AEROSPACE RECOMMENDED PRACTICE

ARP694 REV. C

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Revised 2015-07

Superseding ARP694B

(R) Aerial Refueling Lights - Design Criteria

RATIONALE

This SAE Aerospace Recommended Practice (ARP) is revised to update and improve specification of technical requirements. References to specific older lighting technology have been updated to include newer technologies. References to covert lighting have also been added.

1. SCOPE

This 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.

ARP4087C Wing Inspection Lights – Design Criteria

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

SAE values your input. To provide feedback on this Technical Report, please visit
http://www.sae.org/technical/standards/ARP694C

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

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

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

3. STANAG ATP-56(B) AIR-TO-AIR REFUELLINGGENERAL REQUIREMENTS

3.1 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 such a manner so as to assure that all required functions are performed.

Table 1 - Types of lights for aerial refueling

		Use with Probe & Drogue		Use with Boom/Receptacle	
Light Type		Receiver	Tanker	Receiver	Tanker
Rendezvous Lighting (4.1)			X		X
Tanker Illumination (4.2)			X		X
Receiver Illumination (4.3)		X		X	
Tanker Mounted Receiver Illumination (4.4)					X
Probe Lighting (4.5)		X			
Boom Nozzle Lighting (4.6)					X
Slipway/Receptacle and Area Lighting (4.7)				X	
Drogue Lighting (4.8)		X	X		
Hose Illumination Lighting (4.9)			X		
Boom Illumination Lighting (4.10)					X
Pilot Director Light (4.11)					X
Signal Lights (4.12)	Equipment Malfunction		X		
	Breakaway		X		X
	Equipment is Ready		X		
	Receiver too Close to Tanker		X		
	Fuel is Flowing		X		

3.2 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.

3.2.1 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.

3.2.2 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.

3.2.3 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.

3.2.4 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 107 600 lx (10 000 fc).

3.2.5 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.

3.3 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.

3.4 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

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

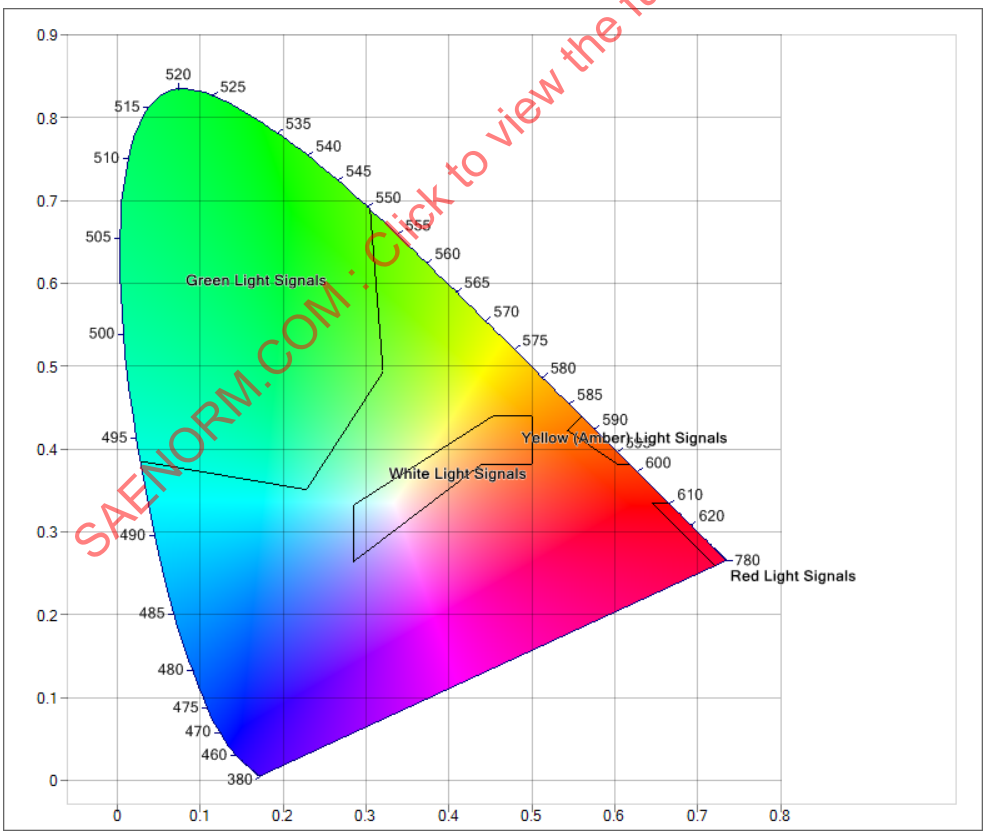

Figure 1 - CIE 1931 chromaticity chart with ARP694 colors

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.

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 (see 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).

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.

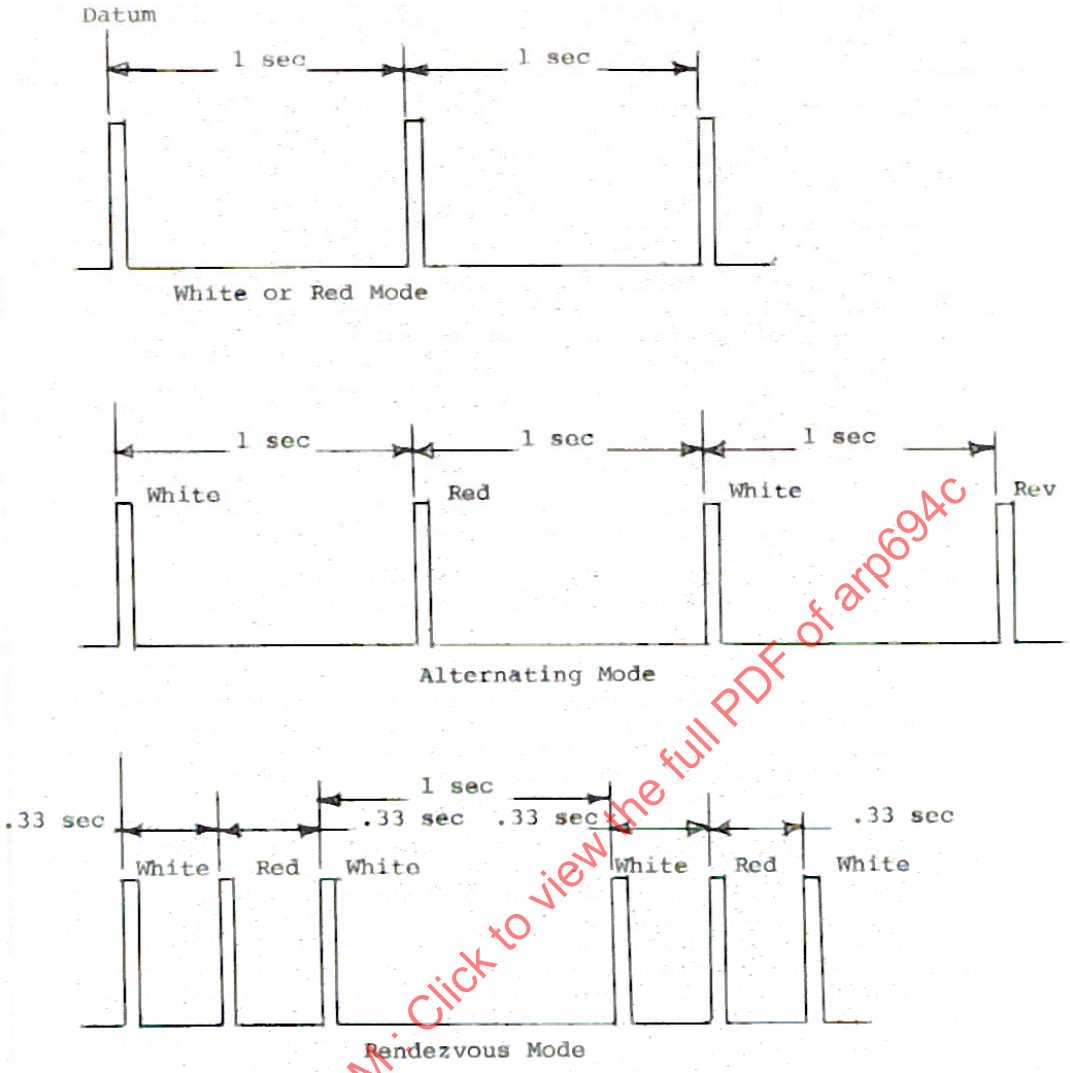

Figure 2 - Rendezvous light flash patterns

4.2.3 Color

White or Red. If the tanker is intended for use by receiver pilots with night vision goggles (NVGs), additional 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.

4.2.5 Suggested Design

Use lights of sufficient intensity to create an illuminance of 5 to 22 lx (0.46 to 2.0 fc) on the target surface, measured normal to the incident light (see ARP4087C). 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 fc) on the wings, measured normal to the incident light (see ARP4087C).

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

White or Red. If the tanker crew is 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 fc) at the optimum refueling position, uniformly illuminating the air refueling envelope. Care should be taken to prevent the tanker illumination from blinding the crew of the receiver aircraft.

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. 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 easily visible to the receiver pilot under any ambient light conditions. An illuminance value of 3 to 21.5 lx (0.28 to 2 fc) at the probe nozzle will typically be sufficient.

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.

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

White or 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 fc), resulting in a boom nozzle luminance of at least 0.69 cd/m^2 (0.2 fl), will typically be sufficient. If the boom operator will be observing the boom nozzle through a camera, consideration must be made for the camera performance.

4.6.5 Suggested Design

Use lights designed to provide a carefully controlled teardrop-shaped beam pattern area which only illuminates the nozzle.

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

Sufficient intensity to make the receptacle visible to the boom operator under all operating conditions. An illuminance of 6 to 45 lx (0.56 to 4.2 fc) 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.

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.

4.8.4 Intensity

Sufficient intensity to produce a surface luminance on the drogue of 1.4 cd/m^2 (nits) (0.4 fL) or sufficient surface luminance to achieve the desired effect.

4.8.5 Suggested Design

Use small lights mounted in the drogue to illuminate the outside ring of the drogue.

4.9 Hose Illumination Lighting

4.9.1 Function

To enable the receiver pilot to determine the amount of hose that is extended and the relative motion between airplanes while aerial refueling.

4.9.2 Controls

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

4.9.3 Color

White or ultraviolet light as appropriate for the paint used for the markings. If the tanker crew is equipped with NVGs, additional covert illumination should also be provided.

4.9.4 Intensity

Sufficient intensity to produce a surface luminance of 1.7 cd/m^2 (nits) (0.5 fL) from the markings on the hose or sufficient surface luminance to achieve the desired effect.