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<b>15. SUBJECT TERMS</b> ALAS – Automatic Load Alleviation System; AR – Aerial Refueling; IDS – Independent Disconnect System; PDL – Pilot Director Lights; PSIG – Pounds per square inch gauge; TMF – Tail Mounted Floodlight; UARRSI – Universal Aerial Refueling Receptacle Slipway Installation; Also See document Abbreviations and Terminology					
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# ARSAG

## AERIAL REFUELING SYSTEMS ADVISORY GROUP

### Guidance document

## Aerial Refueling Boom/Receptacle

Document Number 20-08-17  
Date 28 July 2017



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**Distribution Statement:** This is an ARSAG Document prepared by a group of international contributors during scheduled ARSAG Workshop Sessions. This ARSAG document is intended to provide guidance derived from lessons learned and offer aerial refueling tanker/receiver interface guidance regarding standardization of aerial refueling systems. It is distributed to promote consistent, unambiguous communication among the international aerial refueling community. It does not contain proprietary, sensitive, classified or otherwise restricted information. ARSAG documents, as prepared, are not DOD, MOD or NATO standards, but provide recommendations regarding aerial refueling systems to United States military services, their allied military organizations involved in aerial refueling and their associated contractors. This document is suitable for release in the public domain; it may be included in DOD and NATO databases such as ASSIST, DTIC, Military Specifications, SRDs, STANAGs, etc. Contact: [arsaginc@earthlink.net](mailto:arsaginc@earthlink.net) or 937 760-7407.

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## 1.0 Executive Summary

This ARSAG Guidance document provides users with additional information not contained in NATO Standards ATP-3.3.4.2 (formerly ATP-56B) and ATP-3.3.4.5 (STANAG 7191). It addresses the background of the requirements, lessons learned and recommendations for future improvements which will be useful for development of boom and/or receptacle systems on new or existing aircraft. This document may be used in conjunction with the Joint Service Specification Guide (JSSG). This document covers the Tanker/Receiver Interface, including Tanker Boom and Nozzle, Receiver Receptacle and Slipway, Signal Systems, Receptacle Toggle Latches, Fuel System, Fuel and Fuel Vapor Ignition Sources, Aerodynamic Effects, Operation with a Failure and Boom Operator Visibility. It also includes Tanker Boom Installation, including Boom Location, Structural Design Criteria, Boom Control Envelope and Automatic Disconnect Limits, Boom Nozzle Disconnect Provisions, Aerial Refueling Fuel System and Tanker Aids and Cues for the Receiver Aircraft. Also included are Receiver/Receptacle Installation and Associated Interface Enhancements, including Receptacle/Slipway Location and Angle of Installation and Clear Entry Receptacle Path, Tanker Boom/Nozzle Slipway Clearances, Slipway and Adjacent Area Loads, Receptacle Housing and Aircraft Structure and Failure Modes, Fuel System, Receiver Aircraft Aids and Cues for Tanker Operations and Receiver Aircraft Pilot Aids. In addition, several potential future concept improvements are discussed, including Wing Mounted Boom/Drogue Conversion Capability and Director Light Position Information for Receiver Aircraft and Improved Tanker Aft Underbody Lighting and Active Underbody Markings.

## 2.0 Acknowledgements

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### **3.0 References**

1. ARSAG Guidance Document: Aerial Refueling Pressure Definitions and Terms, Design and Verification Guidance, 03-00-03R 12 Dec 2010, DTIC Tracking Number AD1025801
2. MIL-R-27521A Receptacle, Flying Boom, Aerial Refueling, June 1971, Org Sept. 1964
3. Mil-STD-464A Electromagnetic Environmental Effects Requirements for Systems
4. RTCA/DO-160 Environmental Conditions and Test Procedures for Airborne Equipment
5. ENFE 77-1, Amendment 5, 9 April 1981, Universal Aerial Refueling Receptacle Slipway Installation, General Exhibit for 1 June 1977
6. Aerial Refueling Lighting Study dated 15. Sept 05, UDRI, USAF's Funding, USAF Distribution No. 05-0082 Public Release, Contract No. F42620-D-0028

### **4.0 Associated Documents**

1. Aerial Refueling Tanker/Receiver Aircraft Clearance Process and Documentation and Record Keeping Repository dated. 2 May 2005 (D. Kalt Briefing, ARSAG '05, Madrid Spain) AFSC DH-2-1 Aerial Refueling (Design Handbook) Section 5A
2. AFSC DH-2-1 Aerial Refueling (Design Handbook) Section 5A
3. ARSAG Document No. 02-88-12WD, Aerial Refueling Equipment: Boom-Receptacle System and Interface Requirements – Draft, Dated 8 July 2013
4. ARSAG Guide Document: Aerial Refueling Interoperability Considerations Document (ARSAG) Dated 1995
5. ARSAG Guide Document: Aerial Refueling Performance and Interface Survey, dated Oct 1981
6. ARSAG Guide Document: Standardized Technical Data Survey for Aerial Refueling, 17-81-03, dated 6 Sept 2016, DTIC Tracking Number AD1027954
7. ARSAG Guide Document: Aerial Refueling Clearance Process Guide, 43-08-14, 21 Aug 2014, DTIC Tracking Number AD1025796
8. MIL-A-8865, Airplane Strength and Rigidity, Miscellaneous Loads
9. MIL-A-87166 (USAF), 2 May, 1983, Aerial Refueling Receiver Subsystems
10. MIL-F-38363B Fuel System, Aircraft, General, dated 1971
11. MIL-S-38449C, 11 June 1976, Signal and Signal/Intercommunications, Amplifiers, Universal, Aerial Refueling
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13. MS-27604, Nozzle, Universal Aerial Refueling Tanker Boom, dated 1968
14. MIL-STD-810G, Environmental Engineering Considerations and Laboratory Tests, 1 Jan 2000,
15. MIL-DTL-83133E, 1 April 1999, Detail Specification: Turbine Fuel, Aviation, Kerosene Type, JP-8
16. MIL-DTL-5624W, 28 Mar 2016, Detail Specification: Turbine Fuel, Aviation, Grades JP-4 and JP-5
17. MIL-PRF-83323B, Tester, Universal Receptacle, Aerial Refueling, 1 Nov 1997
18. NATO ATP-3.3.4.2 (previously ATP-56B), Air-to-Air Refueling (NATO STANAG 3971)
19. NATO STANAG 3447, Edition 5, Aerial Refuelling: Probe-Drogue Interface Equipment Characteristics
20. NATO STANAG 7191 Air-to-Air Refuelling Equipment: Boom-Receptacle System and Interface Requirements, Edition 1, 3 June 2013

21. NATO Standard ATP-3.3.4.5, Air-to-Air (Aerial) Refuelling Equipment: Boom-Receptacle System and Interface Requirements, Edition A, Version 1, June 2013
22. D6-7941, Design Considerations for Aerial Refueling Receiver Installations with the KC-135 Flying Boom, Dated. Nov. 1961, Unlimited Distribution (KC-135A Only)
23. ARSAG Guidance Document: Aerial Refueling Clearance Initiation Request, 16-88-98R, 14 July 2016, DTIC Tracking Number AD1025799
24. ENFE Technical Exhibit 90-1, Tester, Aerial Refueling Boom Nozzle (NSN 4920-01-183-3039)
25. Memorandum of Understanding Between Department of Navy and Department of Air Force, dated 10 July 1981 ARSAG Website: [www.arsaginc.com](http://www.arsaginc.com)
26. NSN 4920-01-01-2153, Draft, Tester, Rotational and Deflection. Boom Nozzle
27. Multipoint Aerial Refueling Boom Feasibility Study, Dated Jan 1972, Contractor: The Boeing Company, Wichita Division.
28. Specification Number ZA015800, "KC-10A Aerial Refueling System Interface Control Document (ICD) Configuration Item Development Spec Type B1, Revision D, Dated November 1991, Douglas Aircraft Company, McDonnell Douglas Corporation, Long Beach CA.
29. Technical Memorandum EN/FEF-TM-76-5 Dated 1 May 1976, Subject: "Internal Explosion Test Universal Aerial Refueling Receptacle Slipway Installation (UARRSI) IE AFXAR 7034
30. Universal Test Set (Fault Isolation Tester) NSN 4920-01-135-8554, UARRSI and Boom Receptacle Type Receptacles, Data Products, New England

#### Drawings

1. AFXAR 7034, Receptacle, Universal UARRSI
2. AFXAR 1011-318, Electrical Schematic
3. AFXAR 6024-31, Adapter Plate, 31 Degrees
4. AFXAR 6024-36, Adapter Plate, 36 Degrees
5. AFXAR 6024-46, Adapter Plate, 46 Degrees
6. AFXAR 6024-41, Adapter Plate, 41 Degrees
7. AFXAR 7034-54, Scuff Plate, Door
8. AFXAR 7034-54-1, Scuff Plate, Door, Raised
9. AFXAR 7034-60, Receptacle Assembly
10. AFXAR 7034-150, Slipway Door Retaining Tool
11. AFXAR 7034-4013-1 Sling: Receptacle (UARRSI) Hoist
12. AFXAR 7034-2008-1 Pedestal/Sliding Valve Assembly Removal Tool

## 5.0 Abbreviations and Terminology

ALAS – Automatic Load Alleviation System  
AR – Aerial Refueling  
IDS – Independent Disconnect System  
PDL – Pilot Director Lights  
PSIG – Pounds per square inch gauge  
TMF – Tail Mounted Floodlight  
UARRSI – Universal Aerial Refueling Receptacle Slipway Installation

**Rolling boom.** The boom rotates up and down (pitch) around the pitch axis as defined in ATP-3.3.4.5 and moves from side to side (laterally) by rolling about the nearly horizontal roll axis as defined in ATP-3.3.4.5.

**Yawing boom.** The boom rotates up and down (pitch) around the pitch axis as defined in ATP-3.3.4.5 and moves from side to side (laterally) about the vertical azimuth axis as defined in ATP-3.3.4.5

**Aerial vs Air-to-Air.** United States term is Aerial Refueling (AR), NATO term is Air-to-Air Refuelling (AAR).

## 6.0 Introduction

STANAG 3447 originally addressed probe/drogue aerial refueling methods only. It was originally planned to upgrade STANAG 3447 to include boom/receptacle aerial refueling methods. Due to the complexity of covering both methods in one document and the desire for prompt NATO ratification of the latest probe/drogue changes, NATO agreed, in 2004, to separate the two documents. NATO assigned Study 7191 for the new boom/receptacle document, in October 2004. Development of the new document proceeded until 2008, at which time it was decided that the proposed STANAG 7191 should only contain true “requirements”, and not recommendations, lessons learned, or improvement recommendations. It was determined at that time that the additional data would be included in this ARSAG guidance document, to supplement STANAG 7191. The ARSAG recommended draft STANAG 7191 was submitted to NATO, for review and ratification, in April 2011. NATO revised their standards system and released STANAG 7191, as the Standardization Agreement, in June 2013. The actual requirements were released concurrently as NATO Standard ATP-3.3.4.5, in June 2013. ARSAG Document 02-88-12WD, Aerial Refueling Equipment: Boom-Receptacle Systems and Interface Requirements, DRAFT, 6 Dec 2013 has been created to document the current requirements in ATP-3.3.4.5 and changes that will be proposed for future revisions of that NATO document.

## 7.0 Cross References between this Document and ATP 3.3.4.5

### 7.1 Cross References from ATP-3.3.4.5 to Guidance Document

ATP-3.3.4.5 Paragraph	Guidance Document Paragraph
<b>Section I Tanker Boom Systems</b>	
1.5 Nozzle Dimensions	8.1.1
1.6 Nozzle Angular Deflection	8.1.2
1.8 Maximum Boom Envelope	8.1.1
1.9 Nozzle Axial Rotation	8.1.2

1.10	Boom Envelope	9.3.1 and Appendix 12.2.1
1.12	Telescoping System	9.2.9
1.13	Independent Disconnect	9.4.2
1.15	Signal System and Secure Communications	8.3.1
1.16	Boom and Tanker Fuel System	8.5 and 9.5
1.17	Boom System Structural Design Criteria	9.2
1.18	Tanker External Lights	9.6

**Section II Receiver Receptacle Systems**

1.19	Receptacle Installation	10.0
1.21	Receiver Aircraft Fuel System	10.6
1.23	Receiver Receptacle Markings	10.7.3 and Appendix 12.3.2
1.24	Receiver Aircraft Lights	10.7

**7.2 Cross References from Guidance Document to ATP-3.3.4.5**

<b>Guidance Document Paragraph</b>	<b>ATP-3.3.4.5 Paragraph</b>
<b>To be added on next revision</b>	

## 8.0 Tanker/Receiver Interface

### 8.1 Tanker Boom and Nozzle.

**8.1.1 Boom and Nozzle Mating and Envelope Dimensions.** The dimensions for the boom nozzle should conform to ATP-3.3.4.5.

**8.1.1.1 Nozzle External Dimensions.** The boom nozzle external dimensions are specified in ATP-3.3.4.5 paragraph 1.5 and ATP-3.3.4.5 A (A-1 thru A-4). These dimensions are the critical interface dimensions and are based on the dimensions of the nozzle equipping the KC-135 tanker, which assures the correct mechanical interface between the tanker and the receiver.

**8.1.1.2 Tanker Boom and Nozzle Physical Envelopes.** The boom nozzle should not exceed the physical envelope specified in ATP-3.3.4.5 paragraph 1.7 and ATP-3.3.4.5 C (C-1). No portion of the boom may impinge upon the envelope specified in ATP-3.3.4.5 paragraph 1.8 and ATP-3.3.4.5 C (C-2). Exceeding these envelopes may result in a reduced receiver refueling envelope, due to clearance issues. The boom should be designed to hold the lower surfaces of the fixed and telescoping tubes as close to the centerline of the telescoping tube as possible. This will allow the receiver to utilize the entire refueling envelope without restrictions due to receiver fuselage or canopy clearance. This will ensure the best visibility of the boom nozzle, the receiver receptacle, and any other features of the receiver that are critical to safe operation of the boom when the viewing angle is from the underside of the boom. This still applies when the viewing angle is from the upper side of the boom, to maintain the best clearance with the receiver. See Figure 12.2.1.10 Boom Physical Envelope. Boom control surface design should also consider maximizing receiver clearance throughout the refueling envelope.

**8.1.1.3 Nozzle Seal.** The nozzle seal surface should interface with the seal in the receptacle sliding valve as specified in ATP-3.3.4.5, paragraph 1.5 and ATP-3.3.4.5, A (A-1 thru A-2), dimensions R, S and T.

### 8.1.2 Nozzle Angular and Rotational Deflections.

**8.1.2.1 Nozzle Angular Deflection.** The boom nozzle should be able to achieve a 60 degree cone angle of deflection, as specified in ATP-3.3.4.5 paragraph 1.6 and ATP-3.3.4.5, A (Figure A-3).

**8.1.2.2 Nozzle Axial Rotation.** The boom nozzle should be capable of rotating axially, as specified in ATP-3.3.4.5, paragraph 1.5 and ATP-3.3.4.5, A (Figure A-3). This is needed to accommodate misalignments caused by the receiver aircraft movement in the azimuth direction, within the boom envelope and the motion of a rolling boom.

**8.1.3 Nozzle Shock Absorber.** The boom nozzle shock absorber should be as specified in ATP-3.3.4.5, paragraph 1.14. Typical nozzle shock absorption characteristics are shown in Appendix 12.2.9. The nozzle shock absorber is needed to absorb part of the kinetic energy of the telescope tube/beam during the contact impact between the nozzle and the receptacle. This allows the impact forces to be within the acceptable limits of the boom and receptacle. Consideration should include the maximum boom extension rate, fuel pressure, telescopic tube weight and receiver closure rate specified in ATP-3.3.4.5 paragraph 1.9 and ATP-3.3.4.5, A (A-4).

**8.1.4 Nozzle Induction Coil.** The nozzle induction coil should be located as specified in ATP-3.3.4.5 paragraph 1.15, item 3 and ATP-3.3.4.5, B (B-2). Signal advance characteristics are specified in ATP-3.3.4.5 paragraph 1.15, item 1 and ATP-3.3.4.5, B (B-1). The nozzle induction coil should be located as to not make contact with the receptacle rollers and to maintain alignment when latched.

**8.2 Receiver Receptacle/Slipway/UARRSI.** When a receptacle installation other than the Universal Aerial Refueling Receptacle Slipway Installation (UARRSI) is used for a given receiver aircraft design, all applicable paragraphs of Associated Documents No. 22 should be complied with. No performance exclusions should be permitted without the approval of the procuring activity technical specialists.

**8.2.1 Receptacle/Slipway Normal Operation.** The following is the sequence of events during normal operation of the typical receptacle/slipway:

**8.2.1.1 Normal opening of the receptacle door.** A variety of methods are used to unlatch the receptacle door lock system, mechanical, electrical or hydraulic. Some airplanes will have a master refuel switch which energizes the receiver system. Then the receptacle door is opened with an electric or manual control.

**8.2.1.2 Redundant Receptacle Door Control.** It is good practice to consider redundant methods to open the receptacle door in order to conduct aerial refueling operation in case of a single failure. For example, on some receiver aircraft, pulling the manual door control handle to the detented "DOOR OPEN" position will release the receptacle door lock and activate a circuit for illuminating a "DOOR UNLOCKED" annunciator light. As the handle is pulled, hydraulic power is supplied to the door actuator which opens the receptacle door. As the receptacle door reaches its fully open and locked position, the circuit for the "READY" annunciator light in the receiver aircraft cockpit is energized. The receptacle is now ready to receive the tanker boom nozzle. Some receptacles have a manual release of the door lock and springs to open the door.

**8.2.1.3 Receiver's Receptacle Contact Switch Actuation.** When the tanker boom nozzle is inserted into the receiver's receptacle, it depresses the receptacle's sliding valve, which actuates the receiver's contact switch. The main contact seal with the nozzle is made before the tanker's nozzle poppet permits fuel to flow, including residual fuel in the boom. After the main contact seal is made, the remaining insertion of the nozzle should fully open the receiver's receptacle spring loaded sliding valve, which, in turn, actuates the receiver's receptacle contact switch. The receiver's receptacle fixed pedestal (Tulip) will open the tanker's nozzle poppet. When the receiver's contact switch is actuated, electrical power is applied to the solenoid of the receiver's receptacle toggle latch control valve which provides power to the receptacle toggle latch actuator, typically hydraulic powered. The receiver's receptacle toggles close and latch the tanker boom nozzle into the receiver's receptacle.

**8.2.1.4 Receiver's Receptacle Latch Switch Actuation.** The receiver's receptacle latch switch actuation occurs when the receptacle toggles close to latch the tanker's boom nozzle into the receiver's receptacle. The actuation of the receptacle latch switch provides an electrical pulse to the receiver's receptacle signal amplifier which advances the receiver's receptacle signal amplifier to CONTACT/LATCHED, thereby extinguishing the receiver's READY light and illuminating the CONTACT annunciator light in the receiver aircraft. An electrical pulse is also applied to the receiver's receptacle induction coil which induces a signal into the tanker's nozzle induction coil and tanker's signal amplifier system. The tanker's signal amplifier is then advanced to CONTACT and illuminates a CONTACT annunciator light on the boom operator's control panel and tanker crew annunciator. Fuel transfer may now take place.

**8.2.1.5 Intercommunication.** As specified in ATP-3.3.4.5 paragraph 1.20, if both aircraft are so equipped, voice communication between the two aircraft may now take place via the mated nozzle and receptacle induction coils and the intercommunication equipment.

**8.2.1.6 Disconnect Initiation.** A disconnect may be initiated by either the boom operator, the receiver aircrew, a Pressure Disconnect Switch in the receiver's aerial refueling manifold, when so equipped, or automatically by the receiver aircraft exceeding the tanker boom's automatic disconnect envelope, or an automatic rate disconnect, if the tanker is so equipped. If the disconnect is initiated by the tanker, a signal pulse is sent to the tanker's induction coil and induced into the receiver's induction coil, which is then transferred to the receiver's signal amplifier, advancing it to DISCONNECT and extinguishing the receiver's CONTACT light, and de-energizing the hydraulic valve solenoid which allows hydraulic pressure to drive the latch to open the receptacle's latches. As long as the tanker's boom nozzle is still in the receiver's receptacle, depressing the Contact Switch, the receiver's DISCONNECT light will not illuminate. The same electrical pulse will also advance the tanker's signal amplifier to DISCONNECT, but the tanker's DISCONNECT light will illuminate immediately, indicating that the boom is unlocked and may be retracted. As the boom is retracted, the Contact Switch in the receptacle is deactivated, illuminating the DISCONNECT light in the receiver, thereby signaling the termination of the contact. The receiver's receptacle door(s) may then be closed and aerial refueling power turned off. If another contact with the tanker is necessary before the receiver's aerial refueling power is turned off, the receiver's Reset Switch must be actuated, which interrupts power to the receiver's signal amplifier momentarily, and when released, returns the signal amplifier to the READY condition. Aircraft with an automatic reset must allow enough time for the nozzle to clear the receptacle. If the disconnect is initiated by the receiver aircraft, the sequence of events is exactly the same, except that the disconnect signal is induced from the receiver to the tanker.

**8.2.1.7 Tanker Independent Disconnect.** If the tanker is equipped with a full-time independent disconnect system, the boom control system should have the capability to initiate a limit disconnect or a rate disconnect using the tanker's independent disconnect system's retractable nozzle latches. The boom operator should also have the capability to command an independent disconnect. Full time independent disconnect or automatic independent disconnect to be commanded when the receiver is rapidly approaching the refueling limits, should be considered, to avoid delays in disconnect due to varying receiver receptacle toggle response.

**8.2.1.8 Completion of Refueling.** When the aerial refueling is completed; the tanker boom operator verifies that the boom nozzle is clear of the slipway and the receiver aircrew may actuate the door control to the "DOOR CLOSED" position. This positions the hydraulic valve so that the hydraulic power is applied to the door close side of the slipway door actuator for door closing. As the door begins to close, the "READY" annunciator light will extinguish, and when the door fully closes and locks, the "DOOR UNLOCKED" annunciator light will extinguish.

**8.2.1.9 Override.** The override mode is required if there is a malfunction of the signal amplifier in either the tanker or the receiver. If the override mode is selected, the appropriate signal amplifier is bypassed, and electrical power is furnished from other sources. In the receiver aircraft, the indicator light operation and the sequence of events are much the same, except that the READY light is illuminated when the slipway door is unlocked (before the door reaches its full open position). The slipway door is spring loaded to open when unlocked and should open by back-driving the hydraulic actuators. If necessary, the slipway door can be fully opened with pressure from the boom nozzle. If the tanker is the only aircraft operating in the override mode, the boom operator may still initiate disconnects because his Disconnect Switch is routed directly to the Nozzle's induction coil. The envelope disconnect capability does not exist, however. If the receiver aircraft is the only aircraft in override mode, or both aircraft are in the override mode, all disconnects must originate from the receiver. Also, if contacts are made while either aircraft is in the override mode, closure of the receptacle latches will not illuminate the CONTACT light in the tanker, because both of the signal amplifiers are required to be operational to enable signals to be induced from one aircraft to the other. Under these conditions the boom operator would normally apply a slight amount of boom retract force to verify that the nozzle is locked into the receiver, and then manually actuate his Emergency Contact Made Switch to start the transfer pumps.

**8.2.2 Receptacle Internal Mating Dimensions.** The mating dimensions for the receptacle/housing (UARRSI) receptacle are specified in ATP-3.3.4.5 paragraph 1.19, item 2 and ATP-3.3.4.5 D (D-1 thru D-3). The sliding valve should conform to ATP-3.3.4.5 D (D-3). Receptacle roller to nozzle interface should conform to ATP-3.3.4.5 D, (D-2). The latch mechanism should conform to ATP-3.3.4.5 D (D-3). The receptacle sliding valve main receptacle seal should seal on the boom nozzle seal surface as illustrated in ATP-3.3.4.5 A, (A-1) dimensions R, S and T.

**8.2.3 Sliding Valve and Pedestal.** The sliding valve should be spring loaded to close, and closure rate should be simultaneous with nozzle extraction at rates up to 10 fps.

**8.2.4 Receptacle Drain.** The receptacle/UARRSI Cavity should incorporate provisions for draining all residual fluids from that part of the receptacle body that is not pressurized.

**8.2.5 Receptacle Induction Coil Location.** The induction coil requirements and interface are specified in ATP-3.3.4.5 paragraph 1.20 and ATP-3.3.4.5, B, (B-2).

**8.2.6 Toggle Latches.** The receptacle cavity should be equipped with actuated toggle latches are specified in ATP-3.3.4.5 paragraph 1.19 and ATP-3.3.4.5 D (D-3) to hold the boom in the locked position during aerial refueling. The toggle latches should function as required in paragraph 1.4 below.

## **8.3 Signal System**

**8.3.1 Signal Coil Pulse Advance.** The signal amplifier/coil pulse advance should conform to ATP-3.3.4.5, paragraphs 1.15 and 1.20 and ATP-3.3.4.5, B, (B-1).

**8.3.2 Signal System Modes.** The signal system states are generally Ready, Contact, and Disconnect.



**8.3.3 Signal Conventions.** The receiver will send a signal pulse to the tanker when the nozzle is engaged. The receiver also sends a pulse to the tanker when requesting a disconnect. The tanker will send a pulse to the receiver when a tanker initiated disconnect is requested.

## **8.4 Receptacle/UARRSI Toggle Latches**

**8.4.1 Toggle Latch Response Time.** The toggle latches should latch or unlatch as specified in ATP-3.3.4.5 paragraph 1.19, item 5.d.

**8.4.2 Tension Disconnect.** The latch actuator should contain an integral relief mechanism to permit disconnects by forcing the latches open. The latch mechanism should hold the boom nozzle in the locked-in position as specified in ATP-3.3.4.5 paragraph 1.19, item 5.

**8.4.3 Toggles Spring Loaded Open.** The receptacle toggle latches should be spring loaded to the open position in the event of toggle shaft breakage or loss of actuation power as specified in ATP-3.3.4.5 paragraph 1.19, item 5.c(1).

**8.4.4 Toggle Shaft Structural Fuse.** The toggle shafts should break under a tension force, produced by the tanker boom on disconnect as specified in ATP-3.3.4.5 paragraph 1.19, item 5.c.(2).

**8.4.5 Operator Initiated Normal/Override.** The tanker/receiver aircraft should be provided normal and override modes for latched and disconnect modes of the system.

**8.5 Fuel System.** The tanker and receiver aircraft fuel systems should be designed to control fuel pressure and function satisfactorily during initial contact, connected and disconnect conditions. See Reference and Source Material #5

**8.5.1 Tanker Offload Rate.** The primary requirement will most likely be driven by the customer of your tanker. Consideration should be given to the type of receivers to be refueled, number of aerial refueling pumps, and the fuel system of the tanker.

**8.5.2 Bypass Valve.** With the receiver in contact and all of the receiver level control and other fuel shutoff valves closed, and the receiver moving forward, telescoping the boom, and any combination of the tanker's aerial refueling pumps operating, the tanker boom system shall not exceed the proof pressure of the tanker and the receiver. Note: Receiver proof pressure may be significantly lower than the tanker.

**8.5.3 Delivery Operating Pressure.** The tanker regulated delivery operating pressure should be as described in ATP-3.3.4.5 Para. 1.16, Boom and Tanker Fuel System.

**8.5.3.1 Nozzle Pressure Loss.** Typical nozzle/receptacle pressure loss ( $\Delta P$ ) should not exceed 22 psig at 1,200 gpm flow rate when tested with a UARRSI meeting ATP-3.3.4.5 A1 dimensions. (Reference #2 New tanker/receiver aircraft designs may overcome this receiver aircraft requirement penalty by increasing the tanker regulated delivery pressure (Paragraph 1.5.1 above). However, any new tanker design should be capable of distinguishing an existing receiver aircraft from a new receiver aircraft design which does not compensate for the nozzle/receptacle  $\Delta P$ .)

**8.5.3.2 Reverse Aerial Refueling Pressure Loss.** If reverse aerial refueling is needed the nozzle/receptacle pressure loss should not exceed 6 psig at 600 gpm in the reverse refueling (receiver to tanker) flow direction.

**8.5.3.3 Pressure Transients.** Pressure transients (fuel pressure surges) should be minimized to or below proof pressure of the tanker and receiver aircraft by use of surge suppressors, reducing nozzle poppet closure rate (Reference and Source Material #5 and #27), reducing receiver level control and line shut-off valve closure rates, boom surge boots and eliminating tanker aerial refueling pump check valves.

**8.5.3.4 Nozzle Poppet Snubbing.** The nozzle poppet should be snubbed within the last 1/4" of closure to minimize fuel pressure transients in the tanker.

**8.5.4 Pressure Disconnect Response and Value.** A pressure disconnect switch located just downstream of the receptacle should be provided to protect the receiver aircraft from steady state overpressure in the event of a tanker pressure regulator failure and/or a receiver aircraft fuel system tank level control valve failure. When a pressure disconnect switch is provided, the switch should be designed for maximum operating and transient surge pressures, i.e.: provide a slow pressure response switch (3 to 5 seconds) to accommodate maximum tanker pressure at low to no flow pressure and thereby avoid over filling tank and premature disconnects of the receiver aircraft.

**8.5.5 Fuel Leakage Values.** As specified in ATP 3.3.4.5 paragraph 1.16 and Reference #2

**8.6 Fuel and Fuel Vapor Ignition Sources.** Two potential sources of fuel vapor ignition exist in the aerial refueling process.

**8.6.1 Static Discharge.** Detailed requirements are found in Reference #3 paragraph 5-7.1. During the initial hook-up (wet or dry contacts) of the tanker and receiver aircraft, a static discharge occurs. This electrical arc may ignite any residual boom nozzle and/or receptacle fuel/vapor leakage; however, experience has shown a fire cannot be sustained at typical aerial refueling airspeeds of over 140 knots. Electronic equipment should be protected from large electrical static discharges. Tanker and receiver aircraft that will receive fuel at speeds slower than 140 knots must provide design features to minimize the possibility of sustained external fire.

**8.6.2 Lightning.** Detailed requirements are found in Reference #3 3-7 and 3-8. Many tankers are built on commercial airframes and their systems can be qualified against civilian standards like Reference #4, or equivalent. Lightning strikes can occur in aerial refueling receptacle locations on the receiver aircraft and ignite fuel vapors existing under the receptacle/slipway external door closure. The receptacle should include provisions to limit the pressure caused by the ignited fuel vapors, to prevent opening of the receptacle sliding valve. Opening of the sliding valve could allow the flame front to travel down the empty fuel lines into the receiver fuel tank. Refer to paragraph 3.6.1.4, below, and Reference #3. Lightning impact may also occur on the boom (stowed or deployed – wet or dry), with the same risk of explosion due to fuel vapors or damages to electronic/mechanical equipment.

## **8.7 Aerodynamic Effects**

**8.7.1 Tanker Downwash.** The attitude of the tanker at various gross weights and the corresponding downwash flow fields behind the tanker are vital to receiver design both for (a) consideration of the angle of the tanker boom (which is referenced to the tanker fuselage reference line or waterline) for receptacle placement (reference paragraph 3.1., herein) and aircraft clearance and, (b) for the attitude of the receiver to maintain and adjust the appropriate speed, control to overcome the downwash effects and the receivers relationship to the tanker.

**8.7.2 Receiver Bow Wave.** The configuration of the forward portion of the receivers fuselage, the location of the receptacle and the receptacle mounting configuration (flush or raised) must be considered in the design of new receivers, especially large blunt nose receiver aircraft, such as the C-5, C-17, B-52 and KC-10, to minimize the effect of receiver airflow on the controllability of the tankers refueling boom. Aft mounted receptacles cause increased tanker/receiver aircraft overlap, causing possible tanker aircraft control problems. (Reference paragraph 3.1., herein).

## **8.8 Operation with a Failure. NO SINGLE FAILURE IN THE TANKER AIRCRAFT SHALL PREVENT FUEL FROM BEING TRANSFERED INTO THE RECIEVER AIRCRAFT DURING AERIAL REFUELING.**

**8.8.1 Receiver Signal Amplifier Module Override.** A signal amplifier override mode should be installed. In the event of a failure of the receiver's signal amplifier module or the inability of the receiver system to detect a contact, the override mode may be selected. Operational sequencing and intercommunication capability will be the same as for normal operation, except that a disconnect using the receptacle toggle latches can only be initiated by the receiver. However if the tanker is equipped with an independent disconnect system, the tanker boom operator may initiate an independent disconnect utilizing the retractable latches on the nozzle.

**8.8.2 Tanker Signal Amplifier Module Override.** A signal amplifier override mode should be installed. In the event of a failure of the tanker's or receiver's signal amplifier module or the inability of the tanker system to detect a contact, the

override mode may be selected. There should be a means to manually advance the tanker system through the operational modes. Intercommunication capability will be the same as for normal operation, except that a disconnect using the receptacle toggle latches can only be initiated by the receiver. However if the tanker is equipped with an independent disconnect system, the tanker boom operator may initiate an independent disconnect utilizing the retractable latches on the nozzle.

**8.8.3 Hydraulic and/or Electrical Power Failure.** Aerial refueling may be accomplished if hydraulic and/or electrical power is not available to the receptacle. When the receptacle is equipped with a spring loaded slipway door, actuation of the manual door control lever to the “door open” position should allow the spring loaded slipway door to open. Refueling can then be accomplished by the pressure refueling” method in which the boom operator maintains sufficient extension force on the nozzle to keep it seated in the receptacle even though the nozzle is not latched into the receptacle.

**8.8.4 Pressure (Stiff Boom) Refueling.** The boom system should provide the capability, with minimal additional workload for the boom operator, to maintain a constant extension load sufficient to maintain a seal between the nozzle and receptacle in the event of receptacle toggle failure in the unlocked position. Telescope force feedback may be required.

**8.8.5 Failed Pressure Regulator.** The tanker unregulated delivery fuel pressure, with a failed pressure regulator, should not exceed 85 psig within 8 seconds at zero flow with all valves closed in the receiver aircraft. The delivery fuel pressure is measured within 31 inches (788 mm) of the boom nozzle inlet, upstream of the ball joint.

## **8.9 Boom Operator Visibility.**

**8.9.1 Boom Operator View of Nozzle and Receptacle.** The boom operator should have a clear, unimpeded view of the boom nozzle, the aft portion of the boom telescopic tube and the receiver’s receptacle throughout the boom operating and disconnect envelopes. This is a function of the look-down angle from the boom operator’s eye-point, or the indirect viewing system’s camera focal point, to the boom nozzle tip in the center of the boom disconnect envelope, the shape of the lower portion of the boom and the location of the receiver’s receptacle. The view of the aft portion of the telescopic tube is very important to allow accurate manual load alleviation of the boom, when necessary. This applies to viewing the boom from the underside. It is possible to view the boom from the upper side, in which case the viewing angles would be different.

**8.9.2 Look-down Angle.** Look down angle is the inclination of the line of sight from the tanker’s waterline or longitudinal axis to the boom tip in the center of the contact or disconnect envelope. The line of sight is from the boom operator’s eye-point, or the indirect viewing camera’s focal point, to the tip of the boom nozzle, when located in the center of the boom contact envelope. Historically, look-down angles between 22 degrees and 25.1 degrees have been proven successful for booms that do not extend excessively below the centerline of the Telescoping Tube.

**8.9.3 Shape of Lower Portion of the Boom.** The shape of the lower portion of the boom, including the telescopic tube and any bulges or protrusions on the fixed boom, has a significant effect on the boom operators visibility of the boom nozzle when the boom is in the upper portion of the disconnect envelope. See Paragraph 8.1.1.2 Tanker Boom and Nozzle Physical Envelope and Figure 12.2.1.10 Boom Physical Envelope.

**8.9.4 Receivers receptacle location.** The location of the receptacle on the receiver can affect the boom operator’s view. Receptacles mounted forward of the cockpit or canopy provide the best boom operator view, independent of the look-down angle. Aft mounted receptacles with a high canopy can block the view of the receptacle, if the look down angle is too shallow. This can result in a restriction to the boom’s upper disconnect limits for those types of receivers.

## **9.0 Tanker Boom Installation and Associated Interface Enhancements.**

### **9.1 Boom Location**

**9.1.1 Fuselage Mounted Boom.** A fuselage mounted boom should be located near the lower aft portion of the tanker aircraft fuselage and clear of any external appendages that could negatively impact and/or influence the boom control, receiver aircraft air flow field and restrict the automatic disconnect and mechanical envelope. The boom size should provide an equivalent length and telescoping tube length minimum as illustrated in Appendix 12.2.1. The nominal trail position

should be 30 ° from the tanker waterline. The unrestricted mechanical limit should be from the centerline stowage position to 50 ° lower elevation and ± 30 ° azimuth. The boom altitude and airspeed envelope should be equivalent to Appendix 12.2.2.

**9.1.1.1 Boom Pivot.** The forward end of the boom should be mounted to the lower surface of the aft fuselage of the tanker aircraft in such a manner to allow the unrestricted mechanical limits defined in paragraph 2.1.1 above. Fairings should be provided at the pivot point to blend with the aircraft, while allowing the required motion.

**9.1.1.2 Boom Latch.** The boom should be secured in the stowed position by a latching mechanism, with positive retention and the capability to resist lateral loads in addition to vertical loads from the boom.

**9.1.1.3 Stowage Shock Absorber/Well.** A shock absorber should be mounted on the upper surface of the boom. In the event of a gust induced impact between the boom and the fuselage during stowing or deploying, this shock absorber will absorb the energy and limit the impact loads. A well in the fuselage should be provided and the shock absorber will nest in this well when the boom is stowed. The shock absorber should be provided with a wheel on its upper end to allow it to roll on the underside of the tanker fuselage if it is not aligned with the well when stowing. When the boom is stowed, the shock absorber should provide preload to hold the boom against the latch.

**9.1.1.4 Boom Deploy/Stow.** The boom should be capable of being deployed and stowed using the boom control surfaces, at any speed within the boom deployed envelope. The boom should also be capable of being deployed or stowed with a hoist, during flight or on the ground. This hoist should be capable of hoisting the boom to the stowed position in flight with a control surface failure. There may be structural failure conditions where it is best to land with the boom in trail.

## 9.2 Structural Design Criteria

**9.2.1 Boom Stowed.** The boom and aircraft attach structure should be designed to withstand inertia loads due to the aircraft and boom response to discrete gusts consistent with those imposed on the aircraft, up to the dive speed of the aircraft. In addition, the boom structure should be designed to withstand loads due to continuous turbulence. Inertial loads due to aircraft landing at sink rates up to the design sink rates should also be considered. The boom and aircraft attach structure should be designed to withstand the air loads due to maximum aircraft sideslip with the boom stowed.

**9.2.2 Boom Free Flight.** With the boom deployed within the disconnect envelope, the structure should withstand the loads imposed by limit discrete gusts applied to the aircraft and accounting for boom response, at speeds up to the boom deployed maximum speed.

**9.2.3 Boom Coupled.** The boom coupled design conditions should be as specified in ATP-3.3.4.5 paragraph 1.17, item 1.

**9.2.4 Arbitrary Axial Loads.** The boom and aircraft support structure, while within the boom coupled design envelope, should be designed for the maximum axial ultimate air loads plus the axial loads as specified in ATP-3.3.4.5, paragraph 1.17, item 2.

**9.2.4.1 Compression Loads.** The boom structure should not collapse when the telescopic tube is jammed in the fully extended position. This requirement also prevents collapse when pressure refueling of receiver aircraft in an emergency fuel situation.

**9.2.5 Emergency Landing Loads.** The boom and aircraft support structure should be designed in order to withstand ultimate inertia accelerations due to emergency landing as stated in CS 25.561, CS 25.963, 14 CFR 25.561, and 14 CFR 25.963 , according to the specific tanker/receiver specification. Typical emergency landing accelerations are:

- a. Forward 9.0g
- b. Downward 6.0g
- c. Sideward 3.0g
- d. Upward 3.0g
- e. Rearward 1.5g

**9.2.6 Boom Stowage Shock Absorber.** The boom stowage shock absorber should be capable of absorbing the maximum impact energy of the boom when it responds to discrete gusts consistent with those imposed on the aircraft, occurring at the most critical distance from the fuselage, up to the boom deployed dive speed of the aircraft. The area of the fuselage adjacent to the shock absorber well may be impacted by the boom and the shock absorber, and should be capable of withstanding the maximum load developed by the shock absorber, in response to the above critical gust, without damage.

**9.2.7 Extension Shock Absorber.** Energy absorption and strength should be provided to withstand a complete failure of the extension drive mechanism throughout the entire aerial refueling envelope, resulting in a runaway telescopic tube.

**9.2.8 Retraction Shock Absorber.** Energy absorption and strength should be provided to withstand the maximum unsnubbed emergency retraction rate that the extension drive mechanism can achieve.

**9.2.9 Telescoping Drive System.** The drive system that moves the telescoping tube should be designed so that no failure of the drive system will allow the telescopic tube to extend in an uncontrolled manner.

**9.2.10 Expected Lifetime Usage.** The aerial refueling boom assembly, backup structure, aircraft primary structure, and required components should be designed to meet the expected usage of the aircraft as a tanker. Expected mission profiles should be used to help design the tanker at the tanker primary structure and component level. When AR equipment is installed on an aircraft not initially designed for aerial refueling missions, the designer should consider that the airplane flight profiles under which it has been initially certificated might be different.

### **9.3 Boom Control Envelope and Auto Disconnect Limits.**

**9.3.1 Boom Envelopes.** The boom envelopes should comply with the requirements specified in ATP-3.3.4.5 paragraph 1.10 as a minimum. Larger envelope dimension size in azimuth/roll and extension is desired.

**9.3.2 Boom Imposed Loads.** The boom control system should have the flight control authority to control the boom so that the radial load at the nozzle ball joint does not exceed 100 lbs., while engaged with the receiver aircraft receptacle anywhere within the disconnect envelope.

**9.3.3 Push/Pull Loads.** Once engaged with the receiver's receptacle system, the boom system should allow for telescoping, both extension and retraction, during the refueling process. Ref ATP-3.3.4.5 paragraph 1.12.

**9.3.4 Automatic Load Alleviation (ALAS).** ALAS should be incorporated in boom design, and should be capable of controlling the boom so that the radial load at the nozzle ball joint does not exceed 500 lbs. while engaged with the receiver aircraft receptacle, anywhere within the disconnect envelope.

**9.3.5 Automatic Disconnect.** The boom elevation and azimuth disconnect limits should be asymmetrically adjustable in the boom control system, for receivers that require restricted limits.

**9.3.5.1 Limit Disconnect.** The boom control system should automatically initiate a disconnect when the receiver reaches the standard or receiver specific disconnect limits in pitch, azimuth and extension.

**9.3.5.2 Rate Disconnect.** The boom control system should automatically initiate a disconnect and retraction when the receiver is moving toward a disconnect limit, considering the instantaneous rate and the nozzle and receptacle disconnect delay, so that actual disconnect is made before the receiver exceeds the disconnect limit. When the control system is set for a specific receiver type, the control system should automatically use the specific receivers receptacle disconnect delay, so that actual disconnect is made before the receiver exceeds the disconnect limit.

## **9.4 Boom Nozzle Disconnect Provisions**

**9.4.1 Normal/Override Electrical Disconnect.** The normal methods of disconnect from the receiver aircraft receptacle should be boom operator initiated, boom disconnect envelope exceedance, rate (see paragraph 2.3.5.2 above), receiver aircraft pressure exceedance, other tanker aircrew (including Instructor boom operator) initiated and receiver aircrew initiated. A backup electrical override capability for the signal amplifier should be provided.

**9.4.1.1 Tanker Initiated Disconnect.** When the tanker transmits a disconnect signal, the nozzle unit should relay the signal to allow the receiver to receive the signal and advance to disconnect status.

**9.4.1.2 Receiver Initiated Disconnect.** When the receiver transmits a disconnect signal, the tanker should receive the signal and advance to disconnect status.

### **9.4.2 Independent Disconnect System (IDS)**

**9.4.2.1 IDS Operation.** An independent disconnect system that allows withdrawal of the nozzle with the receiver toggles latched should be installed. The nozzle latches should independently and simultaneously retract when an IDS disconnect is initiated by the tanker boom operator; or an automated rate disconnect, or envelope limit disconnect, independent of the position of the receiver aircraft toggle latches, in both normal and override electrical disconnect modes. The IDS should be capable of performing, without ground servicing, an unlimited number of disconnects from a receptacle with toggle latches failed in the engaged position, while subjected to loads up to and including the limit loads defined in paragraph 3.5.1. The IDS should not be affected by any environmental or operational conditions specified. The IDS should not interfere with the boom communication system.

**9.4.2.2 IDS Release Response Time.** As stated in ATP-3.3.4.5 paragraph. 1.13.

**9.4.2.3 IDS Reset.** The IDS should be designed to remain in the disconnect configuration for a minimum of 3 seconds allowing time for the nozzle to be retracted from the receptacle after the IDS latches have been moved to the disconnect position or until the signal system is reset to ready. The IDS time delay reset should not be affected by any environmental or operational conditions specified.

**9.4.2.4 Operation with Failure of IDS.** In the event of functional failure (not structural) of the device or devices which actuate the IDS mechanism to the disconnect position, the IDS mechanism should remain in a mechanically locked configuration which provide a rigid attachment point for the engagement of the receptacle toggle latches. Under this condition the nozzle should meet all of the functional, performance and structural requirements specified except those that pertain directly to IDS operation.

## 9.5 Aerial Refueling Fuel System

**9.5.1 Fuel Types.** The aerial refueling fuel system materials should be compatible with the aviation fuels specified in Appendix 12.2.10.

**9.5.2 Pressures.** The tanker fuel system and boom should function without leakage and/or structural deformation at 2 times its typical operating pressures of 120 psig, for a proof pressure of 240 psig. The tanker fuel system and boom should not leak at a burst pressure of 3 times its typical operating pressure, for a burst pressure of 360 psig. Unless otherwise justified, the guidance in Reference #1 should be complied with for operating, transient surge (proof), burst pressures and other design and test related factors.

**9.5.3 Fuel Flow.** The tanker shall provide a pressure regulated (stated in Paragraph 1.5 herein) fuel flow pumping capability to the receiver aircraft maximum flow design capacity, which it is operationally required to support. Reference Appendix 12.2.7 for typical tanker offload capabilities. Reference is made to Paragraph 3.6.3 herein.

**9.5.4 Reverse Aerial Refueling.** The tanker should have the capability to receive fuel, thru the tanker's boom, from a suitably equipped receiver aircraft.

**9.5.5 Fuel Jettison.** The tanker should have the capability to jettison fuel in flight in accordance with appropriate National Directives, either thru the boom or by other methods.

**9.5.6 Fuel Isolation.** For maximum utility, the tanker should have the ability to deliver a fuel thru the boom that is different from the fuel used by the tanker. To do this, the tanker should have the capability to isolate, transport, and offload the secondary fuels listed in Appendix 12.2.10 either in flight using the boom or on the ground. Two control actions or two failures should be required to prevent accidental mixing of the isolated fuels.

**9.6 Tanker Aids/Cues for Receiver Aircraft.** The tanker should provide the necessary aids/cues under all natural lighting (day/night/transition) conditions for safe rendezvous and to adequately assist the receiver aircraft crew to achieve stable formation flying with the boom.

**9.6.1 Anti-Collision Beacon.** A beacon on the upper and lower fuselage should provide an aid for receiver aircraft rendezvous, collision avoidance and tanker/system identity. The upper and lower fuselage beacons should be separately selectable, i.e.: both for rendezvous, upper on, lower off when acting as a tanker and the upper off and lower on when the tanker is acting as a receiver (if so equipped). The beacons should provide four flashing modes for specific tanker identification, as follows; white only, red only and alternating red-white at a rate of once per second and a fourth mode consisting of a series of three flashes, white-red-white separated by a period of 0.25 seconds and repeated once per second.

**9.6.2 Tanker Identity Platform Illumination.** The tanker aircraft should be provided with external lights to aid the receiver aircraft in locating and identifying the tanker aircraft at night. The underbody of the tanker aircraft, including the forward and aft fuselage, including the tailcone, the wings, engine nacelles, vertical tail and the underside of the horizontal tail, should be lighted to aid the receiver pilot in developing his depth perception and maintaining position on the tanker. Reference Appendix 12.2.3. Independent full dimming control should be provided for each of these external lights.

**9.6.3 Formation Lights.** The tanker should be equipped with formation (strip) lights on the sides of the forward and aft fuselage, the vertical tail and the wingtips, to aid waiting receivers in maintaining formation off the tanker. Full dimming control should be provided.

**9.6.4 Tanker/Receiver Aircraft Position Control.** The tanker should provide visual methods (cues/aids) to facilitate the receiver pilot to maintain a stable platform at pre-contact and within the tanker boom position envelope (hook-up/engaged/disconnect).

**9.6.4.1 Tanker/Receiver Aircraft Formation and Boom Position Envelope.** The tanker should provide by visual methods, lateral, vertical and longitudinal reference. The primary method currently used are the receiver pilot director lights (PDL), however they do not provide lateral direction. Currently the only lateral direction is tanker symmetry and the centerline fuselage stripe, which are not active cues. Improvements to the current system should include fore/aft, up/down and lateral display. See Appendix 12.2.5. A tanker turn indication mode of the PDL system should be considered to notify the receiver pilot that the tanker is about to enter a turn. Fluorescent illuminated boom telescoping tube markings should be color coded and illuminated for day/night/transition operations IAW Appendix 12.2.4. During night/transition lighting conditions, all exterior lights should be employed. All exterior lights should have full dimming control, from bright to off.

**9.6.4.2 Tanker Underbody Markings.** Underbody markings should also be provided on the tanker to assist the receiver pilot in achieving and maintaining a stable position with respect to the tanker. A gloss yellow longitudinal centerline receiver alignment stripe, 8 inches wide, should be provided, running from near the nose of the aircraft extending aft to the tailcone, to provide receiver aircraft lateral reference, as shown in Appendix 12.2.3. Consideration should be given to making this stripe active (e.g. electro-luminescent) or illuminated, to maximize its visibility to the receiver pilot. In addition, six (6) lateral stripes (flat black or a contrasting color with the basic aircraft color), 2 inches wide should be provided, to provide receiver aircraft longitudinal reference. The aft lateral strips should be located at the boom pivot point, and the others located at 120 inch intervals between each stripe. The lengths of the stripes should be as shown in Appendix 12.2.3.

**9.6.4.3 Tanker Underbody Lighting.** The underside of the tanker should be well illuminated to provide visual reference for the receiver aircraft pilot. This must include the underside of the aft fuselage, wings, including engines nacelles and pylons, and the horizontal tail. This lighting should have full dimming control, from bright to off.

**9.6.5 Boom Operator Provisions.** The boom operator should be provided all the equipment and system status information necessary to perform the aerial refueling operation. The following describe the minimum tanker features necessary for a successful and safe aerial refueling.

**9.6.5.1 Boom Elevation and Lateral Control.** The boom vertical and lateral control system shall be capable of moving the boom smoothly throughout the Boom Contact, Disconnect and Stowage Envelopes.

**9.6.5.2 Boom Telescoping Control.** The boom telescopic control system shall be capable of moving the boom smoothly throughout the Telescoping range.

**9.6.5.3 Boom Nozzle Normal and Independent Disconnect.** The boom operator shall be able to command the receivers receptacle latches to retract, for a normal disconnect. Normal disconnect can also be commanded automatically based on exceeding the disconnect limits, rate of receiver motion toward any of the disconnect limits or other reasons determined by operational requirements. The boom operator shall be able to command the boom nozzle to independently disconnect from the receivers receptacle, in the event that the receivers receptacle latches fail to retract, for any reason. Independent disconnect may also be commanded automatically for disconnect limit exceedance or rate, if desired for quicker release from the receiver.

**9.6.5.4 Boom Operator Unobstructed View.** The boom operator should be provided an unobstructed view of the boom and receiver aircraft throughout the tanker boom astern (pre-contact), contact and disconnect envelopes. This view by the boom operator should include receiver aircraft receptacle/slipway, antennas and other hardware, lights and the top surface of fuselage and wing, including control surfaces. The boom operator view can be direct thru a window or indirect thru a remote vision system, or other suitable sensor system. See Appendix 12.2.8 for typical boom operator fields of view.

**9.6.5.5 Boom Operator Refueling Field of View.** To support boom refueling operations, the field of view of the direct vision or indirect stereoscopic vision capability should, at a minimum, allow viewing of the boom tip at any location within the following envelope:

- a. Boom elevation between 18 and 42 degrees.
- b. Boom extension between fully retracted and fully extended.
- c. Boom roll (or yaw) between maximum boom roll (or yaw) plus 2 degrees (-27 and +27 degrees).



**9.6.5.6 Boom Operator Situational Awareness Field of View.** The boom operator should be provided an unobstructed view aft from wing tip to wing tip and from 10 degrees above the horizon to 35 degrees below the horizon, with no gaps, to allow monitoring of additional aircraft in formation around the tanker. The boom operator situational awareness view can be direct thru windows, with or without mirrors or indirect thru a remote vision system. See Appendix 12.2.8 for typical boom operator fields of view.

**9.6.5.7 Boom Operator View from Above the Boom.** Some tankers have located the boom operator aft and above the boom. This location has some visibility advantages, including a better view of the nozzle, receptacle and receiver aircraft, and one disadvantage, the nozzle vertical distance above the receiver. This viewpoint could be duplicated with an indirect stereoscopic vision system.

**9.6.5.8 Lighting.** Note: This paragraph may not be applicable to tankers equipped with remote viewing systems, if replaced by a system that provides equal or better visibility. Tanker external lighting is specified in ATP-3.3.4.5 paragraph 1.18. The Boom Operator should be provided with a Boom Nozzle Light and a Tail Mounted Floodlight or Receiver Aircraft Floodlight (or equivalent) to illuminate the receiver aircraft and the receptacle slipway. The nozzle light (if equipped) should have redundant light sources and should provide a spotlight source for illuminating the lead in to the receptacle/slipway, illuminating slipway markings, protuberances such as canopy and antennas and the slipway and receptacle bore. Full dimming capability should be provided for the nozzle light. Indication must be available in the boom operator station denoting that each individual light source is functional. The Tail Mounted Floodlight or Receiver Aircraft Floodlight should be mounted on the tanker aircraft to provide flood illumination of the top surface of the receiver aircraft in the refueling position, to aid the boom operator during night operations. They should have redundant light sources and full dimming capability. These lights should be located as far aft on the tanker aircraft as possible, either at the aft end of the tailcone or on a projection aft of the vertical tail, to minimize the impact on the receiver pilot's night vision.

**9.6.5.9 Voice Communications.** Direct voice communications with the boom operator and receiver aircraft pilot via radio and through-the-boom (normal and override signal system conditions) should be provided.

**9.6.5.10 Dimming Control.** Control of all lighted visual aids should be provided by dimming controls from full bright to full off, except the rotating beacon/anti-collision lights which are on/off only.

**9.6.5.11 System Status Indication.** Status of the boom signal system, boom envelope position, fuel system pressure, fuel flow and fuel offload etc. should be within the peripheral vision of the boom operator's normal view of the boom aerial refueling operation.

**9.6.5.12 Fault Notification.** The boom operator and the flight deck crew should be notified of pertinent faults of the boom or supporting aircraft systems.

**9.6.5.13 Contact Status Lights.** The boom operator and the flight deck crew should be provided with a contact status light, to determine when to activate the AR fuel pumps in the manual mode.

## **10.0 Receiver/Receptacle Installation and Associated Interface Enhancements**

### **10.1 Receptacle/Slipway Location, Angle of Installation, and Clear Entry Receptacle Path.**

**10.1.1 Receptacle Location** The aerial refueling receptacle should be located on or near the centerline of the aircraft and as far forward on the aircraft as practical to minimize tanker/receiver fuselage overlap. Flush or near-flush installations are preferred over externally raised installations, which may disturb the receiver aircraft airflow. This disturbed airflow may impact the boom control stability just prior to hookup and will increase the noise level in the receiver aircraft. Proximity flight tests conducted prior to the receiver aircraft receptacle location selection are recommended. Optional locations represented by taped markings indicating choices for evaluation should be provided. Receptacle/Slipway Installations located forward of the pilot should be located a minimum of 24 inches from the leading edge of the windshield, measured from the face of the receptacle.

**10.1.2 Receptacle Angle of Installation.** The receptacle axial centerline angle of installation should be as specified in ATP-3.3.4.5 paragraph 1.19, item 1. The formula is repeated here, for convenience. Also included is a table of typical tanker and receiver angle of attack ranges, to provide values for the constants in the formula.

Installation Angle. The receptacle bore axis shall be positioned to provide alignment at contact with the tanker boom centerline, in the center of the contact envelope for all identified tankers. The installation angle shall be established using the following formula, with a tolerance of  $\pm 1$  degree:

$$X = 30 - (A+B)/2 + (C+D)/2$$

Where:

X = receiver receptacle axial centerline angle with respect to the receiver aircraft waterline.

A = maximum receiver aircraft fuselage pitch angle, within the receiver's normal airspeed/altitude refueling range, including gross weight and external stores variations.

B = minimum receiver aircraft fuselage pitch angle, within the receiver's normal airspeed/altitude refueling range, including gross weight and external stores variations.

C = maximum tanker aircraft fuselage pitch angle, for all identified tankers, including gross weight variations, within the receiver's refueling speed range. Typical values of C are as follows:

C = 8.4 degrees @ Mach = 0.40, Altitude = 10,000 ft.

C = 5.0 degrees @ Mach = 0.70, Altitude = 25,000 ft.

D = minimum tanker aircraft fuselage pitch angle, for all identified tankers, including gross weight variations, within the receiver's refueling speed range. Typical values of D are as follows:

D = 2.5 degrees @ Mach = 0.40, Altitude = 10,000 ft.

D = 1.0 degrees @ Mach = 0.70, Altitude = 25,000 ft.

**10.1.2.1 Universal Aerial Refueling Receptacle Slipway Installation (UARRSI).** When a UARRSI is selected, the receptacle angle within the UARRSI must consider the UARRSI installation angle with the receiver aircraft fuselage slope. The UARRSI provides close-out receptacle housing angle adjustment plates to accommodate the fuselage slope variations of the receiver aircraft location selected. Those close-out plates currently provide a range from  $46^\circ$  to  $26^\circ$ . When the more positive installation fuselage nose slope is selected, the slipway raised ramp slipway/scuff plate may be required to accommodate a deflected boom nozzle tip assisted hookup. The less positive slopes to flush aircraft waterline installations (flat fuselage angle) will not require the raised (approximately 1") ramp scuff plate. Options of a hinged slipway door UARRSI may provide an equivalent to the slipway raised ramp scuff plate.

**10.1.3 Clear Entry Receptacle Path.** The installation of equipment that protrudes above the aircraft skin line, e.g. antenna, should meet the requirements specified in ATP-3.3.4.5, paragraph 1.19, item 3 and ATP-3.3.4.5 C3. A clear unobstructed boom path to the receptacle will prevent unavoidable damage/removal of such protruding objects. Also, receptacles located aft of the receiver aircraft canopy should not result in a reduced boom contact/disconnect envelope with: 1) a (short boom) telescoping tube inner disconnect limit at  $20^\circ$  boom elevation and maximum receiver pitch angle; or 2) a (long boom) telescoping tube maximum extension at  $20^\circ$  boom elevation and a maximum receiver pitch angle. Receiver aircraft that do not meet these requirements may be subjected to a reduced refueling envelope, for example the F-16 has an upper limit of 25 deg.

**10.2 Tanker Boom/Nozzle Slipway Clearances.** See ATP-3.3.4.5 paragraph 1.7 and 1.8 and ATP-3.3.4.5, figures C-1 and C-2. With the boom nozzle engaged in the receptacle, a tanker boom and nozzle conforming to the maximum dimension envelope of ATP-3.3.4.5 figure C-2 shall not contact any portion of the receptacle slipway when the receiver exceeds the boom disconnect envelope by 5 degrees in pitch, azimuth or roll. This requirement impacts receptacle/slipway sizing and location on the receiver aircraft.

**10.3 Slipway and Adjacent Area Loads.** The receptacle slipway installation should be protected from boom strikes and boom nozzle impacts.

**10.3.1 Ultimate Slipway and Adjacent Area Loads** See ATP-3.3.4.5 paragraph 1.22 item 3.

**10.3.2 Repeated Slipway and Adjacent Area Impact Loads.** The receptacle/slipway installation and an area extending 12 inches around the receptacle installation should withstand, without functional and structural damage, 1,000 impacts received from the equivalent to a boom nozzle weighted to 100 + 2/-0 pounds dropped from a height 9.2 + 0.2/-0.0 inches above the contact point at an angle of 45 ± 2 degrees with the surface contacted.

**10.4 Receptacle Housing and Aircraft Structure and Failure Modes.** The receptacle housing and aircraft structure should be designed for limit and ultimate structural loads imposed at the boom nozzle ball joint.

**10.4.1 Limit Loads.** Limit tension and compression loads are specified in ATP-3.3.4.5 paragraph 1.22, item 1

**10.4.2 Ultimate Loads.** Ultimate tension and compression loads are specified in ATP-3.3.4.5 paragraph 1.22, item 2.a. and 2.b.

**10.4.3 Distribution of Receptacle Loads into Receiver Aircraft.** Nozzle loads are applied at the ball joint which is located 11 inches from nozzle tip. Receptacle housing structural loads should be distributed into the aircraft structure through the mounting bolts.

**10.4.4 Expected Lifetime Usage.** The aerial refueling receptacle assembly, backup structure, aircraft primary structure, and required components should be designed to meet the expected usage of the aircraft as a receiver. Total number of contacts through the life of the aircraft will drive receptacle design. Time spent behind a tanker may affect the usable life of aircraft primary structure, due to tanker downwash, wake turbulence, jet plume turbulence, propeller turbulence, etc. (empennage, engine pylons, etc.).

**10.4.5 Refueling with Receptacle Toggle Latches Failed Open.** The receptacle should be provided with the ability to transfer fuel when the receptacle toggles are failed in an open position, by using boom extend force to maintain the nozzle/receptacle connection (pressure/stiff boom refueling).

## 10.5 Fuel System

**10.5.1 Pressure Disconnect Switch.** The pressure disconnect switch, when properly designed, will only operate when high pressures are experienced in the receiver aircraft fuel system, due to tanker pressure regulator failure. Also, it should not operate upon receiver level control valve closure and/or short pressure spikes, surges, occurrences. The Pressure Disconnect Switch should not operate too quickly causing inadvertent disconnects. The pressure disconnect switch should operate when 60 to 65 psi is exceeded for 3 to 5 seconds. Operating too quickly will cause high surges in the receiver's fuel system and/or premature disconnects. A good receiver aircraft fuel system mockup, including simulated tanker failed regulator pressures, should be used to optimize the pressure and time settings.

**10.5.2 External Fuel Leakage/Spillage.** Fuel leakage/spillage should be as specified in ATP-3.3.4.5, paragraph 1.21, item 1. Failure modes of either a receptacle sliding valve failed open or a boom nozzle poppet failed open may result in additional external fuel spillage. Minimizing the impact of the potential should consider the following:

**10.5.2.1 Air Intakes and Electronic Bays.** See ATP-3.3.4.5 Para 1.21 Section 1.c.

**10.5.2.2 Check Valves.** Provide fuel line check or line valves just downstream of the aerial refueling receptacle to prevent fuel siphoning overboard in the event of a failure of the sliding valve.

**10.5.2.3 Receptacle Drainage.** Provide receptacle/slipway gravity drainage (without traps) to a safe ignition free fuel collection area. When overboard gravity drains are provided, they should exit the aircraft skin at a negative airflow suction area and extend beyond the skin line to avoid aircraft fuel re-entry.

**10.5.2.4 Fuel Vapors.** Collection of fuel vapors trapped within the receptacle slipway cavity, after the aerial refueling is completed and with door closure, can occur. Through testing, lightning strikes have shown to produce ignition sources within that cavity. Pressures sufficient to open the receptacle sliding valve should be avoided. The use of receptacle

slipway door over travel has been shown to minimize the overpressure below that required to open the receptacle sliding valve which could allow flame propagation into the aircraft fuel tank.

**10.5.3 Fuel Receptacle and System Pressure Design Criteria.** The criteria are specified in ATP-3.3.4.5 paragraph 1.21, item 1e. The system design and test pressures for operating, transient surge (proof) and burst should be complied with as specified in Reference #1.

**10.5.4 Fuel Flow Rates.** Reducing time on the tanker by increasing receiver aircraft fuel flow rates is highly desirable. The following table has been used as a maximum refueling time guide for the various receiver aircraft fuel capacities shown.

This Table will be replaced with a Fuel/Time Graph, when available.

Table 3.1 Aerial Refueling Duration

Total Aircraft Fuel Weight (Pounds)	Maximum Aerial Refueling Flow Time, Minutes (Based on 90% total aircraft fuel) 2/
450,000	50
350,000	40
250,000	30
100,000	15
50,000	10
25,000	7
10,000	4
3,900	2.25

Time may be interpolated between divisions

Notes:

- 1 Aerial refueling lines. Fuel lines shall be sized so that all tanks theoretically reach the full position simultaneously when refueling. For aircraft incorporating ground and aerial refueling subsystems, the refueling line sizes shall satisfy the flow requirements of both systems. The line sizes shall be capable of handling flow schedule for pressure refueling as specified in above table. The following criteria shall be used when designing to meet the refueling schedules of this table.
- 2 It shall be assumed that the tanker for boom-type aerial refueling is capable of delivering a minimum of 1,200 gpm at a pressure of 50 psig measured at the inlet to the boom nozzle.
- 3 It shall be assumed that all tanks except main tanks are empty and that 10 percent of the total aircraft fuel capacity is distributed equally in the main tanks(s) at the start of the refueling operations.

**10.5.5 Reverse Aerial Refueling.** When the receiver aircraft has a fuel capacity which makes reverse aerial refueling practical, i.e. greater than 75,000 pounds, the system should be designed to permit reverse aerial refueling, from the receiver aircraft back to a tanker aircraft, up through the boom of the tanker. Surge protection may be required for the fuel system of the aircraft supplying fuel during reverse aerial refueling when an unplanned flowing disconnect occurs. Limiting the number of pumps used for reverse aerial refueling may be sufficient to prevent the surge pressures from exceeding the design limit surge pressure in the fuel system of the aircraft supplying the fuel. See Reference #1 for additional discussions.

**10.6 Receiver Aircraft Aids and Cues for Tanker Operations.** The receiver aircraft should provide the necessary aids and cues under all natural lighting (day/night/transition) conditions for rendezvous and aerial refueling operations. Special precautions and considerations for the use of LED lighting on the receiver aircraft should be given, to be sure that the LED lighting will not degrade the tanker's boom operator's vision. The integrator must be aware of the LED lighting characteristics, and the impact of these characteristics for the particular application. The primary concerns are brightness (especially at spectrum extremes), dispersion profile, effect on the tanker indirect vision systems, and on the operator's perceived colors of drogue system hoses.

**10.6.1 Anti-collision Beacon.** An anti-collision beacon on the upper and lower receiver aircraft fuselage should provide an aid for rendezvous, collision avoidance and receiver identity by the tanker crew. The upper and lower beacon(s) should have separate controls to allow for the upper beacon to be extinguished when the receiver aircraft is in the pre-contact and refueling modes and for the lower beacon to remain operating.

**10.6.2 Upper Surface Lighting.** Over-wing and upper fuselage lighting and slipway/receptacle and area lighting should be provided and should be compatible with remote vision systems. All external lighting should be fully dimmable to full off. Any flood lights should be mounted to shine aft, laterally or downward. Overt as well as covert operations should be considered for all external lights for aerial refueling operations. See Appendix 12.3.1.

**10.6.3 Markings.** The receptacle/slipway should be marked as specified in ATP-3.3.4.5, paragraph 1.23, and ATP-3.3.4.5, E-3, and should be compatible with remote vision systems. The receptacle/slipway should be marked (wide angle reflective paint/tape) with contrasting color with aircraft fuselage/area paint in accordance with Appendix 12.3.2 marking dimensions. When aircraft receptacle/slipway installation permits a triple T-bar configuration, it should be utilized. See Appendix 12.3.2.

**10.6.4 Windshield Paint/Tape Markings.** Windshield paint/tape outline is required for receptacles located forward of the windshield. See Appendix 12.3.2.

## **10.7 Receiver Aircraft Pilot Aids**

**10.7.1 Pilot Vision.** The receiver pilots should have the best possible vision of the tanker from the astern position to the contact position. The receiver pilot should have a clear view of the pilot director lights mounted on the underside of the tanker and other visual references or cues to aid in holding the tight formation required. Structural members between windows should not blank out vision of tanker. Windows that distort because they are not normal to the line of vision should not be used for any part of the aerial refueling envelope. For large receiver aircraft, consideration should be given to pilot fatigue resulting from upward vision for extended periods of time. Any tanker formation cues monitored during contact should be placed as close as possible to the receiver pilot's line of vision. For receivers with receptacles mounted forward of the cockpit, the boom and its lights/markings and the tankers aft fuselage are the primary references.

**10.7.2 Cockpit Status Lights.** Status lights informing the pilot of aerial refueling conditions (ready, latched and disconnect) should be provided with balanced light output and color and/or coded for aerial refueling hookup conditions and should be positioned within the pilots' peripheral view.

**10.7.3 Voice Communication.** The receiver pilot should be provided with direct radio and through-the-boom voice communication with the boom operator.

**10.7.4 Toggle Latch/Unlatch, Disconnect and Override Modes.** The receiver pilot should be provided a nozzle/receptacle disconnect switch for use in either normal or override modes of the signal amplifier latched conditions. Typically, it is located on the receiver pilot's control stick; however, in some cases it is installed on the engine throttles.

**10.7.5 Toggle Override Mode.** The receiver pilot (or crew) should be provided with a mode to engage the toggles in the event of a failure of the normal system.

**10.7.6 Door Opening/Closing Switch.** The receiver aircraft pilot or crew should be provided with a door open/close switch for the receptacle /slipway.

## **11.0 Potential future improvement:**

**11.1 Multi-point Boom Installations.** The effect of airflow over the tanker wings has been considered for multipoint boom installations with the refueling booms mounted on the outer portion of the tankers wings. During proximity flight testing with fighter type receivers (F-100 and F-4), it was found that the receiver aircraft was positioned in undisturbed free stream airflow when refueling from a wing mounted boom. Longitudinally the receiver is close to the wing, but quite a bit lower than the wing, such that the disturbed air passes well above the receiver. Reference 6

**11.2 Wing Mounted Boom.** A wing mounted boom may be reticulated as illustrated by Appendix 12.2.1. The size of the boom structural fixed/telescoping length may be reduced due to the restricted receiver aircraft size, i.e.: fighter type aircraft, unmanned aircraft wingspan and associated tanker fuselage, wing and engine geometry. See Appendix 12.2.1. USAF conducted proximity flight tests of 1972/73 time frame with various tanker and receiver platforms. The shorter boom lengths presented in Appendix 12.2.1 would also be applicable to wing mounted booms of different design. Reference 6

**11.3 Covert Lighting** Consideration should be given to incorporating covert lighting in all of the tanker and receiver lighting systems.

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## 12.1. Tanker/Receiver Aircraft Interfaces

### 12.1.1 Signal Amplifier

Pin Voltages in the Three Signal Amplifier States

Pin Function	Step Sequence		1	2	3	4
	Class 1	Pin	READY	CONTACT	DISCONNECT	RESET
		Classes 2, 3 and 4	4/			
Input (pwr)	A	1	28V dc	28V dc	28V dc	0
Ground (Gnd)	B	2	Gnd	Gnd	Gnd	Gnd
Outputs <u>9/</u>	C	3	28V dc	0	0	0
Outputs <u>9/</u>	D	4	0	28V dc	0	0
Outputs <u>9/</u>	E	5	28V dc	0	0	0
Signal input <u>1/</u>	F	6	<u>6/</u> <u>6/, 7/</u>	<u>6/, 7/</u>	0	0
Outputs <u>9/</u>	G	7	0	0	28V dc	0
Outputs <u>9/</u>	H	8	28V dc	28V dc	0	0
Outputs <u>2/ 9/</u>	I	9	0	28V dc	28V dc	0
Outputs <u>8/ 9/</u>	J	10	0	28V dc	0	0
Input <u>3/</u>		11	28V dc	28V dc	28V dc	28V dc
Audio (classes 3 and 4 only)		12	Audio Comm	Audio Comm	Audio Comm	Audio Comm

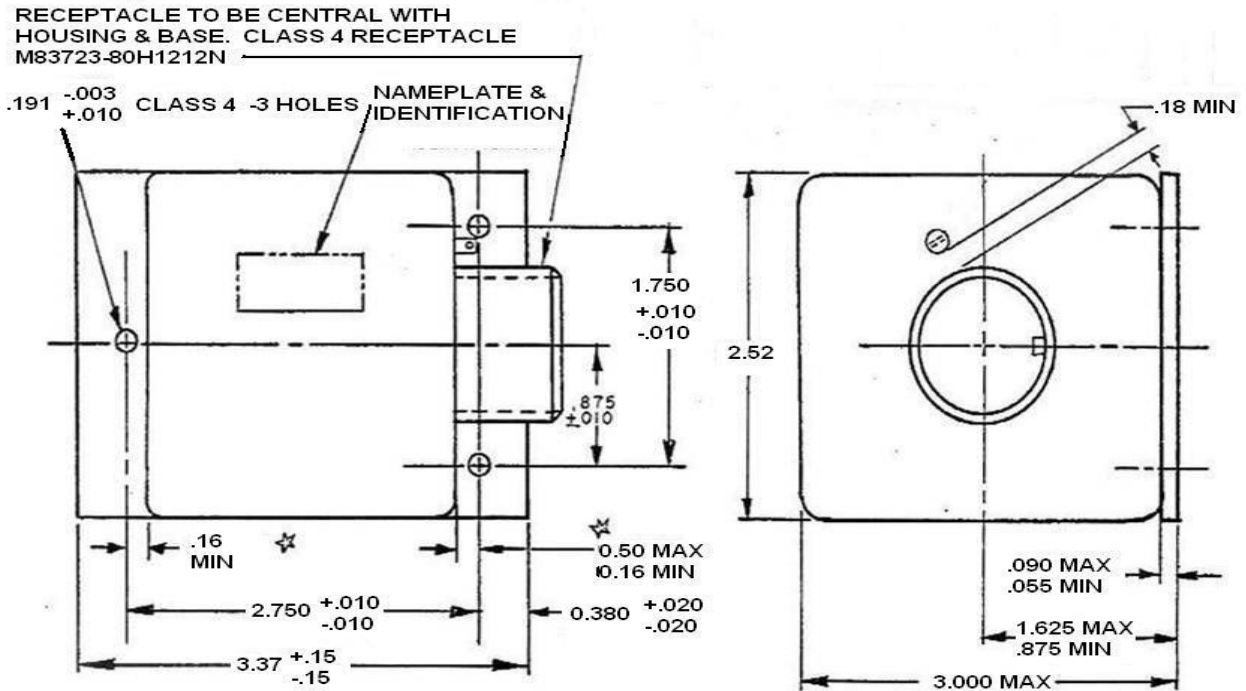
- 1/ In classes 3 and 4, pin 6 also carries the audio intercommunication signals to and from the induction coils.
- 2/ Conditions are for class 1 and 2 units only. Pin 9 is used for the intercommunication (audio) input for the classes 3 and 4.
- 3/ Voltage is applied in the override mode to pin 11 in classes 3 and 4 only.
- 4/ Initial application of power sets the amplifier to READY.
- 5/ Momentary interruption of input power to pin A/1 resets the amplifier to READY.
- 6/ Closing an external circuit between pin F/6 and pin E/5, or applying the first input pulse to pin F/6 shall cause amplifier to go to the CONTACT state
- 7/ With the amplifier in the CONTACT position, closing an external circuit between pin F/6 and pin D/4 or applying a signal pulse to pin F/6 shall cause the amplifier to go into DISCONNECT.
- 8/ Pin 10 is for push-to-talk for class 4 only (see 3.5.1.8).
- 9/ Reverse voltage protection (diodes) shall be provided internally on all applicable outputs for class 3 and 4. Class 1 and 2 shall use external reverse voltage protection.

**Note: Use only Class 4 Amplifiers for new design.**

**Table 12.1.1 Signal Amplifier Pin Voltages**



## 12.1.1 Signal Amplifier (Continued)



- NOTES: ☆ A MINIMUM CLEARANCE OF 0.030 SHALL BE MAINTAINED BETWEEN THE MOUNTING SCREW HEAD AND THE BODY OF THE AMPLIFIER
- THE KEYWAY FOR ALL CLASSES OF CONNECTORS SHALL BE LOCATED AT THE 6 O'CLOCK POSITION AS SHOWN.
- RADIUS ALL SHARP CORNERS TO 0.06 UNLESS OTHERWISE NOTED.
- ALL DIMENSIONS ARE IN INCHES AND ARE MAXIMUM UNLESS OTHERWISE NOTED.

**Figure 12.1.1 Signal Amplifier Envelope, Mounting and Connector**

## 12.2 Tanker Aircraft Installation and Interface Enhancements

### 12.2.1 Boom Operational and Physical Envelopes

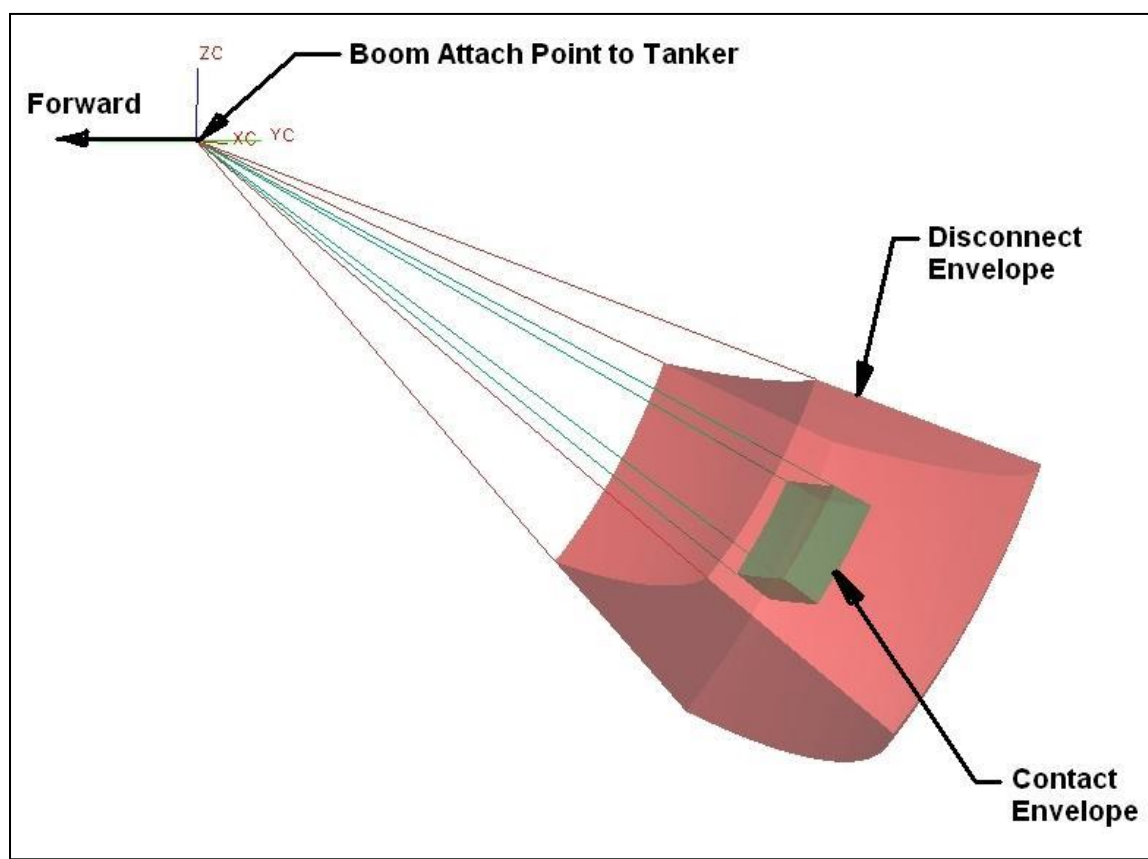


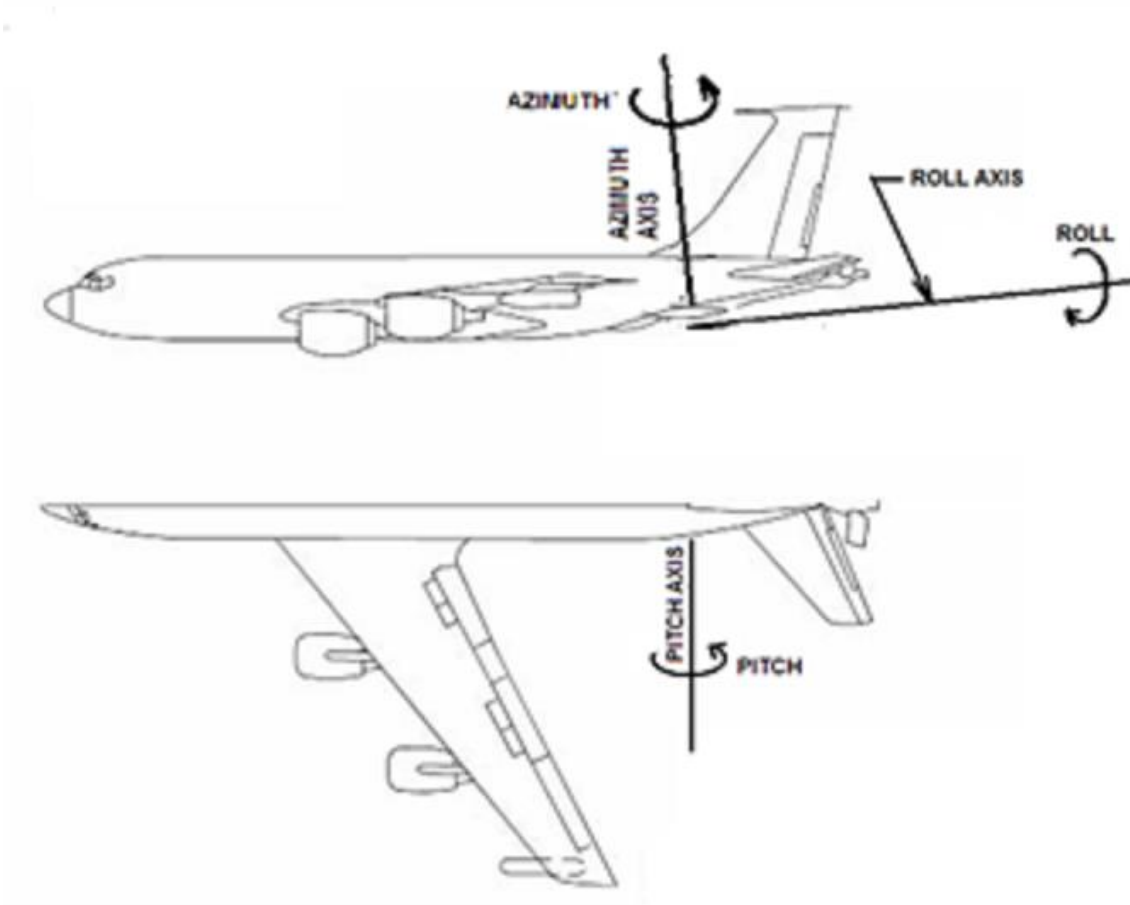
Figure 12.2.1.1 Minimum Boom Operational Envelopes

MINIMUM BOOM OPERATIONAL ENVELOPES						
DIMENSION	AZIMUTH MINIMUMS	PITCH MINIMUMS		LENGTH MINIMUMS		
		UPPER	LOWER	INNER	OUTER	TRAVEL
MINIMUM CONTACT ENVELOPE	± 8°	25°	35°	39 ft. 9 in.	42 ft. 9 in.	6 ft.
Ref. ATP 3.3.4.5 Para. 1.10.b				12,116 mm	13,030 mm	1,829 mm
MINIMUM DISCONNECT ENVELOPE	± 15° *	20°	40°	33 ft. 8 in.	45 ft. 11 in.	12 ft. 3 in.
Ref. ATP 3.3.4.5 Para. 1.10.c				10,262 mm	13,995 mm	3,734 mm

\* Note: Desired minimums are larger than the ATP 3.3.4.5 requirements. Increased length and travel are desired to provide greater clearance between the tanker and receiver. Increased travel and azimuth are desired to maximize the useable refueling envelope and minimize inadvertent disconnects.

Table 12.2.1.1 Minimum Boom Operational Envelopes

## 12.2.1 Boom Envelopes (Continued)



**Figure 12.2.1.2 Boom Axes Definition**

NOTE: Boom Azimuth and Roll axes are not necessarily the same as the aircraft axes

12.2.1 Boom Operational and Physical Envelopes (Continued)

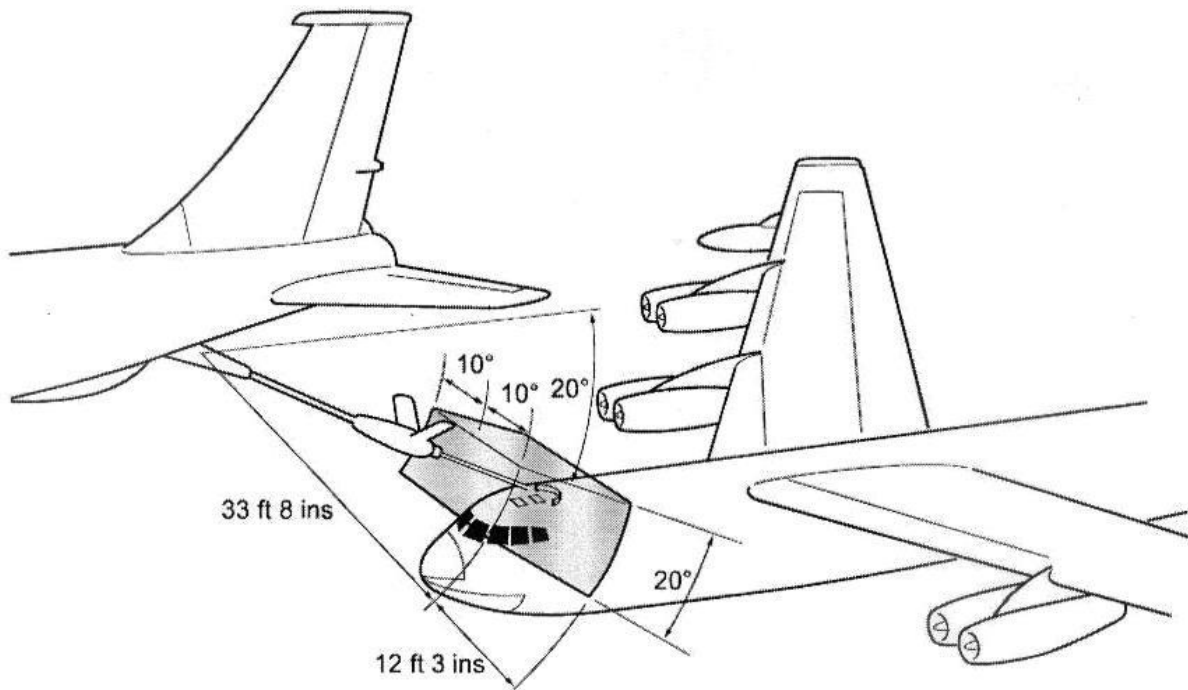


Figure 12.2.1.3 Typical Yawing Boom Operating Envelope

12.2.1 Boom Operational and Physical Envelopes (Continued)

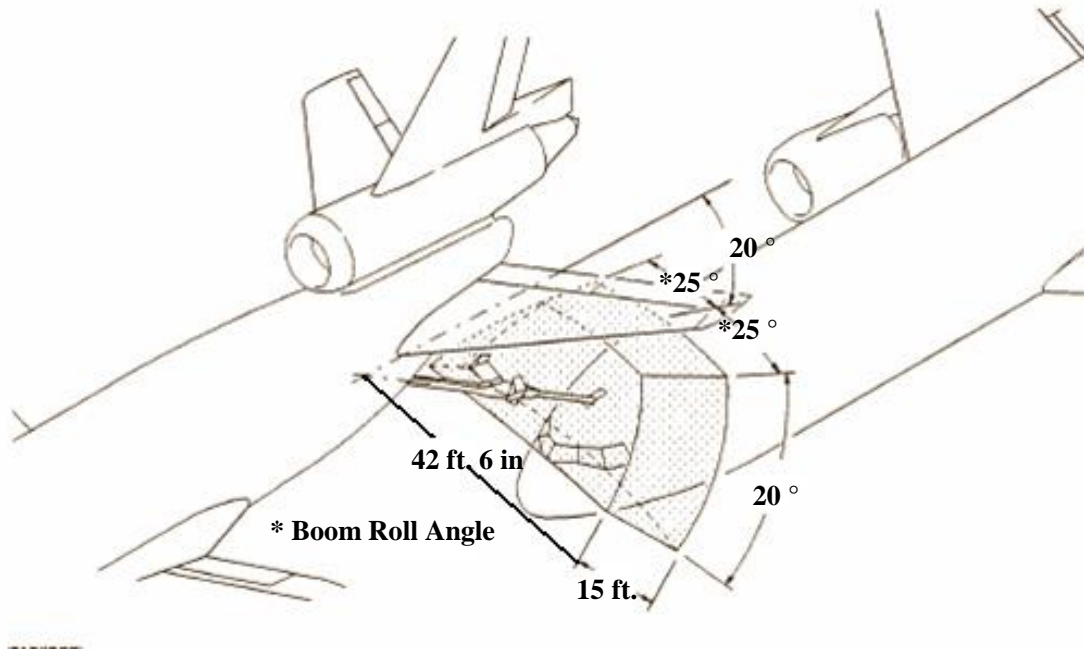


Figure 12.2.1.4 Typical Rolling Boom Operating Envelope

12.2.1

Boom Operational and Physical Envelopes (Continued)

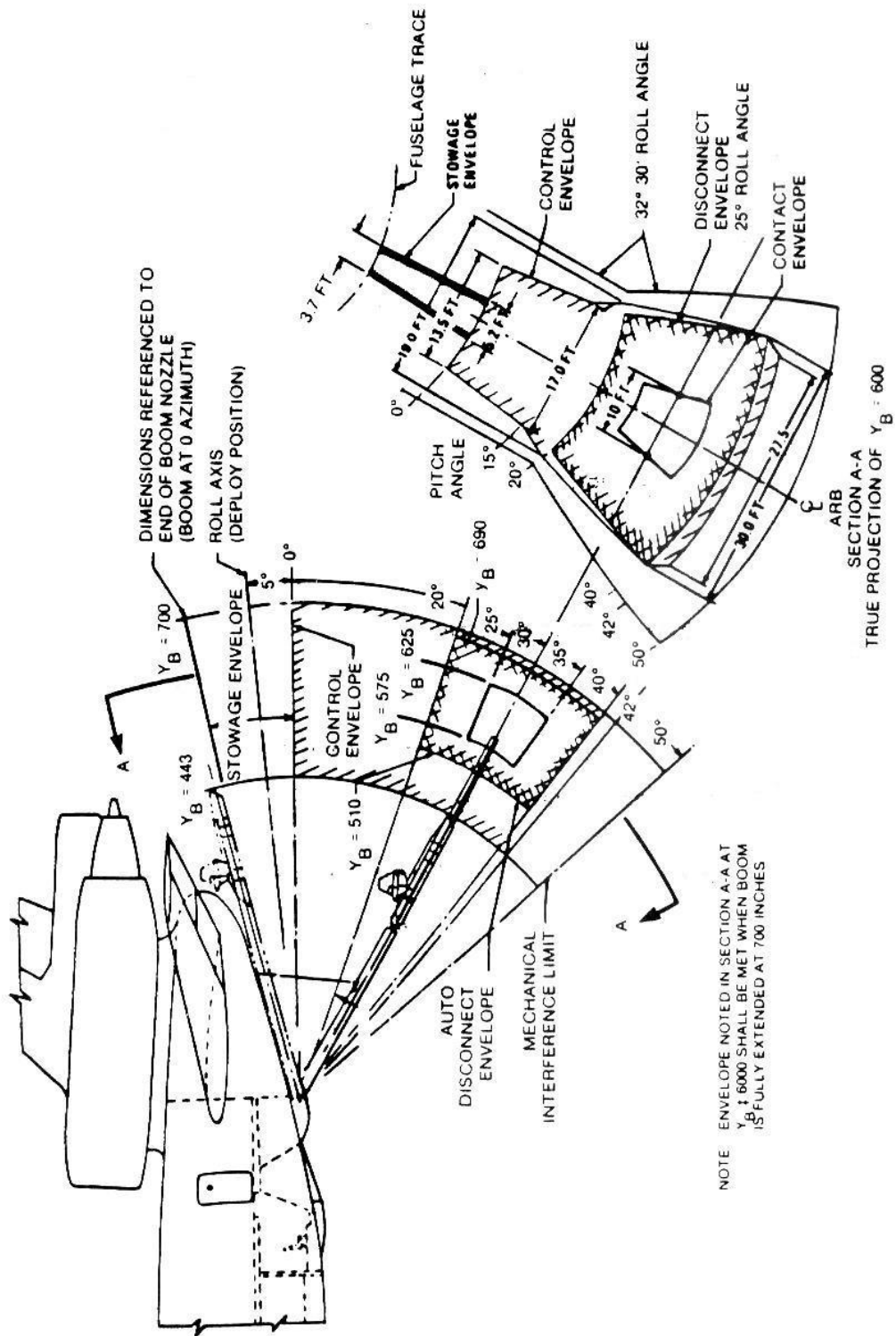
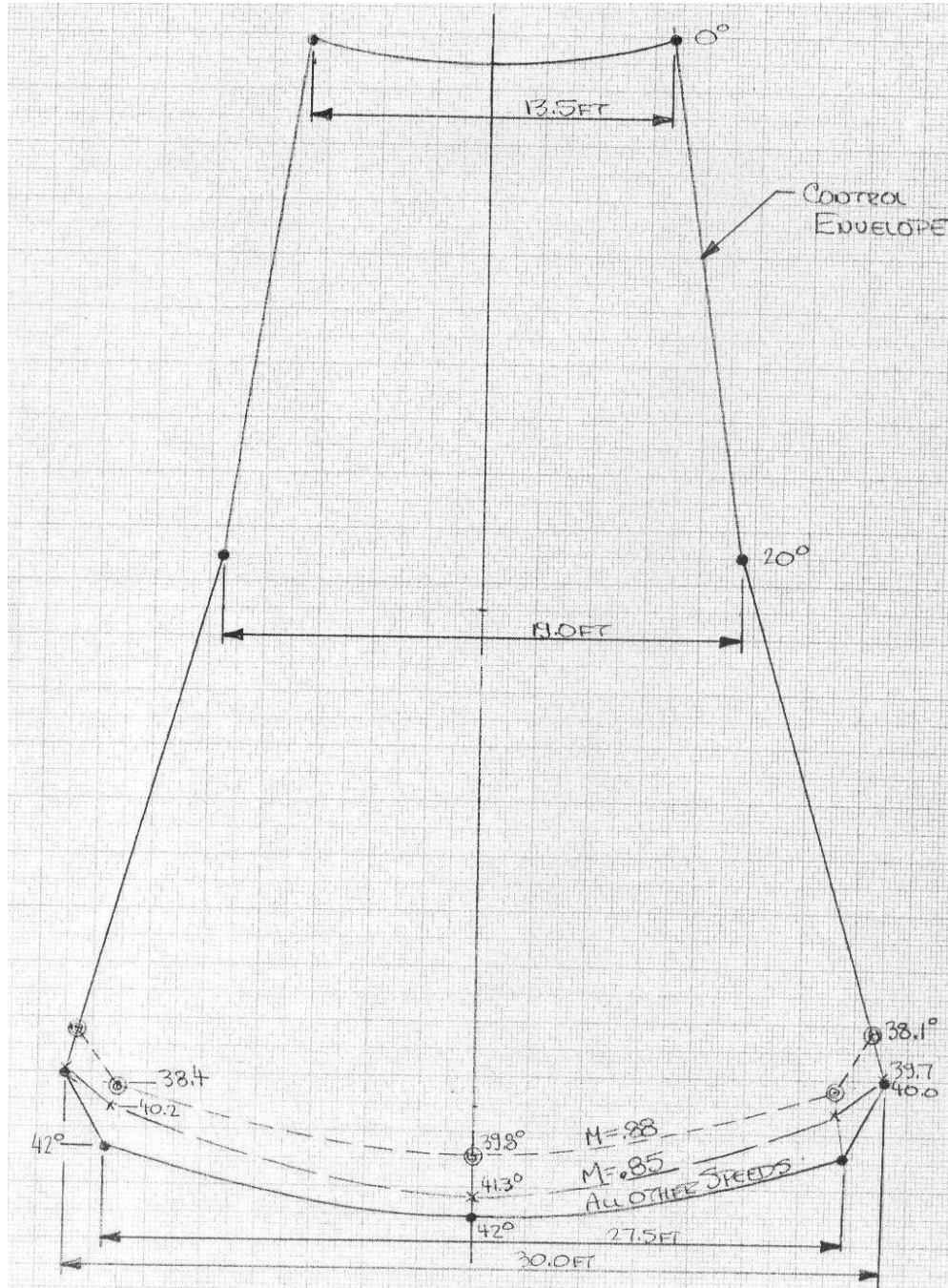


Figure 12.2.1.5 Typical Rolling Boom Envelopes

12.2.1

Boom Operational and Physical Envelopes (Continued)

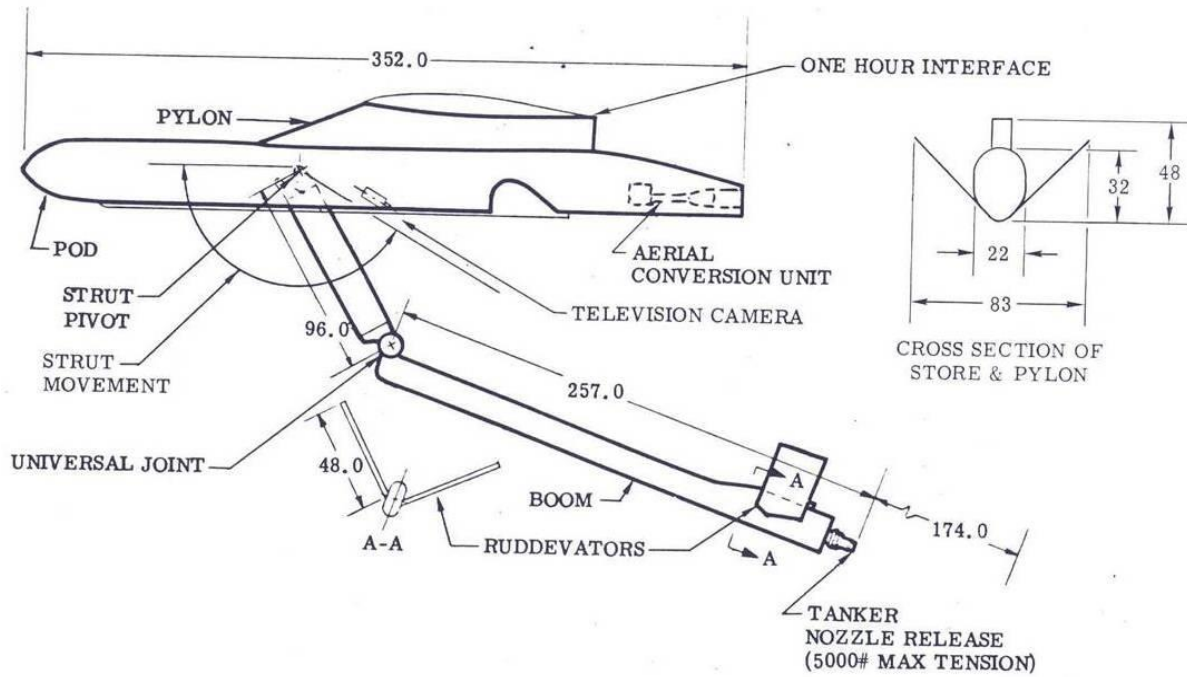


Section A-A @ Center of Contact Envelope

Figure 12.2.1.6 Typical Rolling Boom Control Envelope

## 12.2.1 Boom Operational and Physical Envelopes (Continued)

### Wing Mounted Boom Envelope Requirements



All dimensions are in inches.

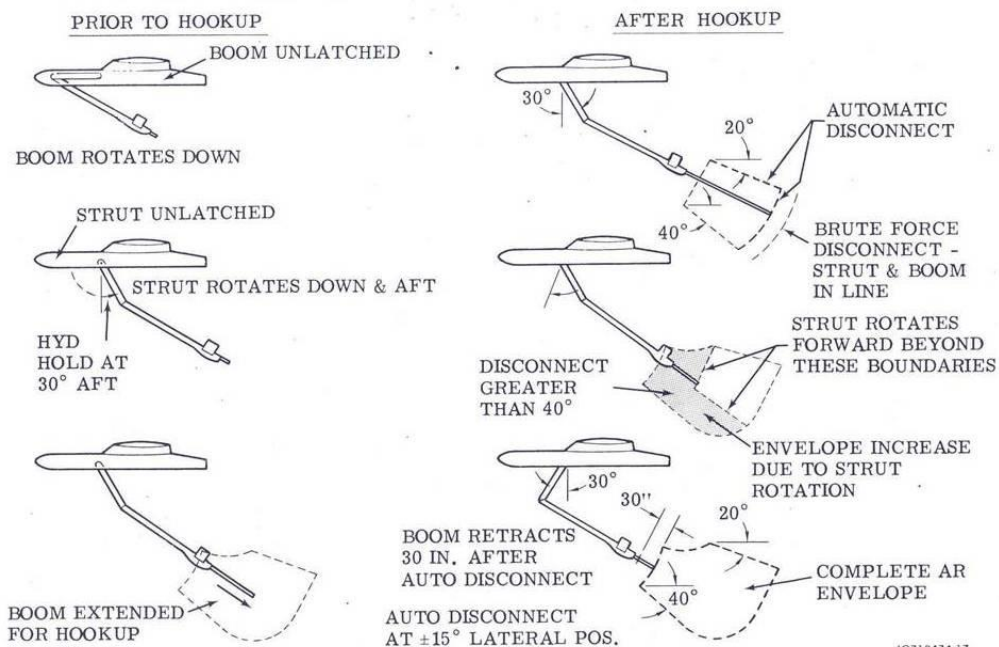
Reference 6

Figure 12.2.1.7 Universal Aerial Refueling Store Concept



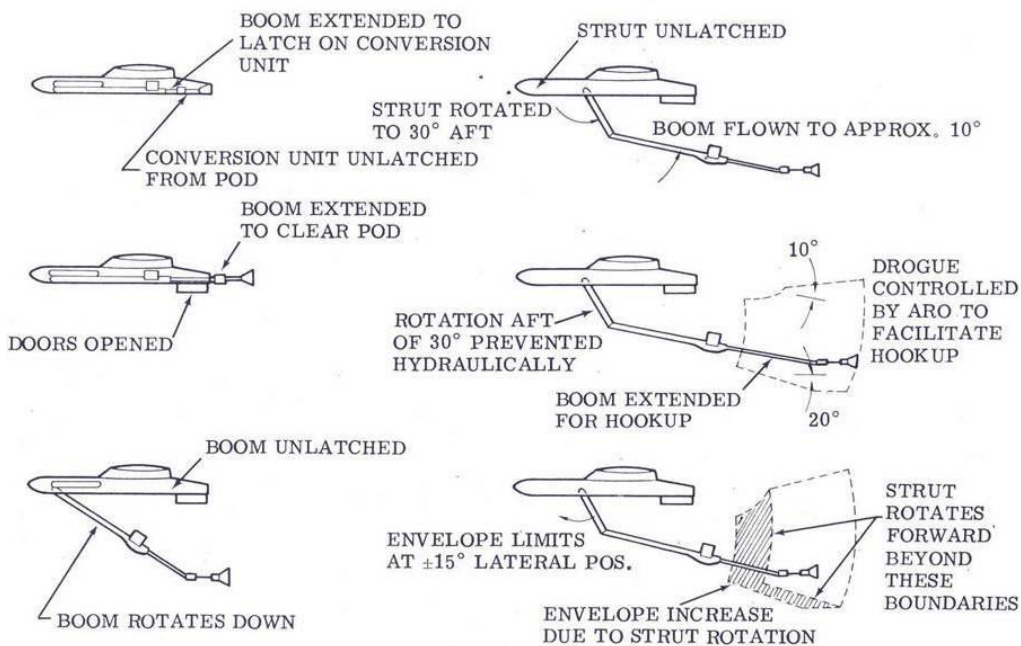
## 12.2.1 Boom Operational and Physical Envelopes (Continued)

### Wing Mounted Boom Envelope Requirements (Continued)



Reference 6

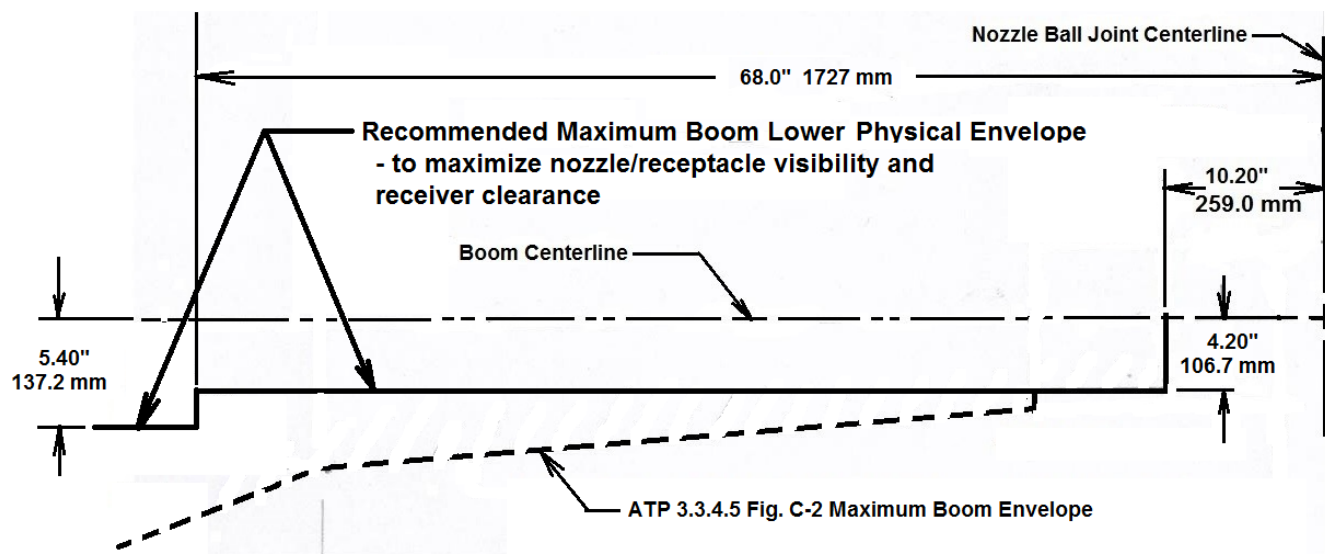
Figure 12.2.1.8 Operating Sequence – Boom/Receptacle Mode



Reference 6

Figure 12.2.1.9 Operating Sequence – Probe/Drogue Mode

## 12.2.1 Boom Operational and Physical Envelopes (Continued)



Side View

Figure 12.2.1.10 Recommended Boom Physical Envelope

12.2.2 Boom Performance

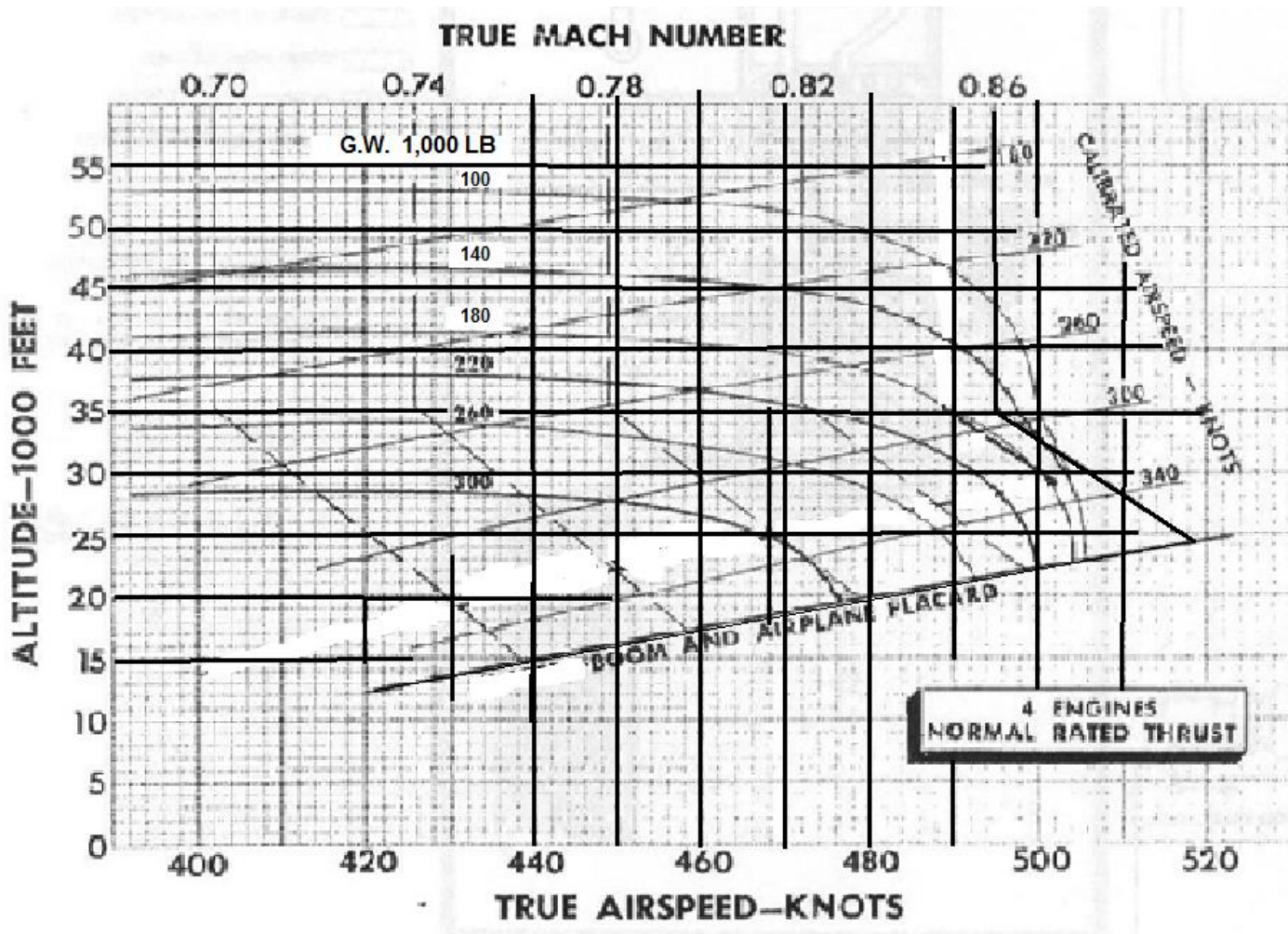


Figure 12.2.2.1 Typical Existing Medium Tanker Airspeed/Altitude

## 12.2.2 Boom Performance (Continued)

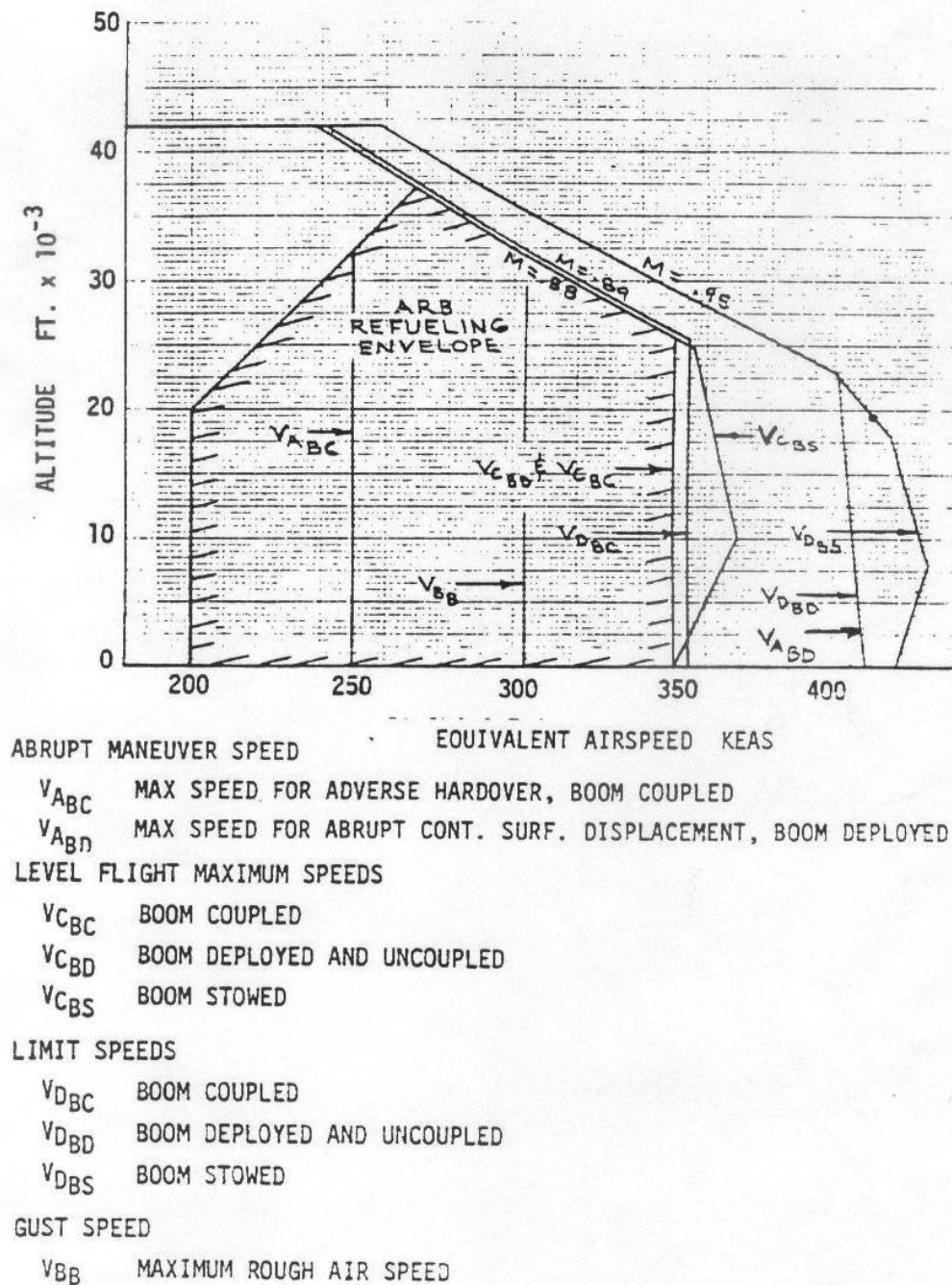
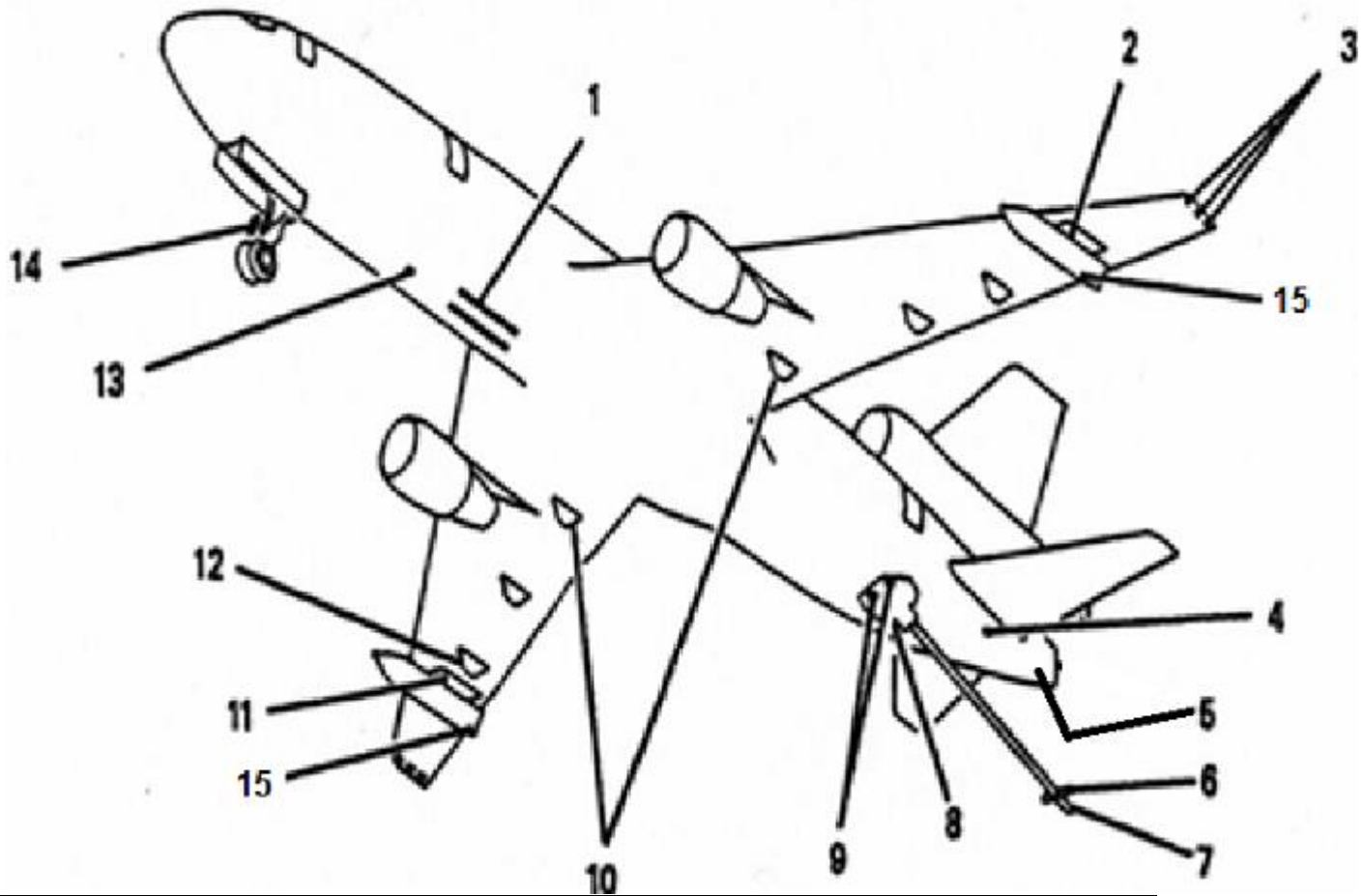


Figure 12.2.2.2 Typical Existing Large Tanker Airspeed vs. Altitude



1	Director Lights	6	Boom Marker Lights (Fluorescent)	11	Inboard Pod Markings Illumination Light ***
2	Outboard Pod Markings Illumination Light ***	7	Boom Nozzle Lights	12	Aft Fuselage Underbody Light (Typical)
3	High Intensity Supplemental Lights (Typical)	8	Hose/Drogue Signal Lights	13	Lower Anti-Collision Rendezvous Light
4	Horizontal Stabilizer Illumination Light (Typical)	9	Wing Illumination Lights	14	Nose Landing Gear Lights
5	Receiver Aircraft Floodlights - in Tanker tailcone	10	Forward Fuselage Underbody Lights	15	Wing Pod Signal Lights

Figure 12.2.3.1 Typical Underbody Lights

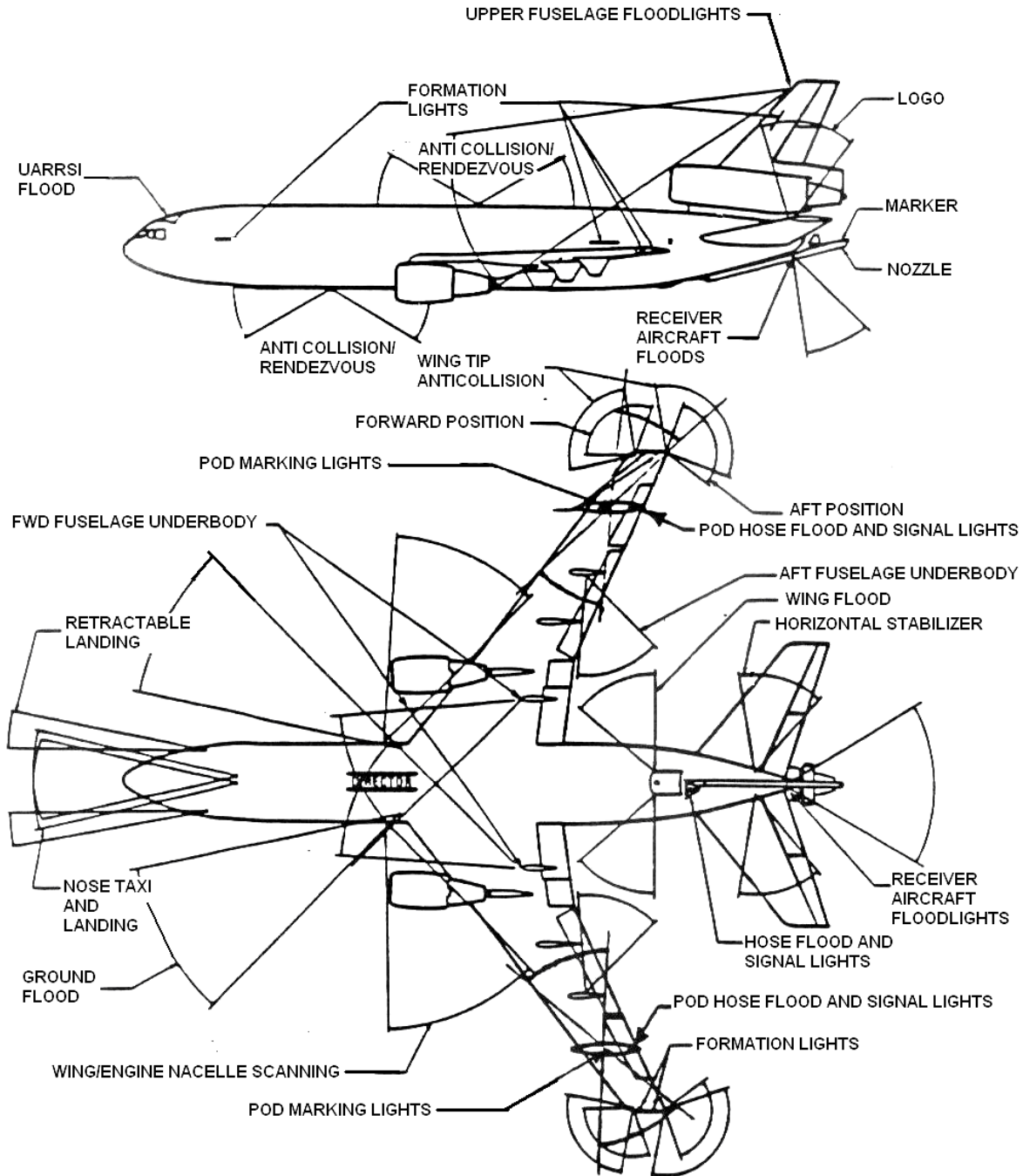
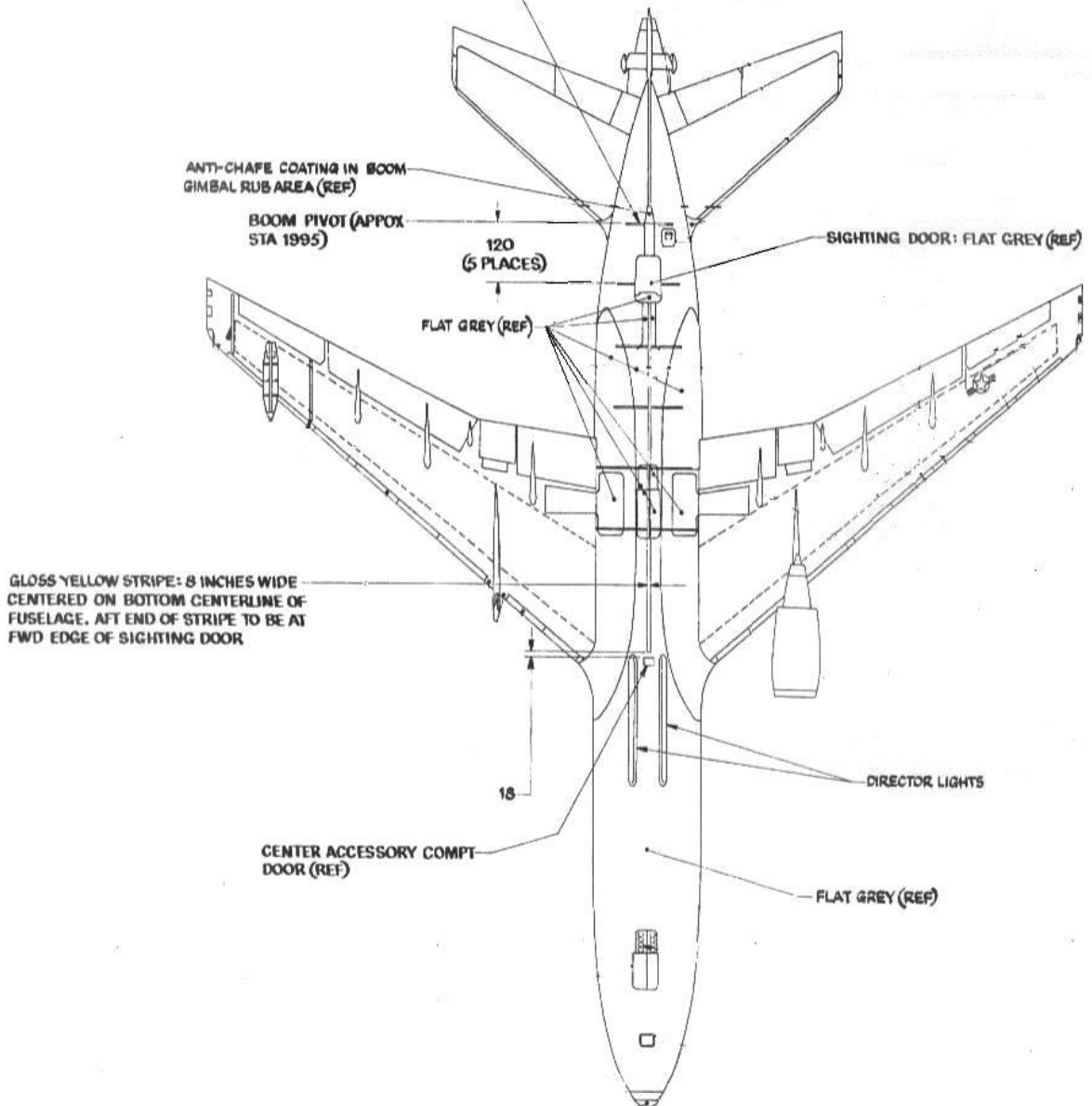


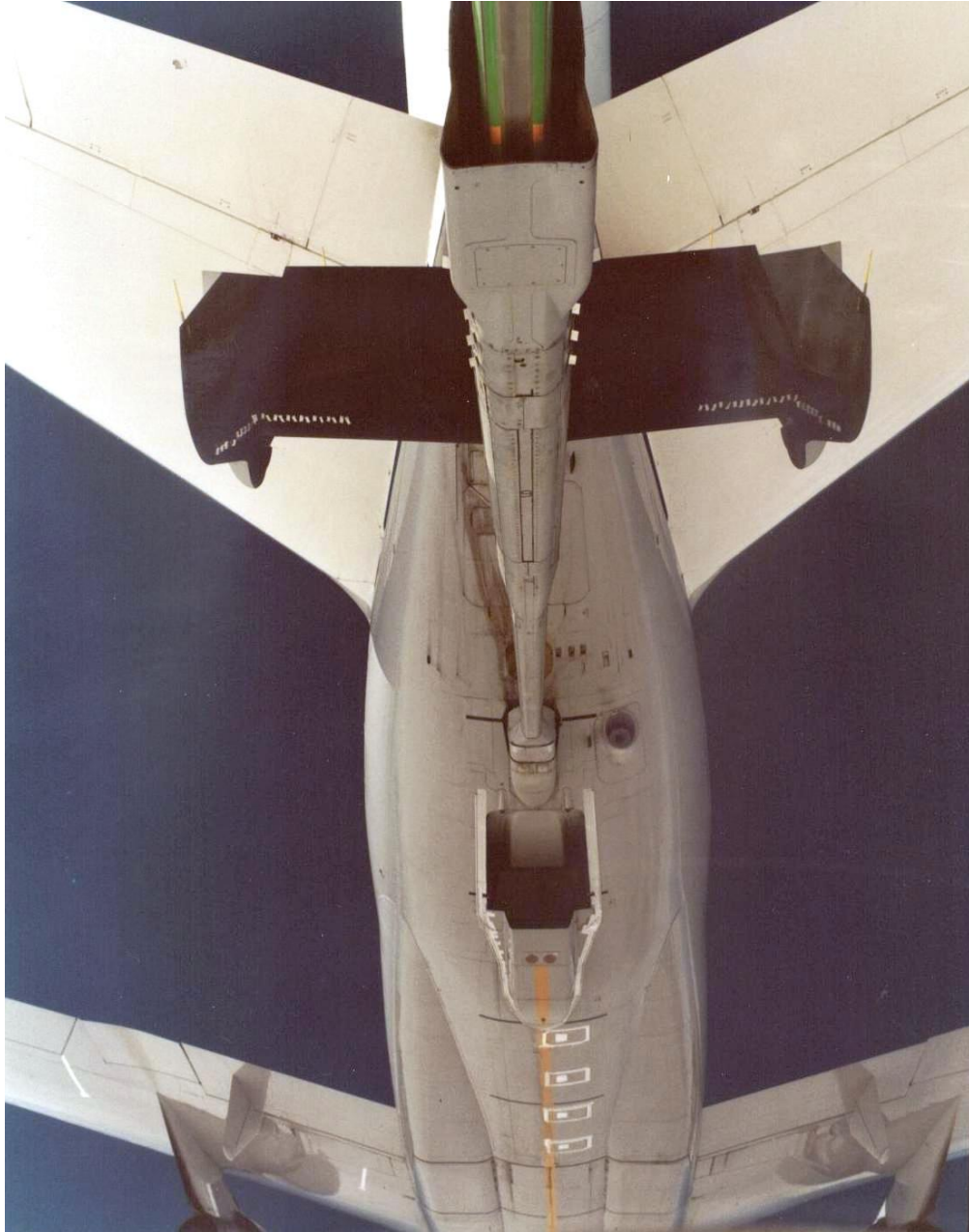
Figure 12.2.3.2 Typical External Lighting

FLAT BLACK STRIPES (6 PLACES): 2 INCHES WIDE. STRIPES ARE INTERRUPTED BY THE BOOM FAIRING, SIGHTING DOOR AND YELLOW STRIPE. THE FWD TWO STRIPES EXTEND OUT TO THE LOWER SURFACE OF THE RIGHT AND LEFT WINGS. THE AFT TWO STRIPES EXTEND OUT TO LONGERON 40 ON THE RIGHT AND LEFT SIDES. THE MIDDLE TWO STRIPES EXTEND OUT ONTO THE WING FAIRING APPROX HALF THE DISTANCE BETWEEN THE FWD AND AFT PAIRS OF STRIPES



To aid the receiver pilot's orientation, the 8 inch wide yellow stripe should run to the aft end of the tanker fuselage tailcone and should be electroluminescent.

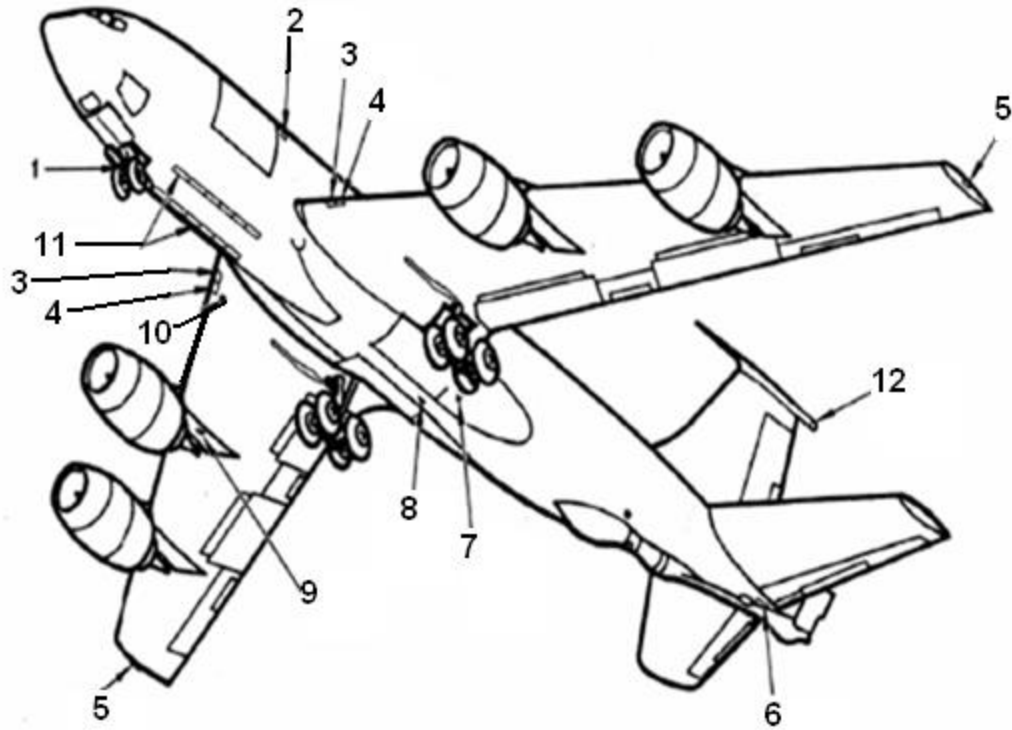
Figure 12.2.3.3 Typical Underbody Markings



To aid the receiver pilot's orientation, the 8 inch wide yellow stripe should run to the aft end of the tanker fuselage tailcone and should be electroluminescent.

**Figure 12.2.3.4 Typical Underbody Markings**

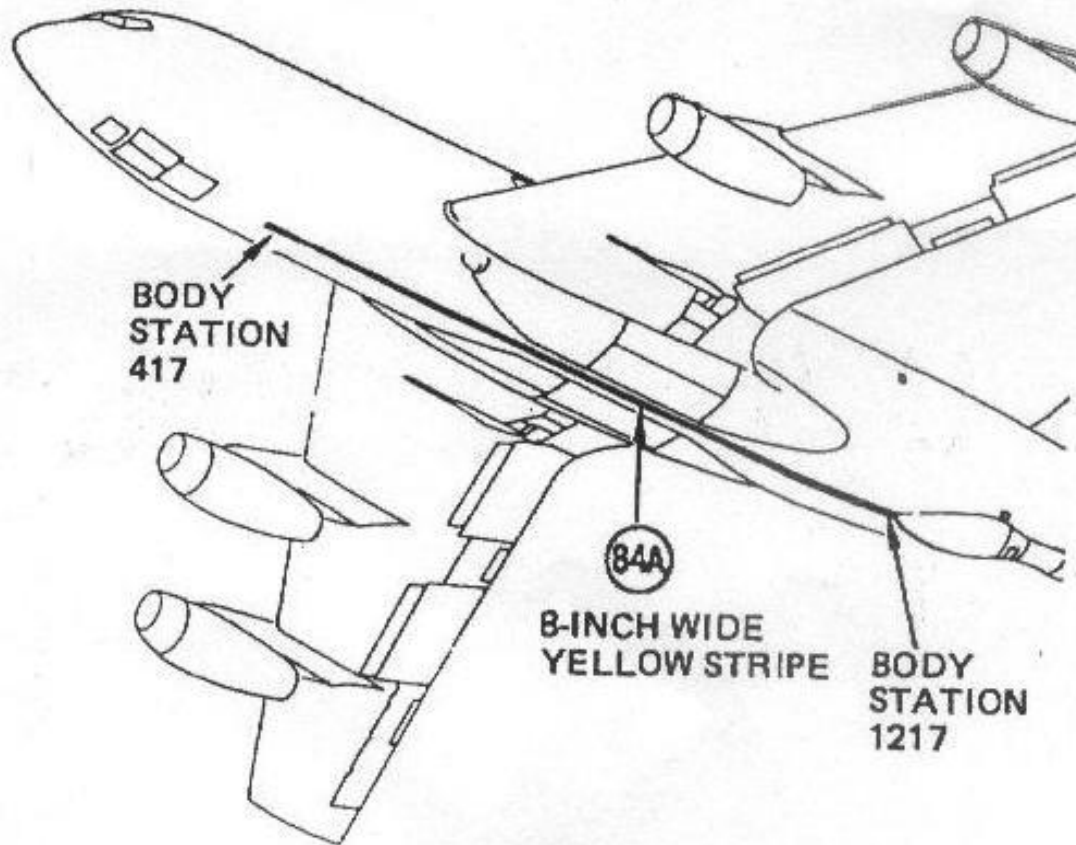




1	Nose Landing and Taxi Light	5	Navigation Light	9	Underbody Illumination (Typical)
2	Nacelle Illumination (Typical)	6	KT Boom Searchlight (Q Tankers Only)	10	Terrain Light (Retractable)
3	Taxi Light	7	Under wing Illumination Light (Typical)	11	Receiver Pilot Director Lights-for boom operator direction to receiver pilot
4	Landing Light (Fixed)	8	Strobe Lights	12	Tail Mounted Floodlight-for Boom Operator visibility of receiver aircraft

To aid the receiver pilot’s orientation, additional lighting is needed on lower aft fuselage and horizontal tail.

Figure 12.2.3.5 Typical Underbody Lighting



To aid the receiver pilot's orientation, the 8 inch wide yellow stripe should run to the aft end of the tanker fuselage tailcone and should be electroluminescent.

**Figure 12.2.3.6 Typical Underbody Markings**



To aid the receiver pilot's orientation, the 8 inch wide yellow stripe should run to the aft end of the tanker fuselage tailcone and should be electroluminescent.

**Figure 12.2.3.7 Typical Underbody Markings**

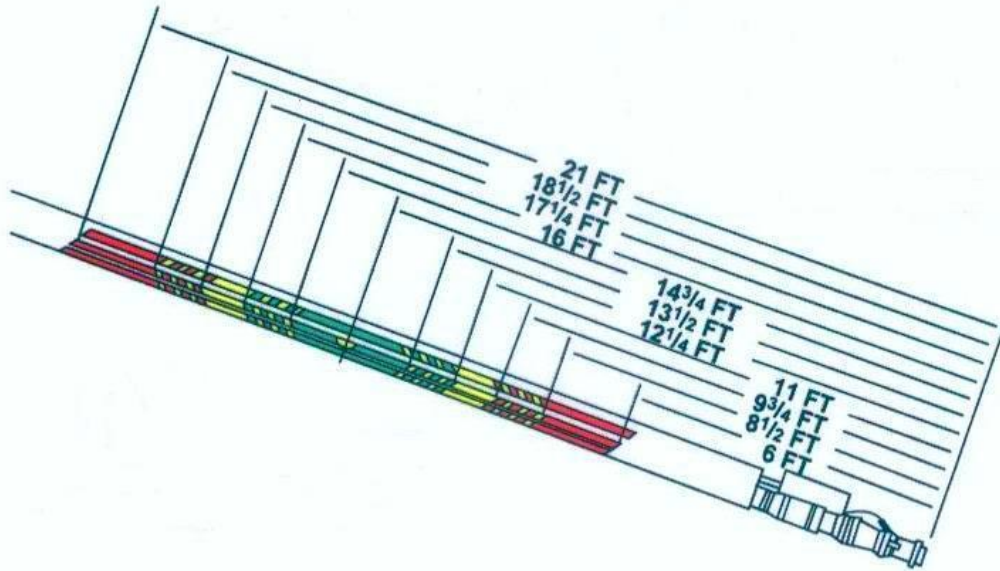


Figure 12.2.4.1 Boom Telescopic Tube Markings



Figure 12.2.4.2 Boom Telescopic Tube Markings

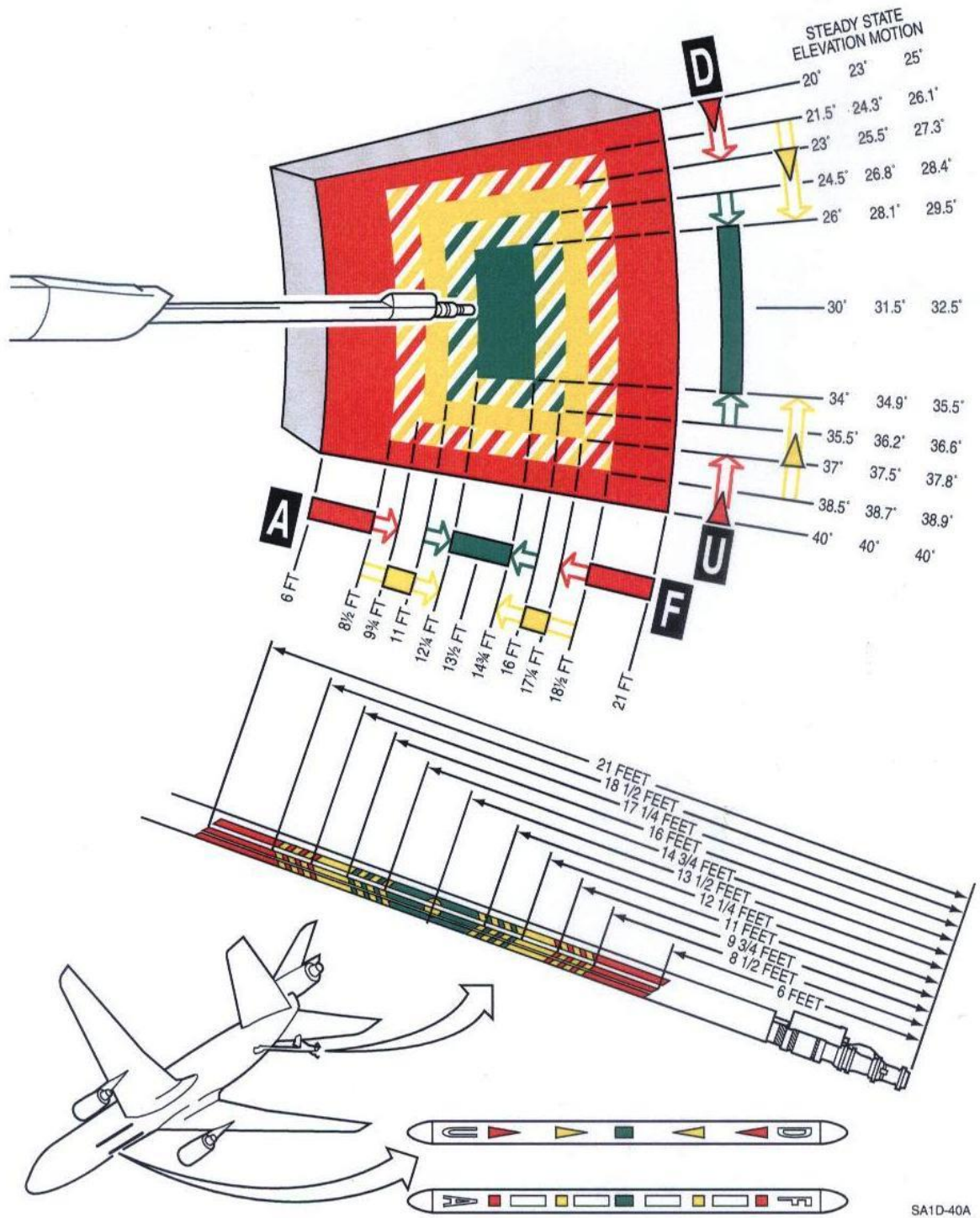
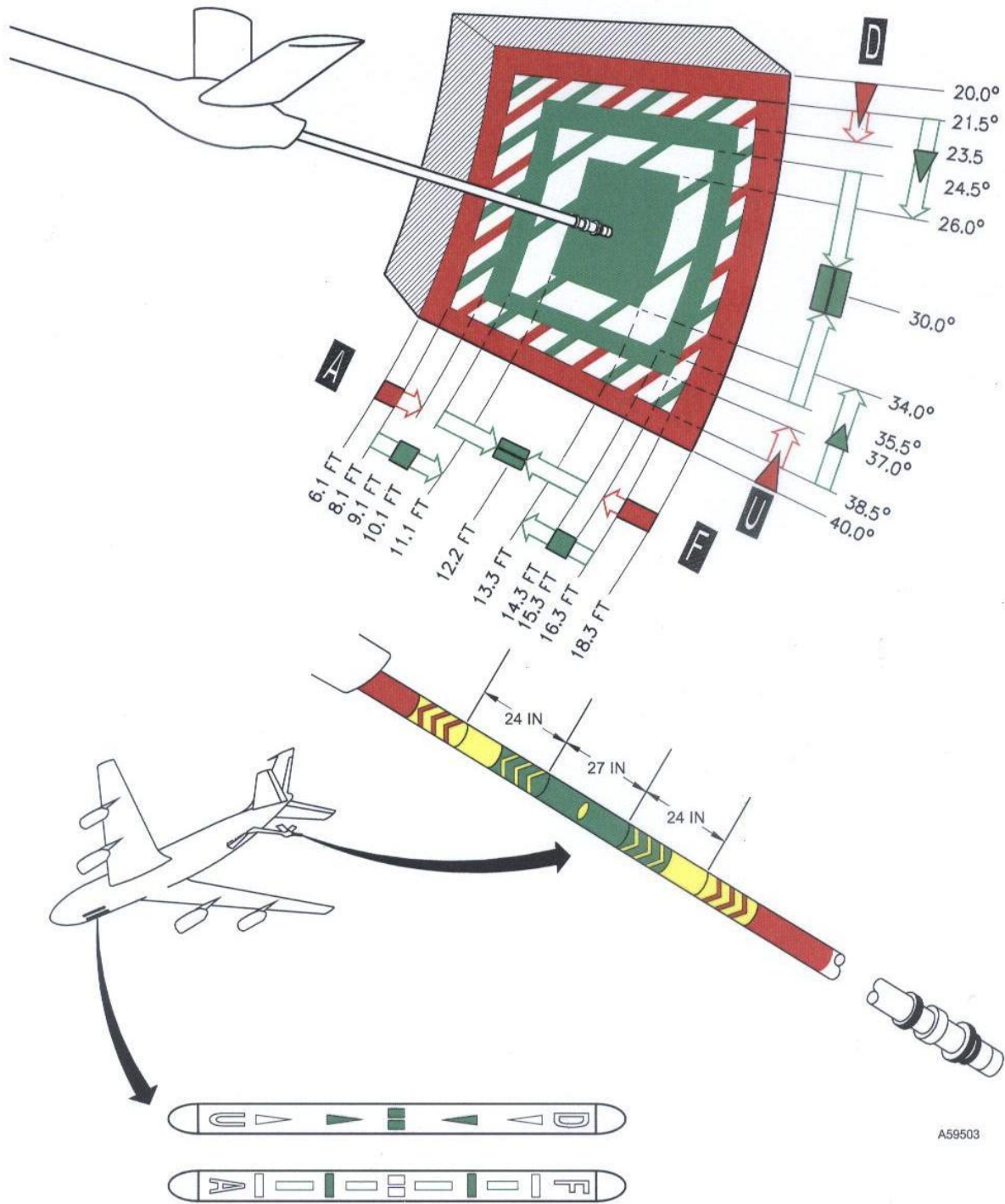


Figure 12.2.5.1 Pilot Director Lights Illumination Profile



A59503

Figure 12.2.5.2 Pilot Director Lights Illumination Profile



**Figure 12.2.5.3 LED Pilot Director Lights**

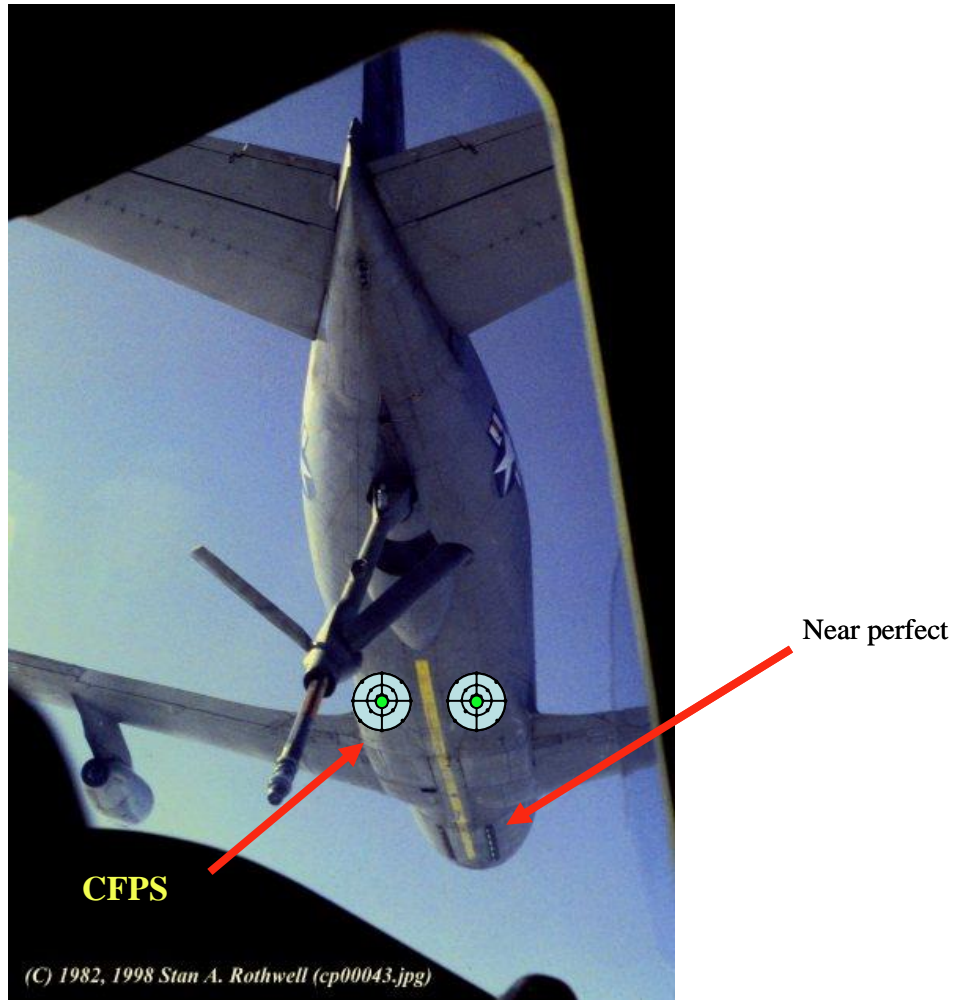
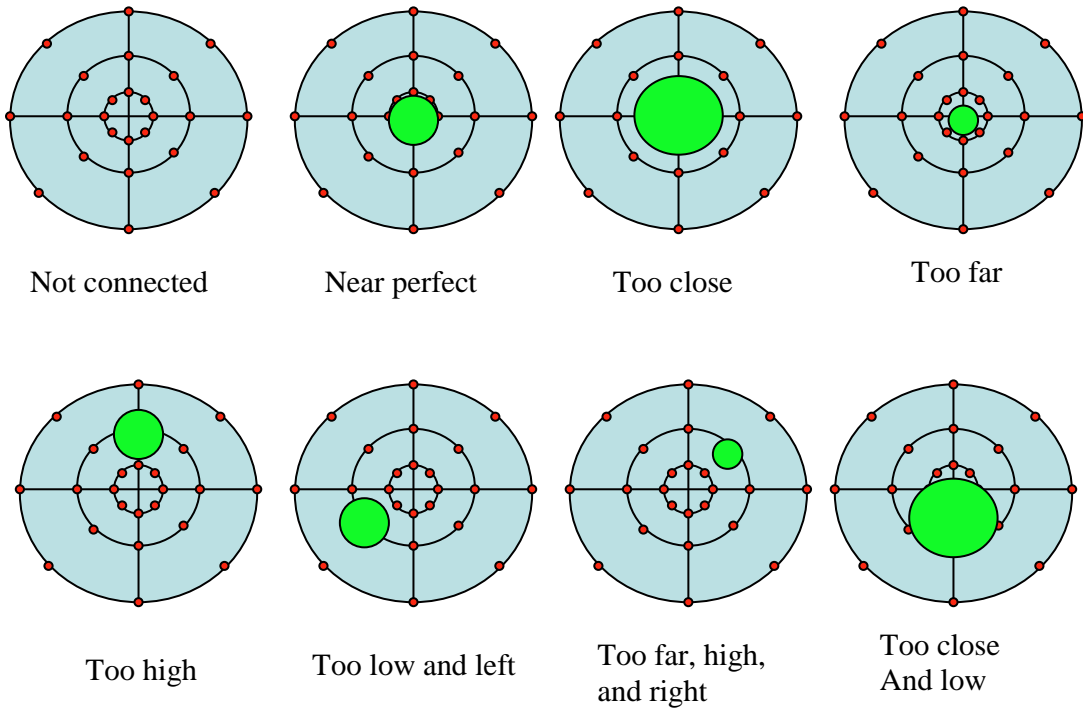


Figure 12.2.5.4 Combined Formation and Position System Concept



**PILOT DIRECTOR LIGHTS (Continued)**



**Figure 12.2.5.5 Combined Formation and Position System Concept**

BOOM STOWAGE SHOCK ABSORBER

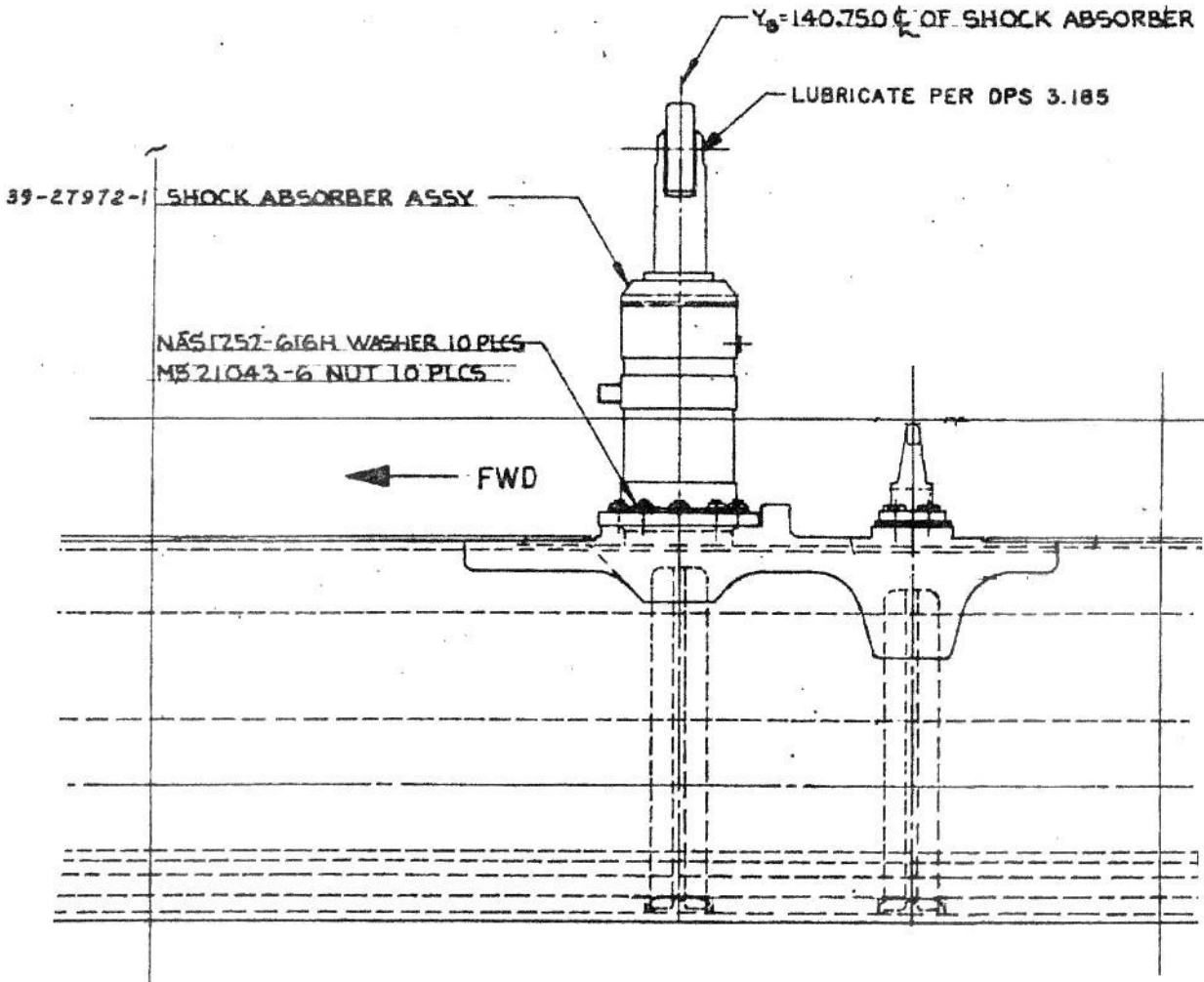


Figure 12.2.6.1 Typical Stowage Shock Absorber Installation

12.2.7

BOOM/TANKER OFFLOAD PERFORMANCE

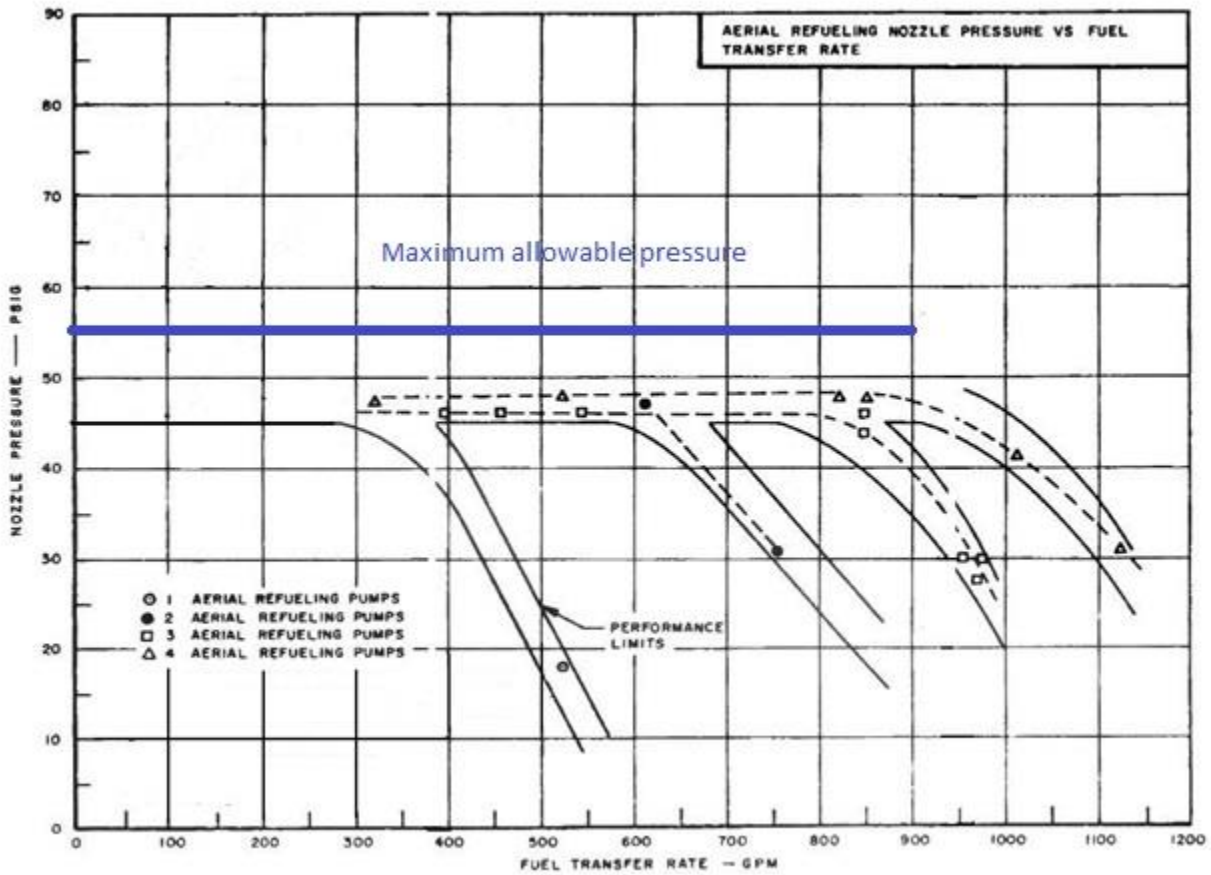
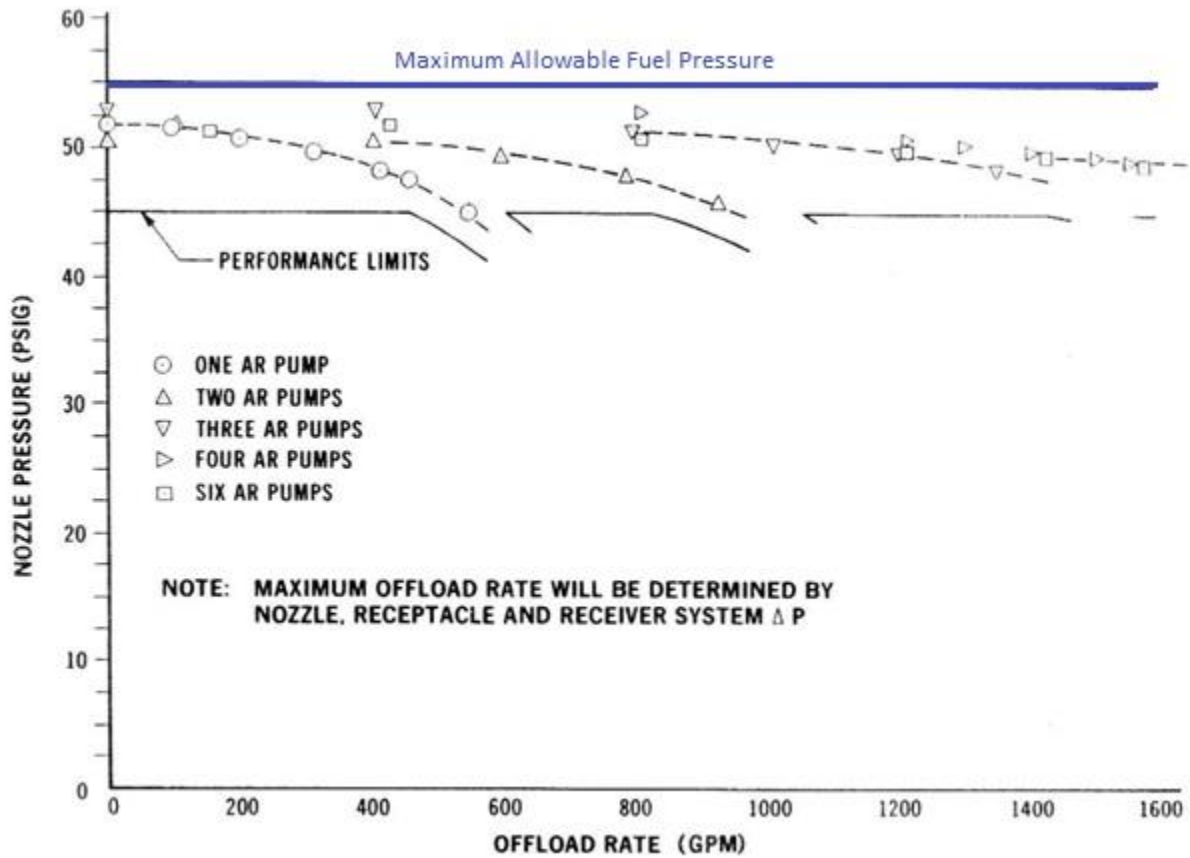
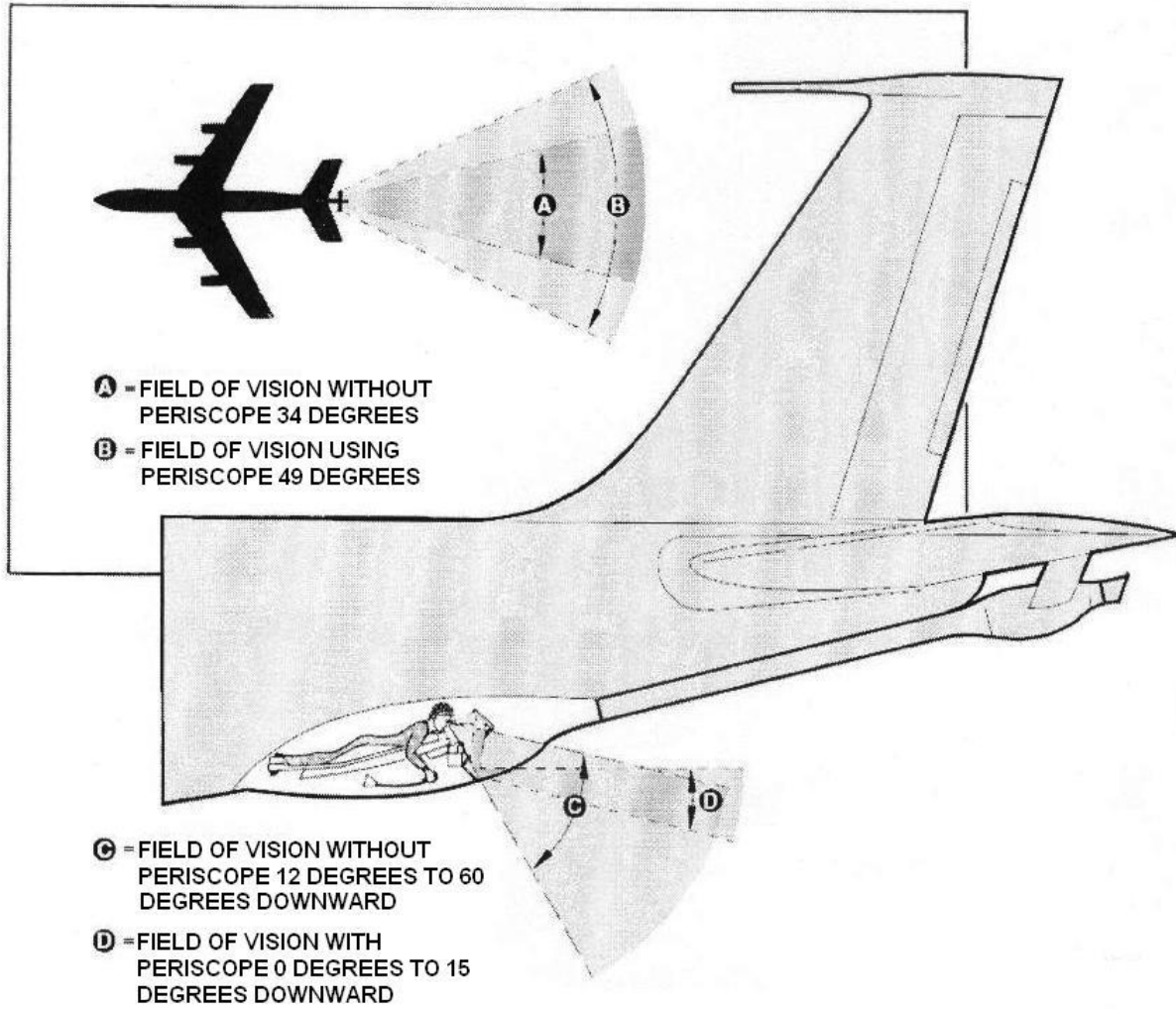


Figure 12.2.7.1 Typical Medium-sized Tanker Regulated Boom Nozzle Delivery Pressure and Flow Capability

**BOOM/TANKER OFFLOAD PERFORMANCE (Continued)**



**Figure 12.2.7.2 Typical Large Tanker Regulated Boom Nozzle Delivery Pressure and Flow Capability**



**Figure 12.2.8.1 Boom Operator Field of View**

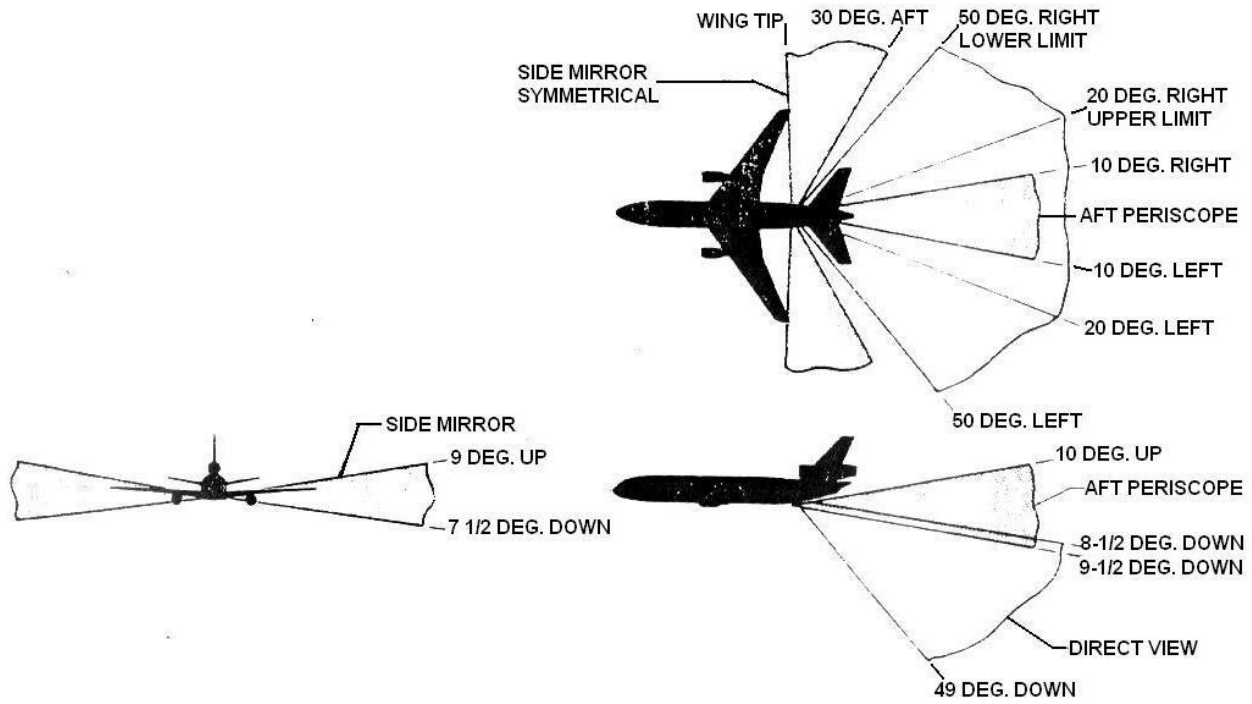
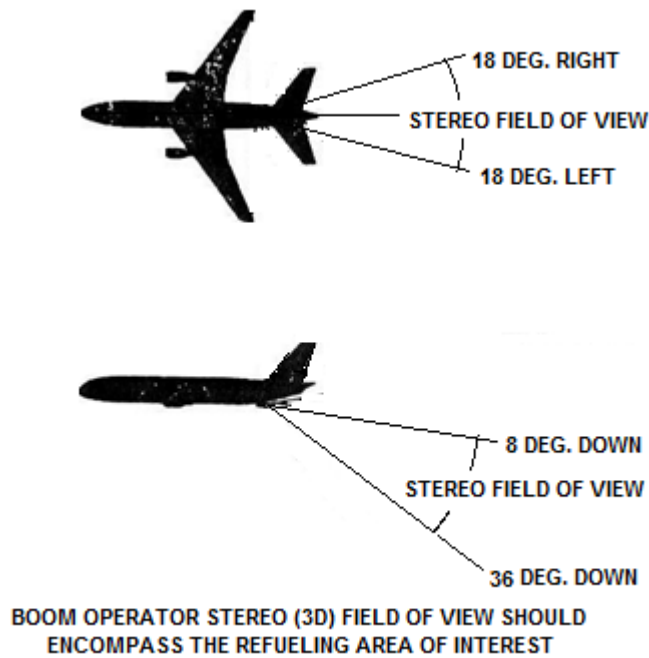
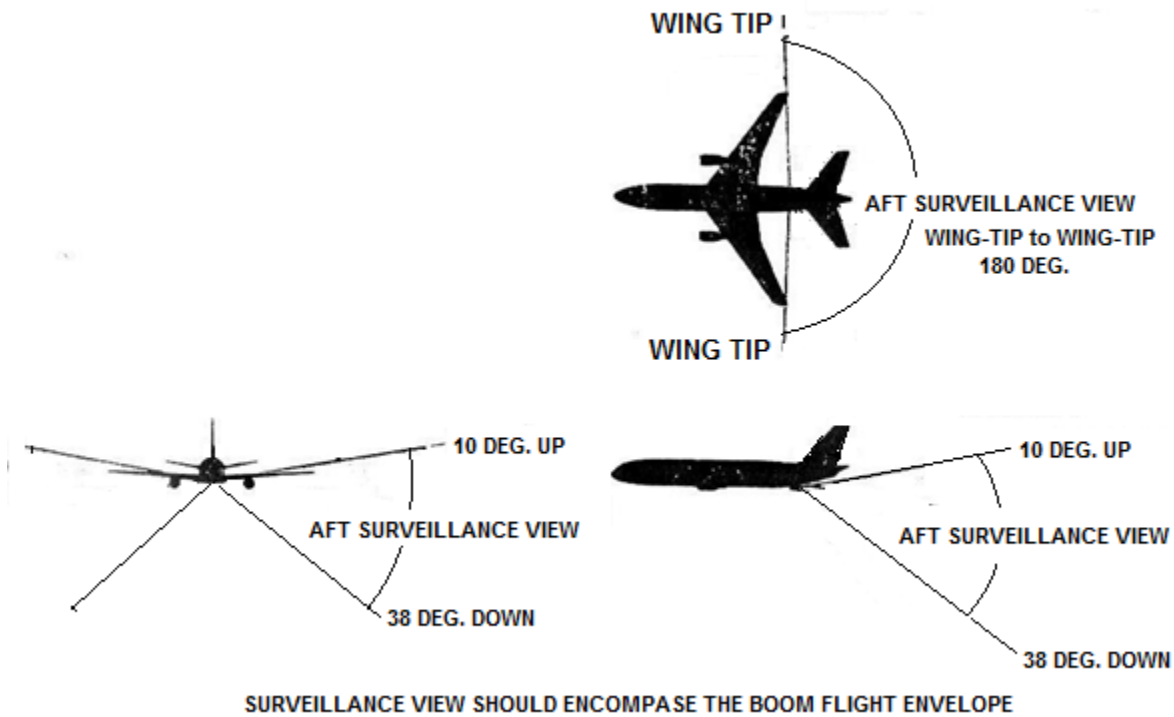


Figure 12.2.8.2 Boom Operator Direct Field of View



**Figure 12.2.8.3 Boom Operator Indirect Field of View  
Boom Refueling View & Aft Surveillance View**



Figure 12.2.8.4 Boom Operator Stereo Field of View



### **12.2.9 BOOM RECOIL SHOCK ABSORBER**

The current boom recoil assemblies are coil spring and friction brake units designed to reduce the impact load on the receiver from a normal contact. The magnitude and the effect of the impact loads on the receiver structure is also a function of the spring rate of the receptacle installation. Therefore the boom data should be used in conjunction with the receptacle installation data in calculating the impact loads. The total weight of the telescopic unit (tube, surge boots, liners, recoil unit, nozzle, fuel, etc.) must be considered. The weight of the nozzle is unsprung weight and is not affected by the recoil unit. The extension rate of the telescopic tube is limited to 4 ft./sec. The recoil shock absorber should be capable of absorbing the kinetic energy of the moving telescopic tube assembly. Damping should be included in the recoil shock assembly.

**Primary Fuels**

The tanker should be capable of utilizing the following primary fuels: JP-8, including synthetic blends, and NATO equivalent F-34.

The tanker should be capable of utilizing the following primary fuels: JP-8, JP-8+100, JP-5, and NATO equivalents F-34, F-37, and F-44.

**Alternate Fuels**

The tanker should be capable of utilizing the following alternate fuels: JP-4, JP-5, Jet B; Jet A/Jet A-1 with CI/LI, FSII: SDA; TS-1 with CI/LI, FSII: SDA; Jet A/Jet A-1 neat (no additives); TS-1 neat (no additives).

The tanker should be capable of utilizing the following alternate fuels: JPTS; JP-4, Jet B, Jet A/Jet A-1 with CI/LI, FSII: SDA; TS-1 with CI/LI, FSII: SDA; Jet A/Jet A-1 neat (no additives); TS-1 neat (no additives).

**Emergency Fuels**

The tanker should be capable of utilizing the following emergency fuels: aviation gasoline (grades 115/145, 100/130)

The tanker should be capable of utilizing the following emergency fuels: aviation gasoline (grades 115/145, 100/130, 100LL, and 80/87), TS-1 with GOST additives, and RP-1.

**Table 12.2.10.1 Primary, Alternate and Emergency Fuels**

## 12.2.10

### FUEL TYPE REQUIREMENTS (Continued)

**The tanker should have the capability to isolate, transport, and offload either in flight using the boom or on the ground (FARP) a secondary fuel.**

The tanker should be capable of carrying all primary, alternate and emergency fuels as well as the following in the isolated fuel part of the fuel system:

China: Jet Fuel #3 (GB 6537-94)

Sweden: Flygfotogen 75 Kerosene (FSD 8607E)

Romania: TH (STAS 5639/88)

South Africa: 50% Synthetic Blend (Def Stan 91-91).

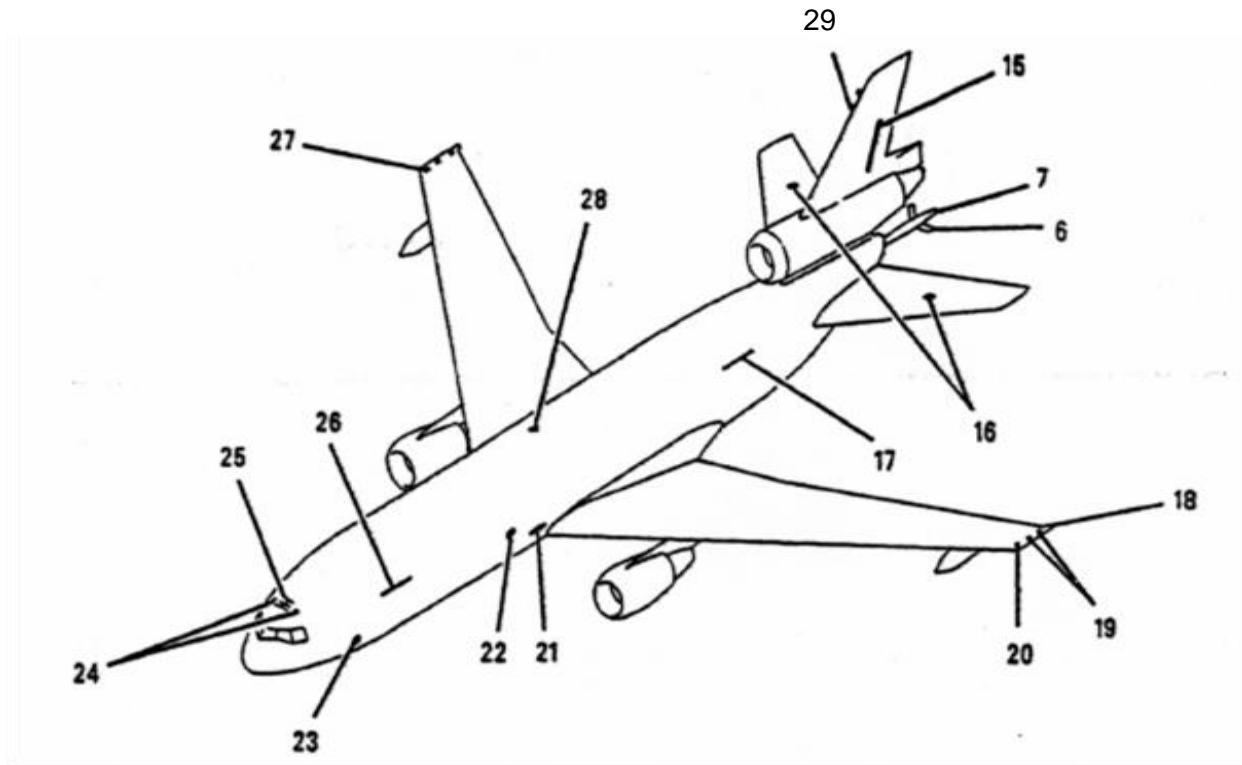
The tanker should also be capable of carrying ASTM D975 diesel fuel for FARP operations only.

**Two actions or 2 failures should be required to mix isolated fuels.**

#### Table 12.2.10.2 Transportable Fuels

### 12.3. Receiver Aircraft Installation and Interface Enhancements

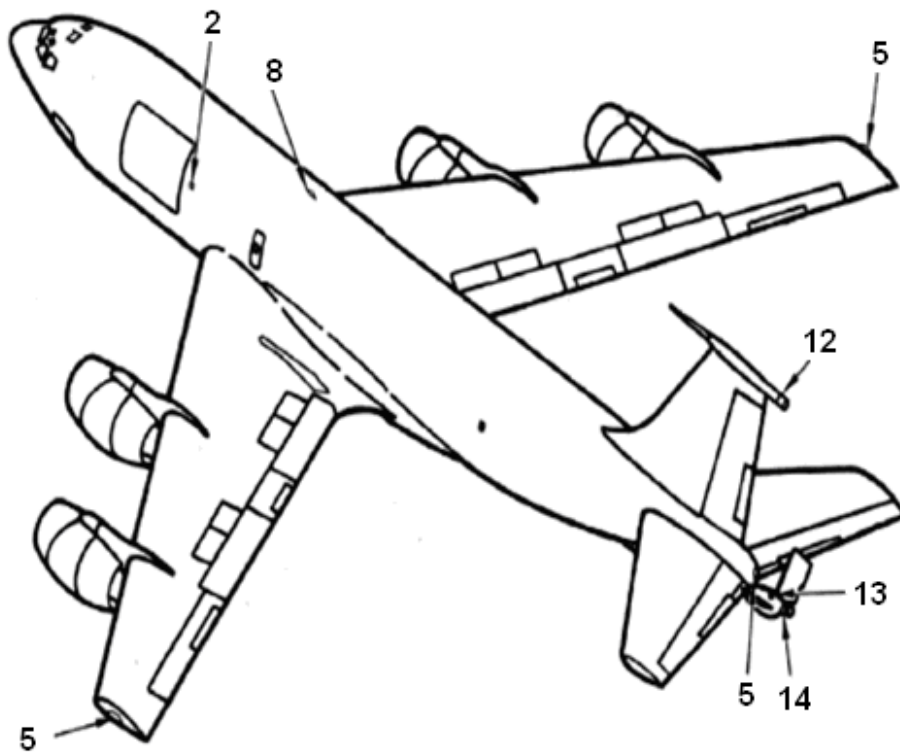
#### 12.3.1 Over-Fuselage and Wing Lighting and Marking



6	Boom Marker Lights (Fluorescent)	19	Formation Light (Typical)	25	Lead-In Stripes/UARRSI Electroluminescent Lighting System
7	Boom Nozzle Lights	20	Forward Position Light, Red	26	Formation Light (Typical)
15	Formation Light (Typical)	21	Taxi and Runway Turnoff Light - Ground Flood (Typical)	27	Forward Position Light, Green
16	Logo Lights	22	Wing and Engine Scan Light (Typical)	28	Upper Anti-Collision/Rendezvous Light
17	Formation Light (Typical)	23	Fuselage Landing Light (Typical)	29	Upper Fuselage Floodlights
18	Aft Position Light White (Typical)	24	Slipway Flood Lights		

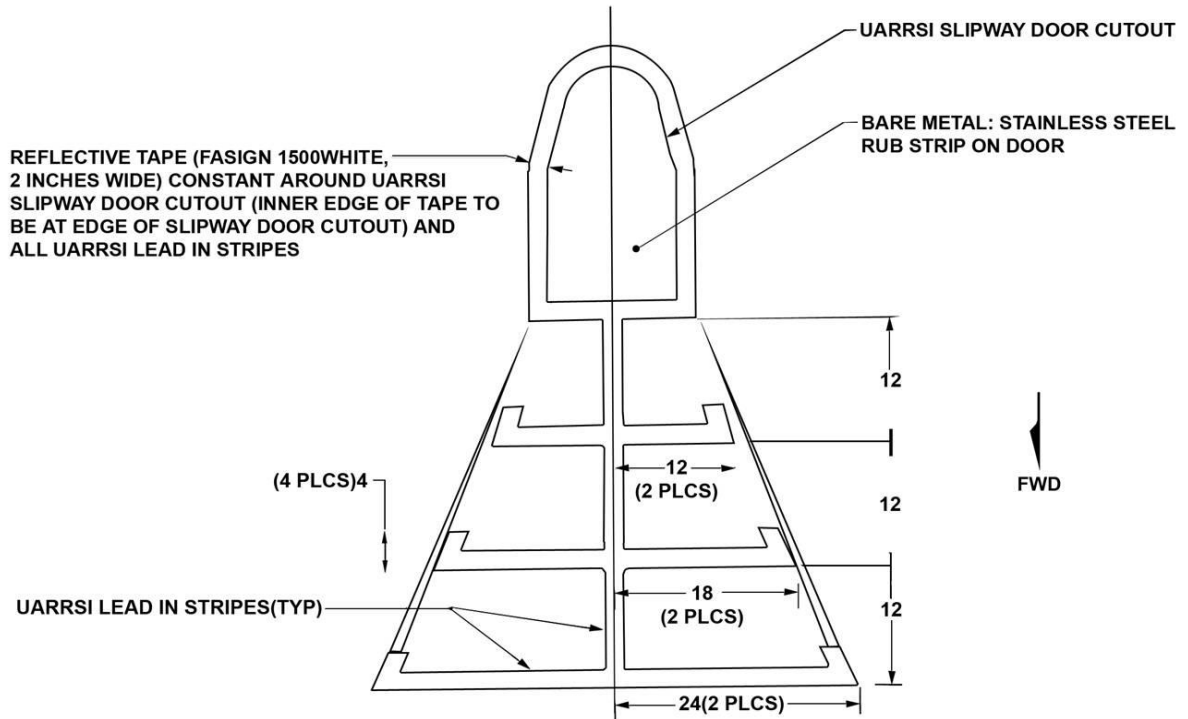
Figure 12.3.1.1 External Lighting - Upper

### 12.3.1 Over-Fuselage and Wing Lighting and Marking (Continued)



2	Nacelle Illumination (Typical)	8	Strobe Lights	13	Boom Marker Lights (Fluorescent)
5	Navigation Light	12	Tail Mounted Floodlight – to aid boom operator visibility of receiver aircrafts receptacle	14	Boom Nozzle Light

**Figure 12.3.1.2 External Lighting - Upper**



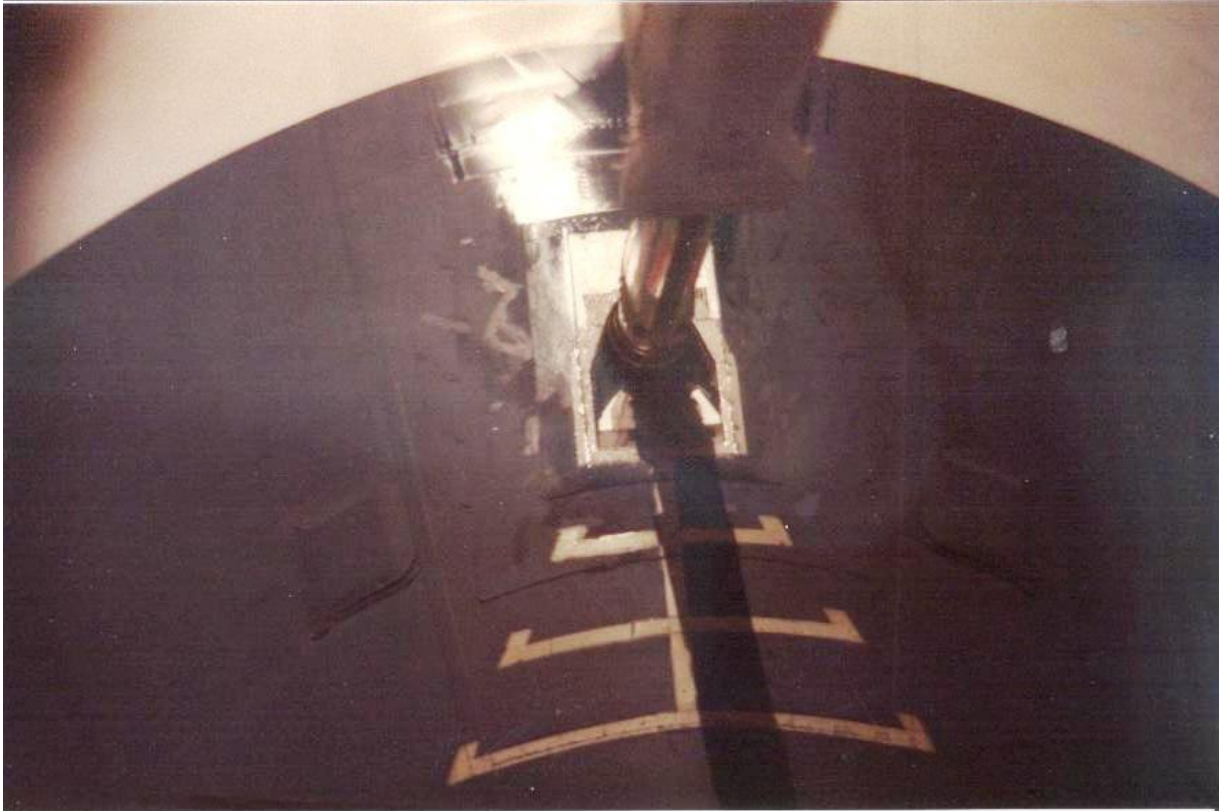
**Note:** Tape color should contrast with aircraft background color

**Figure 12.3.2.1 Recommended Triple Bar Markings**



**Note: Windshield highlighted with reflective tape**

**Figure 12.3.2.2 Triple Bar Receptacle Markings**



**Figure 12.3.2.3 Triple Bar Receptacle Markings**





Note: Optional parallel centerline stripes

Note: Off center Receptacle

Note: Nose stripes to aid distance judgment

**Figure 12.3.2.4 Triple Bar Receptacle Markings**

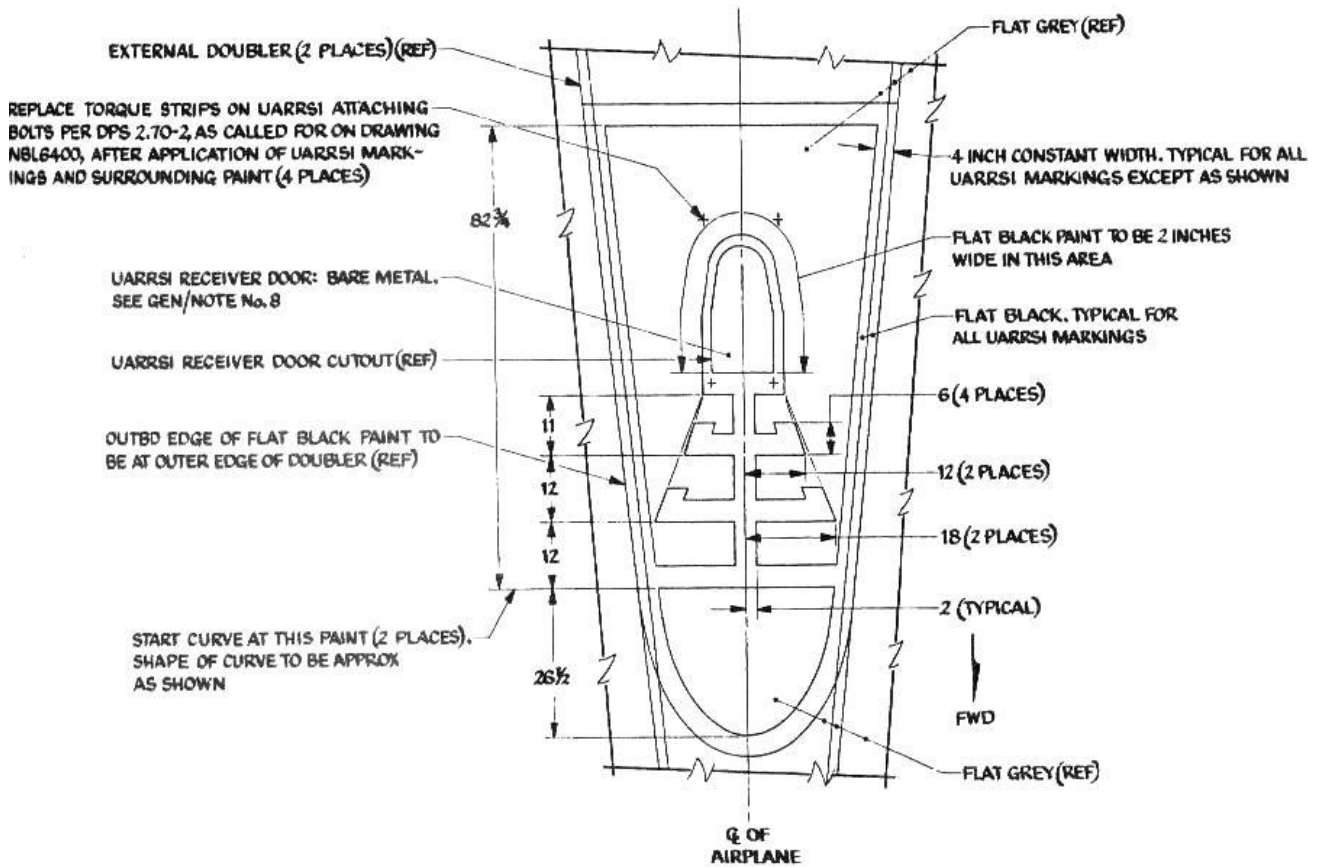


Note: Parallel centerline stripes, Receptacle doors on either side of receptacle.

**Figure 12.3.2.5 Triple Bar Receptacle Markings**

12.3.2

RECEPTACLE SLIPWAY MARKINGS (Continued)



Note: Tape color should contrast with aircraft background color

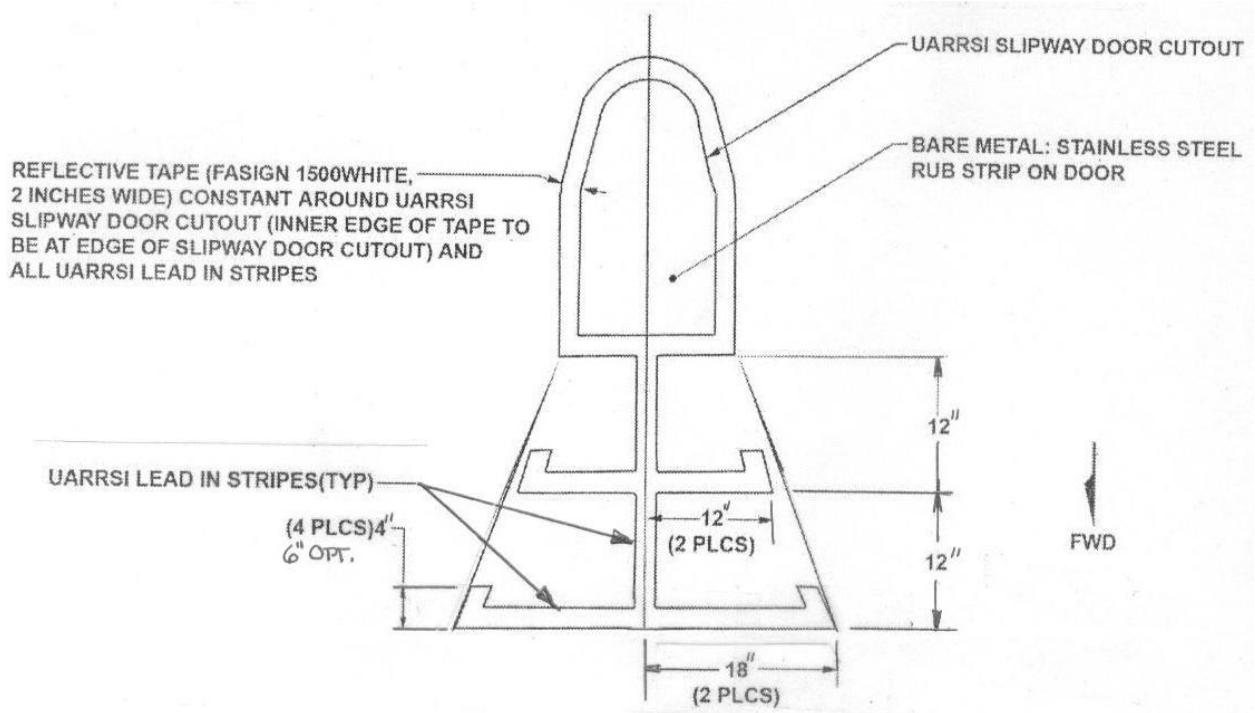
Figure 12.3.2.6 Triple Bar UARRSI Markings - Camouflaged



**Figure 12.3.2.7 Triple Bar UARRSI Markings - Camouflaged**

12.3.2

RECEPTACLE SLIPWAY MARKINGS (Continued)



**Note:** Tape color should contrast with aircraft background color

**(Recommended when Triple Bar Markings do not fit available space)**

**Figure 12.3.2.8 Two Bar Marking**



**Figure 12.3.2.9 Two Bar Receptacle Markings**



Note: Spoiler aft of Receptacle

**Figure 12.3.2.10 Two Bar Receptacle Markings**



**Figure 12.3.2.11 Two-bar Receptacle Markings**



Heavy Receiver – Receptacle Aft of Cockpit



Figure 12.3.3.1 Closing to Pre-contact Position

Heavy Receiver – Receptacle Aft of Cockpit



**Pre-contact Position**



**Contact Position**

**Figure 12.3.3.2 Pre-contact and Contact Positions**

Light Receiver – Receptacle Aft of Cockpit



*Receivers view*

**Figure 12.3.3.3 Contact Position**

Receptacle located forward of windscreen.



Figure 12.3.3.4 contact position

USAF Photo