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DEPARTMENT OF DEFENSE

TEST METHOD STANDARD

TEST REQUIREMENTS AND METHODS FOR AIRCRAFT HYDRAULIC AND EMERGENCY PNEUMATIC SYSTEMS

AMSC N/A

FSC 1650

FOREWORD

1. This standard is approved for use by all Departments and Agencies of the Department of Defense (DoD).

2. This standard established in determining methods for testing aircraft hydraulic and emergency pneumatic systems. This standard covers test methods for aircraft subsystems, weapon system and support equipment. This standard provides contractor for preparation of a detail test procedure for hydraulic and emergency pneumatic systems of a specific aircraft.

3. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Air Warfare Center Aircraft Division, Code 414100B120-3, Highway 547, Lakehurst, NJ 08733-5100, by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

1. SCOPE

1.1 Scope. This standard establishes test and test method requirements for aircraft and weapons hydraulic and emergency pneumatic systems design and installation with operating pressure ranges from 3,000 psi to 8,000 psi and temperature ranges from -65 ^{o}F to + 450 ^{o}F.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3, 4, and 5 of this standard. This section does not include documents cited in other sections of this standard or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements documents cited in sections 3, 4, and 5 of this standard, whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications and standard form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto, cited in the solicitation (see 6.3).

SPECIFICATIONS

DEPARTMENT OF DEFENSE

MIL-F-8785 - Flying Qualities of Piloted Airplanes.

STANDARDS

DEPARTMENT OF DEFENSE

MIL-STD-810 - Environmental Engineering Considerations and Laboratory Tests.

(Unless otherwise indicated, copies of the above specification and standard are available from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

2.2.2 Other Government documents, drawings and publications. The following other Government publication forms a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

United States Government Printing Office GPO Style Manual

(Copies of the GPO Style Manual are available from the Superintendent of Documents. U.S. Government Printing Office, North Capitol and H street, N. W., Washington, DC 20402-0001.)

2.3 Order of precedence. In the event of a conflict between the text of this standard and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITION

3.1 Aircraft varidrive operation. A demonstration of normal operation of the aircraft hydraulic and pneumatic systems with the use of varidrive motor inplace of engine.

3.2 Cycle. A cycle is a full travel of service from down to up and return to original down. An illustration of a full cycle would be a landing gear down when valve closed and up when valve opened and return to original down when valve closed.

3.3 Emergency operation. A hydraulic and pneumatic power system reverts from normal system pressure to emergency system pressure when normal system pressure is reduced in detrimental manner.

3.4 Elapse time. Time duration taken to complete a prescribed operation from start to finish.

3.5 Fatigue life. Anticipated life of component expected to last prior to fail due to repeated stress.

3.6 Functional test. A test performed on systems or system components to ensure components and systems are in proper working order and their performance conforms to the specification.

3.7 Half cycle. A half cycle is a selector valve and control valve operates one complete cycle. It is illustrated as a landing gear from down to up.

3.8 Mission profile. Demonstration of all satisfactory functions of hydraulic and pneumatic systems and components during a mission. A mission includes satisfactory completion of tasks mission from startup to shutdown.

3.9 Normal system. Hydraulic and pneumatic systems and components are functioning properly under the specified condition.

3.10 Post test inspection. Examination of components inspected after actual test.

3.11 Power braking system. A control unit generated pressure by manual actuation and a manually generated pressure is boosted by pressure from a power generating system.

3.12 Pump ripple. Pressure variance produced by the pump.

3.13 Resonant condition. A condition when components are exposed to resonant frequencies.

3.14 Resonance ripple frequencies. Vibration frequencies at a resonant stage transmitted from hydraulic pump.

3.15 Simulator tests. Tests conducted in a simulator where installation of components and tubing are identical to actual aircraft.

3.16 Unsymmetrical loading. Uneven or unbalance loading subjected to the control surface of the aircraft.

4. GENERAL REQUIREMENTS

4.1 Recycled, recovered, or environmentally preferable materials. Recycled, recovered, or environmentally preferable materials shall be used to the maximum extent possible provided that the material meets or exceeds the operational and maintenance requirements, and promotes economically advantageous life cycle costs.

4.2 Acronym use. The use of acronym shall be in accordance with GPO style manual.

4.3 Test requirements, new aircraft. One or more of a new series of aircraft shall complete the tests specified in this standard before first flight. If an aircraft simulator is not available, the simulator tests shall be performed on the aircraft. Test requirements versus test methods are tabulated in table I.

4.4 Simulator. All simulator tubing and component installations shall be identical to those in the first flight aircraft. All tubing flatness greater than 5 percent for 3,000 PSI and above, and 10 percent for less than 3,000 PSI operating pressure shall be pre-stressed.

4.4.1 Proof pressure. Proof pressure testing of simulator hydraulic systems shall be performed with all components installed. System shall be tested to the requirements of table II as applicable.

TABLE I. Cross-reference chart requirements vs tests.

Test item	GENERAL TEST REQUIREMENTS						DETAIL TEST METHODS					
	Simulator tests 4.4	Ground aircraft			Airborne		Simulator tests 5.1	Ground aircraft			Airborne	
		Ground cart tests 4.5	Varidrive Operation tests 4.6	Engine Operation tests 4.7	Flight test 4.8			Ground cart tests 5.2	Varidrive Operation tests 5.3	Engine operation tests 5.4	Flight tests 5.5	
Proof pressure	4.4.1	4.5.1	-	-	-		5.1.1	5.2.1	-	-	-	
System functional or functional	4.4.2	4.5.2	4.6.1	4.7.1	4.8.1		5.1.2	5.2.2	5.3.1	5.4.1	5.5.3	
Failure Modes	4.4.3	-	4.6.2	-	4.8.2		5.1.3	-	5.3.2.1	-	5.5.4	
Mission Profile	4.4.4	-	4.6.2	-	-		5.1.4	-	5.3.2.2	-	-	
Vibration survey	4.4.5	-	4.6.3	4.7.2	4.8.3		5.1.5	-	5.3.3	5.4.2	5.5.5	
Peak Pressure or Pre: Survey	4.4.6	4.5.3	4.6.4	-	4.8.4		5.1.6	5.2.3	5.3.4	-	5.5.3.1	
Pump Ripple	4.4.7	4.5.4	4.6.5	4.7.3	-		5.1.7	5.2.4	5.3.5	5.4.3	-	
System Temperatures	4.4.8	-	4.6.6	4.7.4	4.8.5		5.1.8	-	5.3.6	5.4.4	5.5.3.2	
Post Test Inspection	4.4.9	4 5 5	4.6.7	4.7.5	4.8.6		5.1.9	5.2.5	5.3.7	5.4.5	5.5.6	
Engine Compatibility	4.4.10	-	-	-	-		5.1.10	-	-	-	-	
Pre Flight Check	-	-	-	-	4.8		-	-	-	-	5.5.1	
Taxi Test	-	-	-	-	4.8		-	-	-	-	5.5.2	
Flight Capability	-	-	-	-	4.8.7		-	-	-	-	5.5.7	

4.4.2 System functional. System functional tests shall be performed on the simulator to ensure that the systems and subsystems meet the design objectives. All normal operating requirements and emergency operations shall be demonstrated in their most adverse condition.

4.4.3 Failure modes and effects. Failure modes and effects tests shall be conducted prior to first flight to evaluate the failure modes which are critical from a safety point of view or whose effects are unpredictable from the failure mode and effects analyses.

4.4.4 Mission profile. Mission profile (see 3.8) test shall be performed to demonstrate that all normal missions can be satisfied. This test shall include start-up, taxi, take-off, climb-out, cruise, mission maneuvering, return flight, landing, taxi, park, and shut-down.

4.4.5 Vibration survey. Vibration survey shall be performed on the simulator to ensure that no detrimental resonant conditions (see 3.13) exist induced by the hydraulic system.

4.4.6 Peak pressure. Pressure survey shall be performed on the simulator to verify that system pressure peaks do not exceed the design requirements.

4.4.7 Pump ripple. Pump ripple (see 3.12) test shall be performed to ensure that no resonance ripple frequencies (see 3.14), created by any device, cause detrimental and destructive effects to the hydraulic system or aircraft. All normal speed ranges of the pump or other ripple-generating devices shall be investigated.

4.4.8 System temperatures. System temperatures shall be monitored on the simulator to validate the analytical data. Deviation to predicted temperatures shall be investigated and resolved. Extreme limits of the temperature envelope shall be tested by allowing the system temperature to rise to simulator limits and then extrapolating data to the extremes of the flight envelope.

4.4.9 Post test inspection. Post test inspection (see 3.10) shall be conducted to determine condition of the hydraulic and pneumatic systems at the conclusion of each test. Data such as temperature, fluid level, accumulator pressure, quantity of dissolved air, air bottle pressure shall be noted. Any deviation to predicted values shall be investigated and resolved.

4.4.10 Engine compatibility. Engine mounted hydraulic components and systems shall demonstrate their compatibility with related engine operation on simulators such as engine test stand, air inlet control test stand, and thrust reverser test stand.

4.5 Aircraft ground cart. All systems operable through ground cart test connections shall be demonstrated during the test.

TABLE II. Hydraulic Pressures.

Component or Characteristic	Pressure (1/)		Remarks
	Class 5000 and below 2/	Class 8000 and below 3/	
Pump Pressures			
a. Pump pressure at zero flow	100%	100%	System design pressure
b. Pump minimum pressure at full flow	100% -150 psi	100% -150 psi	
Relief Valve Pressure Settings			
a. Systems relief valve maximum pressure at rated flow	100% +850 psi	100% +850 psi	The pressure settings for a specific valve shall be in accordance with the applicable valve specification
b. Thermal relief valve cracking pressure	100% +1000 psi	100% +1000 psi	
Proof Pressure (minimum)			
a. Lines, fittings, hoses and couplings			Proof pressures values for hoses to be in accordance with the applicable hose specification
(1) Pressure circuits	200%	200%	
(2) Return and case drain circuits	100%	100%	
b. Accumulators	200%	200%	-
c. Low pressure side of reservoir and pump suction line for the following reservoir types			
(1) Bootstrap reservoir	--	--	150% of reservoir operating pressure
(2) Gas pressurized reservoirs	--	--	200% of reservoir operating pressure
d. Components under system pressure	150%	150%	-

TABLE 1I. Hydraulic pressures - (continued)

e. Components under return pressure only	100%	100%	Except for hoses which shall be 125% of system pressure
f. Heat exchangers	150%	150%	150% of maximum operating pressure
g. Complete system (1) Pressure side (2) Return side	150% 75%	150% 75%	Aircraft installed systems only
Burst Pressures			
a. Lines, fittings, hoses and couplings (1) Pressure circuits (2) Return and case drain circuits	400% 400% 200%	- 300% 150%	Burst pressure values for hoses to be in accordance with the applicable hose specification
b. Accumulators	400%	400%	-
c. Low pressure side of reservoir and pump suction line for the following reservoir	-	-	-
(1) Bootstrap reservoir	-	-	300% of reservoir operating pressure
(2) Gas pressurized reservoirs	-	-	400% of reservoir operating pressure
d. Components under system pressure	250%	200%	-
e. Components under return pressure only	150%	150%	Except for hoses which shall be 125% of system pressure

TABLE 1I. Hydraulic pressure - (continued)

f. Heat exchangers	-	-	250% of maximum operating pressure
g. Collapse pressure of parts subject to suction	50 psid external	50 psid external	-

1/ Percentage of supply pressure in psi.
2/ 5000 PSI supply pressure.
3/ 8000 PSI supply pressure.

4.5.1 System proof pressure. Proof pressure of aircraft hydraulic and pneumatic systems shall be performed with components installed. System shall be tested to the requirements of table II as applicable.

4.5.2 System functional. System functional tests (see 3.6) shall demonstrate satisfactory operation of all systems and their compatibility with designated ground carts.

4.5.3 Peak pressure. Pressure survey shall be performed to determine that system pressure peaks from ground cart operation shall not exceed the design requirements.

4.5.4 Pump ripple. Pump ripple tests shall be performed to ensure that no resonant ripple frequencies created by ground cart operation cause detrimental and destructive effects to the hydraulic system or aircraft. Particular attention shall be given to the aircraft hydraulic plumbing installation between the system pump(s) and the pressure line filter(s). All normal speed ranges of the generating device shall be investigated.

4.5.5 Post test inspection. A post test inspection shall be performed to determine any leakage or damage to components, lines and structure.

4.6 Aircraft varidrive operation (see 3.1). Varidrive pumps shall be installed in approximately the normal pump position in the aircraft. This test shall demonstrate normal operation of the aircraft hydraulic and pneumatic systems with engine driven variable pumps.

4.6.1 System functional. Functional test shall perform the start, all engine RPM ranges, and shut down of the hydraulic and emergency pneumatic systems. The systems shall be operated through all normal and emergency modes.

4.6.2 Mission profile and failure mode. Mission profile and failure mode tests specified in paragraph 5.3.2 of this standard shall be performed on the aircraft to demonstrate that safety of flight shall not be endangered.

4.6.3 Vibration survey. A vibration survey shall be conducted to determine if any unusual induced vibration modes exist from the hydraulic system and structural combination.

4.6.4 Pressure survey. Pressure survey shall be performed to determine that system pressure peaks from varidrive pumps shall not exceed the design requirements. Particular attention shall be given to the hydraulic plumbing installation between the system pump(s) and the pressure line filter(s).

4.6.5 Pump ripple. A pump ripple test shall be performed to ensure that no resonant ripple frequencies, created by any device, cause detrimental and destructive effects to the hydraulic system or aircraft. All normal speed ranges of the pump or other ripple generating device shall be investigated.

4.6.6 Temperature survey. Temperature survey shall be performed to determine if system temperatures are within temperature limits specified in the hydraulic system specification.

4.6.7 Post test inspection. A post test inspection shall be performed after each test to determine any leakage or damage to components, lines, and structures.

4.7 Aircraft engine operation. Aircraft engine power shall be used to demonstrate the operation of all hydraulic and emergency pneumatic systems.

4.7.1 Functional tests. Functional tests shall demonstrate satisfactory operation of all systems except landing gear or other subsystems that cannot be safely demonstrated on the ground.

4.7.2 Vibration survey. A vibration survey shall be conducted on critical areas that are instrumented for flight testing.

4.7.3 Pump ripple. A pump ripple test shall be performed to ensure that no resonant ripple frequencies, created by any device, cause detrimental and destructive effects to the hydraulic system or aircraft. Particular attention shall be given to the hydraulic plumbing installation between the system pump(s) and the pressure line filter(s). All normal speed ranges of the pump or other ripple generating devices shall be investigated.

4.7.4 System temperatures. System temperatures shall be monitored to verify analytically predicted temperatures. High temperature areas require continuous monitoring during engine operation on the ground.

4.7.5 Post test inspection. A post test inspection shall be conducted to determine any leakage or damage to components, lines, and structures.

4.8 Aircraft flight test. Flight test shall be performed in accordance with the applicable specifications (see 2.2.1) and as required by this standard. Pre-flight and taxi tests shall be conducted in accordance with 5.5.1 and 5.5.2 to ensure that the aircraft is capable for flight with full performance.

4.8.1 Functional tests. These tests shall demonstrate that all subsystems function within the extreme limits of the flight envelope for which the system was designed such as landing gear retraction at maximum air speed for which the system was designed. Back-up systems shall demonstrate their designed capability; such as emergency landing gear, flaps, and flight controls.

4.8.2 Flight test failure modes. Simulated failure mode tests shall be performed to demonstrate adequacy of the redundant and back-up systems.

4.8.3 Vibration. Critical areas shall be instrumented and monitored during all flight testing. Critical areas are determined from simulator and engine testing.

4.8.4 Peak pressure. Peak pressure shall be monitored during various flight tests. Areas of the system shown to be critical during simulator or other ground testing shall be instrumented for continuous surveillance.

4.8.5 System temperatures. System temperatures shall be monitored to verify analytically predicted temperatures. High temperature areas require continuous monitoring during aircraft critical flight envelope.

4.8.6 Post test inspection. Post test inspection of the aircraft for leaks, damage, or failures shall be conducted after each flight. All anomalies shall be cleared before next flight.

4.8.7 Flight capability. Critical flight envelope to which the system was designed shall be tested to validate the system design. Normal flight envelope obtained in the early flight test program shall be tested to verify the basic design.

4.9 Data submittal and approval. Data submittal and approval requirement for a specific model aircraft shall be covered by a contract with the appropriate acquiring activity. Typical information and data required are described in 6.4. The data shall be furnished in accordance with appropriate line items of the Contractor Data Requirements List (DD Form 1423), as applicable (see 6.4).

5. DETAIL REQUIREMENTS

5.1 Simulator tests. Simulator tests (see 3.15) shall be conducted in accordance with applicable specifications (see 2.2.1) and the requirements of 4.4. The following support equipment shall be utilized:

a. Hydraulic test stand - Ground hydraulic carts or equivalent power sources shall be available to supply sufficient pressure to perform the proof pressure tests and also sufficient flow to move aircraft control surfaces and equipment to alternate positions.

b. External electric power supply - Aircraft electrical power shall be supplied by a ground cart or equivalent power source.

c. Air conditioning - Air conditioning shall be supplied to cool aircraft electronic devices during the tests. A ground air conditioning cart shall be provided to be used as required to cool aircraft hydraulic systems.

d. Switch boxes special equipment - Special equipment shall be provided as necessary to perform all required operations.

e. Simulator servicing - The simulator shall be placed in the following condition: Reservoirs shall be serviced, accumulators charged, and all systems operable.

f. Simulator electrical power system - Verify all power is connected and all switches in their proper positions.

g. Hydraulic system and subsystem configuration - Position all systems to their proper positions.

5.1.1 Proof pressure test. Proof pressure as specified in 4.4.1 shall be applied to the hydraulic system to prove the integrity of connections at each component. Pressure shall be sustained for at least five minutes. After inspection for failures or leaks, system pressure shall be restored to normal pressure. All systems shall be placed in their alternate position and proof pressure applied again. After system has been inspected return simulator to its original condition.

5.1.2 System functional tests. When conducting these functional tests, the systems shall be configured in the following manner:

a. Simulator power supply (equipment for simulator) - The test stand, containing the hydraulic pumps shall be connected to the aircraft system in a like manner the actual power system connected to the aircraft. All special test equipment if necessary shall be installed and system modifications, if any, completed. Hydraulic system shall be adequately bled of entrapped air, and reservoir(s) filled to their specified level with applicable hydraulic fluid. All accumulators shall be properly serviced and the entire system, components, and attached linkages and mechanisms shall be properly adjusted. Pneumatic systems shall be lubricated with all system components and attached linkages and mechanisms properly adjusted.

b. Test equipment for simulator - The following test equipment shall be installed on the simulator:

(1) Pump(s) equal in type and quantity to those normally used in the aircraft system.

(2) Variable speed drive(s) equipped with tachometer(s).

(3) Lines identical to the aircraft installation shall be used to connect pump to system.

(4) Calibrated pressure gages (mechanical or electrical), flow meters, and other miscellaneous equipment as necessary.

(5) Temperature indicating equipment.

c. System separable - The system shall be separable if the aircraft is designed to incorporate two or more separate systems. Provisions shall be made to operate the systems in their proper relationship with each other.

d. Artificial loading - If artificial loading of any service is necessary, such as wing flaps, air brakes, surface control boost or power systems, adequate provision to accomplish such loading shall be installed and calibrated. Simulation of pre loads of doors and closures to structure in aircraft is required. Unsymmetrical loading (see 3.16) is required during synchronized testing.

e. Reservoir pressure - Reservoir pressurization shall be identical to aircraft installation. Pressurized air can be substituted for engine bleed air.

5.1.2.1 Normal system test. Normal system (see 3.9) pressure shall be applied to the entire hydraulic system and each selector and control valve shall be operated for at least two complete cycles (see 3.2) of its corresponding service. In addition, each control unit shall be operated through an incomplete half cycle (see 3.7), followed by a complete reversal of direction. The above operations shall be accomplished through both directions of operation. During the above operations, inspection shall be made to determine whether:

a. The various functions are accomplished satisfactorily in accordance with the specification requirements.

b. The movement of all components is smooth and positive.

c. Relief valve devices for automatic termination of an operation, pressure controls, switches and signals, audible or other warning devices, and similar component function as intended. Relief valves shall not by-pass fluid during normal operation of any component.

d. All indicating devices function and synchronize with the movement of their respective component as specified.

e. The specified functioning pressures shall be controlled and shall not be exceeded beyond the operational limit. This requirement may need the pressure indicators installed at various locations in the system. Pressure shall be obtained by system pressure gages, auxiliary mechanical gages, or electronic equipment as applicable (see 6.5.1).

f. All tubing and fitting joints and component external seals are free of leaks. Allowable leakage shall be defined by contractor test plan (see 6.5.1).

g. All fluid lines, fittings, and components are free from excessive movement and chaffing.

h. There is a full engagement of mechanical locks and latches, and that hydraulic back pressure does not cause inadvertent unlocking.

i. The clearance for all moving parts, where applicable, throughout the entire range of movement is such that damage to adjacent parts shall not occur. Particular attention shall be given to flexible connections to ensure that pinching or stretching does not occur.

j. Simulated normal flight operating conditions, or any possible inadvertent operation, which shall cause system malfunction.

k. Operating temperatures and ambient temperatures shall be noted.

5.1.2.2 Fluid level. The following reservoir conditions shall be demonstrated as part of the simulator tests:

a. Low level. The fluid in the reservoir(s) shall be set to the lowest permissible indicated level, and all the gas charge removed from the largest accumulator in the system and minimum gas charge in all other accumulators. Reservoir pressurization, if applicable, shall be set to the low limit of the normal pressurization range. The controls shall then be operated at least once through the normal sequence of operations. The control valves shall be set to simulate normal flight operation, whereby the minimum amount of fluid is returned to the reservoir. For gas to fluid in contact type reservoirs, the pump suction line opening shall be checked for any possibility that the opening has been uncovered and air introduced into the system. For gas fluid separation type reservoirs, the pump suction line opening shall be checked to determine that the pump inlet pressure shall be not less than the recommended minimum values. A simulation of an inverted flight condition or zero "g" shall also be included, if applicable.

b. Overfill test. Reservoir shall be filled with test fluid to overflow condition. A normal sequence of operation from taxi, take-off, landing, to park and shut down shall be simulated. Any damage to reservoir or other components shall be noted. Fluid loss to the extent of the over-fill is allowed.

5.1.2.3 Hand or auxiliary pump operation. Where hand pump, or auxiliary pump operation are applicable, the test stand shall be disconnected and each service shall be operated through at least one complete cycle. Any applicable items recorded or inspected under 5.1.2.1 shall be repeated herein. In addition, any inadvertent fluid transfer between reservoirs, if applicable, shall be noted for necessary correction. The number of cycles of hand pump operation required for functioning with each part of the system shall be recorded. The amount of this force shall be measured with a spring scale and recorded. Care shall be taken in this test not to overheat electric motors driving pumps if such motors are not of the continuous duty type.

5.1.2.4 Emergency operation. All emergency operations (see 3.3) shall be tested upon those items normally to be operated by the hydraulic or pneumatic systems. The maintenance publications shall include the procedure concerning the maintenance necessary to bleed or reset the system to normal operating conditions, including recharging of air bottles. In the case of surface control boost or power systems, which automatically revert from main system pressure to emergency system pressure, main system pressure shall be reduced in the most detrimental manner, allowing the emergency pressure to automatically take over. System shall be inspected for smooth, continuous operations during the changeover. If the emergency provision consists of dual systems that simultaneously operate an aircraft service, each system shall be operated with the opposite system inoperable (simulated) and the applicable service actuated. The actuated service shall function within design requirements at its most severe operating condition such as lowest air bottle pressure.

5.1.2.5 Time of operation. Requirements for measuring the elapsed time (see 3.4) of operation for full or half cycles in the foregoing test procedure shall be conducted. Such a measurement during ground tests is desirable and necessary in some services. The time as measured on the ground is unrealistic due to lack of wind, inertia, and similar loads. However, this item is to be considered in the preparation of the test procedure for comparison with production aircraft.

5.1.2.6 Brake systems. In order to hold the 10^{o} slope at the maximum design weight, the following tests shall be performed on all carrier-based aircraft power braking systems (see 3.11).

a. Tests shall include a minimum of 25 rapid pumping operations of each brake pedal, with and without hydraulic power, to assure satisfactory brake operation under these conditions.

b. Demonstrate that the required emergency operations are available.

5.1.3 Failure mode. Failure mode tests for the simulator shall evaluate the hydraulic system's capability to cope with all the following specified failures. Other failure modes shall be evaluated as determined during development of the aircraft.

a. Loss of fluid in any system.

b. Loss of fluid pressure in any system.

c. Fluctuation of fluid pressure in any system.

d. Effect of air in the hydraulic system.

e. Loss of accumulator pressure.

f. Simulated combat damage capability as defined in aircraft specification.

g. Engine shut down.

h. Operation of all emergency procedures.

i. Failed relief valve or failed pump compensator.

5.1.4 Mission profile. The hydraulic system simulator shall operate in a procedure that resembles all the anticipated flight capabilities. Mandatory tests are as follows with additional tests being added to demonstrate capability in more difficult mission profiles.

a. Take-off - maximum speed mission intercept - landing.

b. Maximum times at idle and taxi, return to flight line and shut down (no flight mode).

c. Normal mission (take-off, flight, landing).

d. Turbulent weather conditions (constant control actuation).

e. Inverted flight (partial) if applicable (may be demonstrated by special test).

f. High altitude flight.

g. Zero "g" if applicable (may be demonstrated by special test).

5.1.5 Vibration survey. During the operation of hydraulic and pneumatic systems, visual and instrument data shall be collected on line and component installations to ascertain the levels of acceleration forces induced in the hydraulic system by the different modes of operation. Particular attention shall be paid to those areas of rotation components and those systems having high inertia loads. In addition, high frequency cyclic inputs [as aircraft flight control system (AFCS) and flight control system (FCS)] shall be reviewed carefully.

5.1.6 Peak pressure. Tests shall be performed to measure peak hydraulic system pressures such as those induced by high inertia loads and rapid system reversals, as in landing gear systems. The test shall be conducted under the most adverse realistic mode of operation.

5.1.7 Pump ripple. The maximum stresses induced into lines and components as a result of any pressure ripple-producing component in the system shall be measured. The procedure shall cover all pump speed ranges and multiple pump operation including start and stop to ensure that no detrimental pressure pulsation exists in the hydraulic system. Resonant conditions shall be tested for sufficient periods at each resonant frequency to ensure that the system has adequate fatigue life (see 3.5). MIL-STD-810 shall be used for vibration requirements.

5.1.8 System temperatures. System temperature tests shall be performed to compare the actual operational temperatures with the analytically predicted temperatures. All mission profiles shall be performed and monitored. Comparisons shall be made for each mission simulation. These tests shall be coordinated with the mission profile test as specified in 5.1.4.

5.1.9 Post test inspection. A post test inspection is required after each formal test. Data shall be recorded noting the conditions of the hydraulic system. The following minimum data shall be taken immediately after shut down and compared with initial or predicted values.

a. System temperatures.

b. Reservoir level.

c. Filter button position.

d. Accumulator gas charge.

e. Brake system condition.

f. Position of all actuators.

g. Leakage noted.

h. Filter bowl contents.

i. Contamination level of fluid.

j. Pressure and temperature in air bottles.

k. List of anomalies that occurred and disposition.

5.1.10 Engine compatibility tests. When conducting compatibility tests of hydraulic systems and components with related engine functions; simulators and test stands shall be configured as follows:

a. The hydraulic line runs on the engine shall be identical to the aircraft including clamp location and hardware. The hydraulic line runs from the engine to aircraft structure shall be simulated in so-far-as it is practical.

b. Only aircraft hydraulic components shall be used. Engine mounting shall be identical to the aircraft.

c. The method of providing reservoir pressurization shall be identical to the aircraft.

5.1.11 Data requirements. During the performance tests, the following items shall be determined.

a. Temperature data on the entire hydraulic system shall be collected with particular attention paid to an engine mounted lines and components.

b. Line and component vibrations shall be recorded to ascertain the levels of acceleration forces induced in the hydraulic system by the different modes of operation.

c. Pump flows, temperatures, and pressures shall be monitored.

d. All failures shall be reported and the cause of failure analyzed. Component and fitting leakage shall be determined. Temperatures shall not exceed the allowable maximum values.

5.2 Aircraft ground cart test. These tests shall be conducted in accordance with the applicable specifications (see 2.2.1) and the requirements of 4.5. The following ground test equipment configuration shall be utilized.

a. Hydraulic test stand - Ground hydraulic carts shall be available to supply sufficient pressure to perform the proof pressure and also sufficient flow to move control surfaces to alternate position.

b. External electrical power supply - Aircraft electrical power shall be supplied by a ground cart or equivalent power source.

c. Air conditioning - Air conditioning shall be supplied to cool aircraft electronic components during the tests.

Ground air conditioning cart shall be provided to cool aircraft hydraulic and pneumatic systems.

d. Switch boxes - Switch boxes shall be provided if necessary to perform all required operations.

e. Jacks - Jacks shall be available to raise the aircraft, as required by the test.

f. The aircraft shall be placed in the following conditions:

(1) Aircraft servicing - Reservoirs shall be serviced, accumulators charged, and systems shall be operable.

(2) Electrical power supply - Verify all power is connected and all switches in their proper positions.

(3) Hydraulic system, subsystem, and configuration - Position the hydraulic system, subsystem and configuration to their proper positions.

5.2.1 Proof pressure. Proof pressure as specified in 4.4.1 shall be applied to the hydraulic system to prove the integrity of connections at each component. Pressure shall be sustained for at least five minutes. After inspection for failures or leaks, system pressure shall be restored to normal pressure. All the systems shall be placed in their alternate position and proof pressure applied again. After the system has been inspected return simulator to its original condition.

5.2.2 System functional. When conducting these functional tests the designated ground cart shall be attached to the aircraft with the shortest practical lines and the systems shall be configured as follows:

a. Configuration. Hydraulic system shall be adequately bled of entrapped air, and the system and reservoir(s) filled to their specified level with applicable hydraulic fluid. All accumulators shall be properly serviced and the entire system, components, and attached linkages and mechanisms properly adjusted. Pneumatic systems shall be properly lubricated, with all system components and attaching linkages and mechanisms properly adjusted. The aircraft shall be elevated and safely anchored in place to permit full operation of all hydraulically or pneumatically operated services or units.

b. Test equipment. The following test equipment shall be installed in the aircraft. Calibrated pressure gages, mechanical or electronic, flow meters, and other miscellaneous equipment as necessary. Temperature indicating equipment, if artificial loading of any service is necessary: such as wing flaps, air brakes, surface control boost, or power systems; adequate provision to accomplish such loading shall be installed and calibrated.

5.2.2.1 Normal system. Normal system pressure shall be applied to the entire hydraulic system and each selector and control valve shall be operated for at least two complete cycles of its corresponding service. In addition, each control unit shall be operated through an incomplete half

cycle, followed by a complete reversal of direction. The above operations shall be accomplished through both directions of operation. During the above operations, inspection shall be made to determine whether:

a. The various functions are accomplished satisfactorily in accordance with the specification requirements.

b. The movement of all components is smooth and positive.

c. Relief valve devices for automatic termination of an operation, pressure controls, switches and signals, audible or other warning devices, and similar component function as intended. Relief valves shall not by-pass fluid during normal operation of any component.

d. All indicating devices function and synchronize with the movement of their respective component as specified.

e. The specified functioning pressures shall be controlled and shall not be exceeded beyond the operational limit. This requirement may need the pressure indicators installed at various locations in the system. Pressure shall be obtained by system pressure gages, auxiliary mechanical gages, or electronic equipment as applicable (see 6.5.1).

f. All tubing and fitting joints and component external seals are free of leaks. Allowable leakage shall be defined by contractor test plan (see 6.5.1).

g. All fluid lines, fittings, and components are free from excessive movement and chaffing.

h. There is a full engagement of mechanical locks and latches, and that hydraulic back pressure does not cause inadvertent unlocking.

i. The clearance for all moving parts, where applicable, throughout the entire range of movement is such that damage to adjacent parts shall not occur. Particular attention shall be given to flexible connections to ensure that pinching or stretching does not occur.

j. All hydraulically or pneumatically operated doors and closures are flush with surrounding surfaces within limits provided by the approved drawings for closed position.

k. The movement of flaps is synchronized under load and no-load condition and there is no excess play in the flaps. Unsymmetrical loading is required during synchronized testing. There is no counter part of the test for pneumatic system.

l. Simulated normal flight operating conditions, or any possible inadvertent operation, which shall cause system malfunction.

m. Operating temperatures (if applicable) and ambient temperature shall be noted.

5.2.2.2 Fluid level. The following reservoir conditions shall be demonstrated as part of the simulator tests:

a. Low level. The fluid in the reservoir(s) shall be set to the lowest permissible indicated level, and all the gas charge removed from the largest accumulator in the system and minimum gas charge in all other accumulators. Reservoir pressurization, if applicable, shall be set to the low limit of the normal pressurization range. The controls shall then be operated at least once through the normal sequence of operations. The control valves shall be set to simulate normal flight operation, whereby the minimum amount of fluid is returned to the reservoir. For "gas to fluid in contact" type reservoirs, the pump suction line opening shall be checked for any possibility that the opening has been uncovered and air introduced into the system. For gas-fluid-separation type reservoirs, the pump suction line opening shall be checked to determine that the pump inlet pressure shall be not less than the recommended minimum values. A simulation of an inverted flight condition or zero "g" shall also be included, if applicable.

b. Overfill test. Reservoir shall be filled to overflow condition. A normal sequence of operation from taxi, take-off, landing, to park and shut down shall be simulated. Any damage to reservoir or other components shall be noted. Fluid loss to the extent of the over-fill is allowed.

5.2.2.3 Hand or auxiliary pump operation. Where hand pump, or auxiliary pump operation are applicable, the test stand shall be disconnected and each service shall be operated through at least one complete cycle. Any applicable items recorded or inspected in 5.1.2.1 shall be repeated herein. In addition, any inadvertent fluid transfer between reservoirs, if applicable, shall be noted for necessary correction. The number of cycles of hand pump operation required for functioning with each part of the system shall be recorded. The amount of this force shall be measured with a spring scale and recorded. Care shall be taken in this test not to overheat electric motors driving pumps if such motors are not of the continuous duty type.

5.2.2.4 Emergency operation. All emergency operations shall be tested upon those items normally to be operated by the hydraulic or pneumatic systems. The maintenance publications shall include the procedure concerning the maintenance necessary to bleed or reset the system to normal operating conditions, including recharging of air bottles. In the case of surface control boost or power systems, which automatically revert from main system pressure to emergency system pressure, main system pressure shall be reduced in the most detrimental manner, allowing the emergency pressure to automatically take over. System shall be inspected for smooth, continuous operations during the changeover. If the emergency provision consists of dual systems that simultaneously operate an aircraft service, each system shall be operated with the opposite system inoperable (simulated) and the applicable service actuated. The actuated service shall function within design requirements at its most severe operating condition such as lowest air bottle pressure.

5.2.2.5 Time of operation. Requirements for measuring the elapsed time of operation for full or half cycles in the foregoing test procedure shall be conducted. Such a measurement during ground tests is desirable and necessary in some services. The time as measured on the ground is unrealistic due to lack of wind, inertia, and similar loads. However, this item is to be considered in the preparation of the test procedure for comparison with production aircraft.

5.2.2.6 Brake system. In order to hold the 10^{o} slope at the maximum design weight, the following tests shall be performed on all carrier-based aircraft power braking systems if applicable.

a. Normal system - Tests shall include a minimum of 25 rapid pumping operations of each brake pedal, with and without hydraulic power, to assure satisfactory brake operation under these conditions.

b. Emergency system - Demonstrate that the required emergency operations are available.

5.2.3 Peak pressure. Tests shall be performed to measure peak hydraulic system pressures such as those induced by high inertia loads and rapid system reversals, as in landing gear systems. The test shall be conducted under the most adverse realistic mode of operation.

5.2.4 Pump ripple. The maximum stresses induced into lines and components as a result of any pressure ripple-producing component in the system shall be measured. The procedure shall cover all pump speed ranges and multiple pump operation including start and stop to ensure that no detrimental pressure pulsation exists in the hydraulic system. Resonant conditions shall be tested for sufficient periods at each resonant frequency to ensure that the system has adequate fatigue life. MIL-STD-810 shall be used for vibration requirements.

5.2.5 Post test inspection. A post test inspection is required after each formal test. Data shall be recorded noting the conditions of the hydraulic system. The following minimum data shall be taken immediately after shut down and compared with initial or predicted values.

a. System temperatures.

b. Reservoir level.

c. Filter button position.

d. Accumulator gas charge.

e. Brake system condition.

f. Position of all actuators.

g. Leakage noted.

h. Filter bowl contents.

i. Contamination level of fluid.

j. Pressure and temperature in air bottles.

k. List of anomalies that occurred and disposition.

5.3 Aircraft varidrive operation tests. The tests shall be conducted in accordance with the applicable specifications (see 2.2.1) and the requirements of 4.6 and with the following aircraft configuration and test equipment installed:

a. Aircraft configuration, varidrive - Varidrive driven aircraft pumps shall be installed at approximately the normal pump position in the aircraft. Hydraulic system shall be adequately bled of entrapped air, and the system and reservoir(s) filled to their specified level with applicable hydraulic fluid. All accumulators shall be properly serviced and the entire system, components, and attached linkages and mechanisms shall be lubricated. All system components and attached linkages and mechanisms shall be adjusted. The aircraft shall be elevated and safely anchored in place to permit full operation of all hydraulically or pneumatically operated services or units.

b. Test equipment - The following test equipment shall be installed in the aircraft. Calibrated pressure gages, mechanical or electronic, flow meters, and other miscellaneous equipment as necessary. Temperature indicating equipment, if artificial loading of any service is necessary, such as wing flaps, air brakes, surface control boost, or power systems, adequate provisions to accomplish such loading shall be installed and calibrated.

5.3.1 Functional. Functional tests shall be conducted and shall consist of the following tests:

5.3.1.1 Normal system test. Normal system pressure shall be applied to the entire hydraulic system and each selector and control valve shall be operated for at least two complete cycles of its corresponding service. In addition, each control unit shall be operated through an incomplete half cycle, followed by a complete reversal of direction. The above operations shall be accomplished through both directions of operation. During the above operations, inspection shall be made to determine whether:

a. The various functions are accomplished satisfactorily in accordance with the specification requirements.

b. The movement of all components is smooth and positive.

c. Relief valve devices for automatic termination of an operation, pressure controls, switches and signals, audible or other warning devices, and similar component function as intended. Relief valves shall not by-pass fluid during normal operation of any component.

d. All indicating devices function and synchronize with the movement of their respective component as specified.

e. The specified functioning pressures shall be controlled and shall not be exceeded beyond the operational limit. This requirement may need the pressure indicators installed at various locations in the system. Pressure shall be obtained by system pressure gages, auxiliary mechanical gages, or electronic equipment as applicable (see 6.5.1).

f. All tubing and fitting joints and component external seals are free of leaks. Allowable leakage shall be defined by contractor test plan (see 6.5.1).

g. All fluid lines, fittings, and components are free from excessive movement and chaffing.

h. There is a full engagement of mechanical locks and latches, and that hydraulic back pressure does not cause inadvertent unlocking.

i. The clearance for all moving parts, where applicable, throughout the entire range of movement is such that damage to adjacent parts shall not occur. Particular attention shall be given to flexible connections to ensure that pinching or stretching does not occur.

j. All hydraulically or pneumatically operated doors and closures are flush with surrounding surfaces within limits provided by the approved drawings for closed position.

k. The movement of flaps is synchronized under load and no-load condition and there is no excess play in the flaps. Unsymmetrical loading is required during synchronized testing. There is no counter part of the test for pneumatic system.

l. Simulated normal flight operating conditions, or any possible inadvertent operation, which shall cause system malfunction.

m. Operating temperatures (if applicable) and ambient temperature shall be noted.

5.3.1.2. Fluid level. The following reservoir conditions shall be demonstrated as part of the simulator tests:

a. Low level. The fluid in the reservoir(s) shall be set to the lowest permissible indicated level, and all the gas charge removed from the largest accumulator in the system and minimum gas charge in all other accumulators. Reservoir pressurization, if applicable, shall be set to the low limit of the normal pressurization range. The controls shall then be operated at least once through

the normal sequence of operations. The control valves shall be set to simulate normal flight operation, whereby the minimum amount of fluid is returned to the reservoir. For "gas to fluid in contact" type reservoirs, the pump suction line opening shall be checked for any possibility that the opening has been uncovered and air introduced into the system. For gas-fluid-separation type reservoirs, the pump suction line opening shall be checked to determine that the pump inlet pressure shall be not less than the recommended minimum values. A simulation of an inverted flight condition or zero "g" shall also be included, if applicable.

b. Overfill test. Reservoir shall be filled to overflow condition. A normal sequence of operation from taxi, take-off, landing, to park and shut down shall be simulated. Any damage to reservoir or other components shall be noted. Fluid loss to the extent of the over fill is allowed.

5.3.1.3 Hand or auxiliary pump operation. Where hand pump, or auxiliary pump operation are applicable, the test stand shall be disconnected and each service shall be operated through at least one complete cycle. Any applicable items recorded or inspected in 5.1.2.1 shall be repeated herein. In addition, any inadvertent fluid transfer between reservoirs, if applicable, shall be noted for necessary correction. The number of cycles of hand pump operation required for functioning with each part of the system shall be recorded. The amount of this force shall be measured with a spring scale and recorded. Care shall be taken in this test not to overheat electric motors driving pumps if such motors are not of the continuous duty type.

5.3.1.4 Emergency operation. All emergency operations shall be tested upon those items normally to be operated by the hydraulic or pneumatic systems. The maintenance publications shall include the procedure concerning the maintenance necessary to bleed or reset the system to normal operating conditions, including recharging of air bottles. In the case of surface control boost or power systems, which automatically revert from main system pressure to emergency system pressure, main system pressure shall be reduced in the most detrimental manner, allowing the emergency pressure to automatically take over. System shall be inspected for smooth, continuous operations during the changeover. If the emergency provision consists of dual systems that simultaneously operate an aircraft service, each system shall be operated with the opposite system inoperable (simulated) and the applicable service actuated. The actuated service shall function within design requirements at its most severe operating condition such as lowest air bottle pressure.

5.3.1.5 Time of operation. Requirements for measuring the elapsed time of operation for full or half cycles in the foregoing test procedure shall be conducted. Such a measurement during ground tests is desirable and necessary in some services. The time as measured on the ground is unrealistic due to lack of wind, inertia, and similar loads. However, this item is to be considered in the preparation of the test procedure for comparison with production aircraft.

5.3.1.6 Brake systems. In order to hold the 10^{o} slope at the maximum design weight, the following tests shall be performed on all carrier-based aircraft power braking systems if applicable.

a. Tests shall include a minimum of 25 rapid pumping operations of each brake pedal, with and without hydraulic power, to assure satisfactory brake operation under these conditions.

b. Demonstrate that the required emergency operations are available.

5.3.2 Mission profile and failure mode. These two tests mission profile and failure mode shall be conducted in accordance with the applicable specifications (see 2.2.1) and the requirements of 4.6.2.

5.3.2.1 Failure mode. Failure mode tests for the aircraft shall evaluate the hydraulic system's capability to cope with all the following failures as a minimum. Other failure modes shall be evaluated as determined during development of the aircraft.

a. Loss of fluid in any system.

b. Loss of fluid pressure in any system.

c. Fluctuation of fluid pressure in any system.

d. Effect of air in the hydraulic system.

e. Gun fire.

f. Loss of maneuverability.

5.3.2.2 Mission profile. The hydraulic system shall operate in a procedure that resembles all the anticipated flight capabilities. Mandatory tests are as follows with additional tests being added to demonstrate capability in more difficult mission profiles.

a. Take-off - maximum speed mission intercept - landing.

b. Maximum times at idle and taxi, return to flight line and shut down (no flight mode).

c. Normal mission (take-off, flight, landing).

d. Turbulent weather conditions (constant control actuation).

e. Inverted flight (partial) if applicable (may be demonstrated by special test).

f. High altitude flight.

g. Zero "g" if applicable (may be demonstrated by special test).

h. Loss of accumulator pressure.

i. Simulated combat damage capability as defined in aircraft specification.

j. Engine shut down.

k. Operation of all emergency procedures.

l. Failed relief valve or failed pump compensator.

m. Backup system if one system fail (dual systems).

n. Backup system if two systems fail (three systems).

o. Fire proof, fire resistant.

p. Gun proof.

5.3.3 Vibration survey. During the operation of hydraulic and pneumatic systems, visual and instrument data shall be collected on lines and component installations to ascertain the levels of acceleration forces induced in the hydraulic system by the different modes of operation. Particular attention shall be paid to those areas of rotation components and to those systems having high inertia loads. In addition, high frequency cyclic inputs (as AFCS and FCS systems) shall be reviewed carefully.

5.3.4 Peak pressure. Tests shall be performed to measure peak hydraulic system pressures such as those induced by high inertia loads and rapid system reversals, as in landing gear systems. The test shall be conducted under the most adverse realistic mode of operation.

5.3.5 Pump ripple. The maximum stresses induced into lines and components as a result of any pressure ripple-producing component in the system shall be measured. The procedure shall cover all pump speed ranges and multiple pump operation including start and stop to ensure that no detrimental pressure pulsation exists in the hydraulic system. Resonant conditions shall be tested for sufficient periods at each resonant frequency to ensure that the system has adequate fatigue life. MIL-STD-810 shall be used for vibration requirements.

5.3.6 System temperatures. System temperature tests shall be performed to compare the actual operational temperatures with the analytically predicted temperatures. All mission profiles shall be performed and monitored. Comparisons shall be made for each mission simulation.

These tests shall be coordinated with the mission profile test as specified in 5.1.4.

5.3.7 Post test inspection. A post test inspection is required after each formal test. Data shall be recorded noting the conditions of the hydraulic system. The following minimum data shall be taken immediately after shut down and compared with initial or predicted values.

a. System temperatures.

b. Reservoir level.

c. Filter button position.

d. Accumulator gas charge.

e. Brake system condition.

f. Position of all actuators.

g. Leakage noted.

h. Filter bowl contents.

i. Contamination level of fluid.

j. Pressure and temperature in air bottles.

k. List of anomalies that occurred and disposition.

5.4 Aircraft engine operation. The aircraft and engine operation tests shall be conducted in accordance with the applicable specifications (see 2.2.1) and the requirements of 4.7. Also the tests shall be conducted with the following aircraft configuration and test equipment installed.

a. Aircraft configuration - This test shall be setup in accordance with 5.2.2a

b. Test equipment - The test equipment shall be in accordance with 5.2.2b.

5.4.1 Functional. Functional tests shall be conducted and shall consist of the following tests:

5.4.1.1 Normal system test. Normal system pressure shall be applied to the entire hydraulic system and each selector and control valve shall be operated for at least two complete cycles of its corresponding service. In addition, each control unit shall be operated through an incomplete half

cycle, followed by a complete reversal of direction. The above operations shall be accomplished through both directions of operation. During the above operations, inspection shall be made to determine whether:

a. The various functions are accomplished satisfactorily in accordance with the specification requirements.

b. The movement of all components is smooth and positive.

c. Relief valve devices for automatic termination of an operation, pressure controls, switches and signals, audible or other warning devices, and similar component function as intended. Relief valves shall not by-pass fluid during normal operation of any component.

d. All indicating devices function and synchronize with the movement of their respective component as specified.

e. The specified functioning pressures shall be controlled and shall not be exceeded beyond the operational limit. This requirement may need the pressure indicators installed at various locations in the system. Pressure shall be obtained by system pressure gages, auxiliary mechanical gages, or electronic equipment as applicable (see 6.5.1).

f. All tubing and fitting joints and component external seals are free of leaks. Allowable leakage shall be defined by contractor test plan (see 6.5.1).

g. All fluid lines, fittings, and components are free from excessive movement and chaffing.

h. There is a full engagement of mechanical locks and latches, and that hydraulic back pressure does not cause inadvertent unlocking.

i. The clearance for all moving parts, where applicable, throughout the entire range of movement is such that damage to adjacent parts shall not occur. Particular attention shall be given to flexible connections to ensure that pinching or stretching does not occur.

j. All hydraulically or pneumatically operated doors and closures are flush with surrounding surfaces within limits provided by the approved drawings for closed position.

k. The movement of flaps is synchronized under load and no-load condition and there is no excess play in the flaps. Unsymmetrical loading is required during synchronized testing. There is no counter part of the test for pneumatic system.

l. Simulated normal flight operating conditions, or any possible inadvertent operation, which shall cause system malfunction.

m. Operating temperatures and ambient temperature shall be noted.

5.4.1.2 Fluid level. The following reservoir conditions shall be demonstrated as part of the simulator tests:

a. Low level. The fluid in the reservoir(s) shall be set to the lowest permissible indicated level, and all the gas charge removed from the largest accumulator in the system and minimum gas charge in all other accumulators. Reservoir pressurization, if applicable, shall be set to the low limit of the normal pressurization range. The controls shall then be operated at least once through the normal sequence of operations. The control valves shall be set to simulate normal flight operation, whereby the minimum amount of fluid is returned to the reservoir. For "gas to fluid in contact" type reservoirs, the pump suction line opening shall be checked for any possibility that the opening has been uncovered and air introduced into the system. For gas-fluid-separation type reservoirs, the pump suction line opening shall be checked to determine that the pump inlet pressure shall be not less than the recommended minimum values.

b. Overfill test. Reservoir shall be filled to overflow condition. A normal sequence of operation from taxi, take-off, landing, to park and shut down shall be simulated. Any damage to reservoir or other components shall be noted. Fluid loss to the extent of the over fill is allowed.

5.4.1.3 Hand or auxiliary pump operation. Where hand pump, or auxiliary pump operation are applicable, the test stand shall be disconnected and each service shall be operated through at least one complete cycle. Any applicable items recorded or inspected in 5.1.2.1 shall be repeated herein. In addition, any inadvertent fluid transfer between reservoirs, if applicable, shall be noted for necessary correction. The number of cycles of hand pump operation required for functioning with each part of the system shall be recorded. The amount of this force shall be measured with a spring scale and recorded. Care shall be taken in this test not to overheat electric motors driving pumps if such motors are not of the continuous duty type.

5.4.1.4 Emergency operation. All emergency operations shall be tested upon those items normally to be operated by the hydraulic or pneumatic systems. The maintenance publications shall include the procedure concerning the maintenance necessary to bleed or reset the system to normal operating conditions, including recharging of air bottles. In the case of surface control boost or power systems, which automatically revert from main system pressure to emergency system pressure, main system pressure shall be reduced in the most detrimental manner, allowing the emergency pressure to automatically take over. System shall be inspected for smooth, continuous operations during the changeover. If the emergency provision consists of dual systems that simultaneously operate an aircraft service, each system shall be operated with the opposite system inoperable (simulated) and the applicable service actuated. The actuated service shall function within design requirements at its most severe operating condition such as lowest air bottle pressure.

5.4.1.5 Time of operation. Requirements for measuring the elapsed time of operation for full or half cycles in the foregoing test procedure shall be conducted. Such a measurement during ground tests is desirable and necessary in some services. The time as measured on the ground is unrealistic due to lack of wind, inertia, and similar loads. However, this item is to be considered in the preparation of the test procedure for comparison with production aircraft.

5.4.1.6 Brake systems. In order to hold the 10^{o} slope at the maximum design weight, the following tests shall be performed on all carrier-based aircraft power braking systems if applicable.

a. Tests shall include a minimum of 25 rapid pumping operations of each brake pedal, with and without hydraulic power, to assure satisfactory brake operation under these conditions.

b. Demonstrate that the required emergency operations are available.

5.4.2 Vibration survey. During the operation of systems, instrument data shall be collected on selected lines and component installations to ascertain the levels of acceleration forces induced in the hydraulic system by the different modes of operation. Particular attention shall be paid to high-speed components and those systems having high inertia loads. In addition, high frequency cyclic inputs (as AFCS and FCS systems) shall be reviewed carefully.

5.4.3 Pump ripple. The maximum stresses induced into lines and components as a result of any pressure ripple-producing component in the system shall be measured. The procedure shall cover all pump speed ranges and multiple pump operation including start and stop to ensure that no detrimental pressure pulsation exists in the hydraulic system. Resonant conditions shall be tested for sufficient periods at each resonant frequency to ensure that the system has adequate fatigue life. MIL-STD-810 shall be used for vibration requirements.

5.4.4 System temperatures. A system temperature ground test shall be performed to compare the actual operational temperatures with the analytically predicted temperatures.

5.4.5 Post test inspection. A post flight inspection is required after each formal test. Data shall be recorded noting the conditions of the hydraulic system. The following data shall be taken as minimum immediately after shut down and compared with initial or predicted values.

a. System temperatures (continue monitoring after engine shut down and record maximum temperature).

b. Reservoir level.

c. Filter button position.

d. Accumulator gas charge.

e. Brake system condition.

f. Position of all actuators.

g. Leakage noted.

h. Filter bowl contents.

i. Contamination level of fluid.

j. Pressure and temperature in air bottles.

k. List of anomalies that occurred and disposition.

5.5 Aircraft flight tests. These tests shall be conducted in accordance with the applicable specifications (see 2.2.1) and the requirements of 4.8. Also the tests shall be conducted with the following aircraft systems configuration and test instrumentation.

a. Aircraft systems configuration - The hydraulic system shall be adequately bled of entrapped air, and the system and reservoir(s) filled to their specified level with applicable hydraulic fluid. All accumulators shall be properly serviced and the entire system, components, and attached linkages and mechanisms properly adjusted. Pneumatic systems shall be properly lubricated, with all system components and attached linkages and mechanisms properly adjusted.

b. Aircraft instrumentation - The aircraft shall be instrumented to measure and record (manually or automatically) as applicable all necessary pressures (operation peak or surge) as applicable, ambient air and system temperatures, time of operation, and other data required on any individual system. The system(s) shall be properly serviced for adjustments, normal fluid level, bleeding of air. All necessary special components, by-pass circuit as required, shall be installed and checked for proper and safe function. Those areas of the aircraft, which are, suspect, as high vibration areas shall be monitored to automatically record "g" forces and vibration levels.

5.5.1 Pre-flight check. With engine power on and prior to taxi, all applicable services except landing gear shall be operated through a complete cycle to ensure proper operation. As a result of this check, the capability of the aircraft to continue the flight tests with full performance shall be determined.

5.5.2 Taxi test. The aircraft shall be taxied to a speed equal to the landing speed, if safe, and provided conditions allow. Both normal and emergency brake systems applied. The brakes shall function satisfactorily under each system. The steering system, if provided, and any other services intended for use during taxiing or landing and take-off ground conditions shall also be operated in their normal and emergency manner. These services shall function satisfactorily under each applicable system.

5.5.3 Functional flight test. During flight, each of the services, as applicable and as specified below, shall be operated with the normal hydraulic system three times at each of the following altitudes. The aircraft shall fly at a conservative speed, not approaching maximum speed.

a. Minimum safe altitude.

b. Operational ceiling as defined in aircraft detail specifications, or that intermediate altitude, which presents more severe conditions. For this functional flight test, operation of the services shall be made at the end of a simulated operational mission wherever possible. In any event, the aircraft shall be flown until system temperatures have stabilized prior to testing.

5.5.3.1 Pressure survey. During the tests, operating, peak, or surge pressures shall be measured. The type of gages used shall be noted and all the services and power system(s) function within their design pressure limitations. Consideration shall be given, during the tests, to check the hydraulic reservoir supercharging pressure, if applicable, variation of pressurization with flight and altitude conditions, hydraulic pump(s) inlet, outlet, and drain, or by-pass pressures. In emergency pneumatic systems the pressure of the stored gas shall be measured.

5.5.3.2 Temperature survey. Highest and lowest stabilized operating temperatures at all critical points and anticipated hottest and coldest points in the systems shall be determined and identified with the corresponding data, such as compartment air temperature, outside air temperature, and aircraft speed. In a hydraulic system, the reservoir inlet and outlet temperatures, pump inlet and bypass fluid temperatures, and heat exchanger inlet and outlet temperatures are considered critical due to high or restricted flow, low heat transfer conditions, proximity to sources of heat producing equipment. In an emergency pneumatic system, the pressure and temperature of the stored gas shall be measured. It shall be demonstrated that the temperatures shall not exceed those to which the components of the system are designed, with consideration given to the percentage of operating time expected to be encountered at the various temperatures and conditions. The temperatures recorded shall be converted to the standard 100 ^{o}F hot day and listed in the chart shown in table III.

5.5.3.3 Time of operation. The time of operation of all services shall be determined, in each case, under a flight condition which duplicates as near as practical the average expected design conditions. The following specific operations shall be checked for time of operation as follows:
a. Landing gear retraction - The landing gear retraction under the flow conditions, representing take-off rpm of engine(s) and flight attitude, at design take-off indicated air speed (IAS), and near ground level. The temperature of the entire landing gear system shall be warmer than -20 ^{o}F at the time of this test. This can be accomplished if necessary by cycling the gear in flight to warm it

up. Actual ambient air and applicable hydraulic system temperature shall be determined. The sequence of operation of the various landing gear elements: main gear, nose gear, tail wheel shall be noted. Time shall start when the landing gear control lever is actuated and stop when the landing gear is up and locked, and all fairing doors closed.

b. Landing gear extension - The landing gear extension with normal system shall be under normal approach engine rpm, and at placard IAS. System temperature and sequence of operation of landing gear elements shall be recorded. Time shall start when gear control is actuated and stops when all gears are down and locked.

5.5.3.4 Symmetrical lift and drag devices. The hydraulically or pneumatically operated devices, which consist of two or more control surfaces or panels designed to operate together, shall be tested for synchronous operation in flight. The device shall be operated while the aircraft is in a side step or other manner, which will induce maximum safe unsymmetrical loading on the separate panels or surfaces. Any unsynchronized operation of any device shall be measured.

5.5.3.5 Surface control boost or power systems. The surface control boost or power systems shall be operated under all possible extremes of flight attitude, speed, and altitude to ensure safe, smooth operation under normal power. Bypass valves, system shut-off valves and devices, or automatic devices to revert operation from normal system to emergency system shall be operated in flight and with simulated normal system failure. The operation of such devices and to prove that the aircraft is controllable during and after the change in system power shall be in compliance with MIL-F-8785.

5.5.3.6 Fluid level. For the gas-fluid in contact type reservoirs the pump suction line opening shall be checked for any possibility that the opening had been uncovered and air introduced into the system. For the gas-fluid separation type reservoirs, minimum pump inlet pressures shall be measured. This test shall be conducted with the lowest permissible fluid level in the reservoir. To simulate this condition; first, the fluid shall be drained to lowest permissible level, then the air shall be removed from the accumulators as specified in 5.4.1.2 or from as many as safe flight conditions shall permit up to half the applicable accumulators.

5.5.3.7 Possible malfunctions. The operation of all control valves shall be checked for possible malfunctions. Such as each control unit shall be operated through the incomplete half cycle, followed by a complete reversal of direction. This operation shall be accomplished through both directions of operation.

5.5.3.8 Hand or auxiliary pump operation. Hand or auxiliary pumps shall be used to operate all the designated services at applicable conditions. If necessary, power pumps shall be bypassed for this test. A directional control valve shall be employed to bypass the pump output to the reservoir.

TABLE III. Ground and flight test hydraulic system maximum temperatures.

LOCATION	GROUND OPERATION OAT °F				FLIGHT OPERATION								ENGINE SHUTDOWN OAT °F			
	TEMP °F				TEMP °F			Pump RPM	Mach No	Total time (min) 3/	Alt	OAT °F	SOAK TEMP °F			Total Time (min) 3/
	Comp Struct	Comp Air	Fluid 1/ 2/	Total time (min) 3/	Comp Struct	Comp Air	Fluid 1/ 2/						Comp Struct	Comp Air	Fluid 1/ 2/	
Reservoir																
Pump pressure line																
Accumulator																

1/ RECORDED
2/ CONVERTED TO 100 °F STANDARD HOT DAY
3/ TOTAL TIME AT MAXIMUM TEMPERATURE IN MINUTE

Note: Method used by contractor to determine the valves obtained under the 100 °F standard hot day temperatures and state method used.

5.5.3.9 Emergency system operation. There shall be at least one operation of all applicable services by all emergency systems. All pneumatically operated services shall be checked as to the number of consecutive full cycles of operation possible before the air bottle(s) are discharged to a pressure below which operation is impossible. This shall be accomplished at both altitudes (see 5.5.3) and any other applicable conditions. For services actuated by multiple systems in simultaneous operation, each system shall be tested with the other system(s) failed (simulated). Services operated by multiple systems shall be operated to the lowest level of design redundancy.

5.5.3.10 Self-contained hydraulic systems. Applicable features of the tests specified herein shall be employed for the testing of gun drive, radar drives powered by wire servo actuating packages, and any other such type external store system.

5.5.3.11 Zero or negative "g" performance. The satisfactory performance of all applicable systems shall be demonstrated at "g" levels within the design envelope of the aircraft unless analysis proved that performance at these levels is not critical.

5.5.4 Failure modes. Failure modes shall be simulated in flight to evaluate the hydraulic system's capability to cope with specified failures.

5.5.5 Vibration survey. During the operation of hydraulic and pneumatic systems, instrument data shall be collected on selected line and component installations to ascertain the levels of acceleration forces induced in the hydraulic system by the different modes of operation. Particular attention shall be paid to high-speed components and those systems having high inertia loads. In addition, high frequency cyclic inputs (as AFCS and FCS systems) shall be reviewed carefully.

5.5.6 Post flight inspection. A post flight inspection is required after each flight test. Data shall be recorded noting the conditions of the hydraulic system. The following minimum data shall be taken after shut down and compared with initial or predicted values:

a. System temperatures.

b. Reservoir level.

c. Filter button condition or position.

d. Accumulator gas charge.

e. Brake system condition.

f. Position of all actuators.

g. Leakage noted.

h. Filter bowl contents.

i. Contamination level of fluid.

j. Pressure and temperature in air bottles.

k. List of anomalies that occurred and disposition.

5.5.7 Flight capability. The hydraulic system's satisfactory operations shall be demonstrated for flight conditions critical to the hydraulic system. The conditions listed below shall be considered.

a. Taxi.

b. Take off.

c. Climb.

d. Cruise.

e. Service ceiling.

f. Maximum speed.

g. Inverted maneuvers, if applicable.

h. Idle descent.

i. Turbulent.

j. Landing.

k. Hover, if applicable.

l. Cargo handling, equipment operation.

m. Auto rotation.

n. Gun fire (if applicable).

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. This standard is for use in determining methods for testing aircraft hydraulic and emergency pneumatic systems.

6.2 Application. The hydraulic or emergency pneumatic system tests required by this standard are to be conducted as an installed system. When the hydraulic or pneumatic systems, or subsystems thus tested are changed before installation in production aircraft for service such that it is required to retest in the opinion of the contractor and the acquiring activity, such tests should be re-performed.

6.3 Issue of DoDISS. When this standard is used in the acquisition, the applicable issue of the DoDISS must be cited in the solicitation (see 2.2).

6.4 Guidelines for preparation of test procedures.

6.4.1 Preparation. A detailed test procedure, applicable to the particular aircraft, should be prepared by the contractor to cover all ground and flight tests required by this standard. Test procedures should include type of test equipment use or function, and any limitations of test equipment used and all special procedures or modifications necessary in the system to perform the required tests. Hydraulic and pneumatic systems in the present aircraft are often too complicated and diversified in function to allow the use of a standard test procedure for every design. Each contractor can evolve a specific test procedure for his individual aircraft's hydraulic and pneumatic system.

6.4.1.1 Non-standard test procedures. Where methods or tests other than those specified in this standard are used, they should be briefly described and submitted to the acquiring activity for review.

6.4.1.2 Review. The contractor's detailed test procedure should be submitted to the acquiring activity for review to ensure consistent with the requirements of this standard.

6.4.1.3 Guidelines for preparation of test report. The test report should be consistent with the data submittal requirements; a final report should be submitted giving full details of the equipment tested and the results obtained. The report should be in paragraph form and should follow, as clearly as practicable, the logical sequence and the headings and sub-headings of the tests outlined herein, and in the contractor's test procedure as approved by the acquiring activity. Temperature data specified in table III should be included in the above report. Where required, tests are not performed as scheduled, substantiating data should be submitted as a part of the report (6.4).

6.5 Superseding document. This standard supersedes MIL-T-5522D.

6.6 Subject term (key word) listing.

Air system test
Engine test
Flight capability
Fluid system test
Functional inspection
Ground cart test
Methodology
Mission profile
Operational inspection
Simulator test

6.7 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to extent of the changes.

CONCLUDING MATERIAL

Custodians:
Army - AV
Navy - AS
Air Force - 99

Preparing activity:
Navy - AS

(Project 1650-0634)

Review activities:
Air Force - 11, 71, 82
Army - MI
Navy - MC, CG
DLA - GS

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STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.

2. The submitter of this form must complete blocks 4, 5, 6, and 7, and send to preparing activity.

3. The preparing activity must provide a reply within 30 days from receipt of the form.

NOTE: This form may not be used to request copies of documents, nor to request waivers, or clarification of requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document(s) or to amend contractual requirements.

I RECOMMEND A CHANGE:	**1. DOCUMENT NUMBER** MIL-STD-5522	**2. DOCUMENT DATE** (*YYYYMMDD*) 20000317

3. DOCUMENT TITLE
TEST REQUIREMENTS AND METHODS FOR AIRCRAFT HYDRAULIC AND EMERGENCY PNEUMATIC SYSTEMS

4. NATURE OF CHANGE (*Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.*)

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME (*Last, First, Middle Initial*)	b. ORGANIZATION	
c. ADDRESS (*Include ZIP Code*)	d. TELEPHONE (*Include Area Code*) (1) Commercial (2) DSN (*If applicable*)	**7. DATE SUBMITTED** (*YYYYMMDD*)

8. PREPARING ACTIVITY

a. NAME COMMANDER NAVAL AIR WARFARE CENTER AIRCRAFT DIVISION	b. TELEPHONE (*Include Area Code*) (1) Commercial (732) 323-2947 (2) DSN 624-2947
c. ADDRESS (*Include ZIP Code*) CODE 414100B120-3 HIGHWAY 547 LAKEHURST, NJ 08733-5100	**IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT:** Defense Standardization Program Office (DLSC-LM) 8725 John J. Kingman Road, Suite 2533 Fort Belvoir, Virginia 22060-6221 Telephone (703) 767-6888 DSN 427-6888