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GUIDE FOR QUALIFICATION TESTING OF AIRCRAFT AIR VALVES

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1. SCOPE:

This Aerospace Recommended Practice (ARP) defines tests to be performed on hydraulically, electrically, pneumatically, and mechanically actuated air valves. They may be further defined as those valves that function in response to externally applied forces or in response to variations in upstream and/or downstream duct air conditions in order to maintain a calibrated duct air condition (e.g., air flow, air pressure, air temperature, air pressure ratio, or air shutoff).

2. PURPOSE:

The purpose of this ARP is to provide the aircraft industry with a guide for laboratory qualification testing of aircraft air valves.

3. CATEGORIES AND DEFINITIONS:

The valves as referenced in this ARP are used to modulate or shut off the flow of air in aircraft pneumatic systems.

3.1 Categories:

For the purpose of this ARP the valves will be grouped into four categories: 1) pneumatically actuated valves, 2) electrically actuated valves, and 3) mechanically actuated valves, and 4) hydraulically actuated valves.

3.1.1 Pneumatically Actuated Valves: Pneumatically actuated valves are those valves that utilize gas as the primary power source to position the valve. This includes valves that are solenoid controlled, but pneumatically actuated.

3.1.2 Electrically Actuated Valves: Electrically actuated valves are those valves that rely only on electrical power to position the valve.

3.1.3 Manually Actuated Valves: Manually actuated valves are those valves that are operated by hand motion applying a force through a mechanical lever or cable system.

3.1.4 Hydraulically Actuated Valves: Hydraulically actuated valves are those valves that utilize an incompressible fluid such as hydraulic oil or fuel for operation. This includes valves that are solenoid controlled, but hydraulically actuated.

3.2 Definitions:

3.2.1 ON-OFF VALVE: An on-off valve controls the flow of air by opening or closing the flow passage. It is used in such a manner that it is not stopped in intermediate positions.

3.2.2 VARIABLE POSITION VALVE: A variable position valve controls flow by selective throttling of the flow passage. Intermediate areas may be infinitely or incrementally selectable.

3.2.3 RELIEF VALVE: A relief valve is a modulating valve that limits supplied pressure by dumping from a system or compartment to a lower pressure region.

3.3.4 CHECK VALVE: A valve that allows flow in a single direction only.

3.2.5 TEST ARTICLE: A test article is a complete functioning valve of the type to be qualified. It is normally a production article, but may (upon agreement between manufacturer and customer) be an equivalent prototype unit.

3.2.6 FLAME TESTS: The flame test requirement imposed on an aircraft valve depends on whether the valve must be fire proof or fire resistant.

Fire-proof valves are usually mounted on the engine side of a firewall or form part of the firewall. Fuel-actuated valves also fall within this category.

Flame-resistant valves are valves mounted in similar regions where fires could occur, but the environment is not as severe.

3.2.7 DESTRUCTIVE TESTS: Destructive tests are those tests that may damage the valves' function or use for further testing. Typical destructive tests are burst pressure, fire-resistance, and fire-proof tests. Following a destructive test the valve does not have to be operational, nor is it expected to be tested to, or meet the requirements of Section 9.

4. APPLICABLE DOCUMENTS:

The following documents are frequently used specifications for deriving environmental test methods and levels. The applicable issue of each should be specified in the customer's detail specification.

MIL-STD-810	Military Standard, Environmental Test Methods and Engineering Guidelines
MIL-STD-202	Test Methods for Electronic and Electrical Component Parts
MIL-L-23699	Lubricating Oil, Aircraft Turbine Engines, Synthetic Base
MIL-STD-45662	Calibration, Systems Requirements
MIL-STD-461	Electromagnetic Emission and Susceptibility, Requirements for the Control of Electromagnetic Interference
MIL-STD-462	Electromagnetic Interference Characteristics, Measurement of
RTCA/DO-160	Environmental Conditions and Test Procedures for Airborne Equipment

5. TEST DOCUMENTATION:

A test procedure and a test report should be furnished to the customer. The customer should approve the test program as presented in the test procedure and all changes thereto, prior to the start of testing. The test procedure should stipulate if customer and/or government witnessing is required.

5.1 The test procedure should describe how to conduct all the tests required by the test program. The location of the test facility, test equipment, temperature stabilization, test sequence, ambient conditions, test input tolerances, and failure criteria should also be defined.

5.2 The test report should reference the applicable test procedure and include the results obtained from each test performed on the valve. Photographs of test setups should be provided if available. The test report should further describe all aberrations, and the action taken to correct any defects that are found during qualification.

5.3 The test report should contain a complete identification and configuration definition of the test article including the manufacturer's part number, serial number, and part name. Complete pretest and posttest disassembly inspection records and photographs, if possible, should be included in the report. If more than one test article is involved, the data should be recorded and referenced to the specific test or tests performed on each individual test article. All test conditions are to be recorded.

5.4 The procedure and report should contain a description of the test setup, including a schematic with all important test setup dimensions and instrumentation locations noted. It is recommended that sketches and photographs be used wherever possible. The type, model, manufacturer, and names of all principal items of test and control equipment should be included. A statement as to methods adhered to for ensuring general test equipment accuracy should be made.

5.5 The test report should clearly state whether or not the test requirements have been met and where failure, if any, has occurred. It should reference the paragraph requirements of the detail specification to facilitate comparison of results with the requirements.

5.6 The test data should be certified by an official or other responsible member of the quality assurance department and government witnesses if required.

5.7 All test reports submitted by a testing organization other than the manufacturer should have the same requirements as the test report prepared by the manufacturer and should become a part of the final test report.

5.8 Reports or excerpts of reports of those tests that demonstrate compliance of a similar test article with any of the requirements of the detail specification may be submitted to substantiate compliance of the new equipment on the basis of similarity. This similarity data should be incorported in the test procedure and reported with substantiation of the similarity of the two items. (See Section 12.)

5.9 Analytical data or certification that justifies the qualification by analysis should be incorporated in the test documentation. (See Sections 13 and 14).

6. TEST FACILITIES:

The facilities used to perform the qualification tests shall be capable of meeting all of the conditions of the detail specification.

6.1 The accuracy of the test instrumentation should be defined in the test procedure and recalibrated periodically in accordance with quality assurance standards or MIL-STD-45662. The accuracy shall be as good as or better than that specified by the customer. The instrumentation should also conform to laboratory standards whose calibration is traceable to the U.S. Bureau of Standards. All test limits are to be adjusted to allow for instrument tolerance.

6.2 The facilities should simulate the system impedance and valve mountings in which the test article is to operate with sufficient accuracy to ensure that the test article will operate under the conditions specified in the detail specification.

6.3 Unless otherwise stated in the detail specification, the allowable tolerances on control of the test parameters should be as follows:

Fluid Temperature:	<15°C ± 5.5 (59°F ± 10) >15°C<121°C ± 8 (>59°F<250°F ± 15) >121°C<260°C ± 14 (>250°F<500°F ± 25) >260°C<650°C ± 28 (>500°F<1200°F ± 50)
Controlled Ambient Temperature	±2.0°C (±4°F)
Altitude	±5% of the absolute barometric pressure
Pressures	±5% absolute value
Flow	±3%
Humidity	±5% absolute value
Acceleration	±10%
Vibration Amplitude	±10% sinusoidal, random see MIL-STD-810 method 514 or RTCA/DO-160 Sec 8.
Vibration Frequency	±2%
Voltage	±2%

7. DEFINITION OF COMPLIANCE:

Satisfactory compliance with the requirements of the customer approved test procedure is established when the designated number of test articles have been subjected to the tests outlined therein, and upon completion of other than destructive tests, have passed the performance record test outlined in Section 9.

7.1 Test Failures:

If a failure during the qualification testing is experienced, further testing and a failure report describing all aberrations, and the corrective action taken by the supplier, should be delivered to and approved by the customer.

8. SEQUENCE OF TESTS:

One or more production or equivalent prototype units should be employed for the qualification test program. The actual number of units employed is at least equal to the number of destructive tests. When three test articles are used, they should be subjected to the following tests, as applicable, approximately as shown:

Test Article No. 1	Test Article No. 2	Test Article No. 3
Examination of product	Examination of product	Examination of product
Performance-record (initial)[1]	Proof pressure	Performance-Record (initial)[1]
Low flow correlation	Performance-record (initial)[1]	Low flow correlation
High and low temperature	Low flow correlation	EMI
Thermal Shock	Fungus resistance	Contaminated fluids
Freezing condensate	Salt fog	Pressure drop
Fluid resistance	Humidity	Vibration
	Dielectric strength	Mechanical shock

[1]Room temperature performance record checks shall be conducted following each of the tests listed. The initial performance record test is done at temperature on at least one of the test articles (see Section 9). Any destructive test does not require a performance record test. The ultimate apportionment and sequence of conducting the tests will be mutually agreed upon between the manufacturer and customer.

8. (Continued):

Test Article No. 1	Test Article No. 2	Test Article No. 3
Altitude		
	Insulation Resistance	Sand and dust
Endurance		
		Disassembly and inspection/reassembly
Disassembly and inspection/reassembly	Disassembly and inspection/reassembly	
		Burst pressure
Explosive atmosphere	Flame test	

If two test articles are selected, the apportionment of tests should be approximately as follows:

TEST ARTICLE NUMBER 1	TEST ARTICLE NUMBER 2
Examination of product	Examination of product
Proof pressure	Performance record (initial)[1]
Performance record (initial)[1]	Low flow correlation
Low flow correlation	EMI
Freezing condensate	Humidity
Fluid resistance	Pressure drop
High and low temperature	Sand and dust
Thermal shock	Fungus resistance
Altitude	Salt fog
Vibration	Dielectric strength
Mechanical shock	Insulation resistance
Disassembly and inspection/ reassembly	Endurance
Explosive atmosphere	Disassembly and inspection/ reassembly
Burst pressure	Flame test

[1]Room temperature performance record checks shall be conducted following each of the tests listed. The initial performance record test is done at temperature on at least one of the test articles (see Section 9). Any destructive test does not require a performance record test. The ultimate apportionment and sequence of conducting the tests will be mutually agreed upon between the manufacturer and customer.

9. PERFORMANCE RECORD TEST:

The initial performance record test should be conducted at ambient pressure and temperature with inlet pressure and temperature at aircraft operating conditions that are judged most severe for valve functional performance. This test should be followed by a test at room ambient conditions with the minimum inlet pressure required to evaluate valve performance. All other performance record checks, conducted following each test, may be conducted at room ambient pressure and temperature with inlet conditions at laboratory air supply temperature and at the minimum required check out pressure. Generally, a performance record test consists of the following:

a. Leakage (internal and external)
b. Minimum opening signal (pressure and/or voltage)
c. Opening and closing time
d. Valve function and checkout of design features
e. Transient performance

10. LOW FLOW CORRELATION:

As an aid to the user it is recommended that low flow testing requirements in lieu of full flow testing for acceptance be established in the buyer's technical specification. This can be implemented by making verification of a low flow correlation test a part of the end item qualification test program. The end item user of the equipment will benefit as follows:

a. Facility costs will be much less
b. Those operators who have limited facilities will be able to test valves
c. Turnaround time problems can be reduced
d. Spare valves required to assure that no aircraft-on-ground situations arise will be greatly reduced

10.1 The low flow test procedure should be established with the objective of verifying the valve performance using the minimum resources of test equipment, pressure, temperature, and air flow. Wherever possible, the test should be conducted, at room temperature, and with air pressure less than 690 kPa gage (100 psig). In some cases the test could be conducted without airflow. Where air flow is necessary, the aim should be to keep it below 4.5 kg/min (10 lb/min).

10.2 Low flow correlation procedures should be considered certified when all qualification valves that have been calibrated by these procedures pass the functional requirements of the manufacturer's full flow acceptance test procedure.

10.3 Failure to achieve 100% correlation between low flow and full flow testing defined in 10.2 should not be cause for the valve to fail qualification. Some valves are not suitable for low flow testing. For valves with a safety function, correlation will have to be 100% prior to instigating low flow testing. Where conformity to a specification is an economic matter, correlation of less than 100% may be acceptable and will provide the operator with a basis for evaluating low flow versus full flow testing.

11. TESTS AND METHODS:

The detail specification should define which of the following tests should be conducted for qualification.

11.1 Examination of Product and Disassembly and Inspection:

The test article(s) should be weighed and subjected to an end item dimensional inspection during the examination of product test. Prior to initial assembly, engineering should identify detail part critical and major dimensions. These dimensions shall be certified prior to and following qualification testing.

11.2 High and Low Temperature Tests:

The test article should be subjected to the high and low temperature tests, of MIL-STD-810, methods 501 procedure II, and 502, respectively, or RTCA/DO-160 Ch 4.

11.3 Freezing Condensate:

The test article should be installed in the test chamber in a manner that will simulate the aircraft installation. The chamber temperature should be held at 32°C (90°F) and the specific humidity of the chamber air held constant at 22 g/kg (154 gr/lb) dry air. This condition should be held for 3 h. During this 3-h period, the valve should be actuated 10 times while air flow is maintained through the valve as follows:

Temperature: 32°C (90°F)
Specific Humidity: 22 g/kg (154 gr/lb) dry air
Air Flow: As specified in detail specification

At the completion of the 3-h period, valve and chamber air flow should be terminated and the chamber temperature should then be lowered to 15°C (59°F) over a 3-h period. The valve should be held for 1 h at 15°C (59°F), and then the chamber temperature raised to 32°C (90°F) within 30 min. This constitutes one cycle. A minimum of ten cycles should be performed for a total time of 60 h. During the eleventh cycle, rather than lower the chamber temperature to 15°C (59°F) over a 3-h period, the temperature should be lowered linearly to -18°C (0°F) over an 8-h period. The valve shall be inoperative and held 1 h at -18°C (0°F). At the completion of the 1-h hold period, the valve should be operated and performance compared with initial performance data.

After the performance tests at -18°C (0°F), the chamber should be lowered to -54°C (-65°F) within a time period of 2 h and held at that temperature for 2 h. A performance test should be made at the completion of this 2-h period while at -54°C (-65°F).

11.4 Salt Fog Test:

The test article should be subjected to the salt fog test defined in MIL-STD-810, or RTCA/DO-160 Ch 14. During this test, all external interface connection ports and electrical connectors may be capped in a manner representative of intended use.

11.5 Humidity Test:

The test article should be installed in a humidity chamber capable of maintaining a relative humidity of 95% and in an attitude simulating that of the aircraft installation. During the exposure period, the ports of the test article should be sealed.

The test unit should be exposed to humidity for a period of 10 days in accordance with procedure I, method 507 of MIL-STD-810, or RTCA/DO-160 Ch 6.

11.6 Vibration Test:

The test article should be subjected to the vibration tests defined in MIL-STD-810, or RTCA/DO-160. During testing, the test article should be pressurized to a nominal pressure condition. Generally, air flow through the test unit will be limited to leakage flow rates, and ambient and inlet temperatures are at room conditions because of facility limitations.

11.7 Fungus Resistance Test:

The fungus resistance test should be conducted only on those test articles employing materials or finishes that may be considered to be fungus nutrients. The test article should be subjected to the fungus test described in MIL-STD-810, or RTCA/DO-160 Ch 13.

11.8 Explosive Atmosphere Test:

The test article should be subjected to the explosive atmosphere test defined in MIL-STD-810 procedure I or RTCA/DO-160 Ch 9. This test pertains to valves that contain an ignition spark source such as an electrical switch or a heat source such as a solenoid whose case temperature can exceed the combustion temperature of the explosive atmosphere.

11.9 Endurance Test:

The test article should be installed in a test setup capable of simulating the aircraft installation and thermal inlet/ambient conditions.

The test article should be subjected to the total number of full cycles expected during its lifetime. One full cycle of operation shall consist of actuation of the valve from full closed to full open or full pressure regulation and the reverse. The three endurance test phases below are a sample recommendation for a pneumatically actuated, turbine engine bleed air valve.

11.9.1 Phase I - The test article should be subjected to 30% of the full cycles as described in 11.9 while under the following nominal conditions:

Inlet air pressure and temperature	Most detrimental single condition
Airflow and ambient temperature	Maximum for above inlet condition
Ambient pressure	Ground level

11.9.2 Phase II - The test article should be subjected to 30% of the full cycles as described in 11.9 while under the following conditions:

Inlet air pressure and temperature	Most detrimental single condition
Airflow rate	50% of flow specified in 11.9.1
Ambient pressure	Ground level

11.9.3 Phase III - The test article should be subjected to 40% of the full cycles as described in 11.9 while under the following conditions:

Inlet air pressure and temperature	Most detrimental single condition
Airflow rate	50% of flow specified in 11.9.1
Ambient temperature	27°C ± 22 (80°F ± 40°F)
Ambient pressure	Ground level

NOTE: During all testing under 11.9, valve electrical position indicators (internal) should be electrically loaded to simulate the aircraft installation. If an altitude compensating device is incorporated in the valve design, altitude testing should also be included in the valve performance test at the end of each phase.

11.10 Proof Pressure:

With the test article in the open position, the test article should be subjected to air flow at the temperature condition specified in 11.9.1 until the test article temperature is stabilized. Ambient air should be at room temperature and pressure unless otherwise covered by the detail specification. Many valve designs feature a control supply port separate from the inlet port. The requirements of this section apply independently to all supply, service, control, and inlet ports of the valve. The test article should then be closed and shall resist without permanent deformation, the application of the appropriate proof pressure level to the inlet and supply port(s) equal to the greater of the following:

a. 1.5 times the gage pressure with the component at the associated temperature for the most adverse pressure and temperature condition that occurs during normal operation.

b. 1.1 times the gage pressure with the component at the associated temperature for the most adverse pressure and temperature condition that occurs in the event of failure of an upstream pressure or temperature control device.

11.10 (Continued):

Note that these factors may be increased to allow for installation variables and additional requirements may be required to deal with thermal deflections. Also note that different values for these factors are defined in military specifications and in European Regulation JAR part 25 paragraph 25.1438.

11.10.1 If a closed valve in a system installation will always have downstream pressure on it, the downstream end of the valve may be pressurized to a level such that the differential pressure across the closed valve is 1.5 times the maximum possible differential pressure.

11.10.2 Repeat test described in 11.10 with valve open.

11.10.3 All proof pressure should be held on the test article for a minimum of 2 min.

11.10.4 Proof pressure at the most severe pressure-temperature combination need only be verified on a single qualification test article. When more than one test article is employed during a qualification test program, the proof pressure test in the production acceptance test procedure is used for the additional test article(s). Normally production acceptance test pressures are conducted at lab compressor inlet temperatures. The proof pressures are higher than the qualification test pressure level to adjust for the reduction in inlet temperature. This higher customer approved proof pressure level is determined by material yield strength data such that equivalent damage potential is presented to the test article.

11.10.5 Following completion of the test, the valve should be visually examined. There should be no evidence of deformation or damage.

11.11 Burst Pressure:

With the test article in the open position, the test article should be subjected to air flow at the temperature condition specified in 11.9.1, until the test article temperature is stabilized. Ambient air should be at room temperature and pressure, unless otherwise specified by the detail specification. Many valve designs feature a control supply port separate from the inlet port. The requirements of this section apply independently to all supply, service, control, and inlet ports of the valve. The test article should then be closed and shall resist without rupture the application of the appropriate burst pressure level to the inlet and supply port(s) equal to the greater of the following:

a. 3.0 times the gage pressure with the component at the associated temperature for the most adverse pressure and temperature condition that occurs during normal operation.

b. 1.5 times the gage pressure with the component at the associated temperature for the most adverse pressure and temperature condition that occurs in the event of failure of an upstream pressure or temperature control device.

11.11 (Continued):

Note that these factors may be increased to allow for installation variables and additional requirements may be required to deal with thermal deflections. Also note that different values of the above factors are defined in military specifications and in European Regulation JAR part 25 paragraph 25.1438.

11.11.1 All burst pressures should be held on the test article for a minimum of 2 min.

11.11.2 Following completion of the test, the valve should be visually examined. There should be no evidence of external rupture although deformation is allowed.

11.12 Dielectric Test:

Equipment designed to operate on 28 V DC should be subjected to a test voltage of 1050 V (rms) at commercial frequency of approximately 60 Hz for 1 min applied between connector pins or terminals and the actuator frame. If a radio noise filter is integral with this unit, it may be disconnected before the test. If the electrical design is such that a short will result, individual components may be subjected to the test prior to assembly. The maximum allowable leakage current shall be as specified in the detail specification.

Equipment designed to operate on 400 Hz 115 V AC should be subjected to a test voltage of 1250 V (rms) at 60 Hz applied both between connector pins or terminals and frame and between each connector pin or terminal and frame. Each connection should be tested a minimum of 1 min. The maximum allowable leakage current shall be as specified in the detail specification.

11.12.1 Capacitors should withstand, for 1 s, a DC voltage of twice the maximum peak voltage in service or a minimum of 500 V, whichever is greater.

11.12.2 Retest Conditions: The conditions for retest are the same as specified in 11.12 except test voltage should be 75% of the voltage.

11.13 Insulation Resistance:

Connect an insulation resistance tester to the ungrounded electrical connector terminals, tied together electrically, and to the case of the electrical component of the valves. Apply a voltage of 500 V DC for a period of 2 min. The insulation resistance shall not be less than 100 MΩ.

11.14 Sand and Dust:

Sand and dust tests normally should not be required except when specified by the detail specification. Omission of this test does not relieve the supplier of the responsibility of furnishing equipment with resistance to the sand and dust conditions incident to the specified application for which it is required. If a sand and dust test is required, the test article should be subjected to the test in accordance with MIL-STD-810 or RTCA/DO-160 Ch 12. During this test all external interface connection ports can be capped.

11.14 (Continued):

At the conclusion of the test, the article should be operated and the test results compared with the results obtained in Section 9.

11.15 Altitude Test:

The test article should be placed within an altitude chamber and tested per method 504 of MIL-STD-810 or RTCA/DO-160 Ch 4. When the pressure and temperature conditions are stabilized, the equipment should be operated with airflow as specified in the customer detail specification for maximum altitude and the results compared with those obtained in Section 9. This test normally should not be required for shutoff valves.

11.16 Fluid Resistance:

The test article might be installed in fluid wetted areas that can cause finish stripping and/or have a plasticizing effect on many organic materials used in the test article. The purpose of this test is to evaluate the resistance of the test article to various chemicals that can wet the external surface of the test article.

The test article should be oriented as in the aircraft installation and sprayed with the wetting chemical that could occur on the external surface of the test article during use. The test article should be sprayed with the test chemical once a day or more often as necessary to retain a surface wetted condition for a period of 1 month. The spray should be a fine mist and be directed toward every major external surface, seal, connector, joint, and shaft of the article. The component should be energized and/or cycled for 10 min of each day.

At the end of the 1-month exposure period, and without removing the excess chemical, the article should be placed in a closed chamber and allowed to age for 7 days at 71°C + 5.5 (160°F ± 10). At the end of this time, the article should be cycled for 2 h and given a complete functional test. The component should meet the requirements of the detail specification for the article. At the conclusion of the functional test, the article should be disassembled and inspected for deterioration or damage. Paint, finish, seals, lubricants, or insulation should not be deteriorated by exposure to the test chemical as applied in the test.

11.17 Contaminated Fluids:

The contaminated fluids test is normally conducted only on engine mounted aircraft valves that may be subjected to contaminants ingested during or near ground operation.

The test should be conducted as specified in the customer specification. A typical test method would be conducted as follows: During Phase III of the Endurance Test (11.9.3) and for a duration representing 25% of the Phase III endurance cycles, inject the inlet air with contaminants as follows:

a. An oil concentration of 3.0×10^{-6} kg (lb) of MIL-L-23699 per kg (lb) of air