MILITARY SPECIFICATION

* FUEL SYSTEM, AIRCRAFT, GENERAL SPECIFICATION FOR

1. SCOPE

* 1.1 This specification covers the requirements for design, performance, installation, and testing and establishes the baseline for subsequent logistics and maintenance support, including operation, inspection, servicing, replacement, repair, overhaul, and modification of the fuel system and fuel subsystems of aircraft powered by air-breathing engines. In the event of conflicts between this document and referenced documents, this document governs.

* 1.2 Subsystems. Requirements for the following fuel subsystems are covered in this specification:

a. Engine feed and transfer subsystem

b. Aircraft fuel tank subsystem

c. Pressurization and explosion suppression subsystems

d. Fuel vent subsystem

e. Fuel quantity gaging subsystem

f. Ground refueling and defueling subsystem

g. Aerial refueling subsystem

h. Fuel dump subsystem.

2. APPLICABLE DOCUMENTS

* 2.1 The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein.

SPECIFICATIONS

Federal

BB-N-411	Nitrogen, Technical
QQ-P-416	Plating, Cadmium (Electrodeposited)

FSC 2915

WW-T-700	Tube, Aluminum and Aluminum Alloy, Drawn, Seamless; General Specification for

Military

MIL-E-5007	Engines, Aircraft, Turbojet and Turbofan, General Specification for
MIL-B-5087	Bonding, Electrical, and Lightning Protection, for Aerospace Systems
MIL-W-5088	Wiring, Aircraft, Installation of
MIL-P-5238	Pump, Centrifugal, Fuel Booster, Aircraft, General Specification for
MIL-T-5578	Tank, Fuel, Aircraft, Self-Sealing
MIL-T-6396	Tanks, Fuel, Oil, Water-Alcohol, Coolant Fluid, Aircraft, Non-Self Sealing, Removable, Internal
MIL-L-6503	Lighting Equipment, Aircraft, General Specification for Installation of
MIL-E-7080	Electric Equipment, Aircraft, Selection and Installation of
MIL-F-7179	Finishes and Coatings: General Specification for Protection of Aerospace Weapons Systems, Structures and Parts
MIL-T-7378	Tanks, Fuel, Aircraft, External, Auxiliary, Removable
MIL-C-7413	Couplings, Quick Disconnect, Automatic Shut-off, General Specification for
MIL-G-7940	Gages, Liquid Quantity, Capacitor Type, Installation and Calibration of
MIL-P-8045	Plastic, Self-Sealing and Non-Self-Sealing Tank Backing Material
MIL-I-8500	Interchangeability and Replaceability of Component Parts for Aircraft and Missiles
MIL-T-8606	Tubing, Steel, Corrosion-Resistant (18-8 Stabilized), Seamless or Welded
MIL-V-8608	Valves, Fuel Shutoff, Electrical Motor Operated
MIL-V-8610	Valves; Fuel Shutoff Solenoid Operated, 28 Volt DC
MIL-F-8615	Fuel System Components: General Specification for
MIL-S-8710	Strainer, Airframe Fuel System, General Specification for
MIL-H-8795	Hose Assemblies, Rubber, Hydraulic, Fuel and Oil Resistant
MIL-A-8865	Airplane Strength and Rigidity Miscellaneous Loads
MIL-S-8879	Screw Threads, Controlled Radius Root with Increased Minor Diameter; General Specification for
MIL-C-22263	Coupling, Fuel Line, Flexible, 125 PSI
MIL-V-25023	Valve, Fuel Drain, Self-Locking
MIL-M-25047	Markings and Exterior Finish Colors for Airplanes, Airplane Parts, and Missiles (Ballistic Missiles Excluded)
MIL-N-25161	Nozzle, Aerial Pressure Refueling, Type MA-2
MIL-E-25499	Electrical Systems, Aircraft, Design and Installation of, General Specification for
MIL-H-25579	Hose Assembly, Tetrafluoroethylene, High Temperature, Medium Pressure
MIL-T-25783	Tank, Fuel, Aircraft and Missile, Non-Self-Sealing, High Temperature, Removable

MIL-A-25896	Adapter, Pressure Fuel Servicing, Aircraft, Nominal 2-1/2 Inch Diameter
MIL-S-25980	Switch, Float, Aircraft Fuel Level, General Specification for
MIL-S-26390	Switch Assemblies, Pressure, Aircraft Fuel
MIL-G-26988	Gage, Liquid Quantity, Capacitor Type, Transistorized, General Specification for
MIL-T-27422	Tank, Fuel, Crash-Resistant, Aircraft
MIL-R-27521	Receptacle, Flying Boom, Aerial Refueling
MIL-V-38003	Valves, Fuel Level Control, Fuel Tank, Aircraft, General Specification for
MIL-C-38373	Cap, Fluid Tank Filler
MIL-S-38449	Signal Amplifier, Universal, Flying Boom Aerial Refueling
MIL-C-81511	Connectors, Electrical, Circular, High Density, Quick Disconnect, Environment Resisting; and Accessories, General Specification for
MIL-B-83054	Baffle Material, Aircraft Fuel Tank
MIL-T-83219	Truck, Tank A/S32R-9
MIL-C-83291	Covers, Self-Sealing, Fuel Line, Aircraft
MIL-I-83294	Installation Requirements, Aircraft Propulsion Systems, General Specification for
MIL-T-83323	Tester, Universal Receptacle, Aerial Refueling

STANDARDS

Military

MIL-STD-100	Engineering Drawing Practices
MIL-STD-143	Standards and Specifications, Order of Precedence for the Selection of
MIL-STD-461	Electromagnetic Interference Characteristics Requirements for Equipment
MIL-STD-470	Maintainability Program Requirements (For Systems and Equipments)
MIL-STD-701	Lists of Standard Semiconductor Devices
MIL-STD-704	Electric Power, Aircraft, Characteristics and Utilization of
MIL-STD-889	Dissimilar Metals
MIL-STD-1247	Markings, Functions and Hazard Designations of Hose, Pipe, and Tube Lines for Aircraft, Missile, and Space Systems
MS24333	Coupling Assembly, Hydraulic, Self-Sealing, Quick Disconnect, Flared Fitting to Internal Thread Boss
MS24335	Flange, Bulkhead Mounting, Hydraulic, Self-Sealing Coupling
MS24354	Drogue Cone, Nozzle and Reception Coupling - Type MA-2 Flight-Pressure-Refueling System, Assembly of
MS24355	Coupling, Reception - Type MA-2, Flight Pressure Refueling, Assembly of

MS27604	Nozzle - Universal Aerial Refueling Tanker Boom
MS29520	Nozzle, Pressure Fuel Servicing Locking, Aircraft, Type D-1
MS29525	Cap, Pressure Fuel Servicing, Aircraft, 2-1/2-Inch Flush Type
MS29526	Cap - Pressure Fuel Servicing, Nominal 2-1/2 Inch Diameter, Non-Flush Type
MS33514	Fitting End, Standard Dimensions for Flareless Tube Connection and Gasket Seal
MS33583	Tubing End - Double Flare, Standard Dimensions for
MS33584	Tubing End - Standard Dimensions for Flared
MS33611	Tube Bend Radii
MS33645	Receptacle, Grounding, Installation of

PUBLICATIONS

Air Force Systems Command Design Handbook

AFSC DH 2-1 Airframe

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

* 2.2 Other publications. The following document forms a part of this specification to the extent specified herein. Unless otherwise indicated, the issue in effect on date of invitation for bids or request for proposal shall apply.

Federal Aviation Administration

FAA Advisory Circular 20-53 Protection of Aircraft Fuel Systems Against Lightning

(Application for copies should be addressed to the Federal Aviation Administration, Washington, D. C. 20553.)

3. REQUIREMENTS

3.1 Selection of specifications and standards. Specifications and standards for necessary commodities and services not specified herein shall be selected in accordance with MIL-STD-143.

3.2 Materials. Materials used in the manufacture of aircraft fuel systems shall be of high quality, suitable for the environment expected for the aircraft, and shall conform to applicable Government specifications or equivalent contractor specifications. The use of contractor specifications must be approved by the procuring activity. All materials shall be sufficiently resistant to applicable fluids specified in the weapon system specification to assure satisfactory operation as defined herein.

3.2.1 Metals. Metals shall be corrosion resistant or treated to resist corrosion due to fuels, salt spray, atmospheric conditions, or wear likely to be encountered in transportation, storage, or during normal service life.

* 3.2.2 Dissimilar metals. Dissimilar metals as defined in MIL-STD-889 shall not be used in intimate contact with each other unless suitably protected against electrolytic corrosion.

* 3.2.3 Magnesium, copper, and cadmium. Alloys of magnesium and copper shall not be used in parts that come into contact with fuel. Cadmium plating used in the fuel system shall be class 2, type II of QQ-P-416.

3.2.4 Protective treatment. When materials are used that are subject to deterioration when exposed to climatic and environmental conditions likely to occur during storage or service usage, they shall be protected against such deterioration in a manner that will in no way prevent compliance with the performance requirements of this specification. The use of any protective coating that will chip, crack, abrade, peel, or scale with usage, age, or extremes of climatic and environmental conditions is prohibited.

* 3.3 Reliability. The reliability program for the fuel system, fuel subsystems, and components shall be integrated with the overall aircraft system reliability program.

* 3.4 Maintainability. The maintainability program for the fuel system, fuel subsystems, and components shall be integrated with the overall aircraft system maintainability program and shall comply with the requirements of MIL-STD-470. All aircraft fuel system components shall be accessible for inspection, cleaning, and adjustment or replacement while installed on the aircraft, with tools normally found in a mechanic's tool kit and without removal of the engine, fuel tanks, or important parts of the aircraft structure.

* 3.5 Design and construction. The fuel system and all of its subsystems and components shall be designed in accordance with the requirements of this specification and those dictated by the operational environment and mission of the weapon system as described in the aircraft system specification. The fuel system shall be designed to supply fuel to the engine(s) on an uninterrupted basis and shall function satisfactorily under all possible design operating conditions for the aircraft. The system shall in no way limit aircraft performance within allowable engine and aircraft operating limits. Maximum use shall be made of existing standard hardware to minimize development and testing costs.

* 3.5.1 Approval of design and development. As the development of the overall aircraft system progresses, procuring activity engineering approval of the contractor efforts shall be obtained for each document that controls the design and development of the fuel system, and for each document that substantiates

performance of the fuel system, its subsystems, and critical components. Procuring activity approval of the installed fuel system shall be obtained before acceptance of production aircraft. Adequate documentation to define and control the development of the fuel system shall be prepared and submitted as specified in the data requirements of the contract. As a guide for the type of information desired, see the appendix to this specification.

3.5.2 Failure concept. A single failure of a functional component of the fuel system or any other subsystem supplying power to the fuel system shall not prevent the completion of the mission. After two failures of the fuel system or other subsystem supplying power to the fuel system, the fuel system shall have the capability for recovery of the aircraft.

3.5.2.1 Failure analysis. A complete fuel system failure analysis shall be conducted and a report prepared. The analysis shall encompass any component or system failure that has any effect on the fuel system and any fuel component or system failure that affects any other aircraft component or system. The study shall not be limited to single failures but should account for multiple failures in critical flight modes and during emergency conditions.

3.5.3 General overall fuel system. The fuel system shall be designed for maximum simplicity consistent with weapon system requirements. The same piping and components may be used in more than one fuel subsystem but not when simultaneous operation of two subsystems will occur. There shall be no external leakage from the fuel system nor shall there be any leakage in the "mated" condition during aerial or ground refueling. All fuel lines shall have thermal relief provisions.

3.5.3.1 Fuel. The fuel system shall be suitable for use of any fuel specified in the engine or aircraft specifications. Degradation of performance or any special maintenance activity caused by the use of an alternate or emergency fuel shall be identified by the contractor.

3.5.3.2 Environmental

3.5.3.2.1 Temperature environment. The fuel system shall be designed to operate throughout the temperature range shown in table I.

3.5.3.2.2 Icing. The fuel system shall be so designed that icing will not adversely affect system operation. Safety of flight of the aircraft shall not be jeopardized when operating with 0.75 cubic centimeter of free water per gallon of fuel in excess of saturation at 80°F at the critical icing temperature. The fuel system shall be capable of continuous operation with fuel initially saturated with water at 80°F and cooled to any temperature down to and including -65°F. The system shall perform satisfactorily under these conditions with fuel containing no anti-icing additive and without draining or cleaning the system.

* TABLE I. Temperature Environment

	Fuel Temperature		Ambient Air Temperature	
	Low Temp	High Temp	Low Temp	High Temp
Class I Fuel system which is not affected by fuel heating 1/	-65°F 2/	+135°F	-65°F operating -80°F non-operating	+160°F
Class II Fuel system with aerodynamic heating or when fuel is used as a heat sink	-65°F 2/	Max fuel temp as determined by engineering design analysis (item 20.2a(2) of appendix)	-65°F operating -80°F non-operating	Max ambient temp as determined by engineering design analysis (item 20.2a(2) of appendix)

1/ Due to location in hot compartments, the temperature requirement for some components in a class I fuel system may exceed the temperatures specified. These components shall be identified and the maximum temperature specified.

2/ For fuels other than JP-4, the freezing point of the fuel should be used if higher than -65°F.

* 3.5.3.3 Pressure. The fuel system and its components, excluding the vent and the refueling subsystems, shall be designed for an operating pressure of 60 pounds per square inch gage (psig); a proof pressure of 120 psig without malfunction, failure, permanent distortion, or external leakage; and an ultimate pressure of 180 psig without external leakage. The components are not required to operate when subjected to ultimate pressure; however, they shall function properly when the pressure is reduced to the proof pressure. The vent subsystem shall be designed for an operating pressure commensurate with the tank design (see 3.7.1.1). The proof and ultimate pressure of the vent subsystem shall be two and three times the operating pressure respectively. The refueling subsystem shall be designed for an operating pressure of 120 psig, a proof pressure of 180 psig, and and an ultimate pressure of 240 psig.

* 3.5.3.4 Components. Components shall comply with the applicable military specification. Fuel system components not covered by specific Government specifications shall conform to the applicable parts of MIL-F-8615. Specifications shall be prepared by the contractor in accordance with the appendix of MIL-F-8615 for all fuel system components except standard hardware such as bolts, O-rings, etc. Whenever possible, components that are used in other weapon systems shall be utilized even though bracketry to adapt these components may be required. Components of modular or "plug-in" construction shall be considered for each subsystem to minimize draining fuel, entering fuel tanks, and disrupting line and manifold connections during replacement. Fixed housings which become life-of-aircraft parts shall not contain moving parts other than those functioning as secondary sealing or line shutoff mechanisms to permit line replaceable unit (LRU) replacement. Separate specifications shall be prepared for each LRU and fixed housing. Attaching parts and fittings shall not be considered or procured as parts of component assemblies. Power and control devices shall be designed to permit use of a common unit in all variations of similar equipment. All provisions of component military specifications, unless specifically prohibited by system design, shall be incorporated. Provisions not required by system design but not prohibited shall not be omitted unless severe weight or cost penalties would be incurred. Component electrical leads shall terminate prior to routing through conduits or wiring ducts. Each LRU and fixed housing shall be provided with individual nameplate identification and serialization. Previously qualified components shall be considered for use.

* 3.5.3.5 Center-of-gravity control. Normal sequencing of the fuel tanks shall be sufficient for maintaining the center of gravity of the fuel system from full to empty with all required payloads and flight speeds. It shall not be necessary to transfer fuel between tanks for the sole purpose of maintaining the center of gravity of the aircraft. Maintenance of a high minimum fuel load in order to effect a safe landing shall not be necessary. Manual controls shall be provided as a backup in the event of failure of the automatic controls.

3.5.3.6 Interchangeability. All parts having the same manufacturer's part number shall be functionally and dimensionally interchangeable in accordance with MIL-I-8500. The item identification and part number requirements of MIL-STD-100 shall govern the manufacturer's part numbers and changes thereto.

* 3.5.3.7 Installation

* 3.5.3.7.1 Plumbing. The prime airframe manufacturer shall prepare a plumbing document covering the installation of the fuel system plumbing. The document shall show the installation criteria for the fuel system plumbing when integrated with the airframe and shall include the following areas:

a. The philosophy for the plumbing installation such as desired location for lines; the design goals for minimum clearance between fuel lines and structure, other subsystem plumbing, and wiring; and criteria for alignment of tubing

b. Illustration of fuel lines in relation to the fuel tanks, structure, other subsystem plumbing, and wiring

c. Illustration and description of each type clamp and illustration of typical installation for each type clamp

d. Inspection criteria for the total plumbing installation

e. Notation of and special inspection procedures for areas where the minimum design clearance was not obtained

f. Design criteria for determining tube wall thicknesses

g. Illustration and description of each type of tube connection

h. Test requirements for the fuel system plumbing and components.

Where a propulsion area plumbing document is prepared in accordance with MIL-I-83294, the fuel system requirements may be incorporated in the propulsion document.

* 3.5.3.7.1.1 Fuel line support and routing. Fuel lines shall be supported in accordance with table II. Fuel lines shall be supported so that the lines will not deflect out of position as a result of internal pressure or aircraft maneuvers. Sufficient clearance shall be provided around fuel lines to prevent chafing of the lines with the aircraft structure or other lines and components. Unlined metal support clamps shall not be used on metal fuel lines. All fuel lines shall be routed in the most efficient manner to obtain maximum protection against battle damage. Where possible, fuel lines shall be routed through the fuel tanks to minimize fuel losses and fire resulting from combat damage or fitting failure. Access for maintenance and inspection of line joints of the fuel system shall be provided. Fuel lines which may be subjected to damage due to maintenance, cargo handling, personnel traffic, or normal aircraft use shall be protected.

TABLE II. Fuel Line Support Distance

Tube Size (Inches)	Maximum Distance Between Supports (Inches)
1 and smaller	24
1-1/4 to 1-3/4	27
2	31
2-1/2	33
3	34-1/2
4	37-1/2
5 and over	40

* 3.5.3.7.1.2 Metal tubing. Metal tubing for fuel lines shall be fabricated from either stainless steel in accordance with MIL-T-8606 or aluminum alloy in accordance with WW-T-700. Aluminum alloy tubing shall be treated in accordance with MIL-F-7179. Welded tees and wyes should be avoided in the fuel system; however, if welded tees and wyes are employed, extreme caution shall be used to obtain satisfactory welds. The welded tees and wyes shall not support any external weight or equipment items unless specifically designed for this purpose. Metal tubing shall be restricted to the following diameters: 1/4, 3/8, 1/2, 5/8, 3/4, 1, 1-1/4, 1-1/2, 1-3/4, 2, 2-1/2, 3, 4, 5, 6, and 7 inches. Minimum bend radii for metal tubing shall comply with MS33611. Forcing, bending, or stretching of metal tubing to accomplish installation shall not be permitted.

* 3.5.3.7.1.2.1 Tubing wall thickness. The fuel line tubing shall have a nominal wall thickness which takes into account the tube material tolerance, wall reduction due to bending, reduced strength due to increased temperature, improper welds, improper heat treat or corrosion, notch effect due to scratches, the location and function of the line, and an appropriate safety factor. In no case shall nominal wall thickness be less than .028 inch for alumimum tubing nor .020 inch for stainless steel tubing.

* 3.5.3.7.1.3 Hose assemblies. Hose assemblies shall be in accordance with MIL-H-8795 or MIL-H-25579. Hose shall be installed with a bend radius not less than the minimum radius specified in the applicable military specification. Flexible hose shall not be stretched or twisted during installation.

* 3.5.3.7.1.4 Fire hazard reduction. Fuel and vent lines shall be so routed that a single failure in the line or a single failure in another subsystem will not cause a fuel fire. Sources of fuel leakage such as joint couplings shall not be located in the vicinity of materials or conditions that will permit ignition of fuel. Airframe fuel lines and fittings in the powerplant compartment shall be fire resistant. Fuel lines shall not be routed through any nacelle or powerplant compartment except the one they feed. Fuel lines shall not be routed through personnel or cargo compartments; however, in some instances an occupied portion of the aircraft is the only space available for routing of an aerial refueling line or a ferry tank fuel line. In this case the joints in the fuel line shall be held to a minimum, and the joints shall be shrouded and drained.

* 3.5.3.7.1.5 Self-sealing fuel line covers. All pressurized fuel lines which are exterior of the fuel tanks and are 1-1/4 inch diameter and larger shall be protected by self-sealing fuel line covers conforming to MIL-C-83291 when such lines would be exposed to enemy ground fire.

* 3.5.3.7.2 Fuel fittings. All fuel system tubes, hoses, or wires which pass through a firewall shall be liquidtight and vaportight. V-band-type connectors shall not be used on fuel lines which are pressurized. Self-sealing-type, quick-disconnect couplings used in the fuel system shall be in accordance with MIL-C-7413. Flexible couplings used in the fuel system shall be in accordance with MIL-C-22263. Tubing ends or fitting ends in accordance with MS33583, MS33584, or MS33514 shall be used with MS standard tube fittings in solid connections.

3.5.3.7.3 Bonding. The aircraft fuel system shall be electrically bonded in accordance with MIL-B-5087.

* 3.5.3.7.4 Fuel drains. Adequate drainage provisions shall be incorporated to remove all normal and accidental fuel leakage to a safe location outside of the aircraft. Sufficient drains shall be incorporated so that all low points of the fuel system can be drained. Fuel drains shall be so installed that no drainage will come in contact with the engine exhaust gas wake or wheel brakes or re-enter the aircraft under any operating condition. Drainage which impinges on the aircraft shall not re-enter the aircraft and cause an unsafe condition. Fuel drains shall not be interconnected with component seal drains, or with drain lines for electrical accessories which drain oil, hydraulic fluid, water-alcohol, etc. Drain lines for each type of fluid may be joined at the overboard point provided it can be shown that there will be no feedback from one to another. Drain lines shall not be used for electrical wiring conduit. All nacelles, bladder tank cavities, dry bays, and sheet metal pockets and traps where fuel may collect shall be drained to the exterior of the aircraft by a sufficient number of 3/8-inch minimum diameter tubing or drain holes, except where larger drains are specified (see 3.7.1.9.3). Drain valves shall be in accordance with MIL-V-25023.

* 3.5.3.7.5 Identification of fuel lines. All fuel system lines shall be identified in accordance with MIL-STD-1247. Markings used on fuel lines inside of tanks shall not chip, crack, peel, abrade, or fade.

3.5.3.7.6 Pipe threads. Tapered pipe threads shall not be used in the fuel system except for permanent closures.

* 3.5.3.7.7 Fault isolation. Components whose functionability is not determinable during normal operation and servicing shall be provided with means for periodic assurance of proper functioning. Components operating in unison through a common control switch shall be provided with means for ground testing to insure proper operation of each component. Components whose proper positioning is critical to safety of flight shall have provisions for position indication. This indication shall be based on physical location of the part whose actual position is controlled rather than relative position of the control unit or application of motive power.

* 3.5.3.8 Electrical equipment. All electrical equipment associated with the fuel system shall be in accordance with MIL-E-25499 and MIL-E-7080 except that connectors shall be in accordance with MIL-C-81511. Where possible, electrical equipment shall be isolated from the fuel to minimize the possibility of fuel leakage and fuel vapor coming into contact with electrical equipment. Wiring shall be in accordance with MIL-W-5088. All electrical equipment shall meet the interference requirements of MIL-STD-461 and shall operate on power in accordance with MIL-STD-704.

* 3.5.3.9 Lightning hazards. The fuel system shall be designed in accordance with FAA Circular 20-53 to prevent fire and explosion when the aircraft encounters direct lightning strikes or conditions of crossfield streamering.

* 3.5.3.10 Cockpit fuel controls. The cockpit fuel controls for the fuel system shall be grouped in a functional manner. A simplified fuel system diagram shall be inscribed on the panel. In this diagram the fuel tanks shall be represented by appropriate symbols, or by the fuel quantity indicators if the panel is located in a position providing adequate view by the operator. The flow control valves shall be represented by their respective control switches. The switches shall clearly indicate the ability of the fuel to either flow through the valve or be stopped by the valve. Critical switches shall incorporate safety guards. Multiposition switches with possible dead spots during switch function change shall not be used on circuits which are required to be continuously energized during the function change. Switches which are in close proximity to each other shall be shape coded.

* 3.6 Engine feed and transfer subsystem. Fuel shall be available to the engines on an uninterrupted basis under all aircraft ground and flight conditions without continuous crew attention. The immediate attention or action

of the pilot (or flight engineer) shall not be required under any condition, including failure. On aircraft normally operated by a single pilot, the engine feed and transfer subsystem shall be completely automatic so that after the system is activated all the fuel aboard the aircraft will be supplied to the engine without further action by the pilot. The engine feed and transfer subsystem shall provide two independent and isolated methods of moving fuel out of each tank on the aircraft except for jettisonable external tanks where only one method is required. Each method of moving the fuel shall meet the flow requirements for the particular tank for all altitudes, attitudes, and maneuvers. If gravity flow will meet all the flow requirements of a tank, then only the gravity flow method will be required.

* 3.6.1 Engine feed. A normally separate independent (main tank and) feed system shall be provided for each engine. On multiengine aircraft, the independent systems shall be interconnected so that fuel may be delivered from any tank to any or all engines. It shall be possible to cut off fuel flow to any engine or combination of engines without adversely affecting the fuel flow to the remaining engine(s). During operation, the fuel feed system shall provide satisfactory performance for all normal maneuvers up to the aircraft service ceiling, with each engine operating from its normal fuel supply and with fuel in each tank at an initial temperature of 110°F or the maximum fuel design temperature. This same performance shall apply in system design where fuel is supplied from a transfer tank directly to the engine through an interconnect manifold by an override-type pump system. The main tank for each engine shall provide sufficient fuel to meet the low fuel warning requirements of 3.6.3.

* 3.6.1.1 Normal operation. The condition of the fuel, with regard to pressures, temperature, and all parameters which may affect engine operation, shall satisfy the conditions listed in the engine detail specification and MIL-E-5007.

* 3.6.1.2 Gravity feed. The engine feed system shall be designed to consume all of the available fuel in the main tank(s) (see 6.2.1) by gravity feed. The vapor liquid (V/L) ratio of the fuel at the inlet to the engine connection shall not exceed the V/L ratio specified for the engine by MIL-E-5007 at altitudes up to 10,000 feet with any fuel flow up to maximum rated power, with the airframe fuel filter in the bypass or impending bypass condition, and with the fuel at 110°F or the maximum fuel design temperature, whichever is higher.

* 3.6.2 Fuel transfer. Where fuel is transferred to a main tank(s) from internal transfer tanks, the rate of fuel transfer to any single main tank shall be not less than the maximum rate of fuel consumption of the engine in the military power condition. Transfer pumps shall be shut off automatically when the tank is empty on aircraft where the controls are not located on the flight engineer's panel. Fuel from jettisonable external tanks with a capacity less than 1,000 gallons shall be transferred by pressurization of the tanks. For unjettisonable external tanks and jettisonable external tanks with a capacity greater than 1,000 gallons, the transfer requirements of 3.6 shall be met.

* 3.6.3 Low fuel warning. A low fuel warning independent of the fuel gaging system shall be provided in each main tank. The low fuel warning shall indicate 20 minutes of fuel remaining at maximum range cruise power and altitude plus fuel for a normal descent and landing plus one missed approach.

* 3.6.4 Unavailable fuel. Unavailable fuel shall be held to a minimum consistent with sump capacity requirements. Tank outlets and boost pumps shall be so located that maximum main tank fuel is usable in landing approach and maximum auxiliary tank fuel is usable during level flight. Ejectors may be utilized to reduce the amount of unavailable fuel.

* 3.6.5 Feed and transfer surge requirement. Surge pressure shall not exceed 120 psig as a result of initiating or stopping intertank transfer or as a result of decreasing power settings of the engine(s).

3.6.6 Feed and transfer subsystem components

* 3.6.6.1 Fuel boost pumps. Boost pumps shall conform to MIL-P-5238. The boost pumps installed in fuel tanks of 1,000 gallons or greater capacity shall be removable without draining the tank. For pumps with three-phase, alternating-current motors which are installed for two-phase operation, the two-phase operation shall be defined in the pump specification approved by the procuring activity. Neutral connection for three-phase pump motors shall be grounded. Where more than one pump is installed in the same tank or adjacent tanks, the pumps shall be so designed that a common unit can be used in the various applications. Boost pump leads shall have a disconnect for ease of removal.

* 3.6.6.2 Fuel pressure switches and indicators. Each engine feedline shall contain a fuel pressure switch. Fuel pressure switches shall conform to MIL-S-26390. Low fuel pressure warning lights shall be installed in the cockpit. Sufficient additional pressure indicators shall be incorporated to determine proper operation of the feed and transfer subsystem.

* 3.6.6.3 Airframe fuel strainers. Only the necessary strainers or filters shall be incorporated in the airframe fuel system to ensure that the particle size of contaminants delivered to the engine is no larger than specified in MIL-E-5007. Airframe fuel strainers shall be in accordance with MIL-S-8710. All fuel strainers shall be readily accessible, properly mounted by means of the mounting lugs provided, and shall have sufficient clearance to permit easy removal of the cover and element. The filter or strainer shall be installed so that the element can be replaced without draining the fuel from the system. Fuel loss equal to the amount of fuel in the assembly is acceptable.

* 3.6.6.4 Fuel shutoff valves. Electrically operated shutoff valves shall be in accordance with MIL-V-8608. The powerline for each engine shutoff valve shall be connected to the power supply with a minimum of electrical components such as plugs and relays in the circuit. The engine shutoff valves shall not

be operated by switches mounted on the throttle quadrant. Cockpit indicating lights shall be provided for electrically operated engine fuel shutoff valves. These lights shall illuminate when the valve is in transition, a fault exists in the valve circuitry, or the valve limit switch fails to operate. Valves shall maintain mechanical stability while in selected position during all aircraft maneuvers to prevent nuisance illumination/flickering of lights. Mechanically operated shutoff valves shall conform to the mechanical requirements of MIL-V-8608. Any linkage for a mechanical valve shall be subjected to the environmental and endurance tests with the valve unless the linkage is qualified by separate tests. Solenoid valves shall meet the requirements of MIL-V-8610 for a continuous-duty solenoid.

* 3.6.6.4.1 Fire shutoff valves. Special consideration shall be given to the location of the fire shutoff valves. For a pylon-mounted engine, the fire shutoff valve shall be mounted on the upper end of the pylon. For a fuselage-mounted engine, the fire shutoff valve shall be mounted as near as possible to the engine compartment, but not in the compartment. Some installations may require both a tank shutoff valve and a fire shutoff valve to minimize the quantity of fuel which can drain into the engine compartment after the valve is closed and to minimize the length of unprotected line which can drain the tank if the line is broken.

* 3.7 Aircraft fuel tank subsystem. All fuel tanks shall be completely drainable while the aircraft is at ground attitude. The type of tankage shall be selected from table III after careful consideration of the aircraft mission relative to reliability, maintainability, passive defense features, and crash safety aspects. The contractor shall identify each tank and the cells of each tank in the description of the tank subsystem. The identification of each tank is necessary for the evaluation of the vent, refueling, defueling, and pumping requirements assessed against each tank. Ample clearance shall be provided to enable the removal of tank bladder cells, external tanks, internal tank components, tank access doors, tank inspection plates, and tank sumps without removing major structural components, engines, or engine accessories except cowling or airframe access panels. It shall be possible to install and remove the fuel cells individually without interference with other cells, preferably through a nonstressed panel without requiring jacks or other structural jigs.

* 3.7.1 Internal tanks

* 3.7.1.1 Tank design and construction. Tank design and construction shall be in accordance with the applicable specification of table III. The construction of the internal structure within the tank, such as baffles, flapper valves, and vent lines, shall be as simple and reliable as possible. The very minimum of such internal devices shall be used to comply with the fuel system performance requirements. The number of tanks and the number of fittings required per tank shall be held to a minimum. The fittings shall be located above the fuel level

* TABLE III. Selection of Propulsion Fluid Tanks for Aircraft

Type of Tankage	Design Criteria Document	Applications and Restrictions
Conventional Bladder Cells	MIL-T-6396	Select conventional bladder cells for applications where protection against small arms or maximum crash resistance is not the primary objective and where fuel temperatures do not exceed 135°F or cell wall temperatures do not exceed 165°F.
Self-Sealing	MIL-T-5578	Utilize self-sealing tanks where protection against gunfire up to 20 mm is a requirement.
Nonintegral, Internal Nonflexible Tanks	MIL-T-6396	Use for special applications subject to approval of the procuring activity.
Crash-Resistant Tanks	MIL-T-27422	Utilize crash-resistant tanks for fuselage and wing tanks when primary mission of aircraft is personnel transport.
High Temperature Tanks	MIL-T-25783	Utilize high temperature tanks in high performance aircraft when fuel temperature exceeds 135°F or when cell wall temperatures exceed 165°F.
External Tanks	MIL-T-7378	Use for range extension or to meet ferry requirements.
Integral Tanks	Detailed requirements of Structural Work Statement	Before selecting integral tanks, consider carefully the problems of structural corrosion due to water collection and microorganism growth.

wherever possible without sacrificing performance. "O" rings or "mold-in-groove" seals shall be used for sealing openings. The contractor shall determine the maximum positive and negative pressure that each tank must withstand. In determining these pressures, all tank pressures which may result from pressures in the fuel feed and transfer, tank pressurization, explosion suppression, ground and aerial refueling, defueling, and fuel dump subsystems shall be considered along with tank pressures induced during all maneuvers and under all failure conditions. The tanks shall be designed for a proof pressure of 1.33 times the maximum pressure and an ultimate pressure of 1.5 times the proof pressure.

* 3.7.1.2 Expansion space. An expansion space to prevent tank overflow shall be provided in each fuel tank. The expansion space shall be equal to or greater than 3 percent of the total fuel volume of the tank with the aircraft in a normal ground attitude. Where two or more cells are interconnected to serve as a single tank, expansion space (see 6.2.11) may be provided for the cell cluster instead of for individual cells.

3.7.1.3 Sumps. Each fuel tank shall be provided with a sump (which shall be the lowest portion of the tank when the aircraft is at ground attitude) for the purpose of collecting sediment and water.

3.7.1.3.1 Sump capacity. The sump shall have a capacity equivalent to 0.0025 gallon per gallon (.25 percent) of tank volume to contain the water released from solution with the fuel in addition to that condensed in the fuel cells. The capacity of the sump shall be not less than 1 pint.

* 3.7.1.3.2 Sump drains. Sump drain valves shall be in accordance with MIL-V-25023. Drain bosses provided on booster pumps shall not be used as fuel tank sump drains. Operation of the drain shall remove all of the collected sediment and water with a minimum loss of fuel.

* 3.7.1.4 Access doors. Each cell shall be provided with an access door of such size that the entire interior of the tank can be inspected and cleaned. Bolts smaller than 1/4 inch in diameter shall not be used for access doors or for installing components on the tank.

* 3.7.1.5 Tank accessories. Tank accessories, such as pumps, sumps, gages, vent lines, and outlet lines, shall be mounted so that their load is carried by structure.

* 3.7.1.6 Filler openings. Filler openings shall be located to permit filling the tanks from outside the aircraft without overfilling into the expansion space. Special adapters such as neck extenders and funnels shall not be used.

Scupper drains shall be used as necessary to prevent spilled fuel from entering any portion of the aircraft or engine compartment. The filler openings shall not incorporate screens but may incorporate a guard to prevent damage to the aircraft by the refueling nozzle. Each filler opening shall have a filler cap in accordance with MIL-C-38373. The mounting of the cap adapter shall be capable of meeting the same lightning strike requirement as required for the filler cap. The tank capacity and type of fuel shall be stenciled adjacent to the filler opening in accordance with MIL-M-25047.

3.7.1.7 Tank identification. Removable tanks shall be marked for identification in accordance with the applicable specification of table III.

* 3.7.1.8 Fuel tank location and separation. Fuel tanks shall not be located over personnel compartments. Fuel tanks located adjacent to personnel, cargo, or engine compartments shall be separated from such compartments by a second liquidtight and vaportight barrier in addition to the barrier provided by the tank. Fuel tanks located over engine compartments or other fire zones shall be provided with a means to determine if the primary barrier (tank wall) has failed. This can be accomplished by providing an adequately vented and drained dry bay between the primary and secondary barrier. The drain outlet can be inspected for leakage which will indicate a failure of the primary barrier. Fuel tank access panels located in personnel or cargo compartments shall be separated from the fuel tank by a ventilated and drained dry bay. Fuel tanks shall not be located in personnel or cargo compartments on a permanent basis.

3.7.1.9 Fuel tank installation

* 3.7.1.9.1 Tank installation time. The time required to completely remove and install a flexible internal (self-sealing or non-self-sealing) fuel cell in an aircraft shall not exceed 10 manhours.

* 3.7.1.9.2 Thin-walled, rigid internal removable tanks. Thin-walled, rigid internal removable fuel tanks shall be supported in padded cradles or on padded supports suitable for distributing the forces into the tank structure. Brackets or lugs attached to the tank walls shall not be used for supporting the tank. Thin-walled metal tanks shall not be mounted rigidly to the aircraft. The padding shall consist of fuel- and oil-resistant material which will not absorb liquids. Felt-type padding shall not be used.

* 3.7.1.9.3 Self-sealing tanks. Metallic fuel lines shall not be installed in contact with the walls of a self-sealing tank. Aircraft structure surrounding or supporting self-sealing tanks shall be designed and constructed to withstand all flight conditions and forces produced by the passage of a projectile through the confined liquid. All external self-sealing surfaces of a flexible self-sealing tank shall be protected by backing board conforming to MIL-P-8045, or superior. The structure surrounding self-sealing tanks shall be liquidtight except for drains which shall be a minimum of 0.5 inch in diameter.

3.7.1.9.4 Bladder tanks. Non-self-sealing bladder tanks shall be installed in cavities free from sharp projections or abrasive surfaces. Cavities shall be free of all metal chips or other foreign material that might damage the bladder. The structure surrounding bladder tanks shall be liquidtight except for drains which shall be a minimum of 3/8 inch in diameter.

* 3.7.1.9.5 Integral tanks. The internal surfaces of integral fuel tanks shall be protected against corrosion. The tanks shall be fueltight. Sealing shall be in accordance with the approved contractor process specification.

3.7.2 External tanks

* 3.7.2.1 Construction. External fuel tanks shall be constructed in accordance with MIL-T-7378 and designed for simplicity, low cost, and ease of mass production. For jettisonable tanks, the vent valves, level control valves, and precheck controls shall be located in the aircraft, not in the tanks. See 3.6, 3.9, and 3.10 for transfer, vent, and fuel gaging requirements.

* 3.7.2.2 External tank installation. External fuel tanks shall be installed in accordance with MIL-T-7378. The tank installation shall provide for the following:

a. A mechanical and electrical release, when jettisoning is required

b. Approved environment-proof electrical connection

c. Approved self-sealing quick disconnects for fuel and air pressure lines

d. Hinged panels incorporating quick-release fasteners in the aircraft and pylon as necessary for tank installation and removal.

* 3.7.2.2.1 Ground clearance. Ground clearance shall be sufficient to prevent ground contact under any combination of the following static or dynamic ground conditions:

a. One or more flat tires

b. One or more shock absorbers flat

c. Pitching, caused by variations in smooth runway surface, amounting to 3 inches (6 inches for rough runway surface) between nose and main wheels or forward and aft main wheels

d. Rolling, caused by variations in smooth runway surface, amounting to 3 inches (6 inches for rough runway surface) between opposite main wheels or between main wheels and outriggers

e. Rotation of the aircraft about its center of gravity or about the main wheels to attain takeoff attitude.

3.7.2.2.2 Installation time. The time required to install the external tank shall not exceed 15 minutes.

* 3.7.2.3 Filler opening marking. The tank capacity and type of fuel shall be stenciled adjacent to each filler opening in accordance with MIL-M-25047.

* 3.8 Pressurization and explosion suppression subsystems

* 3.8.1 Pressurization. The pressurization subsystem shall provide an independent primary and secondary means of pressure relief to prevent overpressurization of the tank as a result of a pressure regulator failure in the full open position. The system shall provide for automatic venting to atmosphere whenever the pressurization source is inoperative or shut off. Wherever possible, the fuel tank pressurization system shall be independent of the cockpit air conditioning system. If a common line is installed, redundant means shall be installed to prevent fumes or fuel from entering the cockpit.

* 3.8.1.1 Temperature of pressurization air. The temperature of pressurization air entering a fuel tank shall not exceed the temperature limits of the components within the tank; however, in no case shall the temperature of pressurization air exceed 450°F.

* 3.8.2 Explosion suppression subsystem. All fuel tanks and vent systems, and dry bay areas in proximity to fuel lines and tanks of aircraft in which air-fuel vapors may be exposed to ignition sources (such as incendiary gunfire, missile fragments, hot engine fragments, high wall temperatures, etc) shall be so equipped that fires and explosions cannot occur in these areas. A study shall be conducted for all hazard areas to determine the most efficient method of eliminating the unsafe condition. When baffle material (reticulated polyurethane foam) or nitrogen inerting are used, the requirements of 3.8.2.1 or 3.8.2.2 shall be met. Other methods may be used with the approval of the procuring activity.

* 3.8.2.1 Baffle material. Baffle material used in the fuel system shall comply with MIL-B-83054 and shall be installed in accordance with the installation criteria provided by the procuring activity. The baffle material shall not degrade the performance of the fuel system beyond the limits specified in the fuel system detail specification. The fuel system shall meet all the performance requirements with or without the baffle material installed, excluding the explosion protection provided by the baffle material. It shall be possible to remove the baffle material from the tanks and operate the aircraft without removing or adding any other hardware. For example, bladder tanks shall be designed for sufficient support without the baffle material installed. Any

components fastened in the tank because of the baffle material shall be sufficiently tested to verify that these components can be retained if the baffle material is removed. For example, if vent guards are placed at vent openings to prevent the baffle material from getting into the vent openings, these guards shall be subjected to vibration tests without the baffle material in place. The baffle material shall be included in all simulator and ground and flight tests specified in 4.4 and 4.5. Testing of components shall be conducted in the most severe condition. For example, the baffle material acts as a slosh and vibration attenuator; therefore, slosh and vibration tests for components shall be conducted without the baffle material installed.

* 3.8.2.2 Nitrogen inerting system. The nitrogen inerting system shall be completely automatic and shall require no attention from the flight crew during flight except for the monitoring of high and low fuel tank pressure indicator lights. The system shall prevent explosions and fire by maintaining the oxygen concentration of the ullage space below the level of 10 percent. The nitrogen may also be made available for fire extinguishing in other areas of the aircraft.

3.8.2.2.1 Configuration. Fuel and vent systems shall be closed systems for nitrogen inerting. Dry bays need not be closed, but must be designed for minimum nitrogen usage.

* 3.8.2.2.2 Inerting gas. The nitrogen gas used for inerting shall be stored on board the aircraft in the liquid form and converted to gas as required. The liquid nitrogen shall comply with BB-N-411, type II, class 1, grade A or B.

* 3.8.2.2.2.1 Nitrogen storage. The liquid nitrogen shall be stored in lightweight dewars. The dewars and their holddown fixtures shall be capable of withstanding loadings as specified for miscellaneous equipment in MIL-A-8865. The dewar assembly shall include a pressure relief valve and a blowout disc. The heat transfer characteristics of the dewar shall be the minimum practicable without sacrificing necessary strength and rigidity. There shall be no leakage from the dewar. The dewar shall have a quantity and pressure readout capability.

* 3.8.2.2.3 Capacity. The capacity of the liquid nitrogen dewar shall be adequate to supply nitrogen gas for inerting for the duration of a mission or, if specified by the procuring activity, for two or more missions. A reserve shall be provided that will supply nitrogen gas for inerting an unattended aircraft for a minimum of 48 hours after completion of the missions without reservicing. Provisions for growth capability shall be incorporated as specified in the aircraft system specification.

* 3.8.2.2.4 Operation. Nitrogen gas shall dilute the oxygen content below 10 percent in all ullage and vent spaces and maintain a slight positive pressure at all times for all operating conditions to prevent the entrance of air. The nitrogen shall fill the volume as fuel is used by the aircraft.

* 3.8.2.2.4.1 Entrained air. The nitrogen inerting system shall remove oxygen from the air entrained in fuel to prevent the oxygen concentration from exceeding 10 percent during increases in altitude. This method shall not include the use of ground equipment.

* 3.8.2.2.4.2 Pressurization. Nitrogen gas shall pressurize the ullage and vent spaces during decreases in altitude to maintain a safe differential pressure between the tanks and ambient.

* 3.8.2.2.4.3 Ground. The nitrogen inerting system shall maintain inerted ullage and vents while no electrical power is applied to the aircraft and the aircraft is unattended.

* 3.8.2.2.4.4 Damage. The nitrogen inerting system shall maintain inert ullage and vent spaces with no electrical power applied for a minimum of 5 minutes with a 100 square inch hole in any one fuel tank.

* 3.8.2.2.4.5 Pressures. At no time shall the positive or negative pressures in the fuel tanks and vents exceed the design pressure limits of the aircraft regardless of the failure of any component. In the event that the supply of nitrogen is depleted or that a malfunction of pressurization occurs, the inerted areas shall vent to ambient.

* 3.8.2.2.5 Servicing. The system shall be serviced through a single-point, dry-break, quick-disconnect coupling. The coupling shall be for liquid nitrogen only, and it shall not be possible to connect any other liquid gas servicing coupling. The system shall be capable of receiving nitrogen at a minimum rate of 10 gallons per minute (gpm) at pressures from 40 to 150 psig. The servicing connection shall be accessible from the outside of the aircraft, and the instrumentation necessary for servicing (such as quantity and dewar pressure gages) shall be visible from the servicing coupling. A cover shall be provided to protect the coupling when not in use.

* 3.8.2.2.6 Nitrogen inerting system components. Components of the nitrogen inerting system shall comply with 3.5.3.4.

* 3.8.2.2.6.1 Vent valves. Vent valves shall control internal tank pressure within the limits of the aircraft.

* 3.8.2.2.6.2 Checkout panel. A panel shall be provided to test all phases of the inerting system for proper operation during preflight checkout. Indicator light(s) shall be provided on the panel to signal when the vent valves have allowed air to enter the system.

* 3.8.2.2.6.3 Gas analyzer. A means shall be provided as part of the aircraft to verify that the fluid serviced to the nitrogen inerting system is an inert gas.

* 3.8.2.2.6.4 Redundancy. Redundancy of components shall be incorporated as necessary to assure a fail-safe system.

* 3.9 Fuel vent subsystem. The vent subsystems shall prevent siphoning and spillage of fuel and protect the fuel tanks from destructive pressures. Fuel spillage through the vent line during any inflight maneuver shall not exceed 0.05 percent of the fuel from any one tank or 1 gallon, whichever is smaller. There shall be no leakage when the aircraft is parked, during engine runup, or during taxiing.

* 3.9.1 Vent line size. The vent line size shall be selected by the length of the vent line and the amount of air, vapor, or liquid that must be handled. The volume of air, vapor, or liquid that must be handled will depend on the fuel consumption of the engine, size of the fuel tank, pressure rating of the tank, rate of refueling, type of fuel being used, rate of climb, rate of dive, and service ceiling of the aircraft. The vent lines shall be of adequate size to prevent tank overpressurization in the event of a level control valve failure during ground and aerial refueling at maximum flow rate when each tank is filled individually. The minimum diameter of vent lines shall be 1/2 inch. (See 3.7.1.1.)

* 3.9.2 Vent outlet location. The tank vent outlet shall be located so that liquids and vapors emitted will not blow back into the aircraft or come in contact with the exhaust system, and foreign matter thrown up by the aircraft wheels will not enter or block the vent outlet. The outlet shall be located so that any moisture collecting in the line will drain to the outlet and prevent the entrance of water into the fuel system. The vent outlet location and configuration shall prevent the formation of ice which will block the outlet. Lightning hazards shall be considered in the vent outlet location (see 3.5.3.9).

* 3.9.3 Interconnected vents. Fuel shall not be transferred through one tank vent to another tank. Several fuel tank vents may be terminated at the same outlet location in the aircraft.

3.9.4 Vent pressures. For flexible nonmetallic and light-walled metallic fuel cells, the vent outlet terminal shall be such that the pressure in the vented space of the fuel tanks is never below ambient pressure. For bladder-type tanks, the cell cavity pressure shall never be greater than the pressure within the tank. Internal fuel tanks with structural metal walls may have negative pressure within the structural limits of the tanks.

3.9.4.1 Pressure checking. For aircraft where the vent system must be blocked during maintenance to pressure check the vent system or tanks, special aerospace ground equipment (AGE) shall be designed for plugging the vent lines. The AGE shall be so designed that it will not cause damage to the tanks in the event it is left in the vent system at the conclusion of the maintenance. The AGE shall have a streamer or marker to prevent leaving the AGE installed.

3.9.5 External tank vents

3.9.5.1 Vent installation. An approved fuel and pressure vent system with self-sealing quick disconnects shall be installed for all jettisonable fuel tanks. The tank shall be capable of automatic venting to atmosphere whenever the pressurizing source is shut off, and this venting equipment shall be provided in the aircraft, not in the tank.

* 3.10 Fuel quantity gaging subsystem. All of the internal and external fuel shall be gaged. The components of the fuel quantity gaging subsystem shall meet the requirements of MIL-G-26988. The gaging subsystem shall be installed in accordance with and satisfy the quality control requirements of MIL-G-7940.

* 3.10.1 Fuel quantity display. There shall be a continuous readout of total fuel quantity and the quantity of fuel in each main tank. Other tanks may be gaged by several indicators or by one indicator with a switching arrangement. Not more than 5 seconds shall be required to obtain a reading when using the switching arrangement.

* 3.10.1.1 Fuel center-of-gravity indicator. In any aircraft where fuel center of gravity is an important factor in stability, controllability, or maneuverability, a fuel center-of-gravity indicator shall be provided, or the fuel quantity gages shall be so constructed that the crew has a clear presentation of the fuel center of gravity. When fuel center of gravity must be monitored, there shall be a fuel distribution warning device which is independent of the fuel gaging system.

* 3.10.2 Contractor specification. The contractor shall prepare a performance specification. This specification shall clearly indicate the differences between it and MIL-G-26988 and MIL-G-7940. In no case shall a contractor specification be prepared wherein less stringent requirements are specified. The contractor specification must be approved by the procuring activity.

3.11 Ground refueling and defueling subsystem

* 3.11.1 Pressure refueling. All aircraft with an internal fuel capacity of 600 gallons or more shall incorporate a pressure refueling system. It shall be possible to refuel the aircraft including external tanks to capacity without the use of external power. The fuel servicing adapters shall conform to MIL-A-25896. The number of adapters shall be in accordance with table IV. It shall be possible to completely fill the aircraft from a single adapter. The refueling system shall have the capability to select any individual fuel tank for filling and conversely to avoid filling any tank. The engine and'engine feedlines shall not be subjected to the pressures imposed on the refueling manifold during refueling. No unusable fuel shall be trapped in the refueling system. All lines shall be scavenged or drained. There shall be no external leakage from the fuel system during or after refueling.

* 3.11.1.1 Adapter marking. The type of fuel and appropriate symbol shall be stenciled adjacent to the refueling adapter in accordance with MIL-M-25047.

* TABLE IV. Pressure Refueling Time

Total Aircraft Fuel Weight (Pounds)	Ground Refueling		Maximum Aerial Refueling Time 1/ (Minutes) (Time may be interpolated between divisions) 2/
	Maximum No. of Servicing Adapters	Maximum Time 1/ (Minutes) 2/	
450,000	4	40	50
350,000	4	32	40
250,000	2	32	30
100,000	2	20	15
50,000	1	18	10
25,000	1	8	7
10,000	1	5	4
3,900	1	2.25	2.25

1/ Based on refueling 90 percent total aircraft fuel (see 3.11.1.5c).
2/ Actual flow time.

* 3.11.1.2 Pressure refueling nozzle bonding. A receptacle shall be installed for bonding the fuel servicing nozzle to the aircraft. The receptacle shall be in accordance with MS33645 except that the receptacle shall be located:

a. Not more than 20 inches nor less than 5 inches from the pressure servicing adapters

b. Not closer than 12 inches from a fuel tank vent opening.

3.11.1.3 Adapter cap. Fuel servicing adapters shall be provided with MS29525 caps for flush-type installations or MS29526 caps for nonflush-type installations.

* 3.11.1.4 Adapter installation. The adapter shall be installed with the adapter face as nearly as possible in a vertical plane to accommodate an MS29520 ground servicing nozzle. The adapters shall be located on the aircraft so that the use of ground support elevating devices will not be required for connecting the nozzle. The installation shall provide ample clearance for

connection and operation of the nozzle by personnel wearing heavy gloves. Multiple adapters shall be spaced no closer than 10 inches from center-to-center There shall be no device installed on the adapter which will not completely clear the nozzle envelope as defined by MS29520 when the nozzle is connected and actuated.

* 3.11.1.5 Refueling and defueling lines. Fuel lines shall be sized so that all tanks theoretically reach the full position simultaneously when refueling. For aircraft incorporating both 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 schedules for pressure refueling as specified in table IV. The following criteria shall be used when designing to meet the refueling schedules of table IV:

a. It shall be assumed that the ground refueling system is capable of delivering 600 gpm for each servicing adapter at pressures of 50 psig measured at the gage point of the refueling nozzle. In addition, it shall be assumed that the ground refueling system will limit the steady-state pressure to a maximum pressure of 55 psig. For surge potential, the ground refueling system shall meet the requirements of MIL-T-83219.

b. It shall be assumed that the tanker for boom-type aerial refueling is capable of delivering 1,200 gpm at a pressure of 50 psig measured at the inlet to the boom nozzle. The probe drogue tanker refueling capability will be provided by the procuring activity in the procurement documentation.

c. 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 tank(s) at the start of the refueling operation.

* 3.11.1.6 Fuel level control valves. Fuel level control valves shall be in accordance with MIL-V-38003. The pilot control devices for the level control valves shall be level sensing and shall not be operated by sensing tank pressure or by a wetting action, such as thermistors. The valves shall prevent surge pressure in the refueling manifold from exceeding the proof pressure of the system. The valves shall be so located that during all normal ground refueling attitudes the fuel levels will not exceed the 3 percent normal expansion space allowance of the fuel tanks. When surge relief valves are either in refueling lines or integral with the valve design, the relief setting shall be of a value compatible with the aerial refueling tanker pressure versus flow curves such as depicted on figure 1. The level control valve sensing devices shall be suitably enclosed to prevent interference with the level control operation. A precheck system which will check the operation of the fuel level control valves in the initial portion of each ground refueling shall be provided as an integral part of the aircraft. The precheck system shall operate on the float principle. The precheck system shall permit isolation of a failed level control valve.

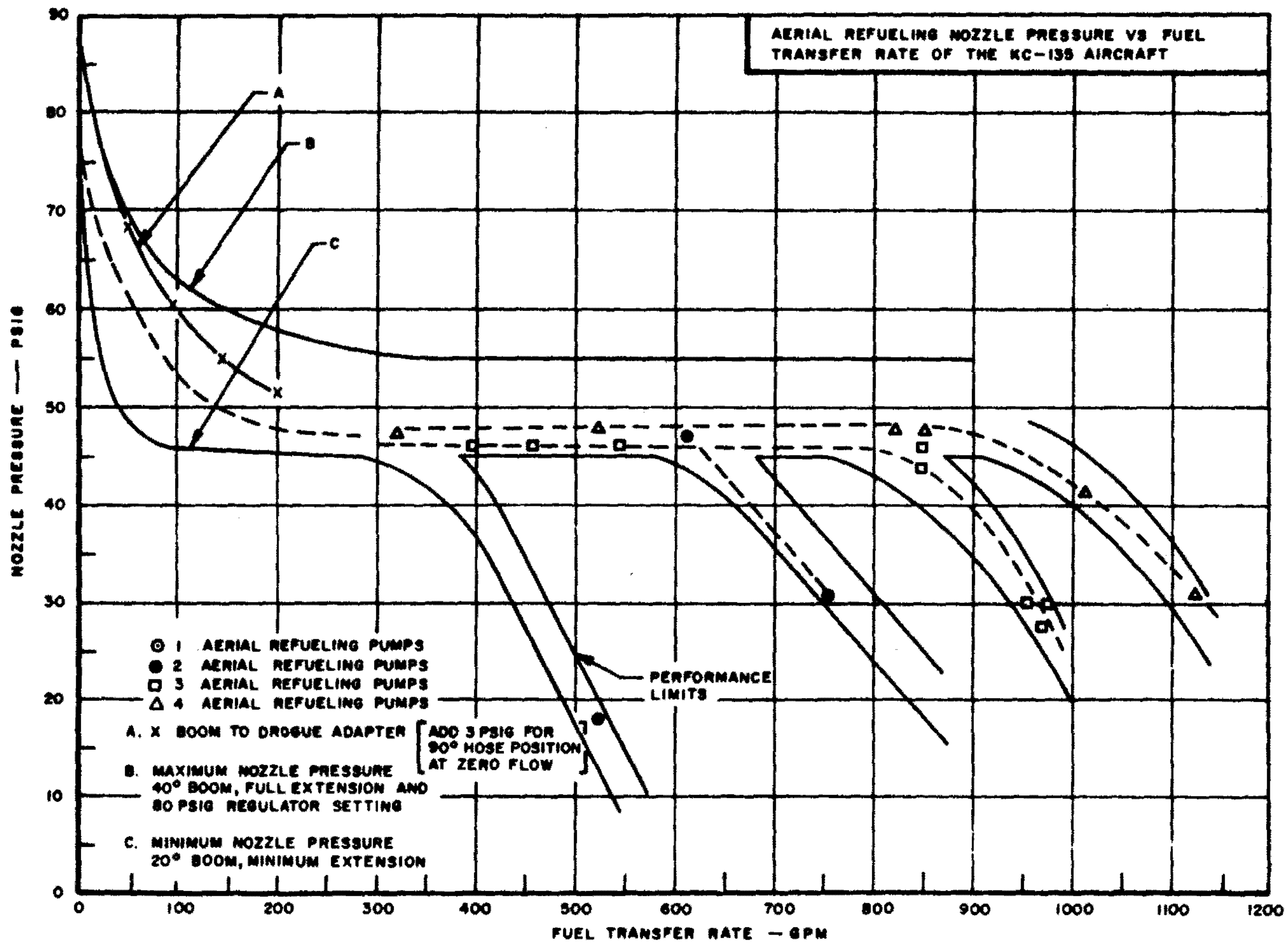


FIGURE 1. Flow Curves

3.11.1.7 Float switches. Float switches used in the system shall meet the requirements of MIL-S-25980.

* 3.11.2 Gravity refueling. It shall be possible to completely gravity refuel the aircraft without external power applied to the aircraft. Each aircraft tank shall be capable of accepting a continuous flow rate of 200 gpm, except during the tank topping portion of the refueling, without requiring any operation other than removing the filler cap and connecting the nozzle bonding plug. Tanks which can be refueled by draining from another tank or by overflow from an adjacent tank need not have a filler cap, provided that the emergency defueling requirements of 3.11.3 can be met. For aircraft with small tanks where the 200 gpm flow rate is not practical, it shall be possible to gravity refuel the aircraft in a maximum of 10 minutes from one refueling source using one hose.

* 3.11.2.1 Gravity refueling nozzle bonding. A receptacle shall be installed for bonding the gravity refueling nozzle to the aircraft. The receptacle shall be in accordance with MS33645 except that the receptacle shall be located:

a. Not more than 42 inches from the gravity filler opening

b. Not closer than 12 inches from fuel tank vent openings or gravity filler cap openings.

* 3.11.3 Ground defueling. It shall be possible to completely defuel the aircraft through a MIL-A-25896 adapter at a minimum rate of 200 gpm per adapter with a suction pressure at the adapter not in excess of 3 psi. When the defueling adapter is not also used for refueling, a positive means such as a check valve shall be used to prevent refueling through this adapter. The aircraft fuel boost pumps may be utilized for defueling. In the event of a wheels-up landing, it shall be possible to defuel the aircraft through the normal fuel servicing adapters or by suction through accessible openings in each tank.

* 3.12 Aerial refueling subsystem. The design information contained in the following subparagraphs is applicable for the design of production or retrofit receiver aerial refueling systems. The procuring activity shall be consulted when the design of tanker aerial refueling systems or provisions are being considered. All aircraft shall have aerial refueling capability installed or the space and structural provisions for aerial refueling. The space and structural provisions for the aerial refueling installation shall be in accordance with the requirements of this specification. Access and appropriate routing holes and support shall be provided for easy installation of all fuel, electrical, and hydraulic lines and control cables. This shall include the access holes for the fuel line routing from the fuel tank or single-point refueling line to the point of the aerial refueling installation.

* 3.12.1 Aerial refueling trade study. A trade study shall be conducted for aircraft with gross weights of 75,000 pounds and smaller for determining the

benefits of probe versus receptacle method of aerial refueling. The study will be based on the use of equipment meeting location, design, and test criteria specified herein. Nonretractable probes shall be included in this study. The following factors shall be considered in the trade studies and given equal ratings: (1) weight, (2) fuselage space, (3) cost, (4) development and test time, (5) drag, (6) reliability and maintainability, (7) safety, and (8) operational usage.

* 3.12.2 Aerial refueling time. The time required for aerial refueling shall be determined in accordance with 3.11.1.

* 3.12.3 Receptacle/slipway - flying boom

* 3.12.3.1 Location criteria

* 3.12.3.1.1 Receptacle/slipway position. The receptacle/slipway shall be located forward of the windshield on the centerline of the aircraft to provide an adequate view of the refueling operation by the pilot. The receptacle face shall be a minimum of 2 feet from the windshield. Components such as antennas, lights, etc, protruding above the skin line which would be subject to damage by the boom shall not be located in an area adjacent to the receptacle/slipway. This area is defined as: (1) an 8-foot-long by 5-foot-wide path forward and centered with the receptacle face, and (2) a 2-foot distance on each side and aft of the receptacle face.

* 3.12.3.1.2 Evaluation guidelines. The receptacle/slipway design and location shall be evaluated based on the criteria contained herein and those designated in chapter 5, DN5A3, sub-note 3.3(1) entitled "Receptacle Location Evaluation" of Handbook DH 2-1. The design and location shall be approved by the procuring activity prior to design freeze and installation.

* 3.12.3.1.3 Slipway visibility. The receptacle/slipway shall be located on the aircraft so that the boom operator can see a minimum of 35 percent of the slipway length and 100 percent of the width as specified in 3.12.3.3.2. For the calculation of the percent of visibility, the following formula shall be used:

$$\text{Percent visibility} = \text{SIN}\ (O_{BO} + O_F + O_S + O_P)\ 100$$

Where $O_{BO} = 24.6^\circ$ = Boom operator's line-of-sight angle

O_F = Fuselage slope angle

O_S = Slipway door angle

O_P = Fuselage pitch angle

This formula is based on a boom elevation of 30°, boom azimuth of 0°, and a tanker fuselage pitch angle of 0°. The boom operator's line-of-sight angle of 24.6° is based upon a 12-foot boom extension being required for a hookup. (See figure 2 for sample calculation.)

* 3.12.3.1.4 Boom envelope clearance. The receptacle/slipway shall be located on the receiver aircraft so there will be no contact between any portion of the receiver aircraft exclusive of the slipway (see 3.12.3.3.2) and the boom anywhere in the mechanical interference envelope of the boom as specified on figure 3. This envelope is approximated as follows: boom elevation 15° to 50°, azimuth ±30°, and extensions of 11 inches (measured from the 12 o'clock ice shield position) to 19 feet.

* 3.12.3.1.5 Telescoping tube and color coding. The receiver pilot shall be able to observe the tanker boom telescoping tube and color code within his normal peripheral vision without changing his normal tanker visual reference.

* 3.12.3.2 Installation requirements

* 3.12.3.2.1 Universal aerial refueling receptacle slipway installation (UARRSI). The receiver aircraft shall incorporate a universal aerial refueling receptacle slipway installation in accordance with figure 4. The UARRSI module shall have the following interfaces with the receiver aircraft:

a. Structural tiedown which can be rapidly disconnected in accordance with figure 4.

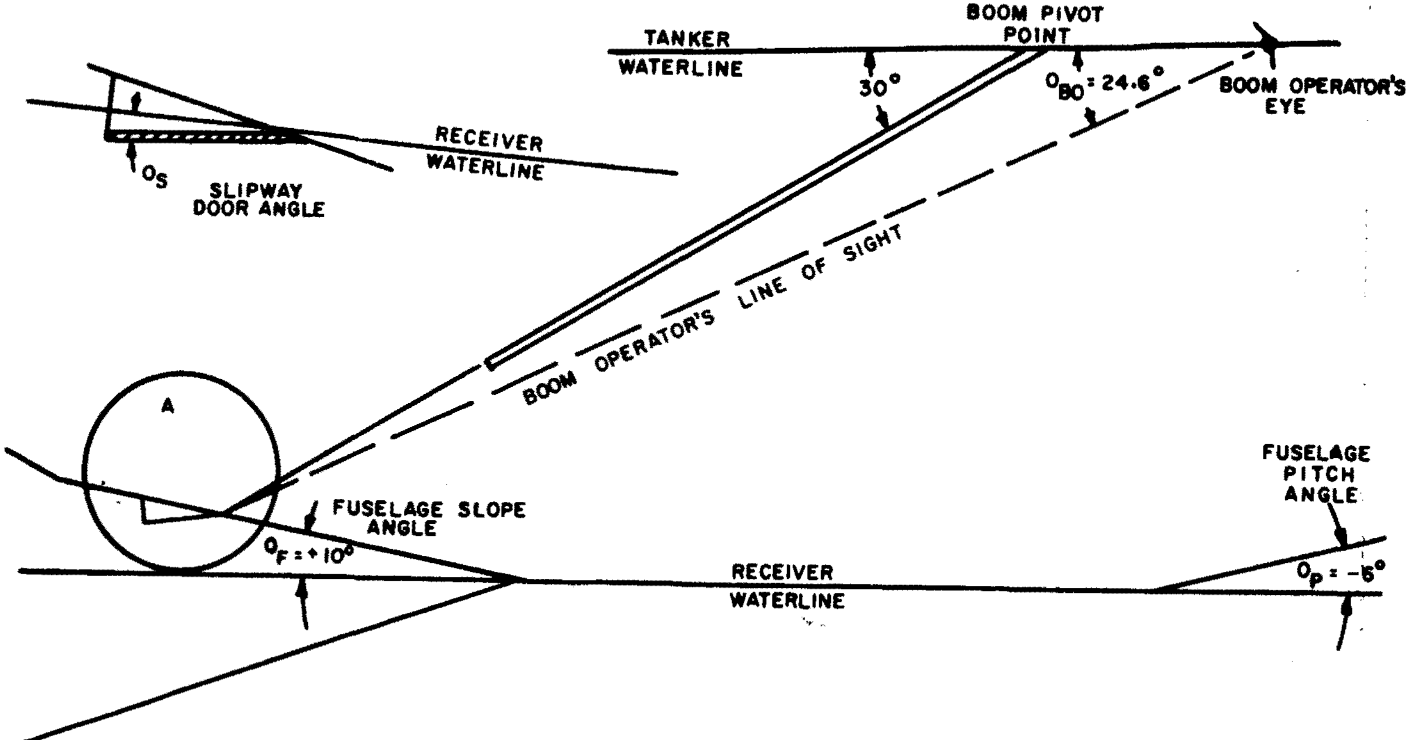
b. The UARRSI receptacle fuel hookup connection shall be in accordance with figure 4. The aircraft mating fuel end fitting shall be similar to that used on the MA-2 coupling conforming to MS24355.

c. Fuel drains shall be provided at the forward and aft ends of the module.

d. Two quick-disconnect hydraulic connectors conforming to MS24333-X-6 and MS24335 shall be located in accordance with figure 4. One connector shall be for a 3,000 psig inlet pressure and the other for a hydraulic return of 0 to 200 psig. The hydraulic system of the UARRSI shall be in accordance with figure 5.

e. One electrical connection in accordance with MIL-C-81511 (M81511/01FG-2P1) with a minimum of 27 pins shall be located in accordance with figure 4. The aircraft and UARRSI aerial refueling electrical system shall be in accordance with figure 6.

f. A quick-disconnect mechanical connection for the cable which operates the slipway door release shall also be located in accordance with figure 4.



% Visibility = $\sin(\theta_{BO} + \theta_F + \theta_S + \theta_P)\,100$

% Visibility = $\sin(24.6 + 10 - 3 - 6)\,100$

% Visibility = 43.3 %

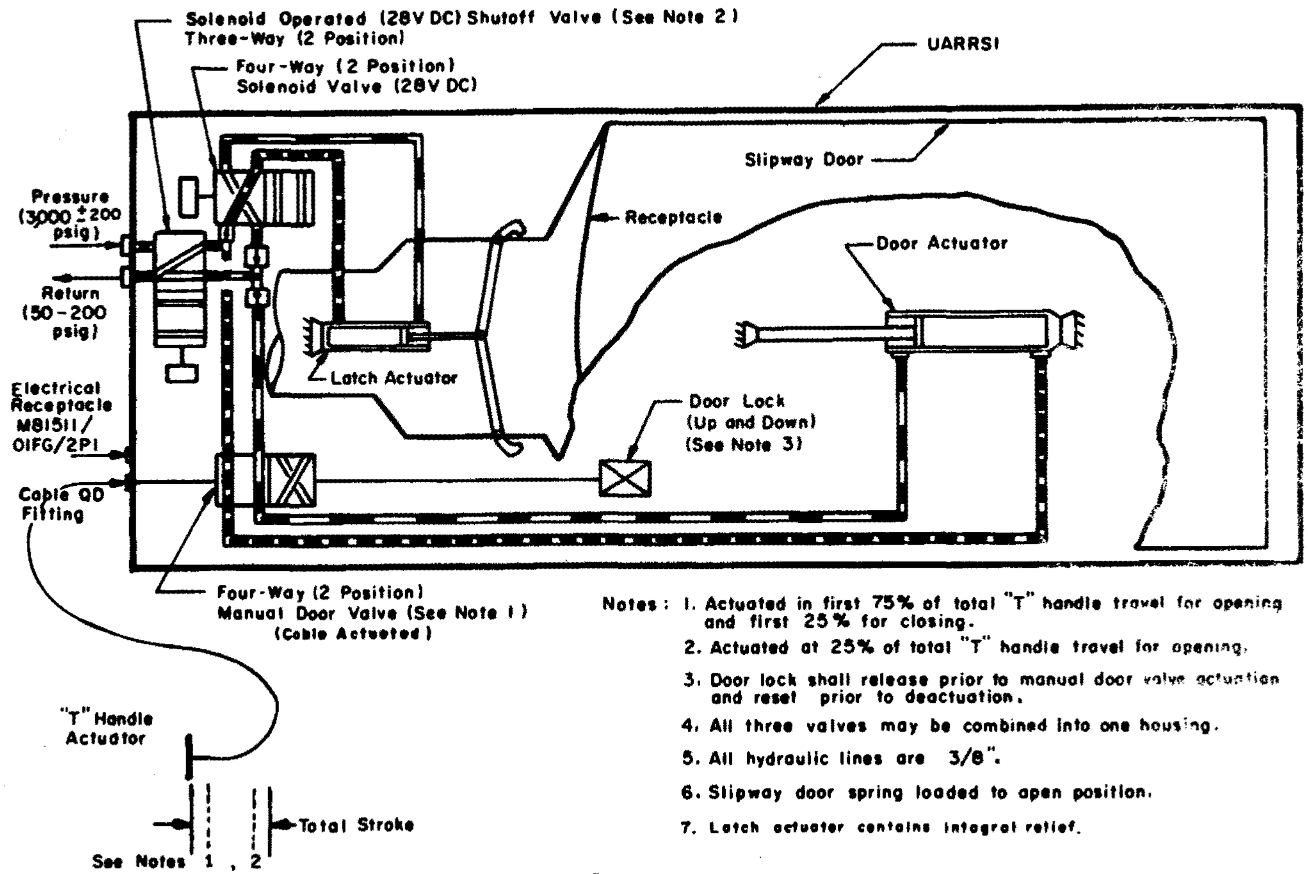
Given − θ_{BO} = 24.6°

Assume for receiver θ_F = 10°

θ_S = -3°

θ_P = -6°

* FIGURE 2. Sample Calculation for Percent of Visibility of Slipway Length



Notes:
1. Actuated in first 75% of total "T" handle travel for opening and first 25% for closing.
2. Actuated at 25% of total "T" handle travel for opening.
3. Door lock shall release prior to manual door valve actuation and reset prior to deactuation.
4. All three valves may be combined into one housing.
5. All hydraulic lines are 3/8".
6. Slipway door spring loaded to open position.
7. Latch actuator contains integral relief.

FIGURE 5. UARRSI Hydraulic System Schematic

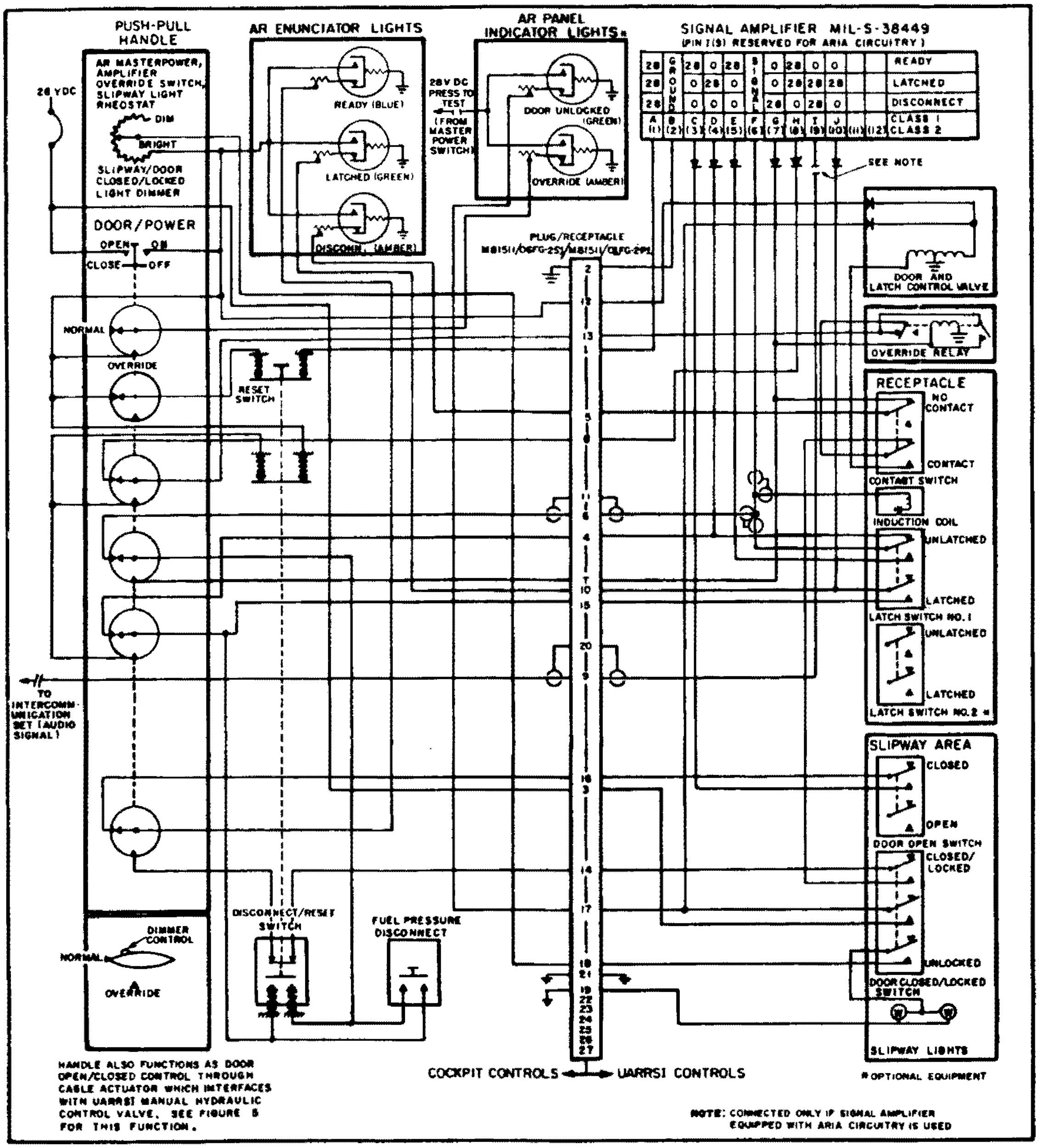


FIGURE 6. Aerial Refueling Electrical Schematic

g. The UARRSI module shall incorporate the following systems and components:

(1) Receptacle in accordance with 3.12.3.3.1

(2) Slipway in accordance with 3.12.3.3.2

(3) Lights in accordance with 3.12.3.3.3

(4) Signal amplifier in accordance with MIL-S-38449

(5) Hydraulic sequencing valve

(6) Override relay

(7) Hydraulic system (see figure 5)

(8) Electrical system (see figure 6)

* 3.12.3.2.2 Angle of receptacle installation. A composite layout shall be prepared to determine the angle at which the receptacle is to be inclined on the receiver aircraft by referencing all normal changes in the receiver fuselage pitch angle relative to the tanker centerline with refueling hardware in the mated configuration. With the smallest receiver fuselage pitch angle at the tanker boom's lower, outer limit (40° elevation, 551 inches extension) as one extreme and the largest receiver pitch angle at the tanker boom's upper, inner limit (20° elevation and 404 inches extension), the angle of installation shall be determined by the following equation:

$$X = 1/2\ (60^\circ - A - B)$$

Where A = minimum fuselage pitch angle during refueling
B = maximum fuselage pitch angle during refueling
X = angle of installation.

The receptacle installation angle as determined by the equation may be slightly adjusted to provide optimum clearance of the tanker boom nozzle with the aircraft structure surrounding the receptacle.

* 3.12.3.3 Aerial refueling components. All receptacle installations shall incorporate the following components and installation features. See figures 4, 5, and 6 for mechanical, hydraulic, and electrical interfaces of the aircraft and UARRSI.

* 3.12.3.3.1 Receptacle. The receptacle, including the induction coil and electrical harness and connector, toggle latches, nozzle contact and nozzle latch switches, latch actuator, sliding valve, hydraulic latch actuator, and

integral relief valve, shall be designed and tested in accordance with MIL-R-27521. The receptacle, mounting provision, and support structure in the aircraft shall be designed to accept the loads as specified in MIL-R-27521. The receptacle interface with the slipway shall be compatible with the universal boom nozzle conforming to MS27604. Discontinuities which will cause hangup of the boom nozzle on hookup or disconnect shall be avoided. The receptacle face shall have a one-piece, 0.062-inch thick, stainless steel scuff plate. The scuff plate shall have at least a 25 rms finish. The receptacle/slipway shall be hydraulically actuated with fail-open provisions for emergency refueling. The receptacle/slipway shall move from "closed to open" or "open to closed" within 5 to 20 seconds under all operating conditions except for the emergency extension mode which shall occur within a maximum of 30 seconds. (See figures 5 and 6.)

* 3.12.3.3.2 Slipway. A slipway shall be provided to assist the boom operator in inserting the boom. The slipway shall be a minimum of 18 inches long, and the sides of the slipway shall be smooth and high enough to guide the nozzle into the receptacle. The nozzle radius of 2-1/2 inches shall be used as a minimum depth for guiding the nozzle into the receptacle. The slipway shall be compatible with the universal boom nozzle, MS27604. Discontinuities in slipway surfaces shall be avoided. The slipway shall mate with the receptacle and provide smooth transition surfaces. The slipway door shall have a one-piece, 0.062-inch thick, stainless steel scuff plate. The scuff plate shall have at least a 25 rms finish. The slipway area shall clear the boom with the maximum receiver pitch angle by a minimum of 5° for any boom angle within the tanker boom automatic disconnect envelope. The slipway shall have a hydraulically operated door. The locking device for the door shall be operated by a direct mechanical connection which is controlled from the pilot's or flight engineer's position. Actuation of the mechanical connection shall also allow the door to go to the open position with a hydraulic power failure. Cockpit indication light shall be provided to show when the receptacle/slipway is opened and locked.

* 3.12.3.3.2.1 Load requirements. In addition to airloads and other loads normally imposed on the aircraft structure, the slipway and its drop doors shall be designed for impact loads imposed by contact with the boom nozzle. Ultimate design loads of 2,000 pounds laterally and 5,000 pounds vertically shall be used for the slipway door design. In addition to normal aerodynamic and inertia loads, the aircraft skin backup structure surrounding the receptacle/slipway shall also be designed for impact imposed by inadvertent contact with the boom nozzle. Ultimate design loads of 750 pounds laterally and 1,800 pounds vertically shall be used for the skin area 12 inches out from the perimeter of the receptacle face slipway installation. See figures 5 and 6.

* 3.12.3.3.3 Night refueling lights. The receptacle/slipway installation shall incorporate two flush lights, one on each side of the slipway, to illuminate the slipway and the receptacle face and bore for night refueling. The lights shall be directed toward the receptacle bore. Large light angles shall be avoided to prevent boom operator or receiver pilot blinding. The prism lens

feature may be utilized. The lights shall meet the requirements of MIL-L-6503, and it shall be possible to dim the lights from the cockpit from full bright to off. The light installation shall be explosionproof. With the lights operating at maximum temperature, the spilling of cold fuel on the lights shall not cause fracture of the lens or the bulb or induce any safety hazard. The aerial refueling lights shall be independent of the airframe exterior and interior lighting controls. (See figure 6.)

* 3.12.3.3.4 Indicator lights. Indicator lights shall be provided to inform the receiver aircraft pilot of the refueling condition. The lights shall read from top to bottom as follows:

Blue	"Ready" for contact	This light may also be used to indicate that the receptacle/slipway is locked in the open position. See 3.12.3.3.2.
Green	"Latched"	
Amber	"Disconnected"	
Green	"Door unlocked" (optional)	Optional aerial panel lights shall be located near the aerial refueling control panel.
Amber	"Override" (optional)	

The lights shall incorporate sunshields, transparent lenses with translucent centers, press-to-test switches, and a rheostat for each light. The lights shall be located where the receiver aircraft pilot and copilot may easily observe without changing their visual reference on the tanker. The lights shall be wired so that illumination occurs only upon termination of the function being indicated. The indicator lights shall meet the requirements of MIL-L-6503. (See figure 6.)

* 3.12.3.3.5 Amplifier, reset switch, and manual override switch

* 3.12.3.3.5.1 Signal amplifier. The signal amplifier used in the aerial refueling system shall be in accordance with MIL-S-38449. All wires connecting to the signal pin of the amplifier or to the receptacle induction coil shall be shielded. In the signal amplifier override mode of operation, the amplifier shall be isolated from the working circuitry with the exception of the induction coil signal lead "pin F" and ground "pin B." If isolation cannot be completely accomplished by manual switch actions, diodes shall be incorporated into the circuitry to isolate all amplifier circuits from external applied voltages. In all cases, pin "A" shall be disconnected in the override mode of operation. Diodes selected for this application shall be in accordance with MIL-STD-701, IN3885. (See figure 6.)

* 3.12.3.3.5.2 Reset switch. A reset switch shall be provided for returning the amplifier to the precontact position (ready for contact). The reset switch shall be integrated into the disconnect switch (see 3.12.3.3.6 and figure 6).

* 3.12.3.3.5.3 Manual override switch. A manual override switch shall be furnished for the signal amplifier to permit operation of the latches for connect and disconnect in the event of an amplifier failure. The override switch shall be located for easy operation by the receiver aircraft pilot without changing his visual tanker reference.

* 3.12.3.3.6 Disconnect switch. A disconnect switch shall be provided in the aircraft control stick grip for the pilot and copilot. If the copilot position is such that the refueling cannot be conducted from this position, the copilot disconnect switch will not be required. (See figure 6.)

3.12.3.3.7 Fuel pressure disconnect switch. A pressure switch shall be provided for initiating disconnects when manifold pressures indicate a full tank condition or that high level fuel valves have all closed. The switch shall be installed in the fuel line near the receptacle, and the settings shall be compatible with the high level control valve relief setting and the tanker pump static pressure; that is, a value which will not create inadvertent disconnects. (See figure 6.)

* 3.12.3.3.8 Slipway and receptacle drains. Slipway and receptacle drains shall be provided to prevent accumulation of fuel spillage or water in the UARRSI module. Overboard drains shall comply with 3.5.3.7.4.

* 3.12.3.3.9 Aerial refueling intercommunication. During radio silence, intercommunication between the tanker and receiver crews shall be provided after hookup is accomplished by using the boom and receptacle induction coils and the aircraft intercommunication system. The intercommunication device shall be compatible with the aerial refueling system signal amplifier (MIL-S-38449). (See figure 6.)

* 3.12.3.4 Reverse refueling. The procuring activity shall be consulted for the specific design requirements for aircraft which have a fuel capacity suitable for reverse refueling.

* 3.12.3.5 Receiver-tanker performance comparison. A performance comparison of aerial refueling speeds and altitude envelopes and pressure and flow envelopes of the tanker and receiver shall be required. The receiver shall be able to close on the tanker for refueling hookups in all refueling speed ranges without abrupt engine thrust changes as would be produced by an unmodulated afterburner.

* 3.12.4 UARRSI AGE. The following AGE is required in support of the UARRSI:

a. Tester in accordance with MIL-T-83323

b. Tester restraints and attach points

c. Slipway door safety restraints

d. Removal tool for receptacle sliding valve and pedestal.

* 3.12.5 Probe drogue refueling. The probe mast and actuating mechanism shall be designed and tested in accordance with MIL-F-8615. The probe mast shall be free of protruding or sharp objects which could catch or damage the drogue (see figure 7 for clearance). A composite layout shall be prepared to determine the angle at which the probe is inclined on the receiver aircraft by referencing all normal changes in the receiver fuselage pitch angle relative to the tanker aircraft centerline with refueling hardware in the mated configuration. The composite layout, angle calculations, and any other information necessary to determine the probe angle of installation must be approved by the procuring activity.

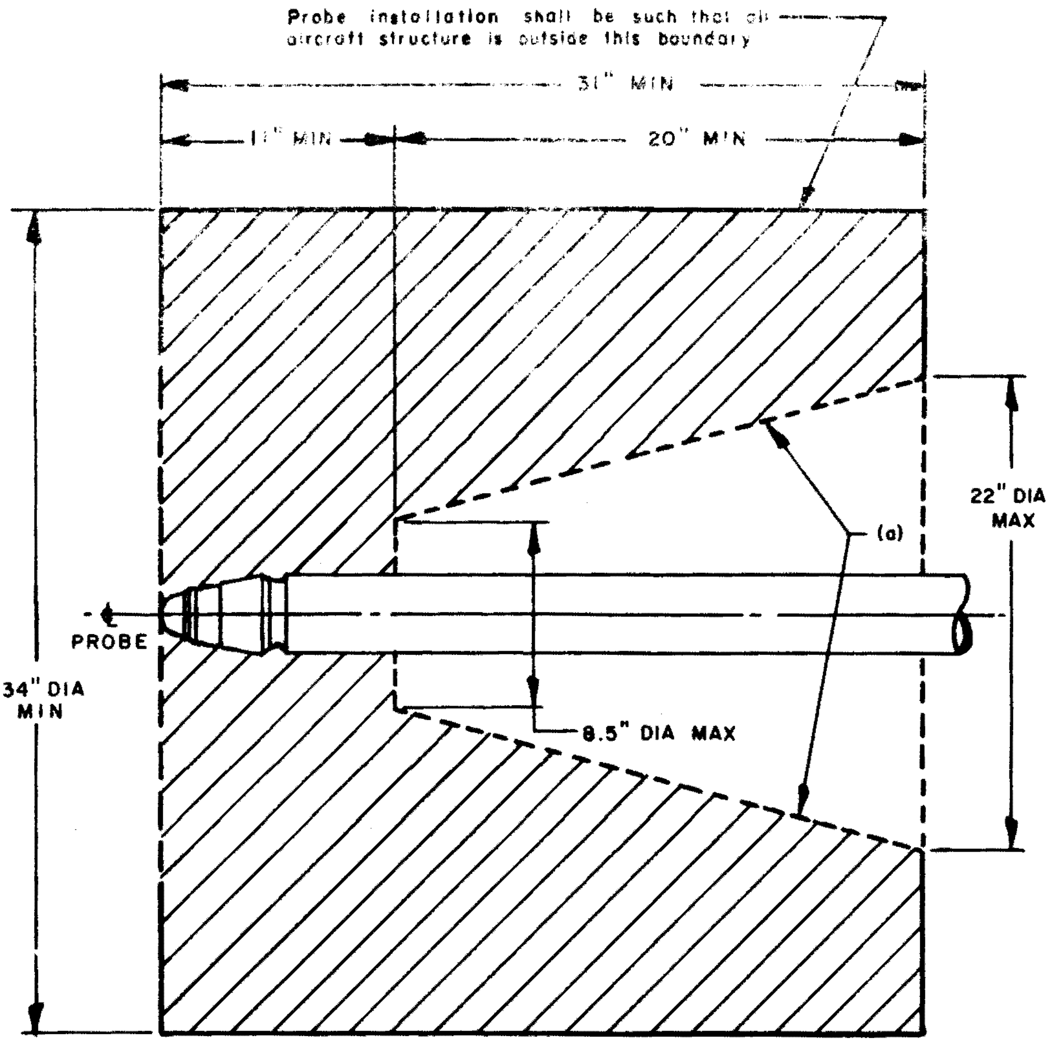
* 3.12.5.1 Probe loads. The probe mast and backup aircraft structure shall be designed for the limit load conditions of MIL-N-25161. Ultimate loads shall be 1.33 percent of the limit loads. No malfunction or deformation to the probe mast or backup structure shall occur upon completion of each ultimate load test.

3.12.5.2 Probe standard parts. Standard parts in accordance with MS24354 shall be used on the probe.

3.12.5.3 Probe location, envelope, and alignment. The probe shall be located so that the receiver aircraft pilot can easily observe the refueling operation without changing his visual tanker aircraft reference. The pilot shall be able to see a minimum of 12 inches of the probe mast measured from the tip of the nozzle. The probe shall have a minimum clearance with respect to the fuselage in accordance with figure 7. The vertical axis plane of the nozzle shall be parallel to the vertical axis plane of the aircraft, and the longitudinal axis of the nozzle shall be parallel to the line of average fuselage pitch angle. The line of average fuselage pitch angle is a line bisecting the angle between the minimum fuselage pitch angle and maximum fuselage pitch angle during the refueling operation.

* 3.12.5.4 Externally mounted probe. Any probe mast which cannot be retracted into the fuselage for a flush installation shall be easily removable on the ground. The probe mast shall be such that it can be drained and removed and the aircraft returned to flight status within 15 minutes. The drain plug shall be lockwired. The aircraft fuel tube inlet and probe mast outlet shall be sealed on removable of the probe mast.

3.12.5.5 Retractable probe mast. Normal extension and retraction shall be accomplished by a hydraulic actuator. Emergency backup shall be provided for extending the probe at least one time per flight. The probe must extend or



(a) This envelope may be used for mounting probe door, lights, etc, when no other aircraft location is available

(b) With the aerial refueling drogue seated on the probe nozzle there shall be a minimum of 1 foot clearance between the drogue and the windshield of the aircraft.

FIGURE 7. Probe Clearance Envelope

retract within 5 to 20 seconds under all operating conditions except the emergency extension mode which shall occur within a maximum of 30 seconds. The probe stowage compartment shall be sealed to prevent fuel leakage into other aircraft compartments. The stowage compartment shall be provided with drains in accordance with 3.5.3.7.4 to prevent accumulation of fuel and water.

3.12.5.6 Telescoping probe mast. The telescoping probe shall have positive mechanical locking and pilot indication of the full extension mode and the fully retracted mode. The probe must telescope or retract within 5 to 20 seconds under all operating conditions except the emergency extension mode which shall occur within a maximum of 30 seconds.

3.12.5.7 Lighting. All probe installations shall be provided with a light(s) in accordance with MIL-L-6503 for night refueling. It shall be possible to dim the light(s) from the cockpit, from full bright to off. Prior to contact, the light(s) shall illuminate a minimum of 12 inches of the probe measured from the nozzle tip and the drogue at a distance of 50 yards. After a hookup is established with the drogue of the boom-to-drogue adapter kit, a minimum of 9 feet of hose and 20 feet of the tanker shall be illuminated, sufficient for pilot monitoring. The boom operator's visibility shall not be impaired by the receiver probe light or any other receiver lights during refueling. After a hookup is established with the drogue of a tanker employing an aerial refueling pod, a minimum of 12 feet of hose and the hose exit from the aerial refueling pod shall be illuminated.

* 3.12.6 Aerial refueling hardware isolation. The boom receptacle or probe nozzle shall be isolated from any aircraft system pressure. When motor-operated valves are employed, they shall incorporate a manual override feature and be accessible during flight. When aircraft employ both the boom receptacle and the probe, check valves shall be used to isolate each system from the other to prevent recirculation and external fuel leakage during a single failure condition of either the nozzle poppet or the receptacle sliding valve assembly.

* 3.13 Fuel dump subsystem. A fuel dump subsystem shall be provided for every aircraft. The fuel dump subsystem is necessary for rapid reduction of fuel load and the hazard associated with fuel during an impending crash condition or an emergency landing.

* 3.13.1 Fuel dump rate. The fuel dump system shall provide a minimum dumping rate per minute equivalent to 1 percent of maximum gross weight of the aircraft, and the aircraft shall be capable of dumping fuel to a safe landing weight in a maximum of 10 minutes.

* 3.13.2 Aircraft controllability. The fuel dump operation shall not in any way adversely affect the controllability of the aircraft.

* 3.13.3 Dump controls. It shall be possible to initiate or stop the fuel dump operation under any flight condition, including gear and flaps extended. The fuel dump control shall be located at the flight engineer's station. In the event there is no flight engineer's station, the control shall be made accessible to the pilot or copilot. The control shall be designed to minimize the possibility of the dump system being inadvertently or accidentally actuated. It shall not be possible to dump fuel below the reserve level of 3.6.3 unless a second initiating action is performed by the operator.

* 3.13.4 Fuel dump safety. During the fuel dump operation, the fuel and fuel vapor shall clear all parts of the aircraft and no fire or explosion hazard shall result. Fuel or fuel vapor shall not impinge upon or re-enter any part of the aircraft.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all the inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or any other facilities suitable for the performance of the inspection requirements specified herein unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification when deemed necessary to assure that supplies and services conform to prescribed requirements.

4.1.1 Procuring activity inspection. The aircraft fuel system will be inspected at the mockup inspection and the inspection of the first complete experimental aircraft by representatives of the procuring activity. The purpose of these inspections will be to assist in determining compliance with the following requirements of this specification:

a. Design

b. Configuration

c. Installation

d. Fire hazard

e. Any other requirements for which visual inspection will be beneficial in supplementing the contractor's engineering, logistic, or test data.

* 4.2 Inspection for compliance with requirements. Compliance with all requirements of section 3 shall be verified by the following methods:

a. Document review

b. Analysis

c. Examination

d. Demonstration

e. Simulator tests

f. Aircraft ground and flight tests.

Some requirements will require that more than one verification method be used.

* 4.2.1 Verification by document review. The system specification, component specifications, drawings, etc, shall be reviewed by the contractor to verify compliance with the appropriate requirements of section 3. The contractor shall prepare a list containing the requirement and a reference to the document which verifies compliance with the requirement.

* 4.2.2 Verification by analysis. The contractor shall perform analyses to verify compliance with the appropriate requirements of section 3. The analysis may be by mathematical solution, by study-type comparison, or by the presentation of historical data.

* 4.2.3 Verification by demonstration. The contractor shall conduct demonstrations to verify compliance with installation features and functional characteristics. The demonstrations may be conducted on a representative mockup, the fuel system simulator, or on the aircraft. The contractor shall prepare a list of the requirements, a description of each demonstration, and the results of each demonstration.

* 4.2.4 Verification by examination. The contractor shall visually examine actual hardware to verify that required equipment or features have been incorporated. The contractor shall prepare a list of the inspection items and the results of the inspection.

* 4.2.5 Verification by tests. The testing of the fuel system shall be conducted in the following phases:

a. Component testing

b. Fuel system simulator testing

c. Ground and flight testing.

4.2.5.1 Component testing. Components shall be tested in accordance with the applicable military or contractor specification. Contractor specifications must be approved by the procuring activity prior to testing.

4.2.5.2 Fuel system simulator testing. The fuel system simulator testing shall be conducted in accordance with all the tests specified under 4.4. With approval of the procuring activity, tests may be interchanged between 4.4 and 4.5.

4.2.5.3 Ground and flight testing. The ground and flight testing shall be conducted in accordance with 4.5.

4.3 Test conditions

4.3.1 Test fluid. Unless otherwise specified and approved by the procuring activity, the aircraft primary fuel shall be used.

4.3.2 Simulator tests. The fuel system simulator shall be capable of demonstrating fuel system performance under all operational temperatures, altitudes, and attitudes of the aircraft. The full-scale aircraft fuel system shall be simulated. The simulator shall incorporate the actual fuel system components (pumps, valves, piping, connections, etc) that are intended to be used in the aircraft fuel system installation. If an explosion suppression system is an aircraft requirement, the explosion suppression system shall be in place for all fuel system tests. The simulator shall also provide the necessary hardware for simulating the fuel flow and pressure characteristics of the aerial refueling tanker. The simulation shall account for the pressure head due to physical separation of the tanker and the receiver and for the surge characteristics of the tanker. A complete test outline and description of the fuel system simulator shall be prepared. Tests shall not be started prior to procuring activity approval of the test outline and simulator description.

4.3.3 Aircraft fuel system. The aircraft fuel system used for the ground and flight testing shall be representative of the production aircraft.

4.3.4 Tolerances. For tests in which a test parameter includes a tolerance, the test shall be conducted at a value of the test parameter as near as possible to the most critical value.

4.4 Simulator test methods

4.4.1 Engine feed and transfer subsystem tests

4.4.1.1 Primary mode of operation. The fuel system simulator shall be operated during simulated mission profiles. During the operation, the following shall be determined:

a. That fuel is continuously available to the engines under all ground and flight conditions

b. That after activation of the fuel system on fighter aircraft, all fuel will be delivered to the engines without further action by the operator

c. The flow rate and pressure of the fuel being pumped out of each tank by each method of moving the fuel

d. That stopping fuel flow to an engine does not affect other engines

e. Adequacy of the system for crossfeed of any engine by any main tank

f. Adequacy of the transfer system to maintain the fuel level in each main tank.

* 4.4.1.2 Hot fuel operation test. The fuel system simulator shall be operated with fuel at 135°F or the maximum fuel temperature determined by the temperature analysis (see table I) from sea level to aircraft service ceiling to determine that:

a. Main tank(s) are adequate for engine(s) fuel feed during maneuvers

b. Engine feed by override pumps in transfer tanks is adequate during all maneuvers.

* 4.4.1.3 Fuel availability. Simulator tests shall be conducted to determine the quantity of fuel available to the engine at sea level engine military rated power conditions utilizing both internal and external tanks by normal feed and alternate methods at the following aircraft attitudes. Fuel remaining in the system subsequent to initial flow fluctuations shall be considered unavailable at normal rated power. The simulator shall be refueled at both the ground and aerial refueling attitudes.

a. Normal ground attitude

b. Takeoff attitude

c. Level flight attitude (landing pattern conditions, low gross weight, low airspeed, low altitude)

d. Landing attitude (touchdown)

e. 10° greater angle than landing attitude.

* 4.4.1.3.1 Low fuel warning test. During the fuel availability test, the quantity of fuel remaining in each main tank shall be determined when its respective low level warning is actuated.

* 4.4.1.4 Gravity feed tests. Each tank shall be tested to determine compliance with the gravity feed requirements of 3.6.1.2. All pumps or pressurization shall be inoperative for the tank being tested.

4.4.1.4.1 Main tank gravity feed takeoff test. With the test tank at least half full of fuel at 135°F or the maximum temperature determined by analysis (see table I) and the simulator positioned to the takeoff attitude, the engine feedline shall be throttled so that the gravity feed flow rate represents the engine fuel consumption for maximum power setting at sea level conditions. The V/L ratio shall be measured at the inlet to the simulated fuel pump. The fuel flow setting and the rate of change of the altitude shall be varied to simulate a maximum performance climbout to 10,000 feet. The V/L shall be measured at a minimum of 2,000-foot increments. The Reid vapor pressure of the fuel shall be measured and recorded before and after each simulated flight.

* 4.4.1.4.2 Main tank gravity feed tank landing test. The tanks shall be filled to a minimum of 10 percent capacity and positioned to representative landing attitudes. The engine feedline from the tank being tested shall be throttled so that the gravity feed flow rate represents the engine fuel consumption for the power setting corresponding to the landing phase being simulated. At the instant the flow rate drops below the required flow rate, the flow shall be stopped and the fuel remaining in the tanks shall be measured and recorded. Tests shall be conducted for various attitudes and power settings encountered in the landing pattern such as touchdown, go-around, etc.

4.4.1.4.3 Gravity feed - maximum altitude test. The test tanks shall be filled to a level equivalent to the low level warning fuel level (see 4.4.1.3.1). The engine feedline from the test tank shall be throttled so that the gravity feed flow rate represents the fuel consumption for maximum range cruise. The altitude shall be increased (with the fuel flow adjusted to correspond to the altitude) until the required fuel flow rate cannot be maintained.

* 4.4.2 Fuel tank subsystem simulator tests

4.4.2.1 Tank capacities. The capacity of each fuel tank shall be determined and compared with the design capacity approved by the procuring activity. The tanks shall be filled at the normal ground attitude.

4.4.2.2 Sump capacity. The sump capacity of each internal cell at normal ground attitude shall be obtained by measuring the fuel drained from the sump drain after all fuel possible has been pumped from the fuel system by the aircraft boost pumps. During this test it shall be determined that:

a. The capacity meets the applicable design requirements

b. All cells may be satisfactorily drained on the ground.

Residual fuel, if any, remaining after the cells and sumps are drained shall be determined.

* 4.4.2.3 Expansion space. The aircraft shall be fueled to normal capacity by pressure and gravity refueling; then the measured fuel shall be added until fuel enters the vent system. (Special provisions may be required.) The quantity of measured fuel added is equal to the expansion space.

* 4.4.3 Pressurization and explosion suppression subsystem simulator tests

* 4.4.3.1 Pressurization regulator tests. The pressurization subsystem shall be operated during simulated mission profiles to verify proper operation of the system. Ullage temperature and pressures shall be measured and recorded during the test. Care must be taken to ensure that the pressurization supply source of the simulator is representative of the pressurization supply source of the aircraft. The effects of a failed pressure regulator shall also be investigated.

* 4.4.3.2 Explosion suppression subsystem simulator tests

* 4.4.3.2.1 Baffle material test. There are no specific simulator tests for the baffle material; however, the fuel system shall be monitored during all testing to determine any detrimental effects on the system caused by the baffle material.

* 4.4.3.2.2 Nitrogen inerting components. The nitrogen inerting system components shall be tested in accordance with approved contractor specifications.

* 4.4.3.2.3 Nitrogen inerting system tests. The operation of the nitrogen inerting system shall be demonstrated for each required mission profile to verify that the quantity of nitrogen is adequate and that the oxygen concentration of the inerted space never exceeds the 10 percent limit. Also, the pressure in each tank shall be measured and recorded during maximum rate of climb and descent with the nitrogen inerting system operating. The failure effect demonstration of the nitrogen system shall be conducted in accordance with 4.4.8.

4.4.4 Fuel vent subsystem simulator tests

4.4.4.1 Siphoning tests. Tests shall be conducted to determine the siphoning characteristics of the fuel vent subsystem. After normal fueling, the aircraft shall be placed at normal flight attitude, and the quantity of fuel, if any, discharged from the fuel vent opening shall be measured. After normal fueling at ground attitude, fuel shall be added until a steady stream of fuel is discharged from the fuel vent opening. The fuel being pumped into the system shall be shut off, and the amount discharged from the vent opening after shutoff shall be recorded.

* 4.4.4.2 Overpressurization tests. Tests shall be conducted to demonstrate that the vent system is adequate to prevent tank overpressurization as a result of maximum rate of climb or dive or as a result of a level control valve failure

during ground or aerial refueling. For the refueling tests, a fuel pressure shall be applied to the aircraft fuel inlet connection which will produce a maximum fuel flow when each tank is filled individually. Maximum flow shall account for ranges of tanker nonregulated pressure and flow such as depicted by curves on figure 1. A pressure pickup shall be provided at each vent outlet and in each tank. Pressure values shall be recorded.

* 4.4.4.3 Interconnected vent fuel exchange. Tests shall be conducted to determine the quantity of fuel which can be transferred from one tank to another through interconnected vents. The tests shall account for all extreme attitudes which can be encountered by the aircraft.

4.4.4.4 External tank venting tests. Tests shall be conducted to demonstrate that the external tanks will automatically go to the vent position when the pressure regulator fails in the closed position.

4.4.5 Fuel quantity gaging subsystem simulator tests

4.4.5.1 Components. The components shall be tested in accordance with sampling plans A and B of MIL-G-26988.

4.4.5.2 System calibration tests. The system calibration tests shall be conducted in accordance with MIL-G-7940. These tests shall not be conducted until approval of the engineering report required in MIL-G-7940 has been granted by the procuring activity.

* 4.4.5.3 Fuel quantity indicator response test. When a switching arrangement is used to obtain fuel quantity data for multiple tanks from a single indicator, the maximum time required to obtain an indication for each tank shall be determined. Also, the time required to obtain an indication for each tank shall be determined for normal fuel distributions associated with a typical mission profile.

4.4.6 Refueling and defueling subsystem simulator tests

* 4.4.6.1 Refueling subsystem operational test. Simulated ground refueling shall be conducted to determine that:

a. The aircraft can be refueled to capacity without the use of external power

b. The aircraft can be filled from any single ground refueling adapter

c. The system has the capability to select any single tank for refueling and conversely to avoid filling any tank

d. The engine feed fuel lines will not be subjected to the refueling pressures

e. All refueling lines can be drained or scavenged

f. The level control valve precheck system is operational and that a faulty level control valve can be isolated.

* 4.4.6.2 Refueling time. The time required to fill the system shall be determined using a starting condition as described in 3.11.1.5.c. The flow rates to the system shall be determined for various tank open conditions and for each tank open singly. Tests shall be conducted for nozzle inlet pressures of 25, 35, 45, and 55 psig for ground refueling and for various tanker pump combinations and maximum flow for aerial refueling.

* 4.4.6.3 Surge pressure tests. The refueling manifold shall be instrumented to determine surge pressures encountered during refueling. There shall be a minimum of one pressure pickup at each fuel level control valve and at each ground and aerial refueling connection. Pressure transducers of the strain-gage type with a response in the order of 1 millisecond shall be used. The transducer pressures shall be recorded in a continuous trace using a recording oscillograph of the galvanometer light-beam type. The amplifier and other electronic equipment shall provide for transient response in the order of 1 millisecond corresponding to the transducer. Copies of the traces showing the largest surges shall be included in the test report. The surge pressures shall be measured under the following conditions while refueling through each ground and aerial refueling connection:

a. Maximum flow - All fuel level control valves closed simultaneously

b. Maximum flow - Each fuel level control valve closed individually with all remaining fuel level control valves in the closed position

c. Maximum flow - All fuel level control valves closed as a result of filling to capacity.

Maximum flow shall account for ranges of tanker nonregulated pressure and flow to the receiver refueling connection such as depicted by the curves on figure 1.

4.4.6.4 Defueling test. Ground defueling shall be demonstrated. Aircraft internal pumps may be utilized to defuel the system. The time required to defuel the internal cells shall be determined for the maximum discharge flow rate. The maximum flow and fuel remaining in the system after defueling shall be recorded. The pressure in each tank shall be recorded during this test.

4.4.6.5 Fuel servicing nozzle clearance. If a switch or valve actuator has been installed on the adapter, a dummy fuel servicing nozzle incorporating the entire usable envelope allowed by MS29520 shall be fitted to the simulator to determine compliance with 3.11.1.4.

* 4.4.7 Fuel dump subsystem simulator tests

* 4.4.7.1 Fuel dump tests. Fuel dumping tests shall be conducted to determine the average dumping rate and the quantity of fuel which cannot be dumped.

4.4.8 Failure effect demonstration. A failure effect demonstration test program shall be conducted based upon the results of the studies of 3.5.2.1. Only those failures where a reduced level of performance may occur or where special crew attention or control techniques are required need be demonstrated. When failure effect has been demonstrated during subsystem tests, the tests need not be repeated; however, the previously conducted failure demonstrations shall be described in the failure analysis report.

4.5 Aircraft ground and flight tests. Components shall be qualified or have passed safety of flight tests approved by the procuring activity prior to conducting the ground and flight tests. Each fuel system shall be proof-pressure-tested prior to flight.

4.5.1 Fuel system icing. The airframe manufacturer shall demonstrate compliance with 3.5.3.2.2. Procuring activity approval of the icing test plan shall have been granted prior to testing.

4.5.2 Engine feed and transfer subsystem tests

* 4.5.2.1 Center-of-gravity travel. Ground tests to demonstrate fuel system center-of-gravity changes shall be conducted under all normal flight conditions and power settings to demonstrate compliance with 3.5.3.5. Tests shall also be conducted under engine inoperative conditions on multiengine aircraft and under gravity feed conditions. The data shall include all possible external and auxiliary fuel tanks and useful load configurations and all possible fuel management control situations. If the failure analysis of 3.5.2.1 indicates any adverse center-of-gravity control or handling problems, tests shall also be conducted for these conditions. Each test shall be conducted from full fuel down to reserve level. At least one test in each series shall include usage from reserve down to unavailable fuel. These tests shall be performed with the aircraft in its normal flying attitude for each condition, and fuel shall be removed from the engine feedlines at the proper flow and pressure. The aircraft weight and center-of-gravity data shall be recorded at intervals of not more than 2 minutes during these tests. Center of gravity (percent mean aerodynamic chord) versus aircraft gross weight plots shall be prepared from this data and compared with the previously calculated data.

* 4.5.2.2 Hot fuel climb. Tests shall be conducted to demonstrate that the aircraft performs satisfactorily during takeoff and maximum rate of climb to the aircraft service ceiling with each engine operating from its normal fuel supply and with a hottest initial fuel temperature as determined by analysis (see table I), but not less than 110°F.

* 4.5.2.3 Maximum altitude. The maximum altitude at which military power and maximum power operation can be maintained on gravity feed shall be determined. The temperature of the fuel and a fuel sample for Reid vapor determinations

shall be taken before and after the flights. The minimum temperature of the fuel immediately before takeoff shall be as determined by analysis. The following tests shall be conducted:

a. A normal takeoff and climb to minimum safe altitude shall be performed. All booster and transfer pumps shall be turned off. On multiengine aircraft one engine may be tested at a time. The aircraft climb shall be made at military power at best climb speed to service ceiling or until 10 percent power loss occurs or until an objectionable engine surge occurs.

b. The test in item a shall be repeated using maximum power.

c. The test in item b shall be repeated for the worst condition of the fuel strainer; i.e., with the filter in the bypass condition or the impending bypass condition.

4.5.3 Fuel tank subsystem tests

4.5.3.1 Cell capacities, sump characteristics, and expansion space. The cell capacities, sump characteristics, and expansion space shall be determined on actual aircraft tanks by the same test methods used in the fuel system simulator tests.

* 4.5.3.2 Tank pressure test. Each fuel tank on the aircraft shall be tested at pressure values of 1.33 times the maximum pressures as determined in accordance with 3.7.1.1. Structural failure, permanent set in excess of that specified on approved drawings, distortion, or fuel leakage shall be cause for rejection.

* 4.5.3.3 External tank tests. External tank tests shall comply with MIL-T-7378.

4.5.4 Pressurization and fuel vent subsystem tests. The vent subsystem shall contain a pressure pickup at each vent outlet, in each tank, and between each bladder cell and cell cavity. The pressure data and other data such as rate of climb, rate of dive, altitude, and quantity of fuel shall be recorded in sufficient quantity to demonstrate satisfactory operation of the vent subsystem during all flight maneuvers and during ground and aerial refueling.

4.5.4.1 Fuel vent subsystem operational tests. Dyed fluid shall be used during the test conditions specified below to mark any fuel impingement on the aircraft. The vent subsystem shall be evaluated under the following conditions and maneuvers:

a. The aircraft shall be flown at maximum rate of climb to service ceiling followed by a maximum practical rate of descent dive to minimum safe altitude. The dive shall be accomplished with the minimum safe quantity of fuel aboard.

b. The aircraft shall be flown at maximum engine power at service ceiling and at minimum safe altitude (approximately 5,000 feet) for 10 minutes duration each.

c. Operating conditions most conducive to heating of the fuel shall be demonstrated. Data shall be recorded to verify the temperature envelope.

d. With full fuel tanks it shall be demonstrated that fuel spillage does not occur as a result of takeoff and landing accelerations, afterburner and speedbrake application, and uncoordinated turns.

e. Aircraft in which design performance includes inverted flight or negative g shall be flown in this manner for a maximum period as determined by the aircraft system specification at the worst altitude condition.

* 4.5.4.2 Vent outlet icing tests. The vent outlets shall be observed following the aircraft icing tests to determine the extent of ice accumulation or blockage around the vent outlet. Any ice accumulation shall be photographed for submittal to the procuring activity.

* 4.5.4.3 Vent system failure tests. Appropriate tests shall be conducted as indicated by the failure analysis and simulator tests. If any component failure can cause fuel to vent overboard, dye tests shall be conducted to determine the impingement effects.

* 4.5.4.4 Pressurization system temperature survey. A temperature survey shall be conducted to verify that the temperatures of components, tank walls, and ullage space meet the requirements of 3.8.1.1. The temperature survey shall account for any temperature rise which may occur as a result of a failed pressure regulator or vent valve.

* 4.5.4.5 Pressure checking demonstration. If AGE is provided for plugging the vents or pressure-testing the tanks, a demonstration shall be conducted to verify satisfactory operation of the AGE.

4.5.5 Explosion suppression system tests. Tests shall be conducted to investigate the most critical condition for which the explosion suppression system was designed. Sufficient data shall be recorded to demonstrate satisfactory operation of the system.

* 4.5.5.1 Dewar holddown test. Before first flight it shall be demonstrated that the holddown fixture for the dewars can withstand the loadings specified for miscellaneous equipment in MIL-A-8865.

4.5.6 Aerial refueling subsystem tests. The aerial refueling test program shall be conducted in the order listed.

4.5.6.1 Retrofit installations

4.5.6.1.1 Proximity flight test. A proximity flight test shall be conducted prior to hardware design and fabrication to determine feasibility, receptacle installation angle, or probe location and installation angle. The proximity test shall consist of the following and shall require color motion picture coverage:

a. Evaluate effects of the tanker aerodynamic conditions and downwash on the receiver aircraft during simulated hookups.

b. Determine aerial refueling speed and altitude envelope and if afterburner and speed brakes, trailing-edge flaps, and leading-edge flaps are required for altitude and speed envelope.

c. Instrument the receiver aircraft to measure the fuselage pitch angle while in position behind the tanker during combinations of the following conditions:

(1) Heavy gross weight

(2) Light gross weight

(3) Aerial refueling speed and altitude envelope as determined in item b

(4) Employ modulated afterburner range as established in item b, if applicable.

d. Determine suitability of receptacle or probe location by making simulated hookups.

* 4.5.6.1.2 Retrofit installation ground test. The retrofit installation shall be tested in accordance with 4.4.2, 4.4.6.2, 4.4.6.3, 4.5.3.2, and 4.5.4.

4.5.6.1.3 Retrofit installation final testing. Retrofit installation final testing shall be the same as the production installation testing.

4.5.6.2 Production installations

* 4.5.6.2.1 Aerial refueling ground tests. The following ground tests shall be conducted prior to the first aerial refueling flight test:

a. Conduct a structural test to limit and then to ultimate load for design conditions specified in 3.12.3.3.1, 3.12.3.3.2.1, or 3.12.5.1 for receptacle/support structure and fuselage skin or probe/support structure as installed on an airframe used for structural testing.

b. Perform a complete functional test of all installed aerial refueling components.

c. Conduct a test to demonstrate that the slipway door/receptacle or probe and probe doors have the ability to extend and retract during hydraulic actuation at -65°F temperatures and icing conditions, if not previously demonstrated during the development phase. Fail-open provisions shall also be demonstrated during the temperature and icing conditions. Time of opening and hydraulic pressures shall be recorded. The actuation shall be accomplished under simulated flight airloads for the most adverse conditions.

d. Conduct a test to demonstrate that the drains have the capability to remove rain and fuel leakage and spillage during all appropriate ground and flight attitudes.

e. (Receptacle installations only.) Evaluate the slipway and transition surfaces from the slipway to the receptacle for possible boom nozzle hangup areas. Conduct a simulated night lighting test to evaluate the night refueling lights.

f. (Probe installation only.) Evaluate the probe for possible drogue hangup points and for proper location. Conduct a simulated night lighting test to evaluate the night refueling lights.

g. Conduct a tanker compatibility demonstration using actual tanker aircraft to demonstrate compatibility between tanker and receiver aircraft in respect to flow rates, pressures, and surge pressures.

* 4.5.6.2.2 Aerial refueling flight test. The following tests shall be conducted as a part of category I testing. Color motion picture coverage is required for all test flights. Items a and b shall be evaluated for both light and heavy gross weight configurations throughout the speed envelope. The fuselage pitch angle for the receiver aircraft during refueling shall be recorded for both light and heavy weight conditions.

a. (Receptacle installations only.) Explore the entire tanker boom envelope including elevation extension and azimuth in 5° and 6-foot increments for disconnect ability, slipway interferences, and the ability of the tanker boom to tow the receiver aircraft. The hookup envelope shall be established. The test shall be conducted with a boom which has been instrumented to measure loads, pressures, and flows.

b. (Probe installation only.) Explore the entire tanker hose envelope. Evaluate for possible hose interference, hookup ability, and disconnect ability. The probe shall be instrumented so that loads resulting from hose flops, off-center disconnects, dead hose of a reel system, and overrun on hookup can be recorded.

c. Determine the optimum receiver aircraft refueling envelope in relation to the following items:

(1) Altitude and speed

(2) Boom extension, azimuth, and elevation angles (for hookup and disconnect)

(3) Wing flap configuration

(4) Use of modulated afterburner and speed brakes, if required for aerial refueling

d. Determine effect of light-to-moderate air turbulence and moderate-to-heavy air turbulence on the time required to accomplish hookup.

e. Determine adequacy of indicator lights, tanker receiver or director lights, cockpit switch, and control locations.

f. Evaluate the night lighting adequacy during a transition from twilight to dusk to full dark conditions and also from light to heavy gross weight conditions. The use of the rheostat and any resulting blinding or objectional reflections shall be recorded.

g. Aerial refuel the receiver aircraft to the maximum aircraft gross weight required by mission definition. A minimum of five hookups shall be made with the receiver having a weight of 90 percent of maximum gross weight. The tanker shall record the number of refueling pumps and corresponding flow rates and pressures during the refueling. With appropriate instrumentation installed, the receiver shall attempt different valve shutoff combinations as specified in 4.4.6.3 Surge, steady-state static pressures, and fill times shall be recorded for each set of test conditions. Instrumentation for surge and static pressure measurement shall be accordance with 4.4.6.3.

h. Accomplish the following types of disconnects:

(1) Manifold pressure switch (receptacle only)

(2) Normal amplifier system and amplifier override initiated by receiver pilot (receptacle only)

(3) Normal and amplifier override initiated by tanker boom operator (receptacle only)

(4) All tanker boom automatic envelope disconnects including combinations of left and right azimuth, elevation extremes, and minimum and maximum boom extensions

(5) Normal and pressure disconnects (probe only)

i. (Receptacle installations only.) Evaluate emergency refueling such as override features, stiff boom, and fail-safe features. Two tension disconnects shall be demonstrated, each performed after a 1-hour flight at 40,000 feet altitude. A minimum of 20 tension disconnects shall be accomplished at all combinations of the already established boom disconnect envelope. This shall be accomplished with an instrumented tanker boom. All tension and compression load data of this paragraph and item h shall be recorded and shall not exceed the "Limit Loads (Tension and Compression Working Loads)" listed in the design load requirements of the paragraph entitled "Structure" of MIL-R-27521.

j. (Receptacle installations only.) When reverse aerial refueling is required, conduct reverse flow tests. The tests shall consist of the receiver aircraft pumping fuel to the tanker at predetermined flow rates and pump combinations. A disconnect shall be accomplished during maximum fuel flow conditions.

* 4.5.7 Fuel dump subsystem tests

* 4.5.7.1 Fuel impingement. It shall be demonstrated that no fuel or fumes impinge or enter any portion of the aircraft or cause any other unsafe conditions under all possible fuel dumping conditions which may be encountered in service. Data including movies shall be recorded during the following operating conditions:

a. Climb at the one-engine-inoperative, best rate of climb, with the critical engine inoperative. The critical engine is defined as that engine which, when inoperative, will cause flight conditions such as yaw to be most unfavorable for safe fuel dumping.

b. Level flight at 1.4 times the indicated stalling speed, one engine inoperative and gear and flaps up

c. Landing attitude with reduced power and gear and flaps extended.

* 4.5.7.2 Controllability. One test shall be conducted to determine the effect on controllability and minimum elapsed time for dumping from full to reserve fuel load.

5. PREPARATION FOR DELIVERY

5.1 This section is not applicable.

6. NOTES

6.1 Intended use. This specification is intended for use by aircraft manufacturers in designing and testing fuel systems for aircraft powered by air-breathing engines.

6.2 Definitions

* 6.2.1 Available fuel. Available fuel is that quantity of fuel which is available to the engines after refueling to the normal ground refueling full level, down to the level where steady flow to the engines ceases. If this quantity varies with attitude and engine power settings, the available fuel should be tabulated for these variables.

6.2.2 Unavailable fuel. Unavailable fuel is fuel remaining in the aircraft after the available fuel has been removed.

6.2.3 Sump fuel. Sump fuel is fuel hich can be drained from the aircraft sumps after the available fuel has been removed from the aircraft.

6.2.4 Trapped fuel. Trapped fuel is fuel remaining in the aircraft after the sump fuel has been drained.

6.2.5 Slipway. The slipway is the specially designed "beefed-up" fuselage skin area forward of the receptacle which serves as a guide to assist the boom operator in hookup operations. The use of this area is required to stabilize the boom nozzle in the vertical and horizontal planes due to the relative motions which exist prior to contact and hookup. Relative motions which exist between the receiver and boom are normally produced when the aircraft are subjected to weather turbulence, when boom hookups are attempted at lower boom elevations (35° to 40°), by out-of-rig booms, and by inherent boom instability.

* 6.2.6 Tension disconnect. Tension disconnect is the process of disconnecting against the force of locked receptacle toggle latches.

6.2.7 Receiver director lights. Two rows of lights are contained on the bottom fuselage forward of the wheel well of the KC-135 tanker. These lights give location information to direct the receiver aircraft pilot in the forward-aft and up-down boom envelope.

* 6.2.8 Reverse refueling. Reverse refueling is the process of transferring fuel from the receiver aircraft to the tanker aircraft.

* 6.2.9 Main tank. A main fuel tank is a tank identified by its primary function to supply fuel directly to an engine.

* 6.2.10 Transfer tank. A transfer fuel tank is a tank identified by its primary function to transfer fuel to another tank or to supply the engine by an override pumping system. For the purpose of this specification, fuel tanks commonly called auxiliary tanks, ferry tanks, or external tanks shall be classified as transfer tanks.

* 6.2.11 Expansion space. Expansion space is the space provided for thermal expansion between the fuel level for a full tank and the fuel level where fuel spillage into the vent system is impending.

* 6.2.12 Stiff boom. A stiff boom is the process of aerial refueling when the receptacle toggle latches are failed to the open position. A technique is involved in maintaining the hookup with a minimum of fuel spillage.

* 6.3 International standardization agreement. Certain provisions (identified by paragraphs below) of this specification are the subject of international standardization agreement. When amendment, revision, or cancellation of this specification is proposed which will affect or violate the international agreement concerned, the preparing activity will take appropriate reconciliation action through international standardization offices including departmental standardization offices, if required.

Paragraph No.	Standard
3.7.1.6	ASCC Air Std 17/11
3.7.1.6	STANAG No. 3212
3.7.1.6	STANAG No. 3294
3.11.1	ASCC Air Std 11/3
3.11.1.2	ASCC Air Std 17/4
3.11.3	ASCC Air Std 11/6
3.12.5.2	ASCC Air Std 17/29

6.4 The margins of this specification are marked with an asterisk to indicate where changes from the previous issue were made. This was done as a convenience only, and the Government assumes no liability whatsoever for any inaccuracies in these notations. Bidders and contractors are cautioned to evaluate the requirements of this document based on the entire content irrespective of the marginal notations and relationship to the last previous issue.

Custodian:
Air Force - 11

Review activities:
Air Force - 70, 82

User activities:
Air Force - 80

Preparing activity:
Air Force - 11

Project No. 2915-F064

APPENDIX

10. SCOPE

10.1 This appendix lists the data necessary for the procuring activity to properly evaluate a developmental fuel system.

20. REQUIREMENTS

* 20.1 Fuel system detail specification. The airframe manufacturer shall prepare a fuel system detail specification. Headings and numbering of sections and paragraphs of the detail specification shall correspond as nearly as possible to those of MIL-F-38363. Omission of reference in the detail specification to a particular requirement of MIL-F-38363 shall indicate complete compliance therewith. When departures from the requirements of MIL-F-38363 are necessary, the details of such departures shall be stated as specific requirements bearing the same section heading, paragraph heading, and numbering as MIL-F-38363. The detail specification shall contain supplementary data and shall be expanded as required to define any special characteristics of the fuel system not covered in MIL-F-38363. The detail specification shall include an index of all current design, analysis, and test reports listed in 20.2. When revisions are made to the detail specification and reports, they shall be designated by the use of a letter following the document number. The revision date shall be shown on page 1 of the document. Each subsequent page shall be identified by the document number and the revision letter if applicable.

* 20.2 Data and reports. The following data and reports are necessary to thoroughly define the fuel system for the procuring activity:

a. Engineering design analysis report. This report shall include the following:

(1) Result of trade studies performed to arrive at the basic fuel system configuration

(2) Temperature calculation showing maximum fuel temperature resulting from aerodynamic/thermodynamic heating of the fuel and maximum ambient air temperature

(3) Calculated system performance

(4) Predicted problem areas with proposed method of solution

(5) Development test program

(6) Special facilities required for testing of the fuel system

(7) Deviations from this specification and reason for deviation

b. Fuel system functional analysis report. This report shall include the following:

(1) Description of fuel system

(2) Fuel system schematic diagrams identifying all components, lines, sizes, and relative location

(3) List of Qualified Products List (QPL) components giving name and location of component, manufacturer's part number, and vendor's part number.

(4) List of off-the-shelf components giving name and location of component, manufacturer's part number, vendor's part number, applicable military specification, approval status, procurement or detail specification, and past usage

(5) List of critical components giving name and location of component, manufacturer's part number, vendor's part number, detail drawings, applicable military specification, procurement specification, and test report

(6) Fuel system electrical functional schematic from the distribution bus to all fuel system components to ground illustrating interlock and system logic

(7) Perspective or isometric drawing illustrating all major components and fuel lines in relation to the airframe structure

(8) Outline of fuel scheduling and management

(9) Failure analysis describing the effect of each possible single failure on the operation of the system

(10) Fuel system passive defense analysis

(11) Plumbing specification

(12) Procuring activity approval items required by paragraphs in this specification:

(a) 3.6.6.1	(e) 3.12.3.3.1	(i) 4.3.2
(b) 3.10.2	(f) 3.12.3.3.2	(j) 4.4.5.2
(c) 3.12.3.1	(g) 3.12.5	(k) 4.5
(d) 3.12.3.2	(h) 4.2.5.1	(l) 4.5.1

c. System test plan. Outline of proposed test program.

d. Simulator test report. Results of tests required by 4.4 of this specification. The test report shall cover in an engineering manner all tests that were conducted on the simulator and shall not be limited to the tests of 4.4.

e. Ground and flight test report.

f. Fuel system detailed weight statement. The following weight statement shall be submitted as complete as possible during the proposal stage. The weight statement should be up-dated for design reviews as data becomes available.

Fuel System Detailed Weight Statement:

ITEM	WEIGHT
(1) Tanks	
(2) Integral Tank Seals and Sealant	
(3) Backing Board	
(4) Tank Supports and Padding	
(5) Tank Bay Sealing	
(6) Tank Release and Controls	
(7) Fuel Quantity Gaging System	
(8) Fuel Heating and Controls	
(9) Fuel Vapor Recovery	
(10) Explosion Suppression System	
Cycle and Supports	
Generators	
Controls, etc	
(11) Pump Installation	
Engine Driven	

Booster

Hand (Including Controls)

Transfer

Electrical System (Including Controls)

Pump Supports

(12) Ground Fueling System

Plumbing

Controls

(13) Aerial Refueling Hardware

Plumbing

Controls

Additional Structure

(14) Engine Feed and Transfer System

Plumbing

Controls

(15) Vent System

(16) Pressurization System

(17) Jettison System

(18) Fuel Drain System

TOTAL

g. System detail design data. The applicable portion of the following list should be submitted as complete as possible during the proposal stage. The list should be updated for design reviews as data becomes available.

(1) Fuel: Primary   Alternate

Consumption at takeoff   (lb/hr/engine)

Consumption at cruise   (lb/hr/engine)

(2) Tanks, Fixed: (Integral, Bladder, Nonintegral, External)

Specification	
Type	
Number Quantity/Tanks	
Location	(Station/WL/BL)
Quantity	
Design Crash	(g/capacity/angle)
Burst	(psig)
Negative Pressure Capability	(psig)
Overall Dimensions	(in.)
Largest Opening/Location	(in./station)
Sump Location/Capacity	(station/gal)
Expansion Space	(gal)
Drain Location	
Baffles Axial/Transverse	(location and number)
Supplier	

(3) Fuel Capacity, Fixed:

Total Fixed Capacity	(gal)
Trapped Main Fuel	(gal)
Usable Main Fuel	(gal)
Sump Fuel	(qt)
Expansion Space	(gal)

(4) Tanks, Auxiliary: (Internal, External) Same as (2).

(5) Fuel Capacity, Auxiliary:

Total Auxiliary Capacity	(gal)
Trapped Auxiliary Fuel	(gal)
Usable Auxiliary Fuel	(gal)
Sump Fuel	(gal)
Expansion Space (Auxiliary)	(gal)

(6) Tank Materials:

Integral Structure

Specification

Heat-Treat/Grade

Sealants

Specification

Method of Application

Bladder Support Structure

Bladder, Self-Seal

Specification

Description

Bladder, Nonseal

Specification

Description

Nonintegral Internal Tank Structure

Specification

Heat-Treat/Grade

Ultimate Tensile Strength

(7) Refuel:

Gravity Fill

Drain Line Size (in.)

Drain Discharge Point

Filler Locations

Maximum Fill Rate (gpm)

Single Point

Location

Receptacle Type/Standard

Rated Flow/Pressure (gpm/psig)

Level Control Valve Pressure Check Method

Line Size (in.)

Burst Pressure (psig)

Fill Sequence

Aerial Fill

Method

Location (station/WL/BL)

Rated Flow/Pressure (gpm/psig)

Line Size (in.)

Fill Sequence

(8) Defuel:

Fixed Tanks Defuel Subsystem

Description

Location (station/WL/BL)

Receptacle Type/Standard

Line Size (in.)

Rated Flow/Pressure (gpm/psig)

Auxiliary Tanks Defuel Subsystem

Description

Location (station/WL/BL)

Receptacle Type/Standard

Line Size

Rated Flow/Pressure (gpm/psig)

(9) Dump:

Description

Location (station/WL/BL)

Line Size (in.)

Rated Flow/Pressure (gpm/psig)

Pressure Source

Method of Low Quantity Cutoff

(10) Vents:

Antisyphon Design Description

Outlet Locations (station/WL/BL)

Size of Line (in.)

Lightning Protection

Special Design Feature

(11) Negative G Provisions:

Type Description

Time at Military Power (min-sec)

Time at Cruise Power (min-sec)

(12) Center of Gravity Control:

Tank Usage Sequence

Normal Center of Gravity Travel

Abnormal Center of Gravity Travel Possibilities

Location and Type of Fuel Management Controls

(13) Critical Components:

Number and Description of Surveillance Items

Number and Description of Single Failure Critical Items

(14) Boost Pumps:

Location (station/WL/BL)

Power

Circuit Protection

Flow/Pressure at Takeoff Power

Flow/Pressure at Cruise

Type

Speed

Supplier

Special Features

(15) Other Pumps: (Transfer, Dump, Ejection, etc)

Function

Type of Pump

Location

Power

Circuit Protection

Speed

Flow/Pressure in Operation (gpm/psig)

(16) Strainers:

Type

Overall Dimensions

Location

Inlet Size

Outlet Size

P at Takeoff Flow/60°F

P at Bypass/60°F

Heater Power

Mesh or Micron Rating

Supplier

(17) Plumbing:

Hose Specification

Fitting Material

Flex Coupling Type

Rigid Line Material

Wall Thickness

Ultimate Tensile Strength

Design Burst Factor

Fitting Type

Line Sizes for:

Vents

Crossfeed

Dump

Single-Point Refueling

(18) Quantity Instrumentation:

Type

Overall Indicator Size

Switch Positions

Probe Location

Low Level Locations

Low Level Quantity

Supplier

(19) Flow Instrumentation:

Type

Sensor Location

Indicator Ranges

Accuracy

Readout Data

Supplier

(20) Pressure Instrumentation:

Type
Function

Sensor Location
Indicator Ranges

Actuation Pressure

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SPECIFICATION ANALYSIS SHEET

Form Approved
Budget Bureau No. 22-R255

INSTRUCTIONS: This sheet is to be filled out by personnel, either Government or contractor, involved in the use of the specification in procurement of products for ultimate use by the Department of Defense. This sheet is provided for obtaining information on the use of this specification which will insure that suitable products can be procured with a minimum amount of delay and at the least cost. Comments and the return of this form will be appreciated. Fold on lines on reverse side, staple in corner, and send to preparing activity. Comments and suggestions submitted on this form do not constitute or imply authorization to waive any portion of the referenced document(s) or serve to amend contractual requirements.

SPECIFICATION

ORGANIZATION

CITY AND STATE	CONTRACT NUMBER

MATERIAL PROCURED UNDER A

☐ DIRECT GOVERNMENT CONTRACT ☐ SUBCONTRACT

1. HAS ANY PART OF THE SPECIFICATION CREATED PROBLEMS OR REQUIRED INTERPRETATION IN PROCUREMENT USE?

A. GIVE PARAGRAPH NUMBER AND WORDING.

B. RECOMMENDATIONS FOR CORRECTING THE DEFICIENCIES

2. COMMENTS ON ANY SPECIFICATION REQUIREMENT CONSIDERED TOO RIGID

3. IS THE SPECIFICATION RESTRICTIVE?

☐ YES ☐ NO *(If "yes", in what way?)*

4. REMARKS *(Attach any pertinent data which may be of use in improving this specification. If there are additional papers, attach to form and place both in an envelope addressed to preparing activity)*

SUBMITTED BY *(Printed or typed name and activity - Optional)*	DATE

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