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FUEL SYSTEM RELIABILITY AND MAINTAIN-
ABILITY INVESTIGATION. VOLUME II.
SUPPLEMENTAL DESIGN GUIDE

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Ultrasystems, Incorporated

Prepared for:

Army Air Mobility Research and
Development Laboratory

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EUSTIS DIRECTORATE POSITION STATEMENT

The recommendations presented in this report concerning helicopter fuel system reliability are based on a highly responsive review of a wide range of failure reports and Engineering Change Proposals, and they are believed to provide a rational basis for improving the design, test, and quality assurance aspects of specifications and requirements documents related to Army aircraft fuel systems. The Supplemental Design Guide presented in Volume II is recommended for use as an attachment to appropriate fuel system specifications and standards pending revisions to these documents. The reliability and maintainability (R&M) improvements available through use of the recommended revisions appear to be achievable with virtually no cost and/or weight penalty.

This contract is one of a series of efforts being conducted by this Directorate aimed at investigating and improving the effects of design, test, and quality assurance requirements documents on Army aircraft R&M characteristics. Other efforts include hydraulic, electrical, and flight control systems.

The technical monitor for this contract was Mr. Gene A. Birocco of the Military Operations Technology Division of this Directorate.

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PREFACE

This volume contains a list of documents, including applicable military specifications, that should be considered in the design of helicopter fuel systems. Recommended specification revisions and newly established requirements in the form of two complete draft specifications are also included.

The revisions and requirements contained herein are based upon the results of a study conducted for the Eustis Directorate of the U. S. Army Air Mobility Research and Development Laboratory under Contract DAAJ02-73-C-0072 (DA Task 1F162205A11903), documented in Volume I.

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APPLICABLE FUEL SYSTEM DOCUMENTS

Design Documents

AFSC DESIGN HANDBOOK, DH 1-6, Chapters 2, 3, Air Force Systems Command, Washington, D. C.

AFSC DESIGN HANDBOOK, DH 2-3 Chapters 2, 3, 4, Air Force Systems Command, Washington, D, C.

FAR, Part 27, AIRWORTHINESS STANDARDS: NORMAL CATEGORY ROTORCRAFT, Federal Aviation Administration, Washington, D. C.

FAR, Part 29, AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY ROTORCRAFT, Federal Aviation Administration, Washington, D. C.

CRASH SURVIVAL DESIGN GUIDE, USAAMRDL Technical Report 71-22, Eustis Directorate, U. S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, October 1971.

CRASHWORTHY FUEL SYSTEM DESIGN CRITERIA AND ANALYSES, USAAVLABS Technical Report 71-8, Eustis Directorate, U. S. Army Air Mobility Research and Development Laboratory, Fort Eustis, Virginia, March 1971.

Military Specifications

MIL-STD-801 Acceptance Standards for Powerplant Fluid Tank Fittings

MIL-V-5018 Valves: Fuel Selector

MIL-P-5238 Pump, Centrifugal, Fuel Booster, Aircraft, General Specification for

MIL-F-5577 Fittings, Tank, Powerplant Fluid, Removable, General Specification for

MIL-T-5578 Tank, Fuel, Aircraft, Self-Sealing

MIL-T-5624 Turbine Fuel, Aviation, Grades JP-4 and JP-5

MIL-G-5672 Gages, Fuel and Oil Quantity, Float-type, Aircraft, General Specification for

MIL-I-6181 Interference Control Requirements, Aircraft Equipment

MIL-T-6396 Tanks, Fuel, Oil, Water-Alcohol, Coolant Fluid, Aircraft, Non-Self-Sealing, Removable, Internal

MIL-C-7024 Calibrating Fluid, Aircraft Fuel System Components

MIL-H-7061 Hose, Rubber: Aircraft, Self-Sealing, Aromatic Fuel

MIL-C-7413 Couplings, Quick-Disconnect, Automatic Shutoff, General Specification for

MIL-V-7899 Valves, Check, Aircraft Fuel System

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-C-8605 Cap; Pressure Fuel Servicing
MIL-V-8608 Valves, Fuel Shutoff, Electric 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-8794 Hose, Rubber, Hydraulic, Fuel, and Oil Resistant
MIL-H-8795 Hose Assemblies, Rubber, Hydraulic, Fuel and Oil Resistant
MIL-C-22263 Couplings Fuel Line, Flexible, 125 PSI, General Specification for
MIL-V-25023 Valve, Fuel Drain, Self-Locking
MIL-H-25579 Hose Assembly, Tetrafluoroethylene, High Temperature, Medium Pressure
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-V-27393 Valve, Safety, Fuel Cell Fitting, Crash-Resistant, Aircraft, General Specification for
MIL-T-27422 Tank, Fuel, Crash-Resistant, Aircraft
MIL-V-38003 Valves, Fuel Level Control, Fuel Tank, Aircraft General Specification for
MIL-F-38363 Fuel System, Aircraft, Design, Performance, Installation, and Data Requirements, General Specification for
MIL-C-38373 Cap, Fluid Tank Filler
MIL-H-58089 Hose Assemblies and Hose, Rubber, Lightweight, Medium Pressure, and End Fittings
MIL-C-83291 Covers, Self-Sealing, Fuel Line, Aircraft

REVISIONS TO EXISTING FUEL SYSTEM SPECIFICATIONS

MIL-STD-801 - Acceptance Standards for
Powerplant Fluid Tank
Fittings

27 May 1959

There are no revisions.

MIL-V-5018A - Valves, Fuel Selector

17 February 1953

Page 3: Add paragraph 3.2.4, as follows:

"3.2.4 Cable-operated valves. Cable-operated remote valves shall be provided adequate end gap to compensate for cable flex in compression mode."

Page 14, paragraph 4.5.7: Delete and substitute the following:

"4.5.7 Contaminated-fuel endurance. Fuel containing the quantity and type of contaminant specified in MIL-F-8615 shall be pumped through the valve in a recirculating system. The valve shall be rotated at an average speed of 1 revolution per minute for 2000 revolutions (1000 clockwise and 1000 counterclockwise). Rotation shall be stepwise, pausing at each valve position for an equal time period. Fuel shall be circulated at the rated flow specified in 4.5.3.6 for the first 500 revolutions, then at 10 percent rated flow for the remaining 500 revolutions. Repeat these flow rates in the opposite direction. Fuel pressures shall not exceed 60 psi. The fuel shall be properly agitated to keep the contaminant uniformly distributed in the circulating fuel. After this test, the valve shall be drained and tested for leakage and torque in accordance with paragraphs headed Interport air-pressure leakage, Interport air-suction leakage, Normal torque, and Torque under pressure. The leakage and torque shall not exceed the values specified therein."

Page 16, Table III: Delete this table.

Page 16, paragraph 4.5.9: Delete and substitute the following:

"4.5.9 Burst pressure. With valve in the closed position, a fluid pressure of 180 psi shall be applied for a period of 1 minute successively to each port. There shall be no evidence of distortion or other injury to any part of the valve. When the pressure is lowered to 60 psi and held at each pressure for 5 minutes, there shall be no evidence of

distortion or other injury to any part of the valve. When the pressure is lowered to 60 psi and held at each pressure for 5 minutes, there shall be no evidence of external leakage from any portion of the valve. The test shall be repeated with each port of the valve successively in the open position and all other ports plugged."

MIL-P-5238B - Pump, Centrifugal, Fuel Booster
Aircraft, General Specification
for 2 February 1961

Page 10, paragraph 4.4.4: Under Pump No. 2, change test designations "(k), (l), (m), (n), (o)" to "(m), (n), (o), (p), (q)".

Page 10, paragraph 4.4.4: Add the following tests to Pump No. 2:

"(k) Service flow rate endurance	4.6.14.2"
"(l) Contaminated fuel endurance	4.6.14.3"

Page 13, paragraph 4.6.14.1.1, line 7: following "altitude of 80,000 feet" add "(25,000 feet for rotary-wing aircraft)".

Page 13, paragraph 4.6.14.1.2, line 10: following "altitude of 50,000 feet" add "(25,000 feet for rotary-wing aircraft)".

Page 13: Add paragraph 4.6.14.2, as follows:

"4.6.14.2 Service flow rate endurance. Pumps shall be operated continuously for 1200 hours at normal service (cruise) flow rates at sea level. The fuel temperature and ambient air temperature shall be held between 60° and 105°F throughout the test. Upon completion of the test, the pump shall be recalibrated and shall conform to the calibration requirements of the model specification."

Page 13: Add a new paragraph 4.6.14.3, as follows:

"4.6.14.3 Contaminated fuel endurance. The contaminated fuel test shall be conducted in accordance with MIL-F-8615. The pump shall be operated 12 hours at rated flow and 12 hours at 10 percent rated flow. Upon completion of the test, the pump shall be recalibrated and shall conform to the calibration requirements of the model specification."

MIL-F-5577B - Fittings, Tank, Powerplant
 Fluid, Removable, General
 Specification for

27 May 1959

Page 8, paragraph 4.5.2.2.1: Delete the first sentence and substitute the following:

"Specimens of rubber stocks for type I fittings shall be subjected to immersion in TT-S-735, type III fluid for 30 days."

Page 12, Table VII: Delete Table VII and substitute the following revised table:

TABLE VII. FUEL RESISTANCE AND EXTREME TEMPERATURE (TYPE I FITTINGS ONLY)						
Cycle	Test Fluid	Temperature (°F)	Pressure (psig)	Time	Vibration	Instructions
1	TT-S-735 (type III)	+135	0	5 days	No	Fitting assembled
2	Air	} +158 ±2	0	1 day	No	Fitting assembled
3	TT-S-735 (type III) with 0.01% by volume entrained water		+135	5	5 days	No
4	Dry Air	} +158 ±2	0	20 hours	No	
5	JP-4		Room	5	3 days	No
6	Dry Air	} +158 ±2	0	120 hours	Yes	Vibrate for first 24 hours
7	TT-S-735 (type I)		-65	0	24 hours	No
8	TT-S-735 (type I)	-65	5	48 hours	Yes	Vibrate for last 24 hours only

31 July 1963

Page 11, paragraph 4.4.1: Add the following at the end of the paragraph:

"(e) Leakage (4.6.1.5)"

Page 12: Add paragraph 4.6.1.5, as follows:

"4.6.1.5 Leakage. The tank, with all openings sealed, shall be subjected to the internal air pressure specified in the manufacturer's approved inspection specification. The tank shall then be completely submerged in water or covered completely with soapy water. Leakage, as indicated by the presence of air bubbles forming in the water or soapy water solution, shall be cause for rejection. If approved by the procuring activity, the tank may be subjected to an unconfined liquid stand test using TT-S-735, type III test fluid at room temperature for 24 hours with a head of 48 inches on the bottom of the tank without evidence of leakage."

Page 12, paragraph 4.6.2: Delete and substitute the following:

"4.6.2 Stand. A class A cell shall be collapsed and held strapped for 30 minutes in a position comparable to that encountered prior to installation in its respective aircraft cavity, then released and adequately supported in normal ground attitude. Both class A and class B cells shall be filled with type III fluid containing 0.1 percent water by volume. During the filling process, the capacity test (4.6.7) shall be conducted on class B tanks to determine conformance with paragraph 3.5.2. Cells shall then be tested in accordance with the following time cycle:

- | | |
|-------------------------|---------|
| (a) First cell selected | 90 days |
| (b) Second cell | 30 days |
| (c) Third cell | 30 days |

This time cycle shall be repeated for additional cells chosen in accordance with paragraph 4.4.2.2 for the duration of the contract. Upon completion of the test and at the intermediate inspections, the cells shall be carefully examined for any evidence of failure. After the examination, if faulty performance is indicated, the cell shall be dissected in the sump area, as shown in Figure 2, and

inspected for evidence of failure. In the event of failure of this test, the procuring activity and the contractor shall be notified. Bulletin No. 107 shall apply."

Page 16, paragraph 4.6.5.1, line 5: Delete "24 hours" and substitute "3 days".

Page 18, paragraph 4.6.5.5: Delete and substitute the following:

"4.6.5.5 Stand. Following the slosh resistance test (4.6.5.2), a 90-day stand test shall be conducted on the No. 3 test cell. For this test, the cell shall be properly supported, completely filled with type III fluid containing 0.1 percent water by volume, and allowed to stand. The cell shall be carefully examined every 30 days for any evidence of failure. After 90 days, if no evidence of failure is found, the cell will be considered as satisfactorily conforming to this test."

Page 20, paragraph 4.6.10, sentence 8: Delete and substitute the following:

"The tank shall then be filled with type III fluid, containing 0.1 percent water by volume and a staining agent, and allowed to stand at ambient temperature for a period of 80 days, at which time the fluid shall be drained and the tank examined for any unsatisfactory condition or indication of fuel leakage as shown by any indication of stain on the brown paper or activation of the tank sealant."

Page 20, paragraph 4.6.10.1: Delete and substitute the following:

"4.6.10.1 Dissection. After completion of the above test, the cell shall be dissected in the sump area, as shown in Figure 2. The sectioned portion of each cell shall be examined for conditions outlined in Bulletin No. 107."

MIL-T-5624H - Turbine Fuel, Aviation,
Grades JP-4 and JP-5

30 October 1970

There are no revisions.

MIL-G-5672 - Gages; Fuel and Oil Quantity,
Float Type, Aircraft,
General Specification for

22 March 1950

Page 13, paragraph 4.3.2.1: Make the following changes:

1. Change heading of "4.3.2.1 Tank unit immersion at room temperature" to "4.3.2.1.1 Fuel immersion".
2. Add general heading of "4.3.2.1 Contaminated fuel endurance".
3. Add the following paragraph:

"4.3.2.1.2 Solid particle contamination. The tank unit shall be immersed for 5 hours in TT-S-735, type III test fluid containing the types and concentrations of contaminants specified in MIL-F-8615. The test fluid and contaminant shall be circulated for 1-minute periods every 30 minutes during the test period. Any corrosion, binding, or tendency to stick shall be cause for the rejection of the lot of tank units."

MIL-I-6181D - Inteference Control Requirements,
Aircraft Equipment

25 November 1959

There are no revisions.

MIL-T-6396C - Tanks, Fuel, Oil, Water-Alcohol,
Coolant Fluid, Aircraft Non-
Self-Sealing, Removable,
Internal

7 June 1965

Page 15, paragraph 4.6.2: Delete and substitute the following:

"4.6.2 Stand test (sampling). The type II cells selected in accordance with 4.4.2.2 shall be subjected to the following test: The cell shall be collapsed and held strapped for 30 minutes in a position comparable to that encountered prior to installation in its respective aircraft cavity, then released and adequately supported in the normal ground attitude. The cell shall then be filled with the applicable test fluid as specified in 4.5.1. The fluid shall contain a satisfactory staining agent. In addition, the test fluid for fuel tanks shall contain 0.1 percent water by volume. The cell shall be stand tested as follows:

- (a) Each cell selected from the lot shall be stand tested for 90 days.
- (b) Each cell shall be inspected at approximately 30-day intervals.

Upon completion of the test, and at the intermediate inspections, the cell shall be carefully examined for any evidence of failure and to determine conformance with the standards listed in ANA Bulletin No. 435. After the examination, if faulty performance is indicated, the cell shall be dissected at strategic points (such as areas adjacent to fittings, repaired sections, sump areas, and points of abrupt change in contour and corners) and further examined for evidence of failure. In the event of failure of this test, the procuring activity and contractor shall be notified. An alternate method for detecting leakage during this test is acceptable if approved by the procuring activity."

Page 18, paragraph 4.6.9: Add "plus 0.1 percent water by volume for fuel tanks" to the end of the second sentence.

MIL-C-7024B - Calibrating Fluid, Aircraft
Fuel System Components

19 May 1969

There are no revisions.

MIL-H-7061A - Hose, Rubber: Aircraft Self-
Sealing, Aromatic Fuel

6 June 1966

Page 5: Add paragraph 3.5.7, as follows:

"3.5.7 Performance of hose assemblies. Hoses assembled with applicable end fittings shall satisfy the performance requirements specified in Section 4 when subjected to the following tests:

- (a) Proof pressure (4.6.2)
- (b) Burst pressure (4.6.6, 4.6.6.1)"

Page 7: Add paragraph 4.4.1.2, as follows:

"4.4.1.2 Additional samples. The qualification test samples shall also include a sufficient length of hose of each size upon which qualification is desired to make up three test assemblies with each of the end fittings conforming to MS28752, MS28753, MS28754, MS28755, and MS28756. The test assemblies shall have a free length of 12 inches between fittings."

Page 7, paragraph 4.5.1: Delete and substitute the following:

"4.5.1 Individual tests. Each length of hose and each hose assembly submitted for acceptance under contract shall be subjected to the following tests:

- (a) Examination of product
- (b) Proof pressure (4.6.2)"

Page 8, paragraph 4.6.1: Delete and substitute the following:

"4.6.1 Examination of product. All hoses and hose assemblies shall be carefully examined to determine conformance with this specification with respect to materials, workmanship, construction and marking."

Page 8, paragraph 4.6.2: Delete and substitute the following:

"4.6.2 Proof pressure. Each length of hose and each hose assembly shall be subjected to 100 ±5 pounds per square inch, using fuel conforming to TT-S-735, or water, for 5 minutes. Hoses shall show no signs of leakage through the hose wall or cover, and hose assemblies shall show no signs of leakage through the hose or between the hose and end fittings. Proof pressure tests of hose only may be accomplished with any suitable end fittings."

Page 8, paragraph 4.6.5.2: Delete this paragraph.

Page 9, paragraph 4.6.5.3: Delete this paragraph.

Page 11: Add paragraph 4.6.15, as follows:

"4.6.15 Fuel immersion. A 12-inch length of hose shall be immersed in fluid conforming to TT-S-735, type III, for 72 hours at a temperature of 135°F. Upon completion of this period, the sample shall be removed and, at room temperature, shall pass the proof pressure test of 4.6.2. The hose shall then be dissected longitudinally, and any indication of disintegration such as ply separation, solubility of component parts, porosity, blistering, or collapse shall be cause for rejection."

MIL-C-7413B - Couplings, Quick-Disconnect,
Automatic Shutoff, General
Specification for

2 February 1970

Page 4, paragraph 3.6.1.1.1: Add the following sentence
to the end of the paragraph:

"The locking mechanism shall be designed to reduce the
possibility of human error during assembly and mainte-
nance."

Page 14, paragraph 4.6.14.3: Add the following sentence
to the end of the paragraph:

"The last three cycles (60 hours duration) shall be con-
ducted with a 5-pound tensile load applied on the coupling
through the hose."

MIL-V-7899A - Valves, Check, Aircraft
Fuel System

16 June 1970

There are no revisions.

MIL-G-7940C - Gages, Liquid Quantity, Capacitor
Type, Installation and Calibra-
tion of

20 August 1971

There are no revisions.

MIL-P-8045B - Plastic, Self-Sealing and
Non-Self-Sealing Tank
Backing Material

10 April 1964

There are no revisions.

MIL-C-8605 - Cap; Pressure Fuel Servicing

14 July 1953

There are no revisions.

MIL-V-8608A - Valves, Fuel Shutoff,
Electric Motor Operated

19 April 1963

Page 11, paragraph 4.6.8: Add the following sentence to
the end of the paragraph:

"(e) Valves equipped with thermal relief provisions
shall be subjected to the thermal relief operation
test (4.6.5)."

MIL-V-8610A - Valves, Fuel Shutoff
Solenoid Operated,
28 Volt DC

11 December 1968

Page 10, paragraph 4.6.4: Delete and substitute the following:

"4.6.4 Contaminated fuel endurance. Fuel containing the quantity and type of contaminant specified in MIL-F-8615 shall be pumped through the valve in a recirculating system. The valve shall be operated at the rate of 6 cpm with the solenoid energized approximately 75 percent of the time for 1000 cycles at rated flow and 1000 cycles at 10 percent of rated flow. The fuel shall be properly agitated to keep the contaminant uniformly distributed in the circulating fuel. An inlet pressure of 25 psi shall be maintained on the valve with the valve discharge restricted to obtain flow rates. The dynamic leakage test, using a shutoff pressure of 25 psi instead of the 60 psi specified in 4.6.6.1, shall be conducted periodically at least once every 200 cycles. At the conclusion of the test, the valve shall be subjected to the calibration tests of 4.6.2."

Page 11, Table I: Delete this table.

MIL-F-8615C - Fuel System Components, General
Specification for

26 February 1969

Page 16, paragraph 4.6.5: Add the following sentence to the end of paragraph:

"(c) All components in which lubrication or sealing is dependent on fuel flow shall be subjected to an endurance test of 1200 hours of continuous operation at normal service (cruise) flow rates in addition to the 1200-hour test at maximum operating load condition."

Page 23, Table IV: Add the following to the altitude test setup:

"(25,000 feet for rotary-wing aircraft)".

Page 24, paragraph 4.6.5.3: Delete the last sentence and substitute the following:

"Altitude shall be at least 60,000 feet for fixed-wing aircraft and at least 25,000 feet for rotary-wing aircraft."

Page 26, paragraph 4.6.7.1: Delete the next to the last sentence and substitute the following:

"Immediately following the circulation period, the component shall be drained and the functional and leakage tests (4.6.3.1 and 4.6.2, respectively) shall be performed."

MIL-S-8710B - Strainer, Airframe Fuel
System, General
Specification for

10 July 1969

Page 7, paragraph 4.3.2: Change test designations from "(f), (g), (h), (i), (j), (k), (l)" to "(g), (h), (i), (j), (k), (l), (m)", respectively. Add the following:

"(f) Functional contamination test (4.6.9)"

Page 13, paragraphs 4.6.9 through 4.6.14: Change paragraph numbers "4.6.9, 4.6.10, 4.6.11, 4.6.12, 4.6.13, 4.6.14" to "4.6.10, 4.6.11, 4.6.12, 4.6.13, 4.6.14, 4.6.15", respectively.

Page 13: Add new paragraph 4.6.9, as follows:

"4.6.9 Functional-contamination test. Fuel contaminated according to MIL-F-8615 shall be circulated through the strainer at normal cruise flight flow rates until the bypass system activates. The pressure drop through the strainer shall be monitored, and full bypass must occur within the pressure range specified by the procurer. Any evidence of strainer malfunction, as reflected by sudden changes in the pressure drop prior to bypass, shall be cause for discontinuing the test. The strainer shall then be disassembled and inspected in accordance with 4.6.15."

MIL-H-8794D - Hose, Rubber, Hydraulic,
Fuel, and Oil Resistant

4 February 1971

Page 14, paragraph 4.5.3.5, line 1: Delete "9 inches" and substitute "12 inches".

Page 14, paragraph 4.5.3.5, line 3: Delete "at room temperature" and substitute "at a temperature of 135°F".

MIL-H-8795B - Hose Assemblies, Rubber,
Hydraulic, Fuel and Oil
Resistant

21 March 1966

There are no revisions.

MIL-C-22263B - Couplings, Fuel Line,
Flexible, 125 psi,
General Specification
for

28 June 1972

Page 9, paragraph 4.6.1.2, line 2: Add "leakage" following "rupture".

Page 9: Add paragraph 4.6.1.3, as follows:

"4.6.1.3 Leakage. The test assembly shall be subjected to pressures ranging from 0 psi to 120 psi in 10-psi increments and held at each level for 1 minute. During this time period the coupling shall be flexed at a frequency of 60 cycles per minute with a 1/2° flexure in any direction. No visible leakage or wetting of the external surface shall be permitted."

Page 10, paragraph 4.6.2.1: Add the following sentence to the end of the paragraph:

"The coupling shall also pass the leakage test of 4.6.1.3."

Page 10, paragraph 4.6.2.2: Add the following sentence to the end of the paragraph:

"The coupling shall also pass the leakage test of 4.6.1.3."

Page 10, paragraph 4.6.2.3: Add the following sentence to the end of the paragraph:

"The coupling shall also pass the leakage test of 4.6.1.3."

Page 10: Add paragraph 4.6.2.5, as follows:

"4.6.2.5 Contaminated fuel. The test assembly shall be subjected to the contaminated fuel endurance test of MIL-F-8615, followed by the leakage test of 4.6.1.3."

Page 11, paragraph 4.6.7: Add the following sentence to the end of the paragraph:

"The coupling shall also pass the leakage test of 4.6.1.3."

MIL-V-25023B - Valve, Fuel Drain, Self-
Locking

17 August 1967

Page 13, paragraph 4.6.6, last sentence: Delete "flushed out with clear fuel and".

MIL-H-25579C - Hose Assembly, Tetrafluoro-
ethylene, High Temperature,
Medium Pressure

20 February 1967

There are no revisions.

MIL-A-25896D - Adapter, Pressure Fuel
Servicing, Aircraft,
Nominal 2-1/2 Inch
Diameter

14 March 1969

There are no revisions.

MIL-S-25980A - Switch, Float, Aircraft
Fuel Level, General
Specification for

15 June 1965

There are no revisions.

MIL-S-26390A - Switch Assemblies, Pressure,
Aircraft Fuel

20 May 1969

Page 12, paragraph 4.4.3 a: Change numbers of Sample No.
1 Tests from "(6), (7), (8), (9), (10), (11)" to "(7), (8),
(9), (10), (11), (12)", respectively. Add new test (6) as
follows:

"(6) Contaminated fuel endurance 4.6.11"

Page 13, paragraph 4.4.3 c: Change numbers of Sample No.
3 Tests from "(6), (7), (8), (9), (10), (11), (12)" to "(7),
(8), (9), (10), (11), (12), (13)", respectively. Add new test
(6) as follows:

"(6) Contaminated fuel endurance 4.6.11"

Page 18, paragraphs 4.6.11 through 4.6.13: Change para-
graph numbers from "4.6.11, 4.6.12, 4.6.13" to "4.6.12, 4.6.13,
4.6.14", respectively. Add new paragraph 4.6.11 as follows:

"4.6.11 Contaminated fuel endurance. The contaminated
fuel endurance test shall be conducted as specified in
MIL-F-8615. Immediately following the test, the switch
shall be drained and subjected to the functional (4.6.4)
and leakage tests (4.6.5)."

MIL-G-26988B - Gage, Liquid Quantity,
Capacitor Type, Tran-
sistorized, General
Specification for

2 February 1968

Page 7: Add paragraph 3.11.8, as follows:

"3.11.8 Crashworthy tank units. If the gage is to be installed in a crashworthy fuel tank or system, the construction of the tank probe unit shall include a slightly rounded shoe at the bottom of the probe. The probe shall be of low flexural rigidity or include a frangible section which allows column failure of the probe at a load no greater than 75 foot-pounds per inch of circumference."

Page 20, paragraph 4.5.2.2: Delete "h. Tank unit water immersion test" and substitute "h. Tank unit immersion test".

Page 30, paragraph 4.6.22: Make the following changes:

1. Change heading of "4.6.22 Tank unit water immersion test" to "4.6.22.1 Water".
2. Add general heading of "4.6.22 Tank unit immersion test".
3. Add the following paragraph:

"4.6.22.2 Contaminated fuel. The tank unit assembly of the gage shall be mounted in a suitable tank and the tank filled three-quarters or more with fuel conforming to TT-S-735, type III. The capacitance reading and fuel level shall be noted. Solid particle contaminants as specified in MIL-F-8615 shall then be added to the fuel. The fuel and contaminants shall be circulated for 1-minute periods every 30 minutes during a 5-hour test period. At the end of the test period, the unit shall be removed and placed in clean type III fluid at the same level recorded at the beginning of the test. The indicator reading shall be noted, and the change of capacitance from the original reading shall not exceed 1.0 percent of the reference capacitance."

MIL-V-27393A - Valve, Safety, Fuel Cell
Fitting, Crash-Resistant,
Aircraft, General Specifi-
cation for

24 February 1964

Substitute draft specification MIL-V-27393B, Valves, Self-Sealing Breakaway, Crash-Resistant, Aircraft Fuel System, contained elsewhere in this report.

Page 13: Add paragraph 4.6.1.4, as follows:

"4.6.1.4 Leakage. The tank, with all openings sealed, shall be subjected to the internal air pressure specified in the manufacturer's approved inspection specifications. The tank shall then be completely submerged in water or covered completely with soapy water. Leakage, as indicated by the presence of air bubbles forming in the water or soapy water solution, shall be cause for rejection. If approved by the procuring activity, the tank may be subjected to an unconfined liquid stand test using TT-S-735, type III test fluid at room temperature for 24 hours with a head of 48 inches on the bottom of the tank without evidence of leakage."

Page 13, paragraph 4.6.2: Delete and substitute the following:

"4.6.2 Stand. Prior to the stand test, type I cells shall be subjected to the fuel resistance of exterior surface test specified in 4.6.6.1. An alternate procedure for conducting this 3-day test may be used if approved by the procuring activity. Upon completion of this test, the outside surface of the cell shall be dried with a cloth, and the cell shall be stored in an airtight bag or immediately installed in the cavity used for the stand test.

Each class A cell shall be collapsed and held strapped for 30 minutes in a position comparable to that encountered prior to installation in its respective aircraft cavity, then released and adequately supported in normal ground attitude. Both class A and class B cells shall be filled with type III fluid containing 0.1 percent water by volume. During the filling process, the capacity test (4.6.7.2) shall be conducted on class B tanks to determine conformance with 3.5.2. Cells shall then be tested in accordance with the following time cycle:

- | | |
|-------------------------|---------|
| (a) First cell selected | 90 days |
| (b) Second cell | 30 days |
| (c) Third cell | 30 days |

This time cycle shall be repeated for additional cells chosen in accordance with 4.4.2.2 for the duration of the contract. Upon completion of the test and at the intermediate inspections, the cells shall be carefully examined for any evidence of failure. After the examination, if faulty performance is indicated, the cell shall be dissected in the sump area, as shown in Figure 2, and inspected for evidence of failure. In the event of failure of this test, the procuring activity and the contractor shall be notified. Bulletin No. 107 or 435 shall apply."

Page 19, paragraph 4.6.6.6, line 2: Add "containing 0.1 percent water by volume" after "type III fluid".

MIL-V-38003 - Valves, Fuel Level Control,
Fuel Tank, Aircraft,
General Specification for 19 May 1966

Page 13, Table II: Add the following contaminant and quantity:

<u>Contaminant</u>	<u>Quantity</u>
Salt water solution shall contain 4 parts NaCl to 96 parts H ₂ O by wt.	0.01% entrained

MIL-F-38363B - Fuel System, Aircraft,
General Specification
for 13 October 1971

Substitute the draft military specification entitled Fuel System, Aircraft, Standard and Crashworthy, General Specification for, contained elsewhere in this report.

MIL-C-38373A - Cap, Fluid Tank Filler 26 February 1969

There are no revisions.

MIL-H-58089 - Hose Assemblies and Hose,
Rubber, Lightweight,
Medium Pressure, and
End Fittings 10 March 1969

There are no revisions.

MIL-C-83291A - Covers, Self-Sealing,
Fuel Line, Aircraft 10 August 1972

Page 8, paragraph 4.5.8: Delete and substitute the following:

"4.5.8 Fuel resistance. The covers shall be immersed for 1 hour in TT-S-735 (type III) fluid at 135°F. Any swelling, cover deterioration, or cover activation shall be cause for rejection. If the cover is to be used in an immersed location, the test time shall be lengthened to 72 hours."

DRAFT MILITARY SPECIFICATION

VALVES, SELF-SEALING BREAKAWAY, CRASH-RESISTANT,
AIRCRAFT FUEL SYSTEM

1. SCOPE

1.1 Scope. This specification covers the general requirements for self-sealing breakaway valves for crash-resistant aircraft fuel systems.

1.2 Classification. This specification covers fuel system self-sealing breakaway valves of the following types:

- Type I - Cell-to-line
- Type II - Cell-to-cell
- Type III - Line-to-line
- Type IV - Line-to-bulkhead

2. APPLICABLE DOCUMENTS

2.1 The following documents, of issue in effect on date of invitation for bids or request for proposal, form a part of this specification to the extent specified herein. In the event of conflict between these specifications and the text of this specification, the latter shall govern.

SPECIFICATIONS

Federal

NN-P-530	Plywood, Flat Panel
QQ-C-320	Chromium Plating (Electrodeposited)
QQ-P-35	Passivation Treatments for Austenitic, Ferritic, and Martensitic Corrosion-Resisting Steel (Fastening Devices)
TT-S-735	Standard Test Fluids, Hydrocarbon
TT-W-572	Wood-Preservative; Water-Repellent
PPP-B-601	Boxes, Wood, Cleated Plywood

Military

MIL-D-1000 Drawing, Engineering and Associated List
MIL-J-5161 Jet Fuel, Referee
MIL-G-5572 Gasoline, Aviation, Grades 80/87, 100/130,
115/145
MIL-T-5624 Turbine Fuel, Aviation, Grades JP-4 and JP-5
MIL-C-6021 Casting, Classification and Inspection of
MIL-C-7024 Calibrating Fluid, Aircraft Fuel System Com-
ponents
MIL-I-8500 Interchangeability and Replaceability of Com-
ponent Parts for Aircraft and Missiles
MIL-F-8615 Fuel System Components, General Specification
for
MIL-A-8625 Anodic Coatings, for Aluminum and Aluminum
Alloys
MIL-S-8879 Screw Threads, Controlled Radius Root with
Increased Minor Diameter, General Specifica-
tion for
MIL-N-25027 Nut, Self-Locking, 240 Deg. F, 450 Deg. F,
and 800 Deg. F, 125 Ksi Ft_u, 60 Ksi Ft_u, and
30 Ksi Ft_u
MIL-C-45662 Calibration System Requirements

STANDARDS

Military

MIL-STD-129 Marking for Shipment and Storage
MIL-STD-130 Identification Marking of U. S. Military
Property
MIL-STD-143 Standards and Specifications, Order of Prece-
dence for the Selection of
MIL-STD-794 Parts and Equipment, Procedures for Packaging
and Packing of
MIL-STD-810 Environmental Test Methods
MIL-STD-889 Dissimilar Metals
MS20995 Wire, Safety or Lock
MS33540 Safety Wiring and Cotter Pinning, General
Practices for
MS33588 Nut, Self-Locking, Aircraft Design and Usage
Limitations of

3.4 Materials. Materials and processes used in the self-sealing breakaway valves shall be suitable for the purpose and shall conform to applicable Government specifications. Materials conforming to contractors' specifications may be used provided the specifications are released to the Services and contain provision for adequate tests. The use of contractors' specifications shall not constitute waiver of Government inspection.

3.4.1 Metals. All metals used in the construction of the valves shall be corrosion-resistant or shall be suitably protected to resist corrosion during the normal service life of the valves.

3.4.1.1 Dissimilar metals. Unless suitably protected against electrolytic corrosion, dissimilar metals as defined in MIL-STD-889 shall not be used in intimate contact with each other.

3.4.1.2 Magnesium. Magnesium or magnesium alloy shall not be used in the manufacture of breakaway valves.

3.4.1.3 Copper, copper alloys, and cadmium plating. Copper, copper alloys, and cadmium plating shall not be used in breakaway valves.

3.4.2 Fungus-proof materials. Materials that are nutrients for fungi shall not be used where it is practicable to avoid them. Where used and not hermetically sealed, they shall be treated with a fungicidal agent acceptable to the procuring agency.

3.4.3 Castings. Castings shall be clean, sound, and free from blowholes, porosity, cracks, and any other defects. Castings shall be in accordance with MIL-C-6021.

3.4.4 Fluid media. The valves shall be suitable for use with fuels conforming to MIL-G-5572, MIL-T-5624, MIL-J-5161, test fluid Types I and III per TT-S-735, and test fluid Type II per MIL-C-7024.

3.5 Parts

3.5.1 Standard parts. Standard parts (MS or AN) shall be used wherever they are suitable for the purpose and shall be identified on the drawing by their part number. Commercial utility parts such as screws, bolts, nuts, and cotter pins may be used provided (1) they possess suitable properties and are replaceable by the standard parts without alteration and (2) the corresponding standard number is referenced in the parts list and, if practicable, on the vendor's drawing. In the event that there are no suitable corresponding standard parts in effect

on the date of invitation for bids, commercial parts may be used if they conform to all requirements of this specification.

3.5.2 Threaded parts. Threaded parts shall be in accordance with MIL-S-8879. The use of pipe threads is prohibited.

3.5.3 Elastomeric parts. Age-sensitive elastomeric parts shall be subject to age controls in accordance with ANA Bulletin No. 438.

3.6 Design. The valves shall be designed with a frangible section constructed to fail at predetermined loads in accordance with the requirements of this specification. Upon separation, internal self-sealing mechanisms in each valve section shall automatically close and seal, preventing fluid leakage. The valves shall be designed to prevent external leakage between valve separation and closure of both valve halves. The valves shall be the simplest possible design consistent with the requirements of this specification. Moreover, the valve design shall facilitate quantity production.

3.6.1 Special tools. The design shall be such that no special tools are required to accomplish the installation of each valve or its removal from the fuel system.

3.6.2 Valve configuration. The outside configuration of each valve, such as the method of mounting, the type of fluid connections, and the permissible envelope, shall be determined by the contractor to meet the specific needs of each fuel system.

3.6.3 Weight. Each valve shall be of the lowest possible weight commensurate with the design requirements associated with the application of the valve.

3.7 Construction. Each valve shall be constructed to withstand the strains, jars, vibrations, and other conditions incident to shipping, storage, installation, and service use. A valve shall not require, except for initial preservation, special treatment or controlled environment during storage.

3.7.1 Locking of parts. All threaded parts shall be locked by safety wiring, self-locking nuts, cotter pins, or other approved methods. Safety wiring shall be installed in accordance with MS33540 and shall conform to MS20995. Self-locking nuts shall be in accordance with MIL-N-25027 and MS33588. Where loosening or disengagement of the self-locking nut could result in the nut or other parts entering the fuel system, approval of the installation shall be obtained from the procuring activity. Lockwashers or staking is prohibited.

3.8 Maintainability.

3.8.1 Interchangeability. All parts having the same manufacturer's part number shall be directly and completely interchangeable with each other with respect to installation and performance in accordance with MIL-I-8500. Changes in manufacturer's part numbers shall be governed by the drawing number requirements of MIL-D-1000.

3.8.2 Replaceability. Each valve replacement must be effected without requiring special tools, facilities, or highly skilled personnel.

3.8.3 Serviceability. Each valve shall be so designed that, except for preservation procedures, scheduled maintenance, adjustments, or cleaning is not required to maintain physical or functional capability; and no repairs shall be required during normal service life.

3.8.4 Service life. Service life shall be 6,000 flight hours or 10 calendar years. Service life shall be computed from date of initial aircraft installation to completion of calendar/flight hour schedule, whichever comes first.

3.9 Performance.

3.9.1 Rated pressure. Each valve shall be designed to operate at 60 psi or the maximum anticipated fuel system pressure, whichever is greater.

3.9.2 Temperature range. Each valve shall be designed to function normally in temperatures ranging from -65°F to +160°F.

3.9.3 Pressure drop. Unless required by specific fuel system needs, the maximum ΔP at rated flow shall produce a maximum K factor of 4.0. K is defined by the equation

$$K = \frac{V_H}{\Delta P}$$

where

V_H is the calculated velocity head in psi through the valve at rated flow.

ΔP is the net pressure drop in psi across the valve under the same flow conditions at which V_H was determined.

The valve shall not exceed the specified pressure drop when it is subjected to the test of 4.5.2.

3.9.4 Leakage.

3.9.4.1 Leakage, before valve separation. There shall be no external leakage when the valve is subjected to the leakage test of 4.5.3.

3.9.4.2 Leakage, after valve separation. External leakage shall not exceed 15 cc/min when each separated valve section is subjected to the leakage test of 4.5.17.

3.9.5 Proof pressure. There shall be no external leakage when a valve is subjected to the proof pressure test of 4.5.4.

3.9.6 Burst pressure.

3.9.6.1 Burst pressure, before valve separation. There shall be no external leakage when a valve is subjected to the burst pressure test of 4.5.5.

3.9.6.2 Burst pressure, after valve separation. Each separated valve section shall be subjected to the burst pressure test of 4.5.18. Upon return to rated pressure, the leakage rate shall not exceed 15 cc/min.

3.9.7 Vibration. A valve shall not close nor shall there be any evidence of structural failure, loosening of parts, or leakage either during or as a result of the vibration test of 4.5.6.

3.9.8 Fuel resistance and low temperature. There shall be no leakage when a valve is subjected to the test of 4.5.7.

3.9.9 Corrosion resistance. The valve shall function properly and shall not show evidence of corrosion following the accelerated corrosion test of 4.5.8.

3.9.10 Shock. A valve shall not close nor shall there be any evidence of structural failure during or following the shock test of 4.5.9. The valve shall meet the requirements of the leakage test of 4.5.3 following the shock test.

3.9.11 Surge flow. A valve shall not close nor shall there be any evidence of failure or loosening of parts following the surge pressure test of 4.5.10.

3.9.12 Contaminated fuel endurance. Following the contaminated fuel endurance test of 4.5.11, a valve shall satisfactorily pass the tests of 4.5.15 and 4.5.17.

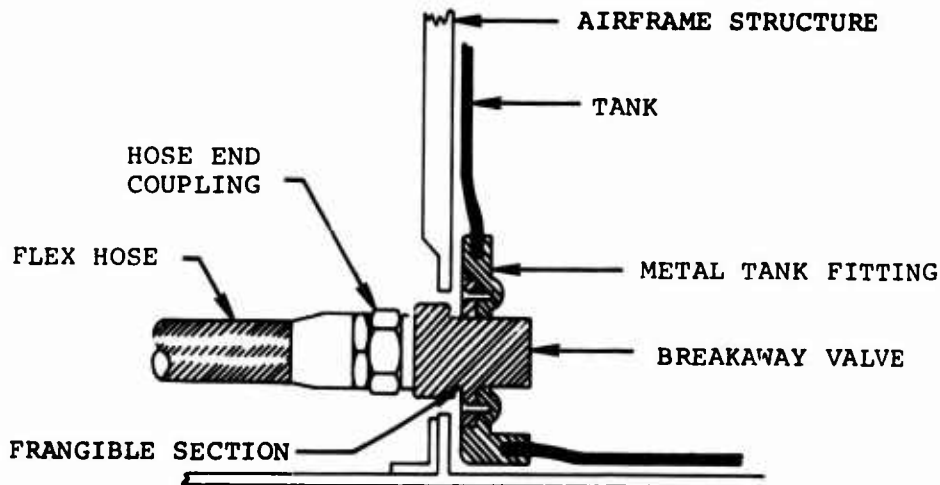
3.9.13 Acceleration. A valve shall not close nor shall there be any evidence of structural failure following the acceleration test of 4.5.12. The valve shall meet the requirements of the leakage test, 4.5.3, after the acceleration test.

3.9.14 Fungus. A valve shall function properly, and there shall be no evidence of corrosion or deterioration following the fungus test of 4.5.13.

3.9.15 Icing. A valve shall function properly, and leakage shall not exceed that specified in 3.9.19, when it is subjected to the icing test of 4.5.14.

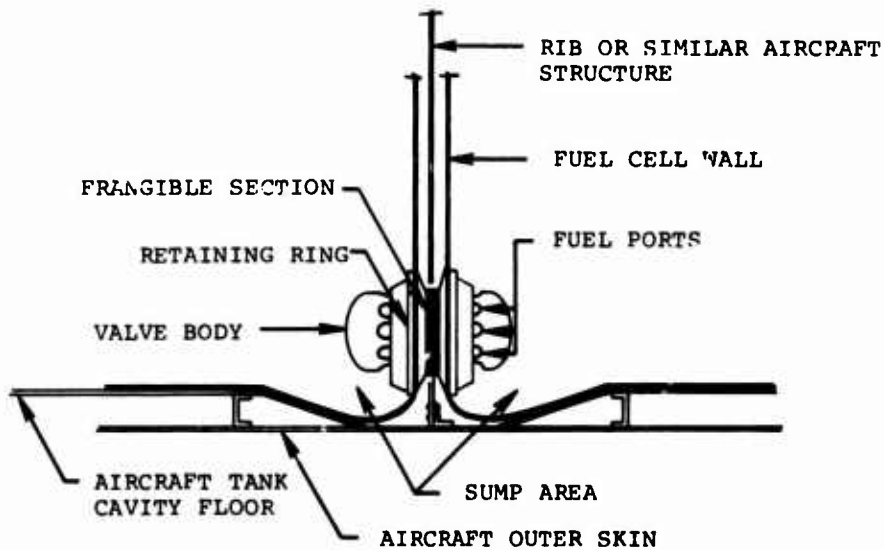
3.9.16 Separation modes. Each valve shall separate and seal upon application of a predetermined load (3.9.17) caused by a force producing tension, bending, shear, or combinations thereof in the frangible section of a valve when subjected to the static separation test of 4.5.15. Each valve shall also separate and seal under these modes during the dynamic separation tests of 4.5.16. No load requirements are imposed during dynamic tests except that the valve must separate and seal before any of the attached hardware fails. If an analysis of the surrounding aircraft structure and probable impact forces and directions indicate that a valve cannot be loaded in a particular direction, that separation mode requirement may be waived subject to the approval of the analysis by the procuring activity and at the discretion of the procuring activity.

3.9.17 Separation loads. Each valve shall meet all operational and service loads of the aircraft but shall separate and seal at a force between 25 and 50 percent of the force required to fail the weakest component of the fuel system adjacent to the valve. The separation forces for each valve shall be determined by analyzing the surrounding aircraft structure and the probable impact forces on the fuel system components as illustrated in Figures 1 through 4. Moment arms used in bending load calculations shall be those determined by the aircraft manufacturer's analysis of the fuel system configuration and are constant for the standard and crashworthy system. The results of such analyses shall be subject to the approval of the procuring activity. All valves that are located where they are subject to direct impact during a crash by aircraft structure or components, or by objects outside the aircraft, shall separate and seal at a shear force between 25 and 50 percent of the load required to fail the adjacent fuel system components or the valve housing, whichever is smaller. All separation loads shall be verified by the static separation tests of 4.5.15.



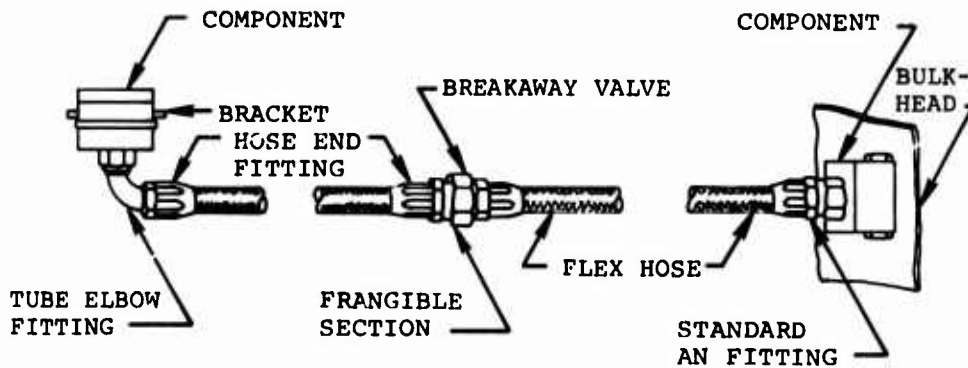
Item	Lowest Failure Load (lb)*	Failure Mode**
Flex Hose	3000	Tension Breakage
Flex Hose	1500	Pullout of End Fitting
Tank Fitting	7500	Pullout of Tank
Hose End Coupling	1650	Break (Bending)
Breakaway Valve	2500	Pullout of Tank Fitting
Breakaway Valve	Not more than $\frac{1500}{2} = 750$	Break at Frangible Section - Tension Mode
	Not less than $\frac{1500}{4} = 375$	
Breakaway Valve	Not more than $\frac{1650}{2} = 825$	Break at Frangible Section - Bending Mode
	Not less than $\frac{1650}{4} = 412$	
*Loads may or may not be representative; values are for explanatory purposes only.		
**Conduct similar calculations for shear failure mode.		

Figure 1. Sample Separation Load Calculation for Type I (Cell-to-Line) Breakaway Valve.



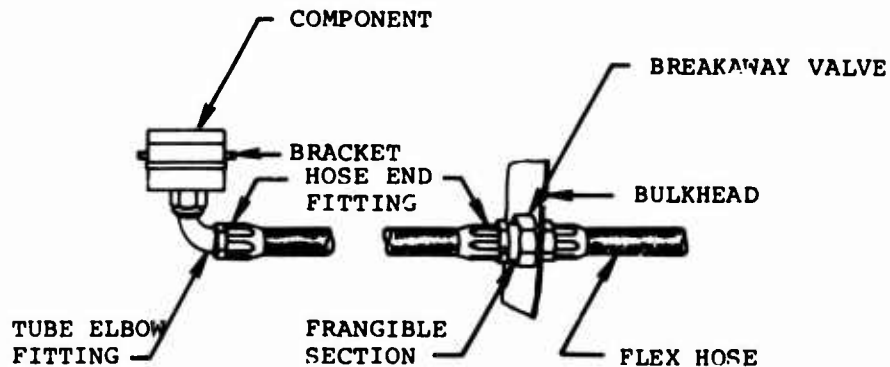
Item	Lowest Failure Load (lb)*	Failure Mode**
Tank Fitting	7500	Pullout of Tank (Tension)
Retaining Ring	10000	Break (Bending)
Fuel Cell Wall	3000	Tear Around Valve
Breakaway VALVE	Not more than $\frac{3000}{2} = 1500$ Not less than $\frac{3000}{4} = 750$	Break at Frangible Section - Shear Mode
Breakaway Valve	Not more than $\frac{7500}{2} = 3750$ Not less than $\frac{7500}{4} = 1875$	Break at Frangible Section - Tension Mode
*Loads may or may not be representative; values are for explanatory purposes only.		
**Conduct similar calculations for bending mode.		

Figure 2. Sample Separation Load Calculation for Type II (Cell-to-Cell) Breakaway Valve.



Item	Lowest Failure Load (lb)*	Failure Mode**
Flex Hose	3000	Tension Breakage
Flex Hose	1500	Pullout of End Fitting
Hose End Fitting	1650	Break (Bending)
Standard AN Fitting	1700	Break (Bending)
Tube Elbow Fitting	900	Break (Bending)
Component Structural Attachments	4500	Pullout of Structure
Breakaway Valve	Not more than $\frac{900}{2} = 450$	Break at Frangible Section - Bending Mode
	Not less than $\frac{900}{4} = 225$	
Breakaway Valve	Not more than $\frac{1500}{2} = 750$	Break at Frangible Section - Tension Mode
	Not less than $\frac{1500}{4} = 325$	
*Loads may or may not be representative; values are for explanatory purposes only.		
**Conduct similar calculations for shear mode.		

Figure 3. Sample Separation Load Calculation for Type III (Line-to-Line) Breakaway Valve.



Item	Lowest Failure Load (lb)*	Failure Mode**
Flex Hose	3000	Tension Breakage
Flex Hose	1500	Pullout of End Fitting
Hose End Fitting	1650	Break (Bending)
Tube Elbow Fitting	900	Break (Bending)
Component Structural Attachments	4500	Pullout of Structure
Breakaway Valve	Not more than $\frac{900}{2} = 450$	Break at Frangible Section - Bending Mode
	Not less than $\frac{900}{4} = 225$	
Breakaway Valve	Not more than $\frac{1500}{2} = 750$	Break at Frangible Section - Tension Mode
	Not less than $\frac{1500}{4} = 325$	
*Loads may or may not be representative; values are for explanatory purposes only.		
**Conduct similar calculations for shear failure mode.		

Figure 4. Sample Separation Load Calculation for Type IV (Line-to-Bulkhead) Breakaway Valve.

3.9.18 Valve closure. The self-sealing mechanisms of a valve shall close before a maximum relative displacement of 0.125 inch occurs between the separating valve sections at the point of fracture.

3.9.19 Spillage. The amount of fuel spillage upon valve separation shall not exceed four times the volume trapped between the self-sealing mechanisms of the valve.

3.9.20 Dissassembly and inspection. Upon completion of all tests, any evidence of corrosive action or abnormal wear which might cause malfunction shall be reported.

3.10 Color and finishes.

3.10.1 Color identification. Valves shall be marked as specified in MIL-F-8615.

3.10.2 Finishes.

3.10.2.1 Aluminum alloy. Aluminum alloy parts shall be anodized in accordance with MIL-A-8625.

3.10.2.2 Corrosion-resistant steel. Corrosion-resistant steel parts shall be passivated in accordance with QQ-P-35.

3.10.2.3 Chromium plating. Chromium plating shall conform to QQ-C-320, class 2.

3.11 Product markings.

3.11.1 Identification. All valves shall be marked for identification in accordance with MIL-STD-130.

3.11.2 Nameplate. A nameplate containing the following information shall be securely attached to each valve, or the information may be etched, engraved, embossed, or stamped in a suitable location on the valve:

Valve, breakaway, self-sealing

Purchaser's part number

Manufacturer's name or trademark

Manufacturer's part number

Manufacturer's serial number

3.11.3 Drawings. Manufacturer's assembly and detail drawings shall conform to MIL-D-1000.

3.12 Workmanship. Attention shall be given to neatness and thoroughness of assembly, alignment of parts, tightness of assembly screws and bolts, marking of parts, painting, and removal of burrs and sharp edges.

3.12.1 Cleaning. All parts shall be clean and free from dirt, sand, metal chips, and other foreign matter during and after assembly.

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 inspection requirements as specified herein. 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 or otherwise specified in the contract or order. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure that suppliers and services conform to prescribed requirements.

4.2 Classification of inspections. The inspection and testing of self-sealing breakaway valves shall be classified as follows:

- a. First article inspection (4.3).
- b. Quality conformance inspection (4.4).

4.3 First article inspection.

4.3.1 First article samples. The first article inspection samples shall consist of a minimum of eight valves.

4.3.2 First article tests. First article tests shall consist of the examinations and tests shown in Table 1 and conducted in the sequence shown.

4.3.3 Rejection and retest of first article samples. If a valve fails any of the first article tests, the tests shall be terminated. The replacement valve shall have a redesigned part or shall have different material in the part corresponding to the failed part, except that if the failure was caused by faulty material or workmanship, the procuring activity may authorize the retest of another valve of the original design. The first article tests shall be considered complete when every valve has concurrently completed the first article tests.

TABLE 1. FIRST ARTICLE TESTS										
Examination or Test	Requirement Paragraph	Method Paragraph	Sample Number							
			1	2	3	4	5	6	7	8
Examination of Product	3.11, 3.12	4.5.1	X	X	X	X	X	X	X	X
Pressure Drop	3.9.3	4.5.2	X							
Leakage Before Valve Separation	3.9.4.1	4.5.3	X	X	X	X	X	X	X	X
Proof Pressure	3.9.5	4.5.4	X	X	X	X	X	X	X	X
Burst Pressure Before Valve Separation	3.9.6.1	4.5.5	X	X	X					
Vibration	3.9.7	4.5.6	X							
Fuel Resistance and Low Temperature	3.9.8	4.5.7	X							
Corrosion Resistance	3.9.9	4.5.8		X						
Shock	3.9.10	4.5.9		X						
Surge Flow	3.9.11	4.5.10			X					
Contaminated Fuel Endurance	3.9.12	4.5.11			X					
Acceleration	3.9.13	4.5.12				X				
Fungus	3.9.14	4.5.13				X				
Icing	3.9.15	4.5.14					X			
Static Separation (T = Tension, B = Bending, S = Shear, A = Tension or Bend)	3.9.16 3.9.17	4.5.15	T	B	S	A	A			
Dynamic Separation (T = Tension, B = Bending, S = Shear)	3.9.16	4.5.16						T	B	S
Leakage After Valve Separation	3.9.4.2	4.5.17	X	X	X	X	X	X	X	X
Burst Pressure After Valve Separation	3.9.6.2	4.5.18	X	X	X	X	X	X	X	X
Disassembly and Inspection	3.9.20	4.5.19	X	X	X	X	X	X	X	X

4.4 Quality conformance inspection. Quality conformance inspection shall consist of the acceptance tests and sampling tests.

4.4.1 Acceptance tests. Each valve shall be subjected to the following examination and tests:

- a. Examination of product (4.5.1).
- b. Leakage before separation (4.5.3).
- c. Proof pressure (4.5.4).

4.4.2 Sampling tests. Samples shall consist of three valves selected from:

- a. Each lot of 200 valves, or
- b. Each 90-day production

whichever occurs first. Samples shall be subjected to the following examinations and tests:

- a. Examination of product (4.5.1)
- b. Leakage before separation (4.5.3)
- c. Proof pressure (4.5.4)
- d. Burst pressure before separation (4.5.5)
- e. Static separation (one valve in tension, one in bending, one in sheaf)* (4.5.15)
- f. Leakage after separation (4.5.17)
- g. Burst pressure after separation (4.5.18)
- h. Disassembly and inspection (4.5.19)

4.4.3 Rejection and retest of quality conformance samples. Failure of any representative sample shall be cause for the rejection of the lot represented. Valves which have been rejected may be reworked to correct the defects and resubmitted for acceptance. Before resubmitting, full particulars concerning previous rejection and the action taken to correct the previous defects shall be furnished the Government inspector.

*If one of the separation modes has been waived by the procuring activity (see 3.9.16), only two valves need to be tested.

Valves rejected after retest shall not be submitted without the specific approval of the procuring activity.

4.5 Test methods.

4.5.1 Examination of product. Each valve submitted for acceptance shall be examined to determine its conformance to the requirements of this specification with respect to design, workmanship, and identification.

4.5.2 Pressure drop. A pressure drop test shall be conducted on the valve in accordance with SAE ARP 868. Sufficient data shall be recorded to permit the plotting of curves. The pressure drop graph shall show the net pressure drop of the valve using test fluid conforming to MIL-C-7024, Type II, and fuel conforming to MIL-T-5624, Grade JP-5. The pressure drop shall not exceed the pressure drop specified in 3.9.3.

4.5.3 Leakage before valve separation. Each valve shall be pressurized over a range of -6 psi to +60 psi. The pressure shall be brought to -6 psi and held at that pressure for 1 minute. The pressure shall then be gradually increased to 60 psi over a period of 1 minute and held at that pressure for an additional 1 minute for the quality conformance tests and 30 minutes for the first article tests. Leakage shall not exceed that specified in 3.9.4.1.

4.5.4 Proof pressure. Each valve shall be pressurized to 120 psi. This pressure shall be held for a period of 1 minute for the quality conformance tests and 30 minutes for the first article tests. There shall be no visible external leakage during this test as specified in 3.9.5.

4.5.5 Burst pressure before valve separation. The valve shall be pressurized to 180 psi for 15 seconds, after which the pressure shall be reduced to 60 psi and held for an additional 1 minute. There shall be no visible leakage as specified in 3.9.6.1.

4.5.6 Vibration. The valve shall be subjected to the vibration tests of MIL-STD-810, Method 514, Procedure 1, Part 1. The vibration test curve to be selected from MIL-STD-810 shall be M or Z, whichever is applicable, or any alternate curve specified by the procuring activity. The valve with its attached hoses shall be attached by its normal mounting means to a rigid fixture capable of transmitting the specified vibration conditions. The hoses attached to the valve shall be supported in such a way as to impose loads that are representative of a production installation. The valve shall not be actuated during the test. Upon completion of the test, the valve shall be subjected to the leakage test of 4.5.3.

4.5.7 Fuel resistance and low temperature. The valve shall be subjected to the fuel-resistance and low-temperature test schedule specified in Table 1, Class A, MIL-F-8615. The leakage test of 4.5.3 shall be conducted after each phase.

4.5.8 Corrosion resistance. The valve shall be subjected to the accelerated corrosion test specified in MIL-F-8615. On completion of the last cycle, the valve shall be washed with warm water to remove all salt accumulation, dried, and subjected to the leakage test of 4.5.3.

4.5.9 Shock. The valve shall be subjected to the shock test of MIL-STD-810, Method 516, Procedure I. The plot of acceleration versus time shall approximate a sawtooth pulse. Following the shock test, the leakage test of 4.5.3 shall be repeated.

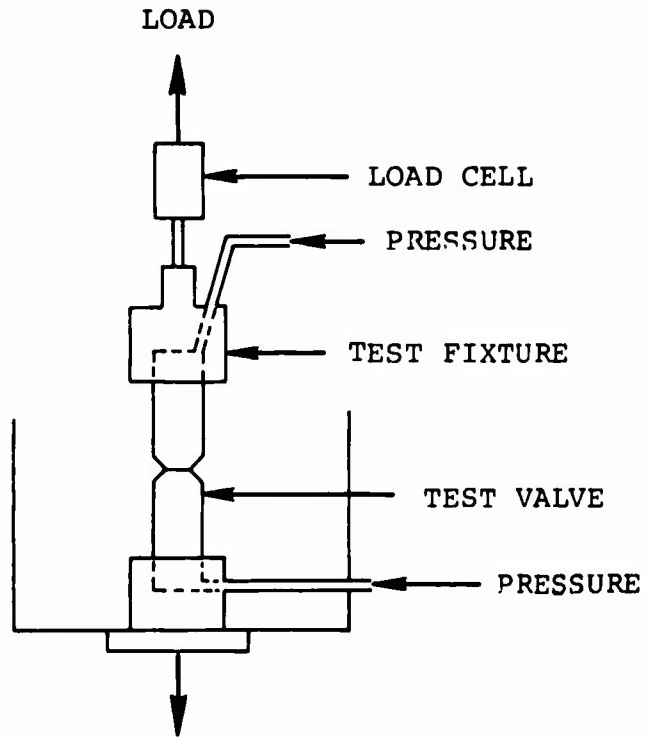
4.5.10 Surge flow. The valve shall be subjected to a flow of five times the rated flow in the normal flow direction for 5 seconds minimum. This surge flow pattern shall be repeated 100 times. The valve shall be examined for evidence of flow blockage and internal damage, and then subjected to the leakage test of 4.5.3.

4.5.11 Contaminated fuel endurance. Test fluid containing the types and concentrations of contaminants specified in MIL-F-8615 shall be circulated through the valve at rated flow for 2-1/2 hours, followed by an additional circulation period of 2-1/2 hours with the test fluid flow rate reduced to 10 percent of rated flow. Following this 5-hour circulation period, the valve shall be subjected to the static separation test of 4.5.15. If a recirculating fluid system is used, the minimum fluid quantity in the system shall equal the total fluid flow for 2 minutes at the rated flow of the valve plus 10 gallons.

4.5.12 Acceleration. The acceleration test shall be performed on the valve in accordance with MIL-STD-810, Method 513, Procedure 1. Upon completion of the acceleration tests, the valve shall immediately be subjected to the leakage test of 4.5.3.

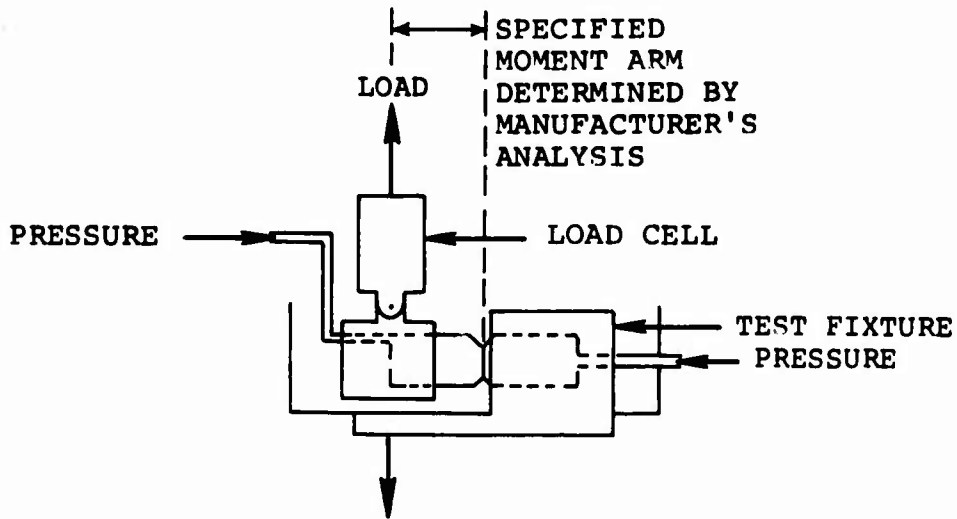
4.5.13 Fungus. The valve shall be subjected to the fungus test of MIL-STD-810, Method 508. The fungus spore suspension shall be sprayed on the inside and outside of the valve until it is thoroughly wet with the spray. Upon completion of the test, the valve shall be subjected to the leakage test of 4.5.3.

4.5.14 Icing. The valve shall be installed in the test system in the attitude that represents the valve's installation in the aircraft. One gallon of water shall then be passed



TENSILE TESTER CROSSHEAD

Figure 5. Typical Test Setup for Static Tension Separation.



TENSILE TESTER CROSSHEAD

Figure 6. Typical Test Setup for Static Bending Separation.

through the system at a flow rate not to exceed 1/2 gallon per minute. The test fluid at 0°F shall then be circulated through the system at 10 percent of rated flow until the valve temperature has stabilized at 0°F for a period of 1/2 hour. The test system shall also incorporate a method for maintaining a 0°F environment on the external parts of the valve. With the chill cycle complete, the valve shall be subjected to the test of 4.5.15. At no time throughout the static separation test shall the temperature of any part of the valve rise above 20°F. Total fluid spillage during separation shall not exceed that specified in 3.9.19. Following the test, each valve section shall be subjected to the leakage test of 4.5.17 and the burst pressure test of 4.5.18.

4.5.15 Static separation. The valve shall be mounted in a test fixture and subjected to tension, bending, or shear forces sufficient to cause complete valve separation. Typical test setups are shown in Figures 5, 6, and 7. The bending force shall be applied through the moment arm anticipated in the aircraft installation as determined by the manufacturer's analysis. A fluid pressure of 5 ±1 psi shall be maintained in the valve throughout the entire test procedure. The test load shall be applied at a constant rate not exceeding 20 inches per minute until separation occurs. The measured force required to separate the valve shall be within the limits specified in 3.9.17. Total fluid spillage occurring upon valve separation shall not exceed that specified in 3.9.19. After completion of the test, each valve section shall be subjected to the leakage test of 4.5.17 and the burst pressure test of 4.5.18.

4.5.16 Dynamic separation. The valve shall be dynamically separated in a tension, bending, or shear mode. The valve shall be mounted to the test fixture with attaching hardware identical to that used in the production installation. Tension and bending forces shall be applied to the valve through attached hoses identical to those used in the aircraft installation. The test load shall be applied in less than .005 second, and the velocity change experienced by the loading jig shall be 65 ±5 feet per second. A fluid pressure of 5 ±1 psi shall be maintained in the valve throughout the test. After completion of the test, each valve section shall be subjected to the leakage test of 4.5.17 and the burst pressure test of 4.5.18.

4.5.17 Leakage after valve separation. Each valve section shall be pressurized over the entire rated pressure range. An initial pressure of -6 psi shall be applied to the valve section and shall be gradually increased to 60 psi over a period of 1 minute for the quality conformance tests and 30 minutes

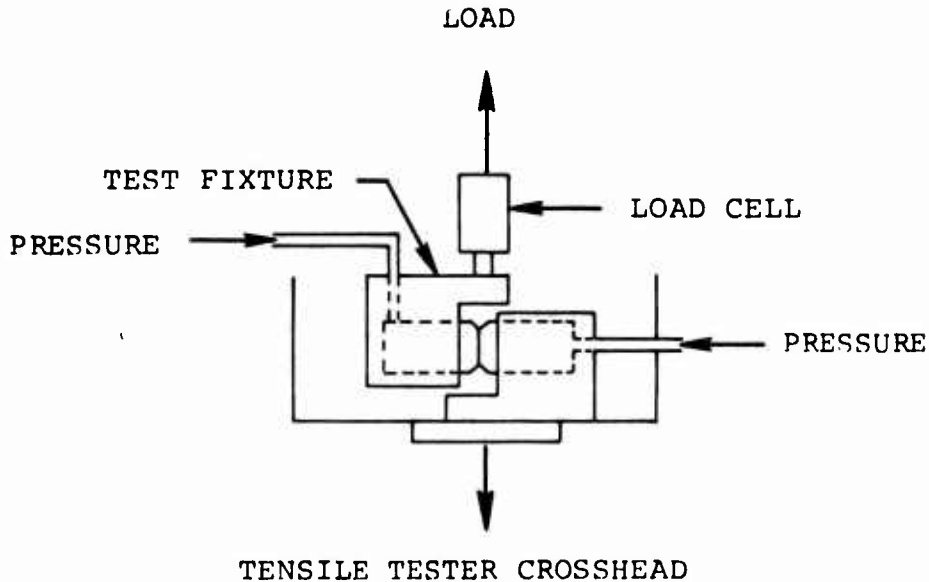


Figure 7. Typical Test Setup for Static Shear Separation.

for the first article tests. Leakage shall not exceed that specified in 3.9.4.2.

4.5.18 Burst pressure after valve separation. Each valve section shall be pressurized to 180 psi and held for a period of 15 seconds, after which the pressure shall be reduced to 60 psi and held for an additional 1 minute. Leakage shall not exceed that specified in 3.9.6.2.

4.5.19 Disassembly and inspection. Each valve section shall be disassembled and inspected for evidence of physical distortion of parts, corrosive action, or abnormal wear which might cause malfunction of the connector assembly. Any such conditions shall be reported.

4.6 Test conditions. Unless otherwise specified, the following test conditions shall apply during the tests performed in accordance with this specification.

4.6.1 Cleaning. Prior to testing any valve, all lubricants and preservative compounds, except permanent protective coatings such as paint, shall be removed from the external parts of the unit and from all internal parts which are normally wetted with fuel.

4.6.2 Test fluid. Unless otherwise specified, the test fluid shall be in accordance with TT-S-735.

4.6.2.1 Type I fluid shall be TT-S-735, Type I.

4.6.2.2 Type III fluid shall be TT-S-735, Type III.

4.6.3 Room temperature and pressure. Unless otherwise specified, all tests shall be conducted at temperatures of 60° to 90°F and at atmospheric pressure (30 ±2 inches Hg).

4.6.4 Temperature tolerance. Unless otherwise specified, the following temperature tolerances shall be maintained:

<u>Specified Temperature</u>	<u>Tolerance</u>
Above 100°F	±10°F
Below 100°F	±5°F

4.6.5 Attitude. Unless otherwise specified, all tests shall be conducted with the valve mounted in the attitude that represents the valve's installation in the aircraft.

4.6.6 Test equipment calibration. Test equipment required to perform the testing described herein shall be calibrated within the specified periods established by MIL-C-45662. Ranges and accuracy of instrumentation shall be capable of providing test data within the specified tolerances.

5. PREPARATION FOR DELIVERY

5.1 Preservation and packaging. Self-sealing breakaway valves shall be preserved and packaged in accordance with MIL-STD-794.

5.2 Packing.

5.2.1 Levels A and C. The valves shall be packed in accordance with MIL-STD-794. Unless otherwise specified, level A containers shall be used and shall conform to PPP-B-601, overseas type, constructed of NN-P-530 plywood conforming to standard grade. The plywood shall have the grade stamp of an approved testing agency and shall be surface treated in accordance with TT-W-572. Level C packing designation shall be used only if specifically authorized by the procuring activity.

5.3 Marking of shipments. In addition to any special marking required by the contract or order, unit packages, intermediate packages, and shipping containers shall be marked in accordance with MIL-STL-129.

6. NOTES

6.1 Intended use. This specification is intended for use by aircraft manufacturers in designing and testing self-sealing breakaway valves for crash-resistant aircraft fuel systems of fixed-wing and rotary-wing aircraft.

6.2 Ordering data. Procurement documents should specify the following:

- a. Title, number and date of this specification.
- b. Classification of valve (1.2).
- c. The responsibility for inspections and the classification of inspections (4.1 and 4.2).
- d. Quality conformance inspection (4.4).
- e. Level of preservation, unit packaging, and packing required (5.1).
- f. Engineering drawings for procuring activity review.

6.3 Definitions.

6.3.1 Valve. Unless otherwise specified, the word "valve" shall be construed to mean a complete assembly.

6.3.2 Valve section. Valve section shall be construed to mean a part of the "valve" after separation.

DRAFT MILITARY SPECIFICATION

FUEL SYSTEM, AIRCRAFT, STANDARD AND CRASHWORTHY, 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 fixed-wing and rotary-wing 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. Explosion suppression subsystems
- d. Fuel vent subsystem
- e. Fuel quantity gaging subsystem
- f. Refueling and defueling 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)
WW-T-700	Tube, Aluminum and Aluminum Alloy, Drawn, Seamless, General Specification for

Military

MIL-E-5007 Engine, Aircraft, Turbojet and Turbofan, General Specification for

MIL-B-5087 Bonding, Electrical, and Lightning Protection, for Aerospace Systems

MIL-W-5088 Wiring, Aircraft, Selection and Installation of

MIL-P-5238 Pump, Centrifugal, Fuel Booster, Aircraft, General Specification for

MIL-T-5578 Tank, Fuel, Aircraft, Self-Sealing

MIL-C-6021 Casting, Classification and Inspection of

MIL-T-6396 Tanks, Fuel, Oil, Water-Alcohol, Coolant Fluid, Aircraft, Non-Self-Sealing, Removable, Internal

MIL-H-7061 Hose, Rubber, Aircraft, Self-Sealing, Aromatic Fuel

MIL-E-7080 Electric Equipment, Aircraft, Selection and Installation of

MIL-F-7179 Finishes and Coating, General Specification for Protection of Aerospace Weapons Systems, Structures and Parts

MIL-T-7378 Tanks, Fuel, Aircraft, External, Auxiliary Removable

MIL-C-7413 Coupling, Quick-Disconnect, Automatic Shutoff, General Specification for

MIL-V-7899 Valve, Check, Aircraft Fuel System

MIL-G-7940 Gage, 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)

MIL-V-8608 Valves, Fuel Shutoff, Electric 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, Aircraft Fuel System, General Specification for

MIL-H-8795 Hose Assembly, Rubber, Hydraulic, Fuel and Oil Resistant

MIL-A-8865 Airplane Strength and Rigidity, Miscellaneous Loads

MIL-C-22263 Coupling, Fuel Line, Flexible, 125 PSI

MIL-V-25023 Valve, Fuel Drain, Self-Locking

MIL-M-25047 Marking and Exterior Finish Colors for Airplanes, Airplane Parts, and Missiles (Ballistic Missiles Excluded)

MIL-E-25499	Electrical System, Aircraft, Design and Installation of, General Specification for
MIL-H-25579	Hose Assembly, Tetrafluoroethylene, High Temperature Medium Pressure, General Requirements for
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, Pressure, Aircraft Fuel
MIL-G-26988	Gage, Liquid Quantity, Capacitor Type Transistorized, General Specification for
MIL-V-27393B*	Valves, Self-Sealing Breakaway, Crash-Resistant, Aircraft Fuel System
MIL-T-27422	Tank, Fuel, Crash-Resistant, Aircraft
MIL-V-38003	Valve, Fuel Level Control, Fuel Tank, Aircraft, General Specification for
MIL-C-38373	Cap, Fluid Tank Filler
MIL-H-58089	Hose Assemblies and Hose, Rubber, Lightweight, Medium Pressure, and End Fittings
MIL-C-81511	Connector, 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	Cover, Self-Sealing, Fuel Line, Aircraft
MIL-I-83294	Installation Requirement, Aircraft Propulsion Systems, General Specification for

STANDARDS

Military

MIL-STD-100	Engineering Drawing Practices
MIL-STD-130	Identification Marking of U. S. Military Property
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-704	Electric Power, Aircraft, Characteristics and Utilization of
MIL-STD-889	Dissimilar Metals

*Refers to draft specification included elsewhere in this report - not to published specification.

MIL-STD-1247	Markings, Functions and Hazard Designations of Hose, Pipe, and Tube Lines for Aircraft, Missile, and Space Systems
MS29520	Nozzle, Pressure Fuel Servicing, Locking, Aircraft, Type D-1
MS29525	Cap, Pressure Fuel Servicing, 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
MS33649	Bosses, Fluid Connection - Internal Straight Thread

(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 the 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
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(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 and processes 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. Materials conforming to contractors' specifications may be used provided the specifications are released by the Services and contain provision for adequate tests. The use of contractors'

specifications must be approved by the procuring activity. All materials shall be sufficiently resistant to applicable fluids specified in the aircraft specification to assure satisfactory operation as defined herein.

3.2.1 Selection of materials. Specifications and standards for all materials, parts, and Government certification and approval of processes and equipment which are not specifically designated herein and which are necessary for the execution of this specification shall be selected in accordance with MIL-STD-143, except as specified in 3.2.1.1.

3.2.1.1 Standard parts. Standard parts (MS or AN) shall be used wherever they are suitable for the purpose, and shall be identified on the drawing by their part numbers. Commercial utility parts such as screws, bolts, nuts, and cotter pins may be used, provided they possess suitable properties and are replaceable by the standard parts (MS or AN) without alteration, and provided the corresponding standard part numbers are referenced in the parts list and, if practicable, on the contractors' drawings. In the event that there is no suitable corresponding standard part in effect on the date of invitation for bids or request for proposal, commercial parts may be used provided they conform to all requirements of this specification.

3.2.1.2 Fungus-proof materials. Materials that are nutrients for fungi shall not be used where it is practicable to avoid them. Where used and not hermetically sealed, they shall be treated with a fungicidal agent acceptable to the procuring activity.

3.2.1.3 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.

3.2.1.4 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.

3.2.1.5 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.

3.2.1.6 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 the 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.

3.2.1.7 Castings. Castings shall be clean, sound, and free from blow holes, porosity, cracks, and any other defects. Castings shall be in accordance with the applicable class designated in MIL-C-6021.

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.

3.4.1 "Stacked" assemblies. When there are "stacked" assemblies, they shall use flanged arrangements which prevent assembly if a part is missing. Alternatively, use indicator markings which are exposed if parts are omitted.

3.4.2 Right-hand and left-hand parts. Right-hand and left-hand parts shall be identical and interchangeable or shall have some design feature to prevent their interchange during assembly.

3.4.3 Bolt sizes. When bolts of different sizes are used near the same location, widely differing sizes shall be specified. Two bolts identical except for length shall not be used in the same location. Design shall protect against damage to parts caused by accidental use of screws or bolts which are too long.

3.4.4 Mounting. Where reversed or rotated mounting of a part cannot be tolerated, nonsymmetrical mounting arrangements (including keyways or pins) shall be used. Parts that are capable of proper operation when mounted in any orientation are more desirable.

3.4.5 Cable receptacles. Identical cable receptacles shall not be used side-by-side unless internal connections to the adjacent receptacles are identical.

3.4.6 Lug-terminated electrical leads. Where lug-terminated electrical leads are required, one of the following systems shall be used (in order of preference): (1) different lead lengths from the cable tie-down point, (2) different sized lugs, (3) identification of leads and terminals, (4) color coding of leads and terminals.

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 aircraft 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 aircraft mission requirements. The same piping and components may be used in more than one fuel subsystem but not when a simultaneous operation of two subsystems will occur. There shall be no external leakage from the fuel system nor shall there be any in the "mated" condition during 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 a fuel temperature range from -65°F to $+135^{\circ}\text{F}$. The ambient air temperature range shall be -65°F , for operating, and -80°F , for non-operating, to $+160^{\circ}\text{F}$. These temperatures shall be applicable to fuel systems which are not affected by fuel heating due to location in hot compartments. In these latter cases, the temperature requirement for some components in the fuel system may exceed the temperatures specified. These components shall be identified and the maximum temperature specified.

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.

3.5.3.3 Pressure. The fuel system and its components 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 (3.7.1.1). The proof and ultimate pressure of

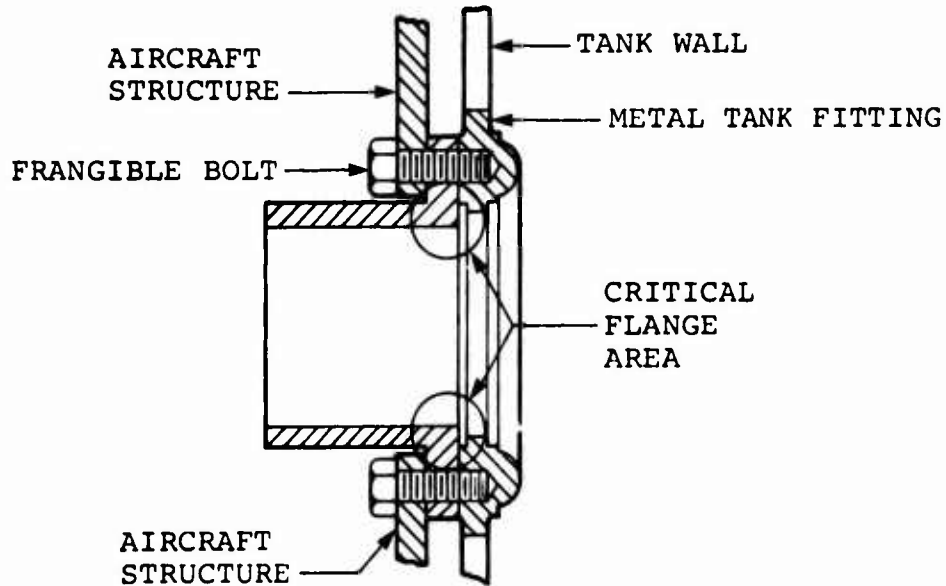
the vent subsystem shall be two and three times the operating pressure, respectively. The refueling subsystem shall be designed for an operating pressure of 60 psig, a proof pressure of 120 psig, and an ultimate pressure of 180 psig.

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 and O-rings. Whenever possible, components that are used in other aircraft systems shall be utilized even though bracketry to adapt these components may be required. However, in a crashworthy fuel system, frangible structures or frangible bolts shall be used at all attachment points between fuel tanks and aircraft structure to prevent fuel tank components from being torn out of the tank wall during impact. Frangible attachments shall be used at other points in the flammable fluid systems where aircraft structural deformation would lead to system failure. All frangible attachments shall meet the requirements of 3.5.3.4.1. In crashworthy fuel systems, self-sealing breakaway valves, conforming to MIL-V-27393B, shall be installed in all fuel tank-to-fuel line connections and in all tank-to-tank interconnects. Self-sealing breakaway valves shall be installed at all firewall line connections and at other points in the fuel system where aircraft structural deformation would lead to system failure.

3.5.3.4.1 Frangible attachments

3.5.3.4.1.1 Separation load. The load to separate a frangible attachment from its support structure shall be between 25 and 50 percent of the load required to fail the weakest component in the attached system. To prevent inadvertent separation during flight and maintenance operations, the attachment separation load shall be greater than all ultimate operational and service loads at the frangible attachment location. Careful analysis must be conducted on each aircraft fuel system to determine the probable failure loads of the system so that frangible attachment breakaway loads may be determined as illustrated in Figure 1.

3.5.3.4.1.2 Mode of separation. A frangible attachment shall separate whenever the required load (as defined in 3.5.3.4.1.1) is applied in the modes most likely to occur during crash impact. These modes, whether tension, shear, compression, or combinations thereof, must be determined for each attachment by analyzing the surrounding aircraft structure and the probable impact forces and their directions.



ITEM	LOWEST FAILURE LOAD (LB)*	FAILURE MODE
Aircraft Structure	4000	Shear
Tank Fitting Flange	3000	Pullout of Tank
Frangible Bolt	5000	Shear
	Not more than	Break
	$\frac{3000}{2} = 1500$	(Tension-Shear)
	Not less than	
	$\frac{3000}{4} = 750$	

*Loads may or may not be representative; values are for explanatory purposes only.

Figure 1. Sample Frangible Attachment Separation Load Calculation.

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 of clamp, and illustration of typical installation for each type of 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 1. 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. Where necessary, protective covers which have been approved by the procuring activity shall be installed around the lines to protect them from chafing. Unlined metal support clamps shall not be used. Frangible clamps shall be used to stabilize fuel lines in a crashworthy fuel system. 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 1. FUEL LINE SUPPORT DISTANCE	
Tube Size (in.)	Maximum Distance Between Supports (in.)
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

3.5.3.7.1.1.1 Routing for crashworthy fuel systems. In a crashworthy fuel system, fuel lines shall exit a fuel tank in a location which is in the least vulnerable area of the tank from the standpoint of anticipated crash loads and structural deformation. The fuel lines shall be routed along heavier basic structural members wherever possible. They shall not be routed through electrical compartments or occupiable areas







unless they are shrouded or otherwise designed to prevent spillage. Fuel lines shall not be routed over landing gears, under heavy masses such as transmissions, in the leading edges of wings, in anticipated areas of rotor blade impact, or in anticipated areas of large structural displacement unless self-sealing breakaway valves are incorporated in the lines. The number of fuel lines in the engine compartment shall be kept to a minimum.

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. Metal tubing shall not be used in crashworthy fuel systems.

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 aluminum tubing nor less than .020 inch for stainless steel tubing.

3.5.3.7.1.3 Hose assemblies. All fuel system hose assemblies shall be in accordance with MIL-H-8795, MIL-H-25579, or MIL-H-58089. 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. All hose assemblies in a crashworthy fuel system shall meet or exceed the requirements of MIL-H-58089. These assemblies shall also meet the tension and bending strength requirements specified in Table 2 when tested in accordance with 4.6.2.

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

TABLE 2. REQUIRED MINIMUM AVERAGE AND INDIVIDUAL LOADS FOR HOSE AND HOSE-END FITTING COMBINATIONS					
Hose End Fitting Type	Fitting Size	Tension Load (lb)		Bending Load (lb)	
		Minimum Average Load*	Minimum Individual Load	Minimum Average Load*	Minimum Individual Load
<u>STRAIGHT</u>	-4	600	475	425	400
Tension = 	-6	700	575	425	400
Bending = 	-8	900	650	650	600
	-10	1450	1175	675	625
	-12	1775	1475	950	850
	-16	2125	1825	1425	1300
	-20	2375	2075	1550	1425
<u>90° ELBOW</u>	-4	600	475	425	400
Tension = 	-6	700	575	425	400
Bending = 	-8	900	650	450	400
	-10	1450	1175	475	425
	-12	1775	1475	500	450
	-16	2125	1825	775	700
	-20	2375	2075	1100	1000

*Minimum of three tests

routed through personnel or cargo compartments; however, in some instances an occupied portion of the aircraft is the only space available for routing of 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. If the ferry tank is mounted in personnel or cargo compartments, a crash-resistant fuel tank conforming to MIL-T-27422 shall be used and the installation of the tank and fuel lines shall conform to the crashworthy fuel system requirements of this specification.

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

Alternatively, self-sealing hoses conforming to MIL-H-7061 may be used if specifically authorized by the procuring activity.

3.5.3.7.2 Fuel fittings. All fuel system tubes, hoses, valves, or wires which pass through a firewall shall be liquid tight and vapor tight. 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. Fuel system check valves shall conform to MIL-V-7899.

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 (3.7.1.9.3). Drain valves shall be in accordance with MIL-V-25023. In a crashworthy fuel system all attachments of fuel drains to aircraft structure shall be made with frangible fasteners.

3.5.3.7.4.1 Shaft seal, seal drain, and vent. All motor-driven fuel system components shall be provided with a shaft seal and a suitable drain chamber with drain and a vent. This allows any fuel which leaks past the seal to drain to the outside, preventing entry into the motor. The drain and the vent each shall terminate on the outside of the component in a boss conforming to MS33649. In the event the driving motor utilized is designed to have its rotating element operating immersed in fuel, this requirement does not apply.

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. Assemblies, subassemblies, and parts shall be marked in accordance with MIL-STD-130.

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 ensure 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. The size and type of connector shall be as specified on the manufacturer's drawing. Each electrical connector used in a fuel system component shall incorporate a ground return terminal. 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 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 crew 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 multi-engine 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 of fixed-wing aircraft shall be designed to consume all of the available fuel in the main tank(s) (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 when the controls are not located on the pilot's control panel.

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. 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. In a crashworthy fuel system, pumps mounted within the fuel tanks shall be fastened to the structure with

frangible attachments. If electric boost pumps are used, the electrical wires shall be 20 to 30 percent longer than necessary and shall be shrouded to prevent their being cut during crash impact. The use of nonsparking breakaway wire disconnects should also be considered.

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.

3.6.6.3.1 Crashworthy fuel system filters and strainers. In-line fuel filters or strainers shall not be located in the engine compartment. Filters and strainers shall retain as small a quantity of fuel as possible. The filters and strainers shall have a structural attachment capable of withstanding a 30G load applied in any direction.

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. 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. The size and number of fuel valves shall be kept to a minimum, and they

shall not be located in the engine compartment. For a crash-worthy fuel system, the fuel shutoff valves shall have a structural attachment capable of withstanding a 30G load applied in any direction.

3.6.6.4.1 Fire shutoff valves. Fire shutoff valves shall be mounted as near as possible to the engine compartment, but not in the compartment. Gravity feed installations may require both a tank shutoff valve and a fire shutoff valve 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 3 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 3. 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 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, explosion suppression, and refueling and defueling subsystems shall be considered along with tank pressures induced during all maneuvers

TABLE 3. 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 20mm is a requirement.
Nonintegral, Internal Non-flexible 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 all helicopters and for fixed-wing aircraft tanks when the primary mission of aircraft is personnel transport.
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 micro-organism growth.

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. Crash-resistant fuel tanks shall have smooth, regular shapes, with the sump area contoured gradually into the tank bottom. A self-sealing breakaway tank-to-tank valve shall be used whenever two crash-resistant tanks are connected directly with no intervening fuel line.

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 5 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 (6.2.7) 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 altitude) 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 of tank volume (.25 percent) 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. In crashworthy fuel systems, all accessory attachments to the structure shall be accomplished with frangible attachments.

3.7.1.6 Filler openings. Filler openings shall be located to permit filling the tanks from outside the aircraft without overflowing 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. In crashworthy fuel systems, filler caps shall be recessed into the tank wall to ensure that the cap stays with the tank if the tank moves relative to the aircraft structure. The filler unit shall be fastened to the structure with a frangible attachment. 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 3.

3.7.1.8 Fuel tank location and separation. Fuel tanks shall not be located over personnel compartments, engine compartments, electrical compartments, or any location where spilled or misted fuel could be ingested into the engine or ignited by the engine exhaust. Fuel tanks located adjacent to personnel, cargo, or engine compartments shall be separated from such compartments by a second liquid-tight and vapor-tight barrier in addition to the barrier provided by the tank. Fuel tanks located adjacent to 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. Fuel tanks shall not be located in probable impact areas or in areas of anticipated aircraft structural deformation without specific approval from the procuring activity.

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 liquid tight 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 liquid tight 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 fuel tight. 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 Explosion suppression subsystems

3.8.1 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 3.8.1 or 3.8.1.2 shall be met. Other methods may be used with the approval of the procuring activity.

3.8.1.1 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.

3.8.1.2 Nitrogen inerting system. The nitrogen inerting system shall be completely automatic and shall require no attention from the pilot or 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.

3.8.1.2.1 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.

3.8.1.2.2 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.

3.8.1.2.2.1 Nitrogen storage. The liquid nitrogen shall be stored in lightweight dewars. The dewars and their hold-down 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.

3.8.1.2.3 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 reservecing. Provisions for growth capability shall be incorporated as specified in the aircraft system specification.

3.8.1.2.4 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.

3.8.1.2.4.1 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.

3.8.1.2.4.2 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.

3.8.1.2.4.3 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.

3.8.1.2.4.4 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.

3.8.1.2.4.5 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.

3.8.1.2.5 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.

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

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

3.8.1.2.6.2 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.

3.8.1.2.6.3 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.

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

3.9 Fuel vent system. 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 in-flight 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. The vent line shall start at the highest point in the tank and traverse the three dimensions of the tank, terminating in a suitable location outside the aircraft. Means shall be provided for admitting air to the high point of the vent system. In a crashworthy fuel system, the vent system shall be designed to prevent fuel flow through the vent lines regardless of the attitude of the aircraft after a crash, either by vent line routing or the inclusion of an antispill or breakaway valve in the vent outlet. It shall also be designed to preclude any fuel spillage due to structural failure of the vent system. All tank vent outlets shall be supported, if necessary, by frangible attachments to the aircraft structure.

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 refueling at maximum flow rate when each tank is filled individually. The minimum diameter of vent lines shall be 1/2 inch (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 (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.

3.9.5 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, 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. In a crashworthy fuel system, a frangible attachment shall be used if it is necessary to stabilize the indicator by fastening it to the aircraft structure. If a capacitance probe is used in a crashworthy system, it shall be fabricated from material possessing as low a flexural rigidity as is consistent with operational requirements. A slightly rounded shoe shall be incorporated at the probe bottom end to avoid any tank cutting tendency. 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 gauges 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 Refueling and defueling subsystem

3.11.1 Pressure refueling. All fixed-wing aircraft with an internal fuel capacity of 600 gallons or more and all helicopters shall incorporate a pressure refueling system. It shall be possible to refuel the aircraft to capacity without the use of external power. It shall be possible to completely fill the aircraft from a single adapter which shall conform to MIL-A-25896. 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.

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. In a crashworthy fuel system, caps shall be recessed into the fuel tank.

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. In a crashworthy fuel system, the adapter shall be fastened to the aircraft structure by a frangible attachment.

3.11.1.5 Refueling and defueling lines. Fuel lines shall be sized so that all tanks theoretically reach full position simultaneously when refueling. The line sizes shall be capable of handling flow rates which will allow 90 percent total aircraft refueling in a maximum of 2.25 minutes for total fuel weights up to 3,900 pounds and a maximum of 5 minutes for total fuel weights between 3,900 and 10,000 pounds. The following criteria shall be used when designing to meet the refueling schedules:

- 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 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. 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.

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 Pressure 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.

3.11.4 Gravity defueling. It shall be possible to completely defuel the aircraft by means of gravity through a drain valve(s) conforming to the requirements of MIL-V-25023. The defueling rate shall be not less than 20 gpm unless specified by the procuring activity. In the event of a wheels-up landing or landing gear failure, it shall be possible to defuel the aircraft through the normal fuel servicing adapters or by suction through accessible openings in each tank.

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 mock-up 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 mock-up, 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. Frangible attachments and fuel line hose assemblies used in crashworthy fuel systems shall be tested as specified in 4.6.

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, plumbing, 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 systems shall be in place for all fuel system tests. 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 combat 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 from sea level to aircraft service ceiling to determine that the main tank(s) is adequate for engine(s) fuel feed 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 the ground attitude.

- 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 fixed-wing aircraft 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 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 (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.

4.4.2.4 Gravity defueling. Gravity defueling shall be demonstrated. The maximum flow rate and fuel remaining in the system after defueling shall be recorded.

4.4.3 Explosion suppression subsystem simulator tests

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

4.4.3.3 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 4.4.7.

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. If there is no fuel check valve in the vent opening, fuel shall be added after normal fueling 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 pressure refueling.

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.

4.4.5 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 Pressure refueling and defueling subsystem simulator tests

4.4.6.1 Refueling subsystem operational test. Simulated 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 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 3.11.1.5.6. 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.

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 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 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.

4.4.6.4 Defueling test. Pressure 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 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 these 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 an initial fuel temperature of 135°F.

4.5.2.3 Maximum altitude. For fixed-wing aircraft, 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 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 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 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.
- 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 served 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.

4.5.5 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 hold-down test. Before the first flight, it shall be demonstrated that the hold-down fixture for the dewars can withstand the loadings specified for miscellaneous equipment in MIL-A-8865.

4.6 Crashworthy fuel system component testing

4.6.1 Frangible attachments. The aircraft manufacturer shall issue procurement specifications for all frangible attachments which include the following tests (4.6.1.1 and 4.6.1.2).

4.6.1.1 Static tests. All frangible attachments shall be tested in the three most likely anticipated modes of operation, as defined in 3.5.3.4.1.2. Test loads shall be applied at a constant rate not to exceed 20 inches per minute until failure occurs. The failure loads shall meet the requirements of 3.5.3.4.1.1.

4.6.1.2 Dynamic tests. All frangible attachments shall be proof tested under dynamic loading conditions to ensure that they function satisfactorily in the three most likely anticipated modes of operation. The test load shall be applied in less than 0.005 second, and the velocity change experienced by the loading jig shall be 65 ±5 feet per second.

4.6.2 Hose assemblies. To ensure compliance with the crash-worthy requirements of 3.5.3.7.1.3 (Table 2) hose assemblies shall be subjected to tension loads and to bending loads applied at a 90-degree angle to the longitudinal axis of the end fitting, as shown in Figure 2. Loads shall be applied at a constant rate not to exceed 20 inches per minute. The test assembly shall be pressurized to 5 psi with test fluid. The maximum applied load recorded up to the time of steady stream leakage occurring due to hose pullout or hose or end fitting failure shall be designated as the failure load.

5. PREPARATION FOR DELIVERY

5.1 This section is not applicable.

6. NOTES

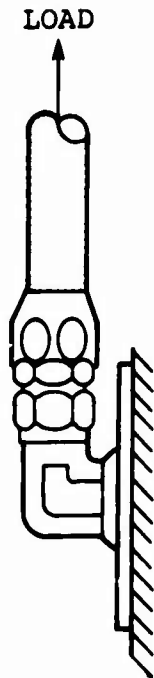
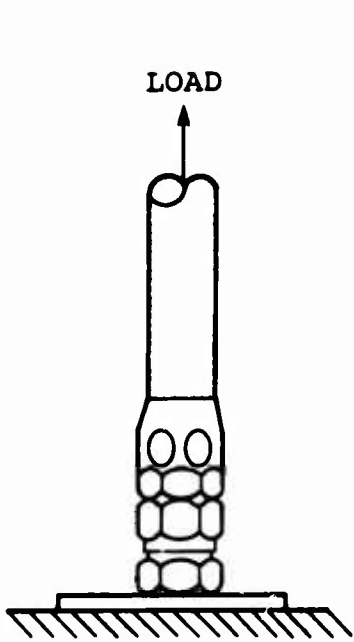
6.1 Intended use. This specification is intended for use by aircraft manufacturers in designing and testing fuel systems for fixed-wing and rotary-wing aircraft powered by air-breathing engines.

6.2 Definitions

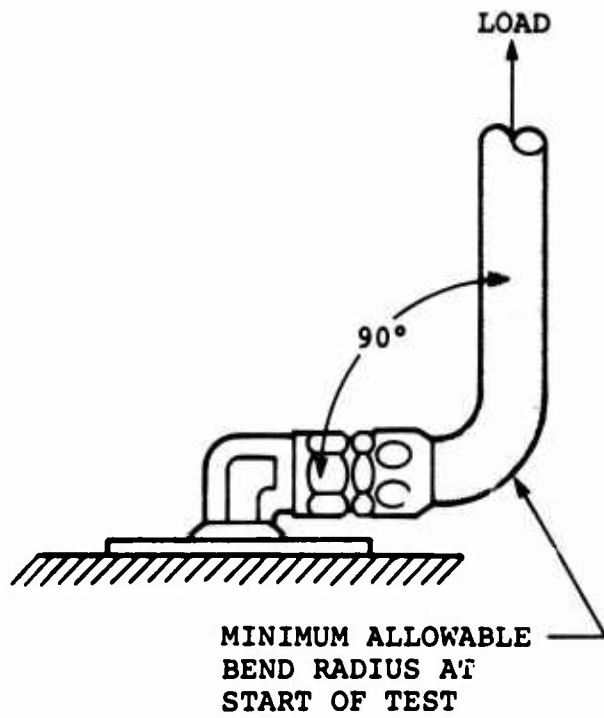
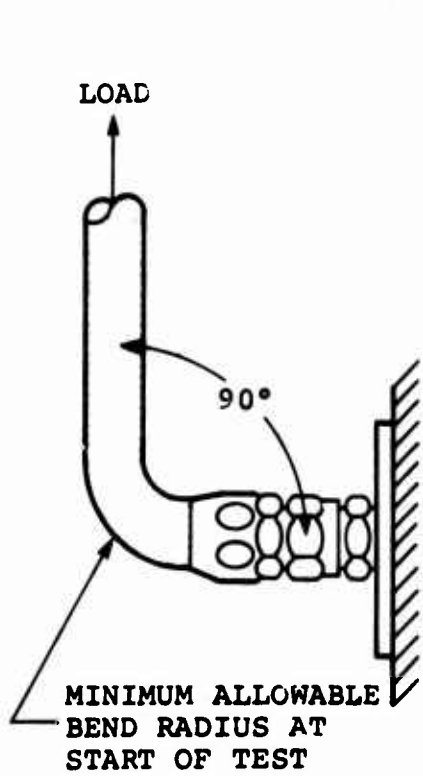
6.2.1 Available fuel. Available fuel is that quantity of fuel which is available to the engines after refueling to the normal refueling full level down to the level where steady flow to the engines ceases. If this quantity varies with attitude and engine power settings, the available fuel should be tabulated 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 which can be drained from the aircraft sumps after the available fuel has been removed from the aircraft.



TENSION TESTS



90-DEGREE TESTS

Figure 2. Hose Assembly Tests.

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

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

6.2.6 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.

6.2.7 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.

6.2.8 Fire resistant. Fire-resistant components must be able to perform their intended functions under the most severe conditions of fire likely to occur at the particular location for a period of at least 5 minutes.

6.2.9 Firewall. A partition which will resist flame penetration under the most severe condition of fire likely to occur at its location.

6.2.10 Frangible attachment. An attachment possessing a part which is constructed to fail at any predetermined point and load.

6.2.11 Impact area. That part of an aircraft which encounters an object during a crash. In helicopters, rotor-blade impact must also be considered. Most probable impact areas must be determined for each aircraft based upon design operational characteristics and accident records of similar aircraft.

6.2.12 Self-sealing breakaway valve. A fluid line or tank valve which will separate at a predetermined load and seal both ends of the valve so that an absolute minimum of fluid is lost.

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
Number

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

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 this specification. Omission of reference in the detail specification to a particular requirement of this specification shall indicate complete compliance therewith. When departures from the requirements of this specification are necessary, the details of such departures shall be stated as specific requirements bearing the same section heading, paragraph heading, and numbering as this specification. 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 this specification. 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) Results 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

(b) 3.10.2

(c) 4.2.5.1

(d) 4.3.2

(e) 4.4.5.2

(f) 4.5

(g) 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 updated for design reviews as data become available.

Fuel System Detailed Weight Statement:

	<u>Item</u>	<u>Weight</u>
(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	

<u>Item</u>	<u>Weight</u>
(8) Explosion Suppression System	
Cycle and Supports	
Generators	
Controls, etc.	
(9) Pump Installation	
Engine Driven	
Booster	
Hand (Including Controls)	
Transfer	
Electrical System (Including Controls)	
Pump Supports	
(10) Fueling System	
Plumbing	
Controls	
(11) Engine Feed and Transfer System	
Plumbing	
Controls	
(12) Vent System	
(13) Jettison System	
(14) 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 become 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

(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) Vents:

Antisiphon Design
Description

Outlet Locations (station/WL/BL)

Size of Line (in.)

Lightning Protection

Special Design Feature

(10) Negative G Provisions:

Type Description

Time at Military Power (min-sec)

Time at Cruise Power (min-sec)

(11) 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

(12) Critical Components:

Number and Description
of Surveillance Items

Number and Description
of Single Failure
Critical Items

(13) Boost Pump:

Location (station/WL/BL)

Power

Circuit Protection

Flow/Pressure at Takeoff
Power

Flow/Pressure at Cruise

Type

Speed

Supplier

Special Features

(14) Other Pumps: (Transfer,
Ejection, etc.)

Function

Type of Pump

Location

Power

Circuit Protection

Speed

Flow/Pressure in
Operation

(gpm/psig)

(15) 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

(16) 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

Single-Point Refueling

(17) Quantity Instrumentation:

Type

Overall Indicator Size

Switch Positions

Probe Location

Low Level Locations

Low Level Quantity

Supplier

(18) Flow Instrumentation:

Type

Sensor Location

Indicator Ranges

Accuracy

Readout Data

Supplier