			
	Receiver too close to tanker		X			
	Fuel is flowing		X			

3.1 Light Locations

The light fixtures should be designed and located properly so they can perform their functions. Due to the various airplane designs it is not practical to specify the exact location and design of each type of light. However, there are a number of factors which must be considered and methods of evaluation which should be used to determine if the location and design are satisfactory. Suggested design information is given in Section 4.

3.1.1 Field of Vision

The field of vision of the receiver pilot and boom operator is limited. The lights must be visible when the crew members are in design eye position and the airplanes are at or near the expected relative positions. Drawings, computer simulations, and mockups showing the airplanes in various relative positions and attitudes should be used. Consideration should be given to visual obstructions such as canopy bows, heads-up displays, gun sights, etc.

3.1.2 Glare

Lights should not cause hot spots or glare either for the receiver pilot or the boom operator. Light sources used to illuminate the airplane should not be visible to the crew.

3.1.3 Reliability

When a light is operating, the crew that controls the light should be provided with an indication that the light is operating satisfactorily. Redundancy of critical lighting/light bulbs should be considered.

3.1.4 Contrast

Lights should be designed to have sufficient color and intensity contrast when necessary. All colored lights that can be dimmed should be operated both at full brightness and dimness to determine that the color is satisfactory. A signal light used in daytime operations should be tested to determine if the observer can positively identify that the light is “on” or “off” and specific consideration should be given to flying over undercast skies where high ambient light conditions exist. The reflected illuminance from such an undercast can easily be 107600 lx (10000 foot-candles).

3.1.5 Ambiguity

The signal lights should be designed to give an unambiguous signal. It should not be possible for the signal lights to direct the pilot to perform multiple operations which are in contradiction to one another.

The floodlights should outline the airplane clearly and sufficiently.

3.2 Requirements as defined herein are intended for normal operation for both day and night. Certain operations involving combat tasked tankers and receivers may require the use of night vision goggles. In this case, lighting should be provided which would be compatible with night vision goggles.

3.3 Color

The red, green, white, and yellow colors shall be within the boundaries listed below on the CIE 1931 chromaticity diagram. The corner points define the intersections of the lines defined by the equations below with each other or with the spectrum locus.

Red light signals

Purple boundary	y = 0.980-x
Yellow boundary	y = 0.335

Red corner points

0.720, 0.260
0.645, 0.335
0.665, 0.335

Green light signals

Yellow boundary	x = 0.360-0.080y
White boundary	x = 0.650y
Blue boundary	y = 0.390-0.171x

Green corner points

0.0280, 0.385
0.2281, 0.3509
0.3205, 0.4932
0.305, 0.6875

White light signals (alternatively, aviation white per SAE AS25050 may be specified.)

Yellow boundary	x = 0.500
Red boundary	y = 0.382
Purple boundary	y = 0.047 + 0.762x
Blue boundary	x = 0.285
Green boundary	y = 0.150 + 0.640x
	y = 0.440

White corner points

0.500, 0.382
0.500, 0.440
0.4531, 0.440
0.285, 0.3324
0.285, 0.263
0.4396, 0.382

Yellow light signals (amber)

Red boundary	y = 0.382
White boundary	y = 0.790 - 0.677x
Green boundary	y = x - 0.120

Yellow corner points

0.6175, 0.382
0.6027, 0.382
0.5426, 0.4226
0.560, 0.440

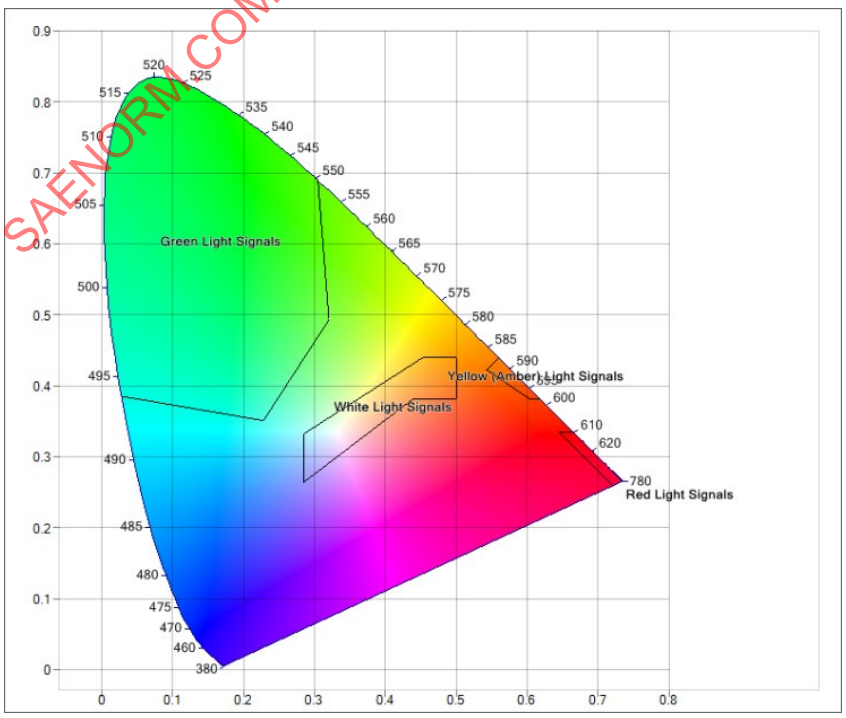

Figure 1 - CIE 1931 chromaticity chart with ARP694 colors

4. DETAILED REQUIREMENTS

4.1 Rendezvous Lighting

4.1.1 Function

Enable a receiver to visually identify a tanker and enable a receiver to identify his tanker in a formation of tankers.

4.1.2 Controls

These lights normally have dual use as anti-collision and as rendezvous functions and must be controlled either from the flight deck or the boom operator's position. Controls must permit selection of the desired code sequence and of upper or lower lights only during refueling operation if necessary to eliminate blinding of the receiver pilot, tanker boom operator, or the pilots of other airplanes in the formation.

4.1.3 Color

Red and white.

4.1.4 Intensity

Equivalent intensity of an anti-collision light per CFR 14 Part 23 Section 1401. For lights including a covert (IR) mode, a peak radiant intensity of at least 0.2 NRI is recommended, with a similar angular radiant intensity pattern to the visible mode. The rendezvous light may have reduced or zero IR light below the horizon, depending on aircraft mission.

4.1.5 Suggested Design

Use two red-white Xenon or LED flashing anti-collision/rendezvous lights. Each light—red and white—should be of equal intensity, have a peak intensity of at least 400 effective candelas, and the upper and lower lights should be synchronized. Four modes should consist of the following (refer to MIL-STD-3009):

a. Mode 1 - White only - to identify aircraft in formation.

b. Mode 2 - Red only - to identify aircraft in formation.

c. Mode 3 - Alternating red-white - to identify aircraft in formation.

d. Mode 4 - Rendezvous mode, a periodic sequence of three flashes, first white, then red, then white to provide positive aircraft identification during initial visual contact. The sequence should consist of three 0.1 second long pulses, each separated by a 0.33 ms interval. A 1 second long interval should elapse before the sequence is repeated (see Figure 2).

For lights including a covert (IR) mode, there should be at least six pilot selectable flash patterns in the covert mode. One of the six patterns should have equal on and off times.

When a flashing red signal light is not available for use as a breakaway function, the lower rendezvous or anti-collision light can be used for this function by flashing at an increased rate.

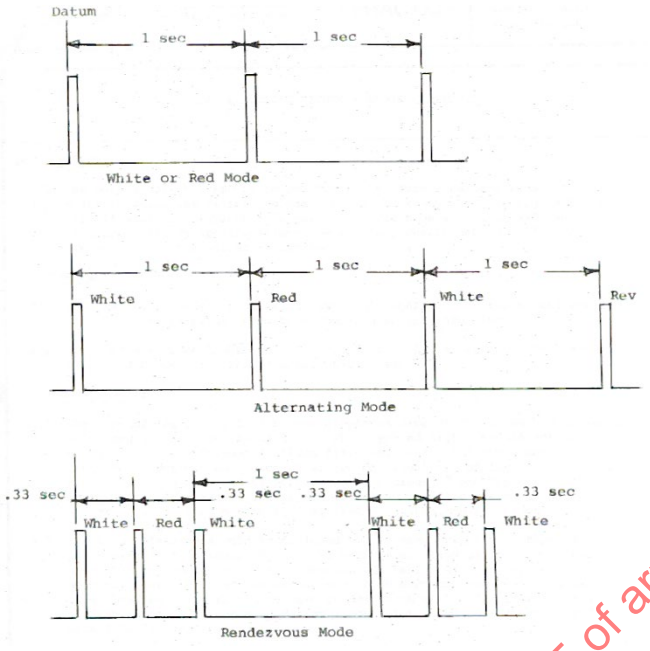

Figure 2 - Rendezvous light flash patterns

4.2 Tanker Illumination

4.2.1 Function

With respect to the position of the tanker relative to the receiver, enable the receiver pilot to determine the geometry/definition (stereopsis) of the tanker in all positions before hookup and during refueling operations.

4.2.2 Controls

To permit intensity to be varied from off to full intensity.

4.2.3 Color

White or red. If the tanker is intended for use by receiver pilots with night vision goggles (NVGs), additional NVIS friendly and/or covert illumination should also be provided.

4.2.4 Intensity

Sufficient intensity to illuminate the most distant regions of the target surface so that a receiver pilot can determine the position of the tanker. Consideration should be made for remotely operated receiver aircraft where the pilot may be viewing the tanker via a camera, or for tankers where the boom operator may be viewing the receiver aircraft with a camera.

4.2.5 Suggested Design

Use lights of sufficient intensity to create an illuminance of 5 to 22 lx (0.46 to 2.0 foot-candles) on the target surface, measured normal to the incident light (refer to ARP4087). For tankers with NVIS friendly lighting, the recommended NVIS radiant intensity of the visible mode is 0.02 to 0.2 NRI. For tankers with covert lighting, the intensity of any visible photopic light in covert mode should be less than 0.02 cd. The IR sources should have a peak emission wavelength between 750 to 850 nm to correspond with the maximum response of the night vision goggles. In order to help the receiver pilots to identify the shape of the aircraft, lights should be mounted to illuminate the underside of the wings, body, and tail surfaces. Since the illumination on the target surfaces decreases as the cosine of the angle between the incident light and the normal to the surface, it is important to keep this angle as small as possible. This can be done by mounting the lights in the fuselage, wing pylons, or other locations with good visibility to the target surface. Care should be taken in the lighting design to minimize light that extends beyond the target surface to prevent unwanted glare.

4.3 Receiver Illumination

4.3.1 Function

Enable a boom operator to achieve stereopsis (determine geometry/definition) of the receiver in all positions of the receiver relative to the tanker, before hookup and during refueling operations.

4.3.2 Controls

To permit intensity to be varied from off to full intensity.

4.3.3 Color

White or Red. If the tanker crew is equipped with NVGs, additional covert illumination should also be provided.

4.3.4 Intensity

Sufficient intensity for all ambient conditions such that the boom operator can determine the position, velocity, and acceleration of the receiver aircraft.

4.3.5 Suggested Design

Use lights of sufficient intensity to create an illuminance of 5 to 22 lx (0.46 to 2.0 foot-candles) on the wings, measured normal to the incident light (refer to ARP4087). For receiver aircraft with covert lighting, the recommended radiant intensity of the covert mode is 0.02 to 0.2 NRI-B.

4.4 Tanker Mounted Receiver Illumination

4.4.1 Function

These lights enable the boom operator to determine the receiver geometry/definition, the location of canopies/windshields/antennae, and the position and velocity of the receiver before hookup and during refueling operations. The goal is to enhance the ability of the boom operator to perceive depth thereby enhancing safety.

4.4.2 Controls

To permit intensity to be varied from off to full intensity.

4.4.3 Color

Red. If the tanker crew and receiver pilot are equipped with NVGs, additional covert illumination should also be provided.

4.4.4 Intensity

Sufficient intensity for all ambient conditions such that the boom operator can determine the receiver geometry/definition, the location of canopies/windshields/antennae, and the position and velocity of the receiver.

4.4.5 Suggested Design

Use lights providing 4 to 22 lx (0.37 to 2.0 foot-candles) at the optimum refueling position, uniformly illuminating the air refueling envelope, with the exception of the expected position of the receiver aircraft crew. Care should be taken to prevent the tanker illumination from blinding the crew of the receiver aircraft. For tankers with covert lighting, the recommended radiant intensity of the covert mode is 0.02 to 0.2 NRI-B.

4.5 Probe Lighting

4.5.1 Function

Enable the receiver pilot to determine the position of the probe in relation to the drogue.

4.5.2 Controls

To permit the intensity to be varied from off to full intensity.

4.5.3 Color

White or red. Lower color-temperature white lights may be used to reduce glare for the boom operator. If the tanker crew is equipped with NVGs, additional covert illumination should also be provided.

4.5.4 Intensity

Sufficient intensity to make the probe and drogue easily visible to the receiver pilot under any ambient light conditions.

4.5.5 Suggested Design

Use a light mounted on the receiver airplane to illuminate the probe nozzle and the drogue. The shape of the beam should be designed to illuminate both the probe nozzle and the drogue in all expected locations. Figure 3 is an illustration of a recommended beam pattern (refer to MIL-L-006730). The light is mounted behind the probe and provides a conical beam with an intensity sufficient to provide a minimum illuminance of 2.7 lx (0.25 foot-candle) at the tip of the probe, with a maximum illuminance of 21.5 lx (2.0 foot-candles). the recommended conical beam is 40 degrees wide, with a centerline 10 degrees above the centerline of the probe nozzle in a vertical plane. The recommended minimum intensity of the beam is 250 cd along the beam centerline, with a minimum of 25 cd at the edges.

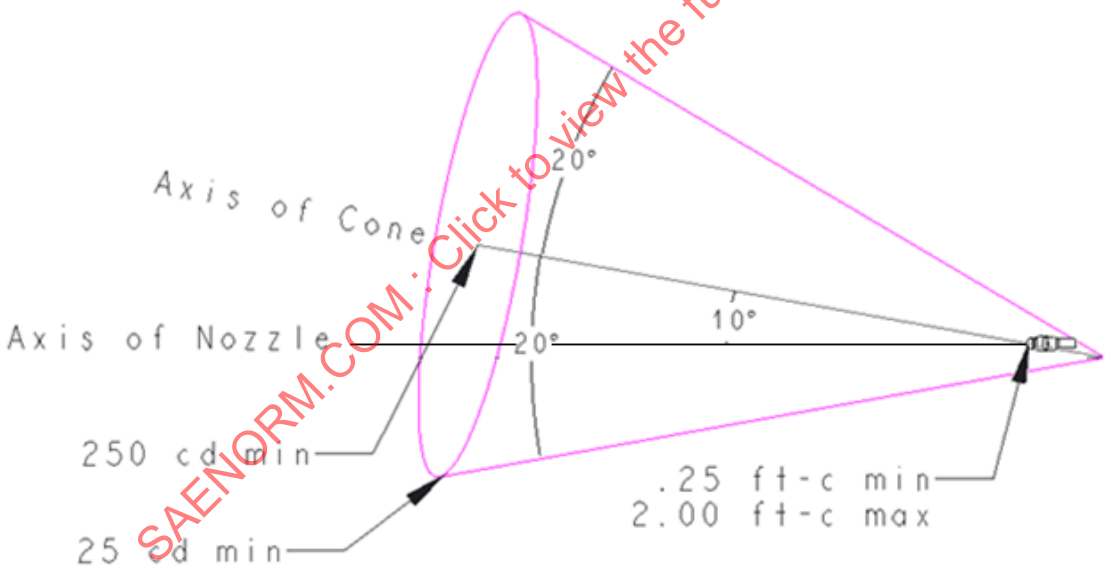

Figure 3 - Recommended probe light beam pattern

4.6 Boom Nozzle Lighting

4.6.1 Function

Enable the boom operator to determine the position of the boom nozzle relative to the receiver aircraft structure.

4.6.2 Controls

To permit intensity to be varied from off to full intensity.

4.6.3 Color

Red. If the tanker crew is equipped with NVGs, additional covert illumination should also be provided.

4.6.4 Intensity

Sufficient intensity to make the boom nozzle visible to the boom operator under all ambient lighting conditions. An illuminance of 3 to 22 lx (0.28 to 2.0 foot-candles), resulting in a boom nozzle luminance of at least 0.69 cd/m^2 (0.2 fL), will typically be sufficient. For tankers with covert lighting, the recommended radiant intensity of the covert mode is 0.02 to 0.2 NRI-B. If the boom operator will be observing the boom nozzle through a camera, consideration must be made for the camera performance in both visible and covert modes.

4.6.5 Suggested Design

Use lights designed to provide a carefully controlled teardrop-shaped beam pattern area which illuminates all possible nozzle locations without spilling over into the receiver pilot's expected location.

4.7 Slipway/Receptacle and Area Lighting

4.7.1 Function

Enable a boom operator to determine the location of the slipway/receptacle and see a sufficient area surrounding the slipway/receptacle in an effort to identify adjacent skin contours.

4.7.2 Controls

To permit intensity to be varied from off to full intensity.

4.7.3 Color

White or red. If the tanker crew is equipped with NVGs, additional covert illumination should also be provided.

4.7.4 Intensity

An intensity of 15 cd within the fuel receptacle or slipway, and 2.5 cd in the area surrounding the receptacle. Alternatively, an illuminance of 6 to 45 lx (0.56 to 4.2 foot-candles) should produce a surface luminance around the receptacle of 1.4 cd/m^2 (0.4 fL) which should be sufficient to achieve the desired effect. For tankers with covert lighting, the light should produce sufficient radiance to be seen with NVGs in all expected conditions.

4.7.5 Suggested Design

Use small lights inside the receptacle to illuminate the receptacle and surrounding area.

4.8 Drogue Lighting

4.8.1 Function

To enable the receiver pilot to determine the position of the drogue and the drogue geometry/definition before hookup and during refueling operations. For multiple installations, each drogue should have a separate light. Consideration should be made for remotely operated receiver aircraft where the pilot may be viewing the tanker via a camera.

4.8.2 Controls

To permit intensity to be varied from off to full intensity.

4.8.3 Color

White or green.