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Aerial Refueling Lights - Design Criteria

FOREWORD

Changes in this revision are format/editorial only.

1. SCOPE:

1.1 This ARP is intended to cover all external lights on the tanker and fixed wing receiver airplanes used to accomplish serial refueling.

1.2 This ARP describes lights used for two basic types of aerial refueling: The Probe and Drogue, and the Boom/Receptacle method.

2. PURPOSE:

2.1 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 waiver is obtained.

3. REQUIREMENT:

3.1 The type of lights required by the airplanes depends on the method of aerial refueling as indicated in Table I. 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.

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TABLE I

TYPES OF LIGHTS FOR AERIAL REFUELING

		Use with Probe & Drogue		Use with Boom/Receptacle	
		Receiver	Tanker	Receiver	Tanker
1.	Rendezvous Lighting (4.1)		X		X
2.	Tanker Illumination (4.2)		X		X
3.	Receiver Illumination (4.3)	X		X	
4.	Tanker Mounted Receiver Illumination (4.4)				X
5.	Probe Lighting (4.5)	X			
6.	Boom Nozzle Lighting (4.6)				X
7.	Slipway/Receptacle and Area Lighting (4.7)			X	
8.	Drogue Lighting (4.8)	X	X		
9.	Markings on Hose (amount of extension) (4.9)		X		
10.	Markings on Boom (amount of extension) (4.10)				X
11.	Signal Up or Down, Forward or Aft (4.11)				X
12.	Signal Equipment is Ready (4.12)		X		
13.	Signal Fuel is Flowing (4.13)		X		
14.	Signal to Breakway (4.14)		X		X
15.	Signal Equipment Malfunction (4.15)		X		
16.	Signal Receiver Too Close to Tanker (4.16)		X		

3.2 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 4.0 Detail Requirement.

3.2.1 Field of Vision: The field of vision of the receiver pilot and boom operator is limited. The signal 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, head up displays, gun sights, etc.

3.2.2 Glare: Lights should not cause hot spots or glare. Light sources when used to illuminate the airplane or parts of it, 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 of such an undercast can easily be 107,600 lux (10,000 foot candles).

3.2.5 Ambiguity: The signal lights should be designed to tell the pilot what to do. It should not be possible for the signal lights to direct the pilot to do contradictory things at one time. 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, signal lighting should be provided which would be compatible with night vision goggles.

3.4 Color:

The red, green, white and yellow colors will be within the boundaries listed below on the CIE 1931 Chromaticity Diagram.

Red Light Signals

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

Green Light Signals

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

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

Yellow Light Signals (Amber)

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

4. DETAIL REQUIREMENTS:

4.1 Rendezvous Lighting:

4.1.1 Function: Enable receiver to visually identify 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 anticollision and as rendezvous functions and must be controlled either from the flight deck or the boom operator's position. Controls must permit selection of desired code sequence and of upper or lower lights only during refueling operation if necessary to eliminate blinding of receiver pilot, tanker boom operator or pilots of other airplanes in the formation.

4.1.3 Color: Red, white, alternating red-white, and periodic sequence of three flashes, first white, then red, then white to provide positive aircraft identification.

4.1.4 Intensity: Equivalent intensity of an anticollision light per FAR's.

4.1.5 Suggested Design: Use two red-white Xenon flashing anti-collision/rendezvous lights. Each light, red and white, should be of equal intensity, be a minimum of 400 effective candelas and the upper and lower lights should be synchronized. Four modes should consist of the following:

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, 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 0.33 second interpulse and one second intervals (see figure 1).

4.2 Tanker Illumination:

4.2.1 Function: Enable receiver pilot to determine geometry/definition (stereopsis) of the tanker in all positions of the tanker relative to the receiver, 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.

4.2.4 Intensity: Sufficient intensity for all ambient conditions so that receiver can determine position of tanker.

4.2.5 Suggested Design: Use 50-watt lamps having 1,400 to 10,000 maximum beam candlepower (candelas) to illuminate wings, body, and tail surface or use area type lighting.

4.3 Receiver Illumination:

4.3.1 Function: Enable 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.

4.3.4 Intensity: Sufficient intensity for all ambient conditions so that boom operator can determine position, motion and rate of motion of receiver.

4.3.5 Suggested Design: Use 50-watt lamps having 1,400 to 10,000 maximum beam candlepower (candelas) to illuminate wings or use area type lighting in these areas.

4.4 Tanker Mounted Receiver Illumination:

4.4.1 Function: Enable the boom operator to determine receiver geometry/definition, the location of canopies/windshields/antennae, the rate and motion 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.

4.4.4 Intensity: Sufficient intensity for all ambient conditions so the boom operator can determine receiver geometry/definition, location of canopies/windshields/antennae, rate and motion of the receiver.

4.4.5 Suggested Design: Use dual lamps each providing 0.20 foot-candles 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 receiver aircraft.

4.5 Probe Lighting:

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

4.5.2 Controls: To permit intensity to be varied from off to full intensity.

4.5.3 Color: White or aviation red.

4.5.4 Intensity: Sufficient intensity to make the probe easily visible to the receiver pilot under any ambient lighting conditions. An illuminance value of 2.7 to 21.5 lux (0.25 to 2 foot-candles) at the probe nozzle will normally produce this lighting.

4.5.5 Suggested Design: Use incandescent light sources mounted on the receiver airplane to illuminate the probe nozzle and the drogue.

4.6 Boom Nozzle Lighting:

4.6.1 Function: Enable boom operator to determine position of boom nozzle relative to receiver aircraft structure.

4.6.2 Controls: To permit intensity to be varied from off to full intensity.

4.6.3 Color: White.

4.6.4 Intensity: Sufficient intensity to make the boom nozzle visible to the boom operator under all ambient lighting conditions. Illuminance values which will result in a boom nozzle luminance of at least 0.69 candelas per square meter (0.2 footlamberts) when viewed by the boom operator will produce this lighting.

4.6.5 Suggested Design: Use incandescent light sources mounted inside a tube with an aperture to provide light on a carefully controlled teardrop area to illuminate only the receptacle.

4.7 Slipway/Receptacle and Area Lighting:

4.7.1 Function: Enable boom operator to determine location of the slipway/receptacle and see sufficient area surrounding the slipway/receptacle 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.

4.7.4 Intensity: Sufficient intensity to produce a surface luminance around receptacle of 1.4 candelas per square meter (nits) (0.4 footlamberts) or sufficient surface luminance to achieve desired effect.

4.7.5 Suggested Design: Use small incandescent lamps or small floodlights to illuminate receptacle and surrounding area.

4.8 Drogue Lighting:

4.8.1 Function: Enable the receiver pilot to determine position of drogue and drogue geometry/definition before hookup and during refueling operations. Each drogue should have a separate light for multiple installations.

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 drogue of 1.4 candelas per square meter (nits) (0.4 footlamberts) or sufficient surface luminance to achieve desired effect.

4.8.5 Suggested Design: Use small incandescent lamps or self-luminous (radioactive) lamps to illuminate outside ring of drogue.

4.9 Markings of Hose (Amount of Extension):

4.9.1 Function: Enable receiver to determine amount of hose that is extended and 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: Color design illuminated with white or ultraviolet light as appropriate for paint used.

4.9.4 Intensity: Sufficient intensity to produce a surface luminance of 1.7 candelas per square meter (nits) (0.5 footlamberts) at point of reference or sufficient surface luminance to achieve desired effect.

4.9.5 Suggested Design: Use floodlights to illuminate markings with visible or ultraviolet light.

4.10 Markings on Boom (Amount of Extension):

4.10.1 Function: Enable receiver pilot to determine amount of boom that is extended.

4.10.2 Controls: Fixed intensity.

4.10.3 Color: Color design illuminated with white light or ultraviolet light as appropriate for paint used.

4.10.4 Intensity: Lighting to produce a surface luminance of 1.7 candelas per square meter (nits) (0.5 footlamberts) at point of reference or sufficient surface brightness to achieve desired effect.

4.10.5 Suggested Design: Use floodlights to illuminate boom markings with visible or ultraviolet lights. The boom extension tube is painted with green, red and yellow reflector fluorescent paint.

4.11 Signal Up or Down, Forward or Aft:

4.11.1 Function: To signal receiver pilot for proper positioning before hookup and to enable the receiver pilot to maintain proper position during refueling operations.

4.11.2 Controls: Be dimmable, to level required for proper night time visibility.

4.11.3 Color: Color lights of a particular design, to indicate maximum or outside limit of envelope; red for up/down and yellow for forward/aft.

4.11.4 Intensity: Sufficient intensity to produce adequate signal for the bright daytime undercast condition. (See paragraph 3.2.4). In finalizing design, a mockup should be evaluated under simulated conditions.

4.11.5 Suggested Design: Use incandescent lamps to illuminate individual areas to provide diffused light. Provide two rows of light to form a scale, one row indicates amount receiver should move up or down, the other indicates amount receiver should move forward or aft. Provide identification to indicate the purpose of each row. It is desirable to specify the minimum lettering size, signal size, or area of each signal light for the up or down and forward or aft signals on the tanker. The lighted area, color, contrast and luminance photometric brightness will all interact to achieve the necessary visibility under extreme conditions per paragraph 3.2.4. Proposed designs should be evaluated under simulated extreme conditions.

4.12 Signal Equipment is Ready:

4.12.1 Function: To signal receiver pilot that refueling equipment is properly positioned and ready for refueling operation.

4.12.2 Controls: Be able to dim, to level required for proper nighttime visibility.

4.12.3 Color: Steady yellow.

4.12.4 Intensity: Sufficient intensity to produce adequate signal for the bright daytime undercast condition (see paragraph 3.2.4). In finalizing design, a mockup should be evaluated under simulated conditions.

4.12.5 Suggested Design: Use incandescent lamps to illuminate an area to provide diffused light.

4.13 Signal Fuel is Flowing:

4.13.1 Function: To signal receiver pilot that he is in correct position and fuel is flowing.

4.13.2 Controls: Be able to dim to level required for proper nighttime visibility.

4.13.3 Color: Steady green.

4.13.4 Intensity: Sufficient intensity to produce adequate signal for the bright daytime undercast condition (see paragraph 3.2.4). In finalizing design, a mockup should be evaluated under simulated conditions.

4.13.5 Suggested Design: Use incandescent lamps to illuminate an area to provide diffused light.