(R) Aerospace - Impulse Testing of Hydraulic Components

RATIONALE

ARP1383 has been updated to Revision C for the following reasons:

a. Technical changes have been made including adding a section on scatter factors and an appendix that is associated with this topic, and deleting the original Appendix A.

b. The references in the document have been updated.

c. Editorial changes have been made to improve the readability of the document.

TABLE OF CONTENTS

1. SCOPE

This SAE Aerospace Recommended Practice (ARP) defines impulse test procedures that are recommended for hydraulic components.

1.1 Scope and Field of Application

This ARP is applicable to actuators, valves, pressure containers, and other similar fluid system components.

ARP1383 is not applied to the following hydraulic elements, as these are covered as follows:

a. Military hydraulic pumps - refer to AS19692

b. Hydraulic motors - refer to AS7997

c. Hydraulic hose assemblies - refer to AS603

d. Tubing and fittings - refer to AS603 and AS4265

In addition, ARP1383 is not to be applied for elements that are not directly connected to the hydraulic system, such as brake master cylinders.

This ARP is intended to cover the fatigue testing of a component as a pressure vessel - it does not cover the testing of mechanical elements of hydraulic components including levers, actuator rods and end fittings, etc.

1.2 Requirements When Invoking This Recommended Practice

When this document is referenced in a design specification as part of the requirements, additional requirements as identified in 3.3 should be specified.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and 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.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

AS603	Impulse Testing of Hydraulic Hose, Tubing, and Fitting Assemblies
AIR1228	Standard Impulse Machine Equipment and Operation
AS4265	Impulse Testing of Hydraulic Tubing and Fittings, S-N Curve
AIR4298	Impulse Test Machine, Sine Wave, Equipment and Operation of

AS7997 Motors, Aircraft Hydraulic, Constant Displacement, General Specification For

AS19692 Pumps, Hydraulic, Variable Flow, General Specification For

2.1.2 U.S. Government Publications

Available from National Technical Information Service, 5301 Shawnee Road, Alexandria, VA 22312, Tel: 1-888-584-8332 or 703-605-6050, www.ntis.gov.

DOT/FAA/AR-MMPDS-01 Metallic Materials Properties Development and Standardization

2.2 Definitions

MINER'S RULE: This is the Palmgren-Miner cycle-ratio summation theory, also known as Miner's rule, which may be expressed as a method that is used to approximate the cumulative fatigue damage at a point in a metallic part from the repeated exposure to cycles of various stress levels. For given maximum and minimum stress levels, the fatigue life in terms of the number of cycles is found from an S-N curve. The damage fraction is the applied number of cycles divided by the fatigue life. The fractional damage amounts for each stress level are added together to calculate the total fatigue damage. Cumulative fatigue damage greater than or equal to 1 indicates that the part will fail.

RATE OF RISE: This is the slope of the pressure-time curve in the straight portion of the initial pressure increase portion between 10% of the total rise above return pressure and 10% of the total rise below peak pressure. (Note: The rate of rise is the steepest part of the slope and is dependent on volume of pressurized cavity.)

CYCLE: This is the time from minimum pressure to maximum pressure and back to minimum pressure.

DWELL TIME (TIME AT PRESSURE): This is the time for which the pressure exceeds the lower tolerance for P_{Max}.

S-N CURVE: This is a graph of the magnitude of a cyclic stress (*S*) against the logarithmic scale of cycles to failure (*N*), which characterizes materials performance with respect to high-cycle fatigue.

PRESSURE CAVITY: This is the part of the hydraulic component that is either directly connected to the high pressure side of the aircraft hydraulic system, or is downstream of a selector valve or servo valve.

RETURN CAVITY: This is the part of a hydraulic component that is directly connected to the low pressure side (return or reservoir) of the aircraft hydraulic system.

TEST LAYER: This is the process of conducting pressure impulse testing into sections which is the alternative to conducting a complete pressure impulse test on a component without stopping. The use of Test Layers permits the component to be inspected for fatigue induced damage and to replace seals, etc., before the commencement of the next test layer.

CENTER DAM: This is the gland assembly that separates the two hydraulic systems in a dual tandem actuator.

2.3 Abbreviations

n = cycles in one operational life

N = stress life cycle expectancy for each flight segment

P_{Min} = minimum return pressure experienced in normal operation

P_{Max} = maximum supply cavity test pressure

$P_{Mean} = (P_{Max} + P_{Min})/2$

P_{Oper} = nominal system design operating pressure

PR = nominal return line design pressure

PR_{Max} = maximum return cavity test pressure

3. REQUIREMENTS

The pressure-impulse test is basically an accelerated fatigue test. There are two categories of test:

a. Category I - Generically Derived Test Requirements

b. Category II - Specifically Derived Test Requirements

3.1 Category I - Generically Derived Test Requirements

This category is applicable to generic aerospace hydraulic equipment impulse testing, with recommended pressure levels and test cycle requirements being provided. The pressure and return cavities of the component should be tested, as a minimum, to the number of pressure impulse cycles defined below for the applicable aircraft classification.

3.1.1 Fixed Wing Aircraft

a. Flight control actuators/valves/components: 200 000 cycles, $P_{Max} = 1.5 \times P_{Oper}$

b. Utility actuators/valves/components: 100 000 cycles, $P_{Max} = 1.5 \times P_{Oper}$

c. Return ports/passages and components subjected to return pressure only: 100 000 cycles, $PR_{Max} = PR \times 1.5$, with PR taken as $0.5 \times P_{Oper}$

3.1.2 Rotary Wing Aircraft

a. Primary flight control actuators: 1 000 000 cycles, $P_{Max} = 1.5 \times P_{Oper}$

b. Secondary flight control actuators: 1 000 000 cycles, $P_{Max} = 1.5 \times P_{Oper}$

c. Utility actuators: 300 000 cycles, $P_{Max} = 1.5 \times P_{Oper}$

d. Flight control system hydraulic components: 1 000 000 cycles, $P_{Max} = 1.5 \times P_{Oper}$

e. Utility system hydraulic components: 300 000 cycles, $P_{Max} = 1.5 \times P_{Oper}$

f. Return ports/passages and components subjected to return pressure only: 300 000 cycles, $PR_{Max} = 1.5 \times PR$ with PR taken as $0.5 \times P_{Oper}$

3.2 Category II - Specifically Derived Test Requirements

Category II is applicable to all aircraft configurations (including helicopters), both military and commercial, where the test requirements are derived from specifically related system values. The number of test cycles are to produce equivalent fatigue damage, when the component is tested at the design operating pressure, using the selected waveform (see 4.1) to create the damage that the component is expected to receive during the lifetime of the applicable aircraft. The determination of the number of test cycles must consider both mean and alternating stresses for inservice, ground, and test operations of the aircraft during its expected life. The cycles at various stress levels are combined by Miner's Rule to determine the number of equivalent cycles at the design operating pressure.

Appendix A provides details of the method to be used to determine the test cycles by means of an example.

3.3 Test Conditions

Unless otherwise specified, the following general requirements are applicable to test categories I and II.

When this document is referenced in a design specification as part of the requirements, the following additional requirements must be specified:

a. Number of test cycles (for Category I testing, see 3.1; for Category II testing, see 3.2)

b. Test pressures for all cavities

c. Operating temperature(s) (see 4.4)

d. Fluid (see 4.5)

e. Waveform (see 4.1)

f. Component/valve position (see 6.3.1)

g. Minimum return line pressure and return line design pressure (for Category I testing, see 3.1; for Category II testing, see 3.2)

h. Number of actuator cycles extended and retracted and position, if applicable (see 6.3.2)

i. Cycling rate and tolerance (see 4.2)

j. Layering requirements (sequential test condition(s) groupings) (see 6.4.1)

k. Pressure transients/surges (pressure and return if known) (see 4.1)

l. When an S-N curve is to be developed and if less than six specimens are permitted (see Appendix B)

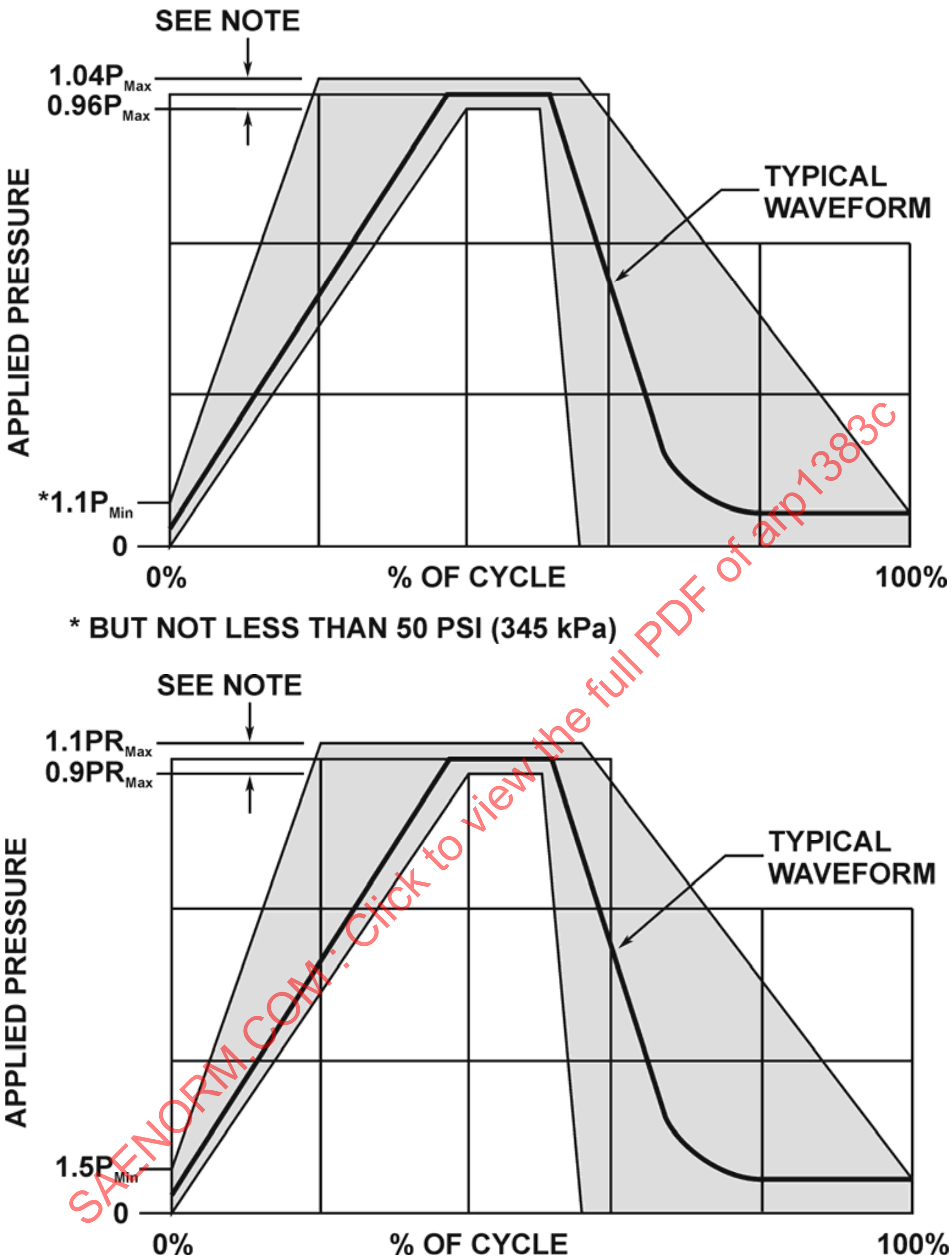
m. Any performance tests/inspections that must be satisfactorily completed following the completion of the impulse test (see 7.1)

4. GENERAL TEST REQUIREMENTS

4.1 Shape of the Impulse Cycle

The limits shown in Figures 1, 2, and 3 define the pressure-time cycle when observed on an oscilloscope or pressure trace and instrumented in accordance with AIR1228.

NOTE: If testing with elevated P_{Min} (for example, testing between 2000 - 6000 - 2000 psig (13.8 - 41.3 - 13.8 MPa)), then the tolerance on P_{Min} should be 1.1 P_{Min} to 0.9 P_{Min}.



NOTE: The applied pressure shall be within this pressure band for not less than 10% and not more than 37% of the cycle time

FIGURE 1 - SUPPLY CAVITY AND RETURN CAVITY WAVEFORM

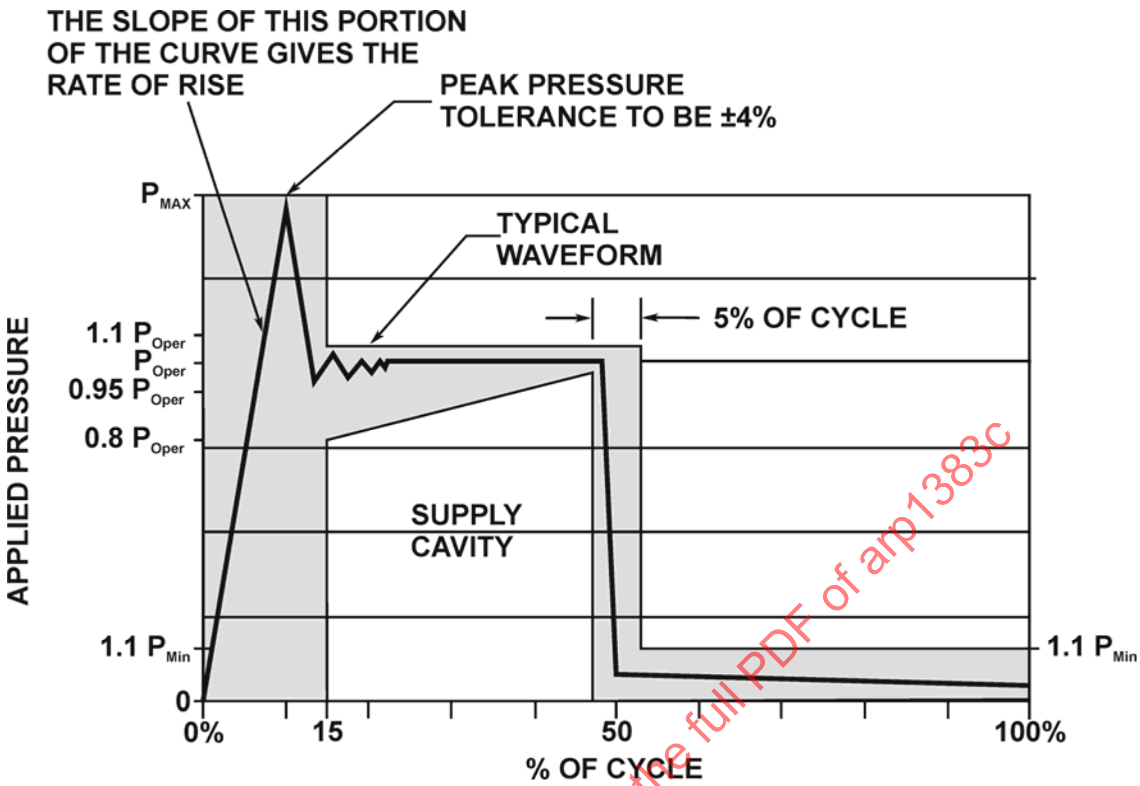


FIGURE 2 - ALTERNATE IMPULSE TRACE - DAMPED WAVEFORM

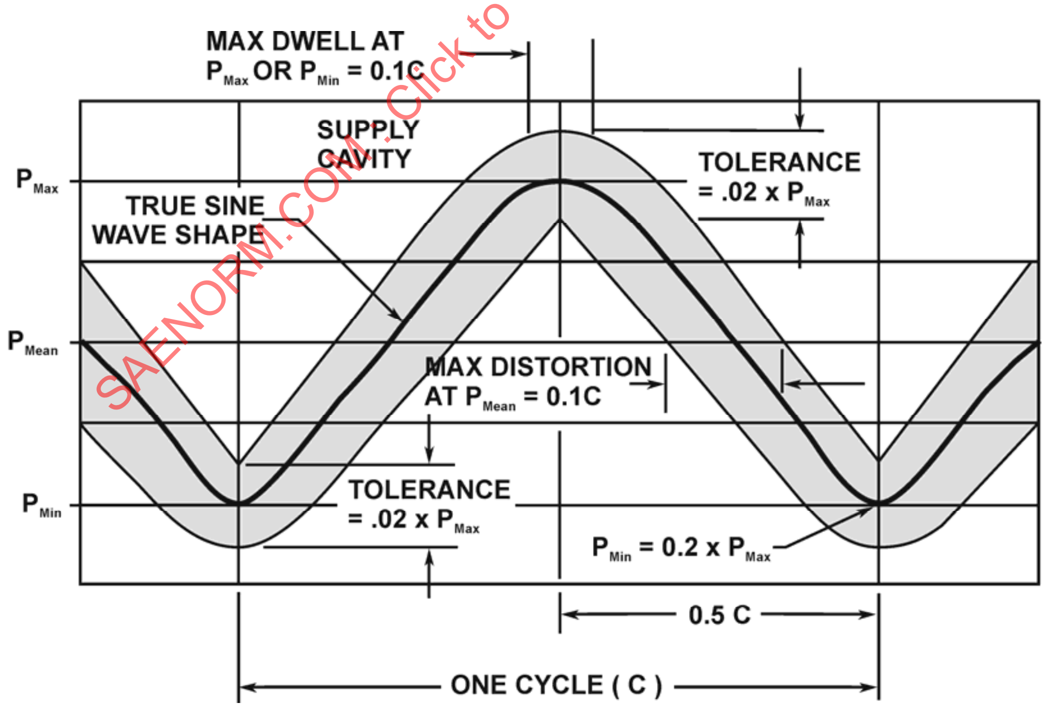


FIGURE 3 - ALTERNATE IMPULSE TRACE SINE WAVEFORM

The dynamic impulse trace, produced by the test machine, should be in conformance with these figures as applicable, and the actual pressure-time curve should be confined to the area shown. Any deviations from the agreed waveform at extreme test conditions shall be agreed between the Supplier and the Purchaser.

It should be noted that there might not be repeatable test results if impulse tests on a component are conducted with different waveforms. Therefore, it is important that the choice of which waveform should be agreed between the Supplier and the Purchaser prior to the commencement of the pressure impulse testing.

If there is a concern about the possible effect of transient pressures on the fatigue life of a component, then the waveform as presented in Figure 2 should be used instead of Figure 1.

4.2 Cycling Rate

A cycling rate of 1 Hz is recommended. Consideration should be given to the cycling rates used when pressures must penetrate between close fitting parts or restrictions or where hysteresis can affect stresses. In addition, if there is difficulty in achieving the required waveform, then consider using a reduced cycling rate.

Cycling rates up to 3 Hz may be allowed for small components (such as solenoid valves, check valves, pressure transducers, etc.), with actual cycling rate defined in the component specification. For test cycling rates exceeding 1 Hz, the stress level of at least one test sample shall be verified by analysis or by reviewing the output from strain gauges that are attached to the component.

Verify that the peak pressures are within their specified tolerances.

The following additional verifications are recommended for impulse tests where the cyclic rate exceeds 1 Hz, or when employing a damped waveform impulse trace as shown in Figure 2.

a. Verify by strain gauge or analysis that the ratio of induced stress to pressure at the test cycling rate is the same as during the static loading.

b. Verify that temperatures of the test component are within allowable limits.

4.3 Rate of Rise

The rate of rise shall be that required to meet the specified waveform and the cycling rate, but should not exceed 200 000 psi/s (1378.95 MPa/s).

4.4 Temperature

The fluid temperature during testing should be maintained at the nominal component operating temperature within ±15 °F (±8 °C). The nominal component operating temperature should be specified in the detail specification.

Components which operate at more than one stabilized temperature and are made from materials which vary in strength properties with temperature are recommended to have a portion of impulse testing accomplished at the temperature that is expected to produce reduced strength properties (for example perform 25% of impulse cycles at high temperature and the balance at room temperature). This shall be defined in the applicable specification.

4.5 Test Fluid

It is recommended that the fluid used for the test should be the service fluid of the component undergoing test; however alternative impulse test machine fluids may be used if agreed with the Purchaser.

4.6 Number of Test Specimens Versus Scatter Factor

NOTE: The requirements of this section are applicable to only testing per Category II.

The cornerstone of safe-life substantiation of hydraulic components is a full-scale pressure impulse test to a scatter factor applied to the service life. Typical scatter factors that are used for one test specimen are 4, 5, or 6. However, this scatter can be reduced if more than one test specimen is used in the pressure impulse test.

A method for determining the scatter factor versus number of test specimens is presented in Appendix B.

5. TEST EQUIPMENT

The test setup shall produce repeatable pressure pulses within the limits defined in 4.1.

5.1 Accuracy

The test equipment and instrumentation should be set up and maintained so that all data is accurate within 4% of the maximum actual value unless otherwise specified. Temperature recording accuracy should be maintained at ±5 °F (±3 °C).

5.2 Oscilloscope

Where oscilloscopes are utilized to record the cycle shape, the sweep rate on the oscilloscope should be adjusted so that the slope of the pressure rise takes advantage of the full size of the screen. The trace and photos of the impulse cycle should be an accurate record of the impulse cycle and show a grid or other means to permit accurate checking.

6. TEST PROCEDURE

The method of testing is intended to determine the ability of hydraulic components (for exceptions, see 1.1) to withstand the hydraulic pressure-impulse cycling for qualification testing.

6.1 Selection of the Test Specimen

The test specimen should meet the following criteria:

a. The test specimen should be a production unit or representative of production. Conservative substitutions, adequately substantiated by the equipment manufacturer are acceptable. Any Material Review Board (this is the Group that provides dispositions/corrective actions for discrepancies occurring in the manufacturing process) actions should be documented and reviewed for the effect on the validity of the testing.

b. The test specimen should not have been previously subjected to loads exceeding the limit load or pressures exceeding proof pressure, unless such application of load or pressure is a normal step in the production process. Any yielding in stress concentration areas may result in unrealistic fatigue life.

c. The test specimen should not have been previously subjected to vibration tests or other fatigue type tests. The life capability used up in such tests may result in unrealistic low pressure-impulse fatigue life.

6.2 Preparation of the Test Specimen

Prior to pressure-impulse testing, the test specimen should be disassembled and thoroughly examined for cracks or structural failure or flaws in accordance with the production requirements, such as visually and by use of fluorescent-penetrant, ultrasonic or magnetic-particle inspection. The inspection of the test specimen for flaws prior to testing shall not include any inspections not required for production units.

The test specimen should then be reassembled with new seals, proof pressure tested, and given a baseline functional test including measurement of internal and external leakage prior to pressure-impulse testing. This requirement may be waived if the unit is inspected prior to assembly and impulse testing is the first qualification type test imposed on the test specimen.

The production acceptance test may be used to satisfy requirements for initial baseline test requirements pertinent to impulse testing and may eliminate non-pertinent tests such as frequency response, insulation resistance, no-load velocity, etc.

NOTE: The test specimen should not be subjected to a proof pressure test prior to the pressure impulse test if it does not have a proof test as part of its ATP (Acceptance Test Procedure).

6.3 Test Setup

All entrapped air should be bled as well as possible from the test specimen and the test circuit. All drains and low-pressure ports that are not part of the area under test should be allowed to drain freely and kept at atmospheric pressure. Metal shot or loosely fitting metal pieces may be placed in the test specimen if desired to minimize fluid volume.

The measurement of the pressure cycle shall be made as close to the test specimen as is practical.

6.3.1 Valve Positions

Variable-position valves, such as directional-control valves and servovalves, should be tested at their various positions so that each port and chamber is appropriately stressed. The total number of pressure-impulse cycles should be apportioned and applied at each position in approximately the same percentage expected in service. Simplifying tests should not result in under testing any area. However, no chamber should see less than the number of cycles appropriate to the procedure selected.

NOTE: It is acceptable to remove the spool(s) and/or sleeve(s) in the valves and, if necessary, substitute dummy components drilled to ensure that all cavities, ports and chambers are appropriately stressed.

6.3.2 Actuator Piston Positions

Actuating cylinders should be tested in a manner that is representative to the aircraft installation. The pressure applications should reflect conditions of operation and all elements exposed to fluid pressure are appropriately stressed.

NOTE: When it is applicable, specific testing should cover snubbing cavities in the actuators. Snubbing cavities can see very high pressures compared to the rest of the actuator.

6.3.2.1 Linear Hydraulic Actuators

Unless otherwise specified in the detail procurement specification, actuators should be tested as follows:

- With the piston rod at the extended position and the applicable number of cycles applied in the extend pressurized direction.

- With the piston rod at the retracted position and the applicable number of cycles applied in the retract pressurized direction.

NOTE: If both sides of a piston are pressurized simultaneously during its normal extend operation then the test conditions should reflect this condition.

6.3.2.2 Servoactuators

There are two alternative test methods as detailed below. The procurement specification for the servoactuator shall specify which test method is to be used for the impulse testing:

6.3.2.2.1 Actuator Piston in the Bottomed Position

Conduct 50% of the servoactuator impulse testing with the actuator piston bottomed in the extended position and the other 50% with the actuator bottomed in the extended position.

6.3.2.2.2 Actuator Piston Restrained in Mid-Position

Conduct the pressure impulse test with the piston rod restrained in mid-position using internal stop members and not external restraints. This is to avoid unwanted fatigue loading of the piston rod, cylinder, tailstock or rod end.

The applicable number of cycles/associated pressure should be applied in the retract pressurized direction, followed by the same process in the extend pressurized direction.

NOTES:

1. Both of these test methods may be used for some applications that have dual functions, for example spoiler actuators that operate as flight control and lift dump.

2. On some dual tandem linear actuator designs, bottoming the actuator adds unrealistic loads on the center dam. In this case the option of pressurizing both sides of the piston simultaneously should be considered.

3. Servoactuators should see the full impulse pressure range P_{Max} to PR during impulse testing.

6.3.3 Components Containing Integrated Valves

For impulse testing of components containing integrated valves, such as check valves, overload relief valves, anti-cavitation valves, etc., these valves should be removed if they prevent full pressure excursions being applied for all the component's sections during testing. If required, these valves should be subjected to a dedicated pressure impulse test.

6.3.4 Dual Pressure Systems

Components that operate at more than one pressure level, such as in dual pressure level systems, should be tested at each pressure level. The percentage of the total impulse test cycles, which are run at the higher pressure, should be equivalent to twice the percentage of the operating time at that (higher) pressure, predicted in service. For Category I testing, the apportioning (percentage) of the cycles to be run at the higher pressure should be defined in the detail specification.

NOTE: It is recommended that the impulse test cycles be conducted only at the higher pressure if it has been determined that the lower pressure will not add any significant cumulative damage.

6.4 Impulse Test

The impulse test should be conducted as required under Section 3 and the detail specification.

6.4.1 Use of Test Layers

When conducting a Category II pressure impulse test on a component, it is recommended that the impulse test be conducted in cyclical layers. Each layer should not be more than the total number of pressure-impulse cycles expected during the component's service life. If testing is done at more than one fluid temperature or test position, those variables should be interspersed within each layer in the same proportions expected in service.

After completion of each test layer, the external surfaces of the test specimen should be visually examined for cracks, leaks, or other evidence of structural failure. Then, if required, before proceeding with the next test layer, the baseline performance should be rerun and the results, including internal and external leakage, recorded. Elastomeric, plastic, or other nonstructural wear sensitive components may be replaced prior to proceeding to the next test layer.

NOTE: If an unacceptable performance degradation is found following the first layer of a multilayer test, the test should be interrupted until corrective redesign or part replacement is implemented.

6.4.2 Replacement of Seals or Gaskets During Testing

If seals or gaskets are replaced during testing, it is recommended that the maximum dynamic removal torque for any fasteners, which occurs immediately after the static breakaway torque, be recorded and that on reinstallation, these fasteners be torqued to the same dynamic value. Thus if the pre-stress has been reduced during the cycles previously conducted, the test is resumed at conditions similar to those conditions before seal replacement was necessary.

7. POST TEST REQUIREMENTS

7.1 Performance After Test

If the test procedure requires performance testing after the completion of the impulse cycling, the test specimen shall conform to the specified post impulse test performance requirements (see 3.3[m]).

If any performance characteristic fails to meet the requirements specified in the detail specification, the test specimen should be reassembled with new seals, proof tested, and re-subjected to the post test performance requirements to determine the reason for deteriorated performance.

7.2 Component Verification

The test specimen shall be disassembled and inspected for cracks or structural failure after the completion of the impulse tests and any post test performance tests, if conducted. The presence of detectable cracks constitutes a failure unless otherwise determined by the procuring activity.

7.3 Approval

Designs are considered acceptable if no cracks or other structural damage occur during or as a result of the impulse test.

Alternatively, in less critical circumstances where some degree of performance degradation is considered acceptable, the detail specification should specify the associated allowable conditions, such as:

a. Maximum acceptable crack size.

b. Inspection methods and procedures to be employed, such as:

- Visual; with degree of magnification

- Penetrant, and/or Magnetic Particle Inspections

c. The resulting minimum acceptable performance requirements.

8. NOTES

8.1 A change bar (l) located in the left margin is for the convenience of the user in locating areas where technical revisions, not editorial changes, have been made to the previous issue of this document. An (R) symbol to the left of the document title indicates a complete revision of the document, including technical revisions. Change bars and (R) are not used in original publications, nor in documents that contain editorial changes only.

PREPARED BY SAE PANEL A-6A2, MILITARY AIRCRAFT OF
COMMITTEE A-6, AEROSPACE ACTUATION, CONTROL AND FLUID POWER SYSTEMS

APPENDIX A - DETERMINATION OF TEST CYCLE REQUIREMENTS APPLICABLE TO CATEGORY II

A.1 SCOPE

This appendix presents an example to show how the number of test cycles applicable to 3.2 Category II can be determined for an application.

To use Category II of this document it is necessary to define the unique characteristics of the fatigue cycles to be encountered during the life of each individual component to be evaluated and determine the number of equivalent cycles at test pressure limits.

The following example uses an aileron actuator for a commercial airplane to illustrate the recommended method. This component, used as an example, has two details that may be sensitive to fatigue and the analysis includes many of the aspects typifying duty cycle definition, as follows.

a. The actuator manifold and cylinder barrel are pressure vessels for which the duty cycle is defined by pressure limits between zero and operating pressure.

b. The piston rod and rod end experience reversing loads during actual service. The piston rod assembly may be tested concurrently with the cylinder by applying impulse pressure alternately to opposing ends of the piston.

Table A1 shows a summary of the determination of the test cycle requirements for this actuator.

NOTES:

1. Although the scope of ARP1383 is limited to the impulse testing of pressure vessels, the fatigue testing of the piston rod and rod end has also been included in this Appendix for completeness.

2. The effect of transient pressures has been excluded from the analysis that is contained in this Appendix.

The following text describes the procedure for defining test cycles and applies it to the example.

TABLE A1 - DETERMINATION OF FATIGUE TEST CYCLES TYPICAL AILERON ACTUATOR, 62 000 FLIGHTS - 1 LIFE

NOTE: References to procedure steps in the Appendix are indicated by <x>

<1> Flight Segment	<1> Flight Segment ~/flt n/flt	<1> Flight Segment n cycles one life	Manifold Detail min press psi	Manifold Detail max press psi	Manifold Detail min stress ksi	Manifold Detail max stress ksi	Manifold Detail (N)	Manifold Detail (n/N)	Rod End Thread Detail min press psi	Rod End Thread Detail max press psi	Rod End Thread Detail min stress ksi	Rod End Thread Detail max stress ksi	Rod End Thread Detail (N)	Rod End Thread Detail (n/N)	Rod End Thread Detail
			<1>	<1>	<3>	<3>	<4>	<5>	<1>	<1>	<3>	<3>	<4>	<5>	
Controls Check	2	1.25×10^5	750	2250	12.5	37.5	5×10^4	2.5	-1500	1500	-40.0	40.0	4×10^4	3.125	
Cruise	435	2.7×10^7	1980	2050	33.0	34.3	$\rightarrow\infty$	0	960	1110	25.6	29.6	$\rightarrow\infty$	0	
Roll Maneuver	40	2.510^6	2160	2595	36.0	43.3	5×10^8	0.005	1320	2190	35.2	58.4	$\rightarrow\infty$	0	
On-Off	1	6.2×10^4	0	1500	0	25.0	3×10^5	0.21	--	--	--	--	--	--	
G-A-G Cycle <2>	1	6.2×10^4	0	2595	0	43.3	1×10^4	6.2	-1500	2190	-40.0	58.4	2×10^4	3.1	
(n/N) <5>								8.915						6.225	
n/N Test Press <6>									-1500	1500	-40.0	40.0	4×10^4	3.125	
N Test <7>															2.49×10^5

A.2 REQUIREMENTS

A.2.1 Step 1 - Determine Manufacturers Design Requirements

Obtain from the aircraft manufacturer a definition of the load cycles (in terms of the fluctuations of hydraulic pressure) that the component experiences during normal operation, the number of times each load cycle is repeated during one flight, and the number of flights in the aircraft lifetime. For components that experience reversing loads, this requires definition of pressures on either side of the piston.

TABLE A2 - AIRCRAFT MANUFACTURERS DATA FOR THE EXAMPLE CHOSEN

Duty Conditions	Manifold/Cylinder Detail	Rod/Rod End Detail
One Life - 62 000 flights	7075-T6 Aluminum	AISI 4340, H.T. to 200 ksi
3000 psig design pressure	K_t = 3 in control pressure	K_t = 3 in threads
Flight segments	Pressure fluctuations	Pressure fluctuations
• Controls check approx 2/flight	• 750/2250 psi	• -1500/1500 psi
• Cruise[1] approx 435/flight	• 1980/2050 psi	• 960/1100 psi
• Roll[1] approx 40/flight	• 2160/2595 psi	• 320/2190 psi
• On/off approx 1/flight	• 0/1500 psi	• --

NOTE: Superscript [1] denotes large load offset from neutral during flight cycles

A.2.2 Step 2 - Determine the Ground-Air-Ground Pressure Cycle

Determine the maximum peak-to-peak pressure variation that occurs during one flight using the data from Step 1.

TABLE A3 - G-A-G CYCLE FOR THE EXAMPLE CHOSEN

Pressure Range	Component Element
0 to 2595 psig	Manifold
-1500 to 2190 psig	Rod End

A.2.3 Step 3 - Determine the Stress Cycle

Select a stress/pressure ratio consistent with the materials and type of construction used in the component. Refer to the notes at the conclusion of this appendix for suggestions related to making this selection.

TABLE A4 - STRESS/PRESSURE RATIO FOR THE EXAMPLE CHOSEN

Component Element	Stress	Pressure	K Factor
Manifold	50 000 psi	3000 psi	16.7
Rod End	80 000 psi	3000 psi	26.7

Apply the ratio K to the pressures from Steps 1 and 2 and to define the stress cycle for each flight segment.

TABLE A5 - STRESS CYCLE FOR THE EXAMPLE CHOSEN

Flight Segment	Manifold Pressure (psi) min	Manifold Pressure (psi) max	Manifold K	Manifold Stress (ksi) min	Manifold Stress (ksi) max	Rod End Pressure (psi) min	Rod End Pressure (psi) max	Rod End K	Rod End Stress (ksi) min	Rod End Stress (ksi) max
Controls Check.	750	2250	16.7	12.5	37.5	-1500	1500	26.7	-40.0	40.0

NOTE: See Table A1 for data for the remainder of the flight segments

A.2.4 Step 4 - Determine the Life Cycle Expectancy

Identify a curve in DOT/FAA/AR-MMPDS-01 that most closely relates to the material and condition being analyzed. See Figures A1 and A2 related to example chosen. Determine from the intersection of lines representing minimum stress and maximum stress, using the results for each segment in Step 3, the life cycle expectancy (N) in cycles for each segment.

TABLE A5 - LIFE CYCLE EXPECTANCY FOR THE EXAMPLE CHOSEN

Flight Segment	Manifold Stress (ksi) min	Manifold Stress (ksi) max	Manifold DOT/FAA/AR -MMPDS-01C	Manifold N	Rod End Stress (ksi) min	Rod End Stress (ksi) max	Manifold DOT/FAA/AR -MMPDS-01C	Rod End K
Controls Check.	12.5	37.5	Figure A1	5×10^4	-40.0	40.0	Figure A2	4×10^4

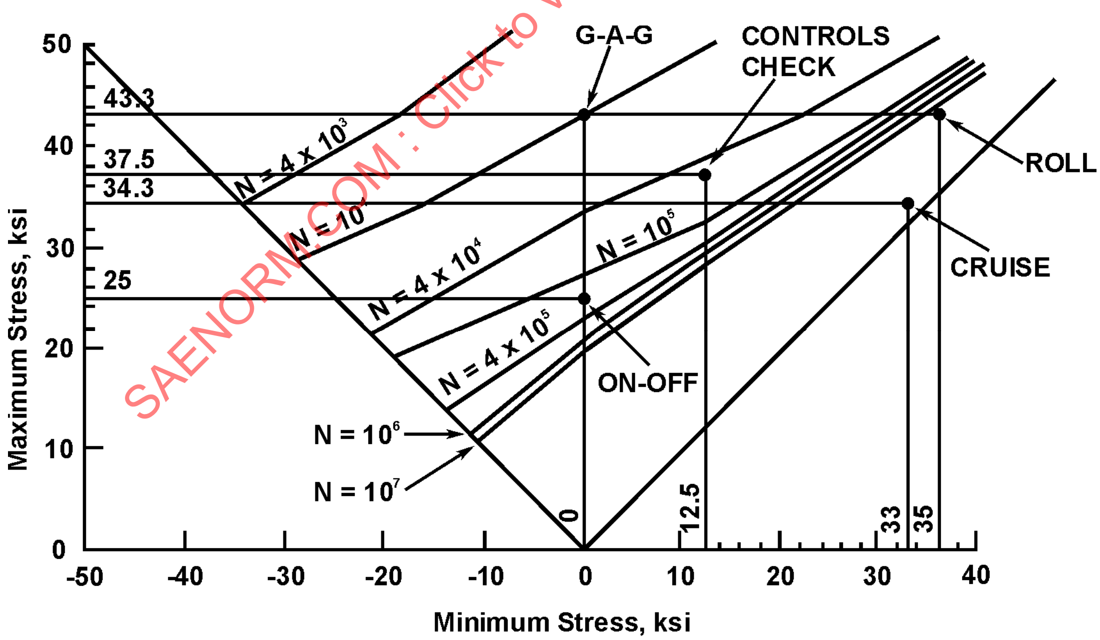


FIGURE A1 - EXAMPLE - TYPICAL CONSTANT LIFE DIAGRAM, 7075-T6 ALUMINUM ALLOY

NOTES:

1. Data from DOT/FAA/AR-MMPDS-01 Figure 3.7.6.1.8(d)

2. Detail Omitted for Clarification of Example