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AEROSPACE RECOMMENDED PRACTICE

SAE ARP1383 REV. A

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IMPULSE TESTING OF AEROSPACE HYDRAULIC ACTUATORS, VALVES, PRESSURE CONTAINERS, AND SIMILAR FLUID SYSTEM COMPONENTS

1. SCOPE:

This SAE Aerospace Recommended Practice (ARP) establishes the minimum requirements and procedures for impulse testing of aerospace hydraulic actuators, valves, pressure containers, and similar fluid system components, except accumulators, for use in aerospace hydraulic systems. It also refers to standard impulse test equipment, which may be used in conducting these impulse tests.

2. APPLICABLE DOCUMENTS:

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

ARP603 Impulse Testing of Hydraulic Hose Assemblies, Tubing, and Fittings
AIR1228 Standard Impulse Machine Equipment and Operation

3. REQUIREMENTS

The pressure-impulse test is basically an accelerated fatigue test. This document defines the impulse test procedure recommended for hydraulic equipment utilized in the following three types of aerospace vehicle hydraulic system applications:

a. Procedure I: Applicable to high-performance fixed-wing military aircraft.

b. Procedure II: Applicable to military and commercial rotary-wing aircraft.

c. Procedure III: Applicable to commercial fixed-wing aircraft and military aircraft as derivatives of commercial fixed-wing airframes.

Unless otherwise specified, the following requirements are applicable to Procedures I, II, and III.

3.1 Shape of the Impulse Cycle:

The limits shown in Figure 1 define the pressure-time cycle for both pressure and return cavities when observed on an oscilloscope and instrumented per AIR1228. It is mandatory that the dynamic impulse trace, produced by the test machine, be in conformance with Figure 1 and that the actual pressure-time curve be confined to the area shown.

Where the expected pressure environment includes water hammer effects or other significant transients, P(max) should be equal to or exceed the maximum value expected. The number of test cycles should be adjusted to include these transients or any unusual number of cycles applied during the components operational life. An alternate pressure-time cycle for the pressure cavity is shown in Figure 2. An additional alternate pressure time cycle for the pressure cavity, the sinewave, is shown in Figure 3.

3.2 Rate of Rise:

The rate of rise is defined as the slope of the pressure-time curve in the straight portion of the initial pressure increase portion between 10% of the total rise above back pressure and 10% of the total rise below peak pressure.

3.3 Cycling Rate:

Unless otherwise specified in the detail specification, a cycling rate of 1 cycle/s is recommended for large components and up to 5 cycles/s for small components with actual cycling rate and tolerance defined in the component detail specification. At rates higher than 1 cycle/s, instrumentation of the components may be required to:

a. Verify that intended stresses are applied and are not exceeded

b. Verify measurable stress amplitudes

c. Verify that temperatures within the test component are within allowable limits (procedure III should use 2 cycles/s)

3.4 Temperature:

The fluid temperature during testing shall be maintained at the nominal component operating temperature +15 to -0 °F (+8 to -0 °C). The nominal component operating temperature shall be specified in the detail specification. Components which operate at more than one stabilized temperature, such as during subsonic cruise and during supersonic flight, shall be tested at each temperature for approximately the same percentage of time predicted for operation during service as defined in the detail specification.

3.5 Test Conditions:

3.5.1 Number of Cycles and Pressure Levels: The pressure and return cavities of the component shall be tested, as a minimum, to the number of pressure impulse cycles defined below for the applicable procedure; where P(oper) is the appropriate design operating pressure, PR is the nominal return line pressure, P(max), and PR(max) are supply cavity and return cavity test pressures.

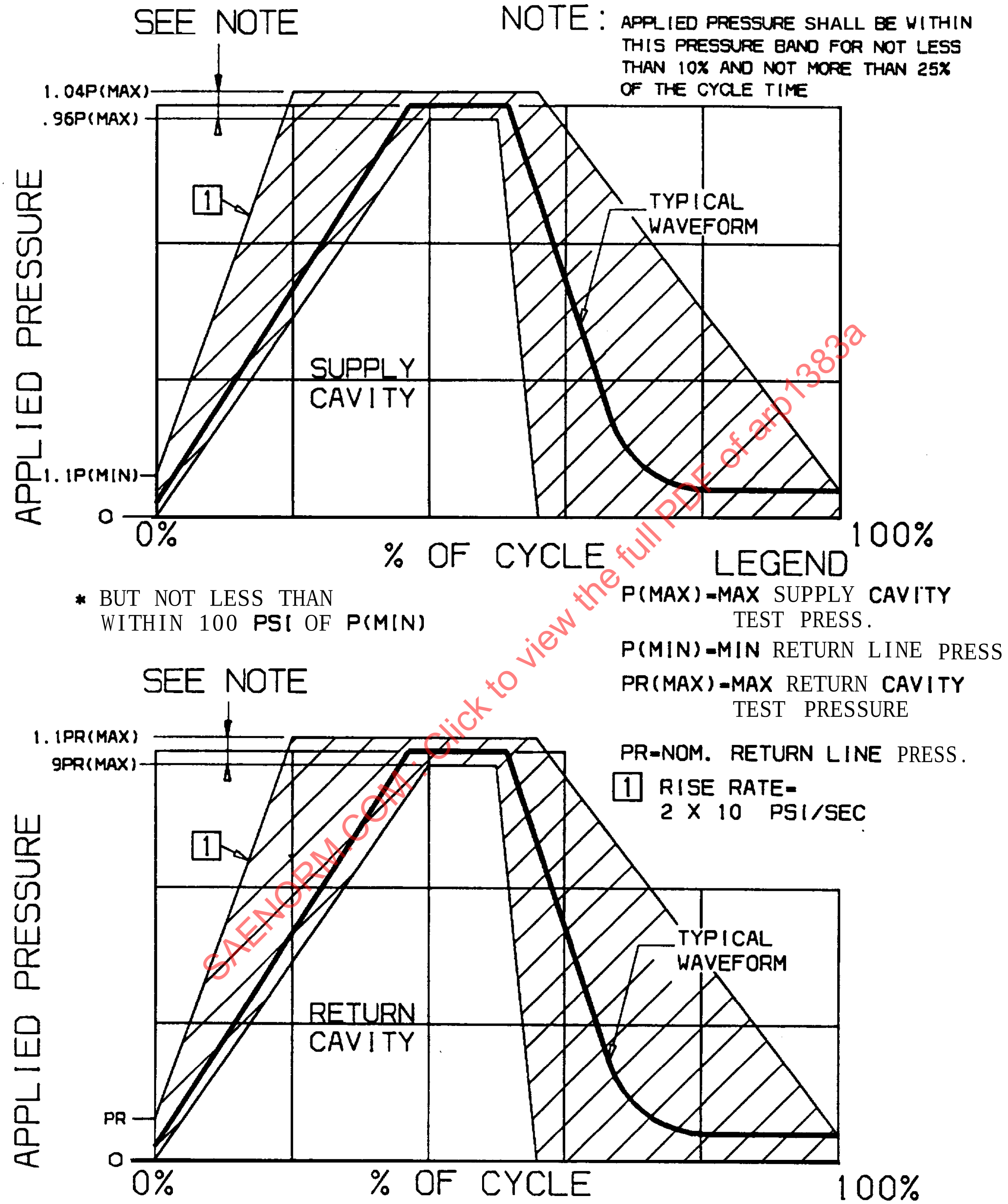


FIGURE 1 - Supply Cavity and Return Cavity Impulse Waveform

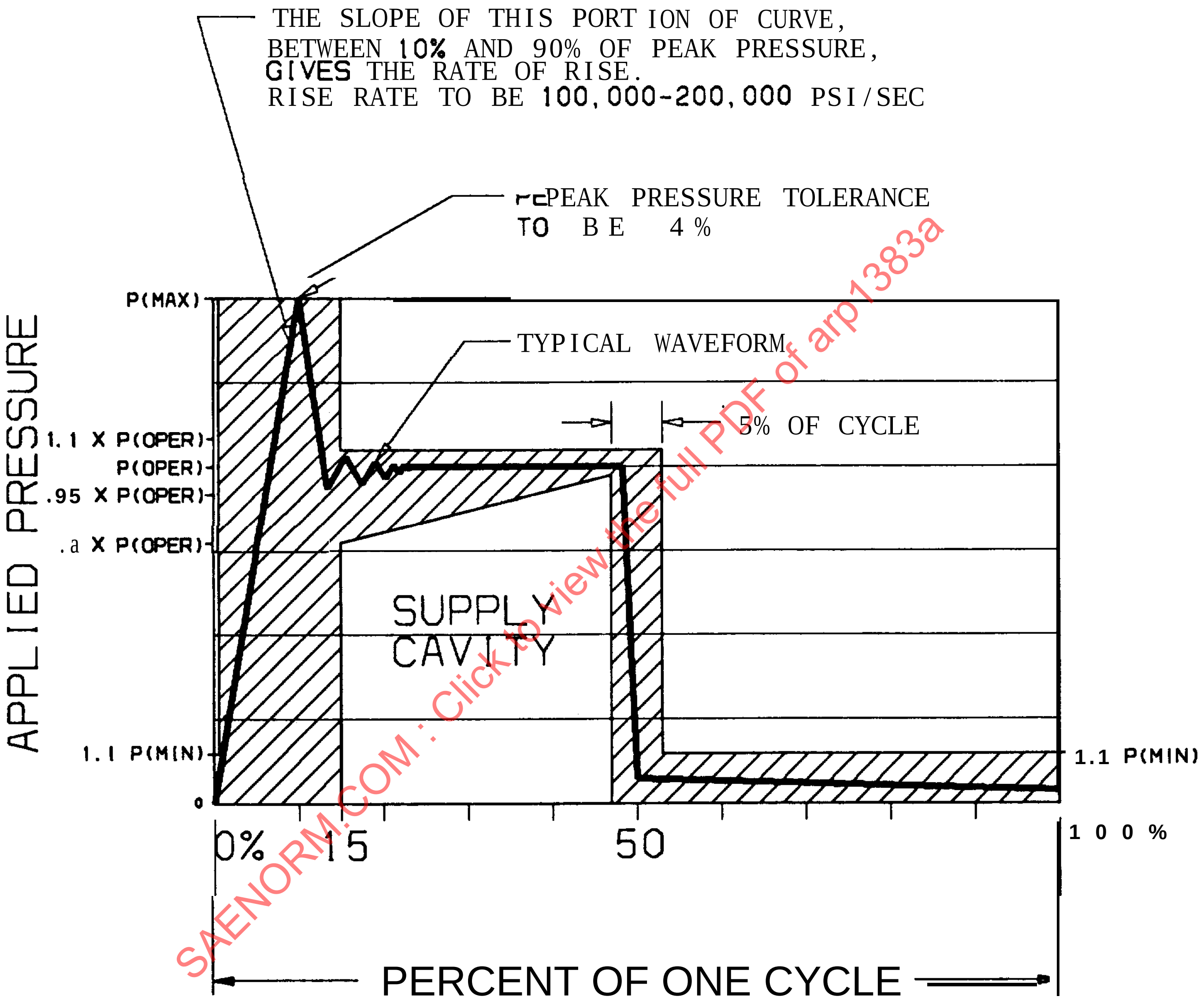


FIGURE 2 - Alternate Impulse Trace - Damped Wave

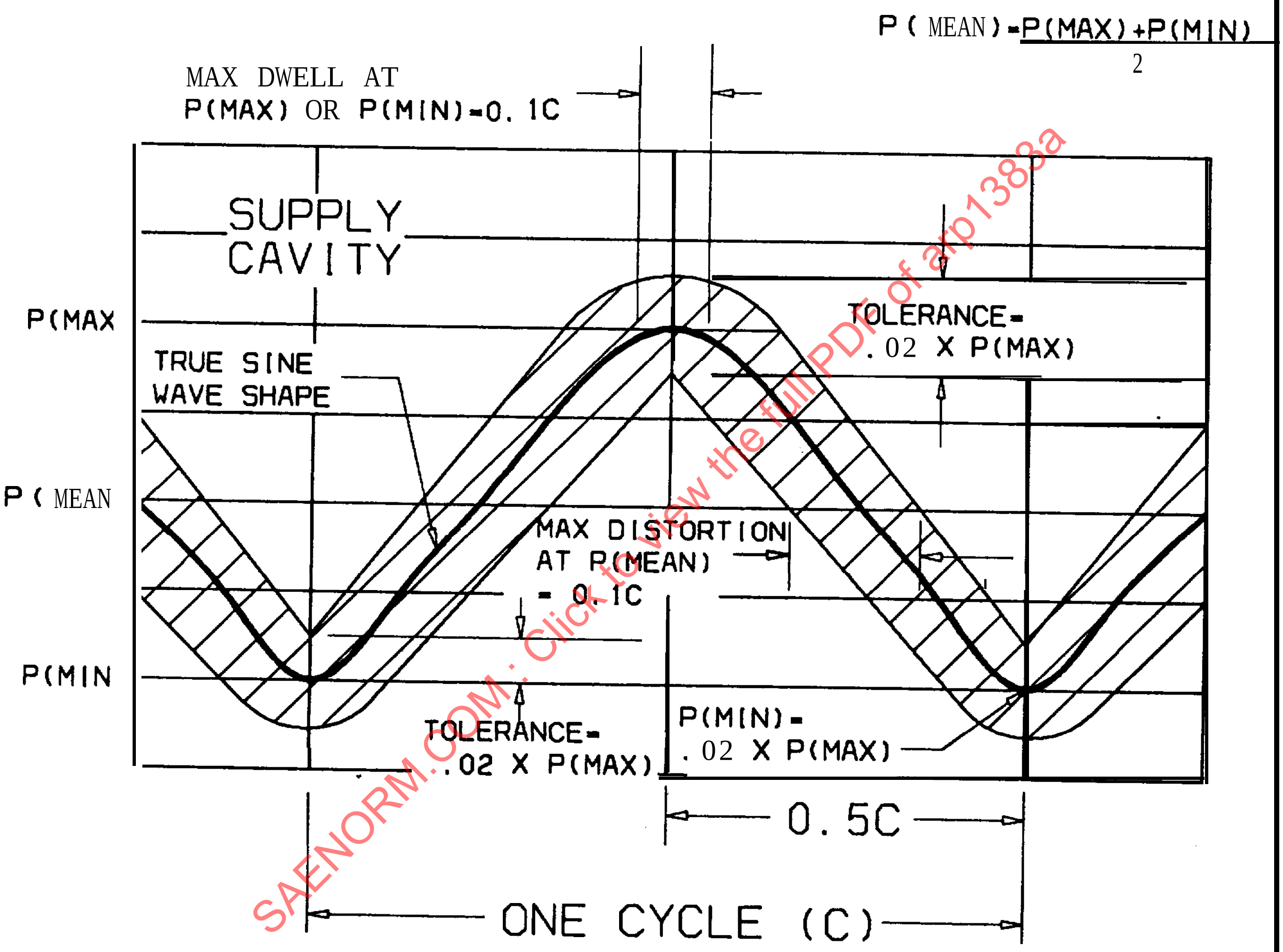


FIGURE 3 - Alternate Impulse Trace Sine Wave

3.5.1 (Continued):

a. Procedure I

(1) Flight control actuators/valves/components, **P(max) =** 1.5 **x P(oper),** 200 000 cycles

(2) Utility actuators/valves/components, **P(max) =** 1.5 **x P(oper),** 100 000 cycles

(3) Return ports/passages and components subjected to return pressure only, **PR(max) =** rated return line pressure **x** 1.5, 100 000 cycles

b. Procedure II

(1) Primary flight control actuators:	1×10^6 cycles	P(max) = 1.5 x P(oper)
(2) Secondary flight control actuators:	1×10^6 cycles	P(max) = 1.5 x P(oper)
(3) Utility actuators:	3×10^5 cycles	P(max) = 1.5 x P(oper)
(4) Flight control system hydraulic components:	1×10^6 cycles	P(max) = 1.5 x P(oper)
(5) Utility system hydraulic components:	3×10^5 cycles	P(max) = 1.5 x P(oper)
(6) Return ports/passages and components subjected to return pressure only:	3×10^5 cycles	PR(max) = 3 x Pr

(7) S-N curve generation. In addition to meeting the criteria specified in 1 through 6 above, an S-N curve shall be generated for critical components in the rotary-wing aircraft hydraulic system. Unless otherwise specified, a minimum of six specimens shall be utilized for testing. See Appendix A for additional data on S-N curve generation and usage.

c. Procedure III

The number of test cycles are to produce equivalent fatigue damage, when the component is tested at the design operating pressure, using the Figure 1 wave shape, to the damage 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 in-service, 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 **B** provides details of the method to be used to determine test cycles by means of an example. Because only one unit is tested during qualification, it is necessary for additional cycles to be performed to verify reliability. (Example: to demonstrate 95% reliability with 95% confidence, it would be necessary to test four lifetimes of one unit.)

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

3.5.3 Actuator Piston Positions: Actuating cylinders shall be tested so that all elements exposed to fluid pressure are appropriately stressed. Unless otherwise specified in the detail procurement specification, actuators shall be tested with the piston rod restrained in mid-position and the maximum number of cycles shall be applied in the retract pressurized direction. The required number of impulse cycles shall be repeated with pressure applied to the extend direction. Pressure shall not be applied simultaneously to extend and retract directions. Servoactuators shall see the full impulse range, P(max) to PR during impulse testing.

3.6 Selection of Specimen:

The test specimen shall meet the following criteria:

a. The unit shall be a production unit or representative of production. Conservative substitutions, adequately substantiated by the equipment manufacturer are acceptable. Material Review Board actions shall be documented and reviewed for effect on test validity.

b. The unit shall 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, however microscopic, in stress concentration areas may result in unrealistic fatigue life.

c. The unit shall 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.

3.7 Test Equipment:

The test setup shall produce repeatable pressure pulses within the limits defined in 3.1.

3.7.1 Accuracy: The test equipment and instrumentation shall be set up and maintained so that all data is accurate within 4% of the maximum actual valve unless otherwise specified.

3.8 Test Fluid:

The fluid used for the test shall be the service fluid of the component undergoing test.

3.9 Performance After Test:

The component shall conform to the post impulse test performance requirements specified in the detail specification after completion of the impulse cycling. Depending upon the test procedure used, performance testing may or may not be required.

4. TEST PROCEDURE:

The method of testing is intended to determine the ability of hydraulic actuators, valves, and pressure containers (except accumulators) to withstand the hydraulic pressure-impulse cycling for qualification testing.

4.1 Preparation of Specimen:

Prior to pressure-impulse testing, the unit shall be disassembled and thoroughly examined for cracks or structural failure or flaws in accordance with production requirements both visually and by use of fluorescent-penetrant, ultrasonic or magnetic-particle inspection. It shall 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 nonpertinent tests such as frequency response, insulation resistance, no-load velocity, etc.

4.2 Test Setup:

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

4.3 Impulse Test:

The impulse test shall be conducted as required under Section 3 and the detail specification. Where applicable (i.e., Procedure III) the impulse test shall be conducted in cyclical layers with each layer including no 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 shall be interspersed within each layer in the same proportions expected in service.

After completion of each test layer, the external surfaces of the component shall be visually examined for cracks, leaks, or other evidence of structural failure. Then, before proceeding with the next test layer, the baseline performance shall 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.

4.4 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 shall be an accurate record of the impulse cycle and show a grid or other means to permit accurate checking.

4.5 Component Verification:

Upon completion of posttest performance tests specified, the unit shall be disassembled and inspected for cracks or structural failure. The presence of detectable cracks constitutes failure unless otherwise determined by the procuring activity. If a posttest performance test is required and any performance characteristic fails to meet the requirements specified in the detail specification, the unit shall be reassembled with new seals, proof tested, and resubjected to the posttest performance requirements of 3.9 to determine the reason for deteriorated performance.

4.6 Approval:

Designs are considered acceptable if no cracks or other structural damage causing leakage or unacceptable performance degradation occurs during or as a result of the impulse test or if the structural requirements of the detail specification are met. If 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. Depending upon the criticality of the component, performance degradation or damage to internal parts during subsequent test layers may or may not be sufficient cause for rejection.

5. NOTES:

5.1 Intended Use:

This document is intended for use as a standard for impulse test requirements and procedures for qualification and evaluation testing of the hydraulic system components indicated. Pressure-impulse tests for hydraulic pump and motor rotating elements are not covered by this document. Testing of hydraulic hose assemblies, tubing, and fittings should be conducted per ARP603.

5.2 Reference:

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

a. Procedure number and cycles if required

b. Operating pressures: P(oper.); minimum, nominal, and rated return line pressure

c. Operating temperature(s)

d. Fluid

5.2 (Continued):

e. Wave shape (Figure Number)

f. Component/valve position

g. Minimum pressure

h. Number of actuator cycles extended and retracted and position, if applicable

i. Cycling rate and tolerance

j. Layering requirements

PREPARED BY SAE COMMITTEE A-6, AEROSPACE FLUID POWER, ACTUATION, AND CONTROL TECHNOLOGIES

APPENDIX A
S-N CURVE GENERATION

A.1 SCOPE:

This appendix specifies the procedure to be used in preparation of S-N curves as required by 3.5.1 Procedure II(g). This appendix is a mandatory part of the document.

A.2 APPLICABLE DOCUMENTS:

This section in not applicable to this appendix.

A.3 REQUIREMENTS:

A.3.1 Upon completion of test, plot the test point(s) as an S-N plot. Designate point(s) as either a run-out (no test failure for the number of cycles tested) or failure point (see legend, Figure Al).

A.3.2 Draw the appropriate curve through the point(s) using the equivalent data point routine. Mean endurance limit is acceptable for a mix of fractures and run-outs. For run-outs the highest run-out may be used to establish the mean S-N curve (Figure Al). The low cycle reduction allows for increased scatter factor at low number of cycles.

A.3.3 Construct a working curve based on the number of samples tested. (The smaller the number of test specimens the greater the reduction in **allowables** in the mean S-N curve). The working curve using the three sigma scatter factor is appropriate (Figures Al, **A2,** and **A3).**

A.3.4 When one specimen is tested, whether a significant run-out or fracture, a 50% reduction in the mean endurance (one-half of the mean curve pressure values at any given number of cycles) shall be used unless otherwise specified by the procuring agency (Figure **A4).** This procedure may be used to establish interim life of the component.

A.3.5 The working S-N curve shall be used to calculate the component life or replacement time.

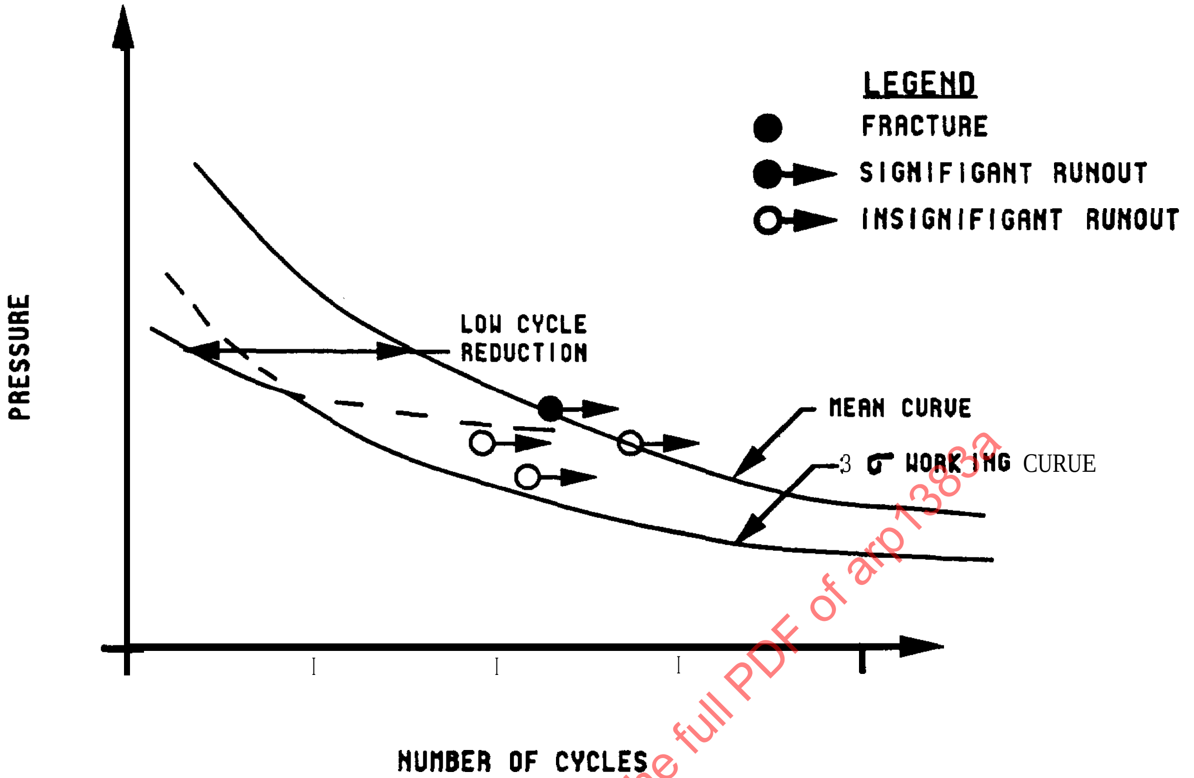


FIGURE A1 - S-N Curves

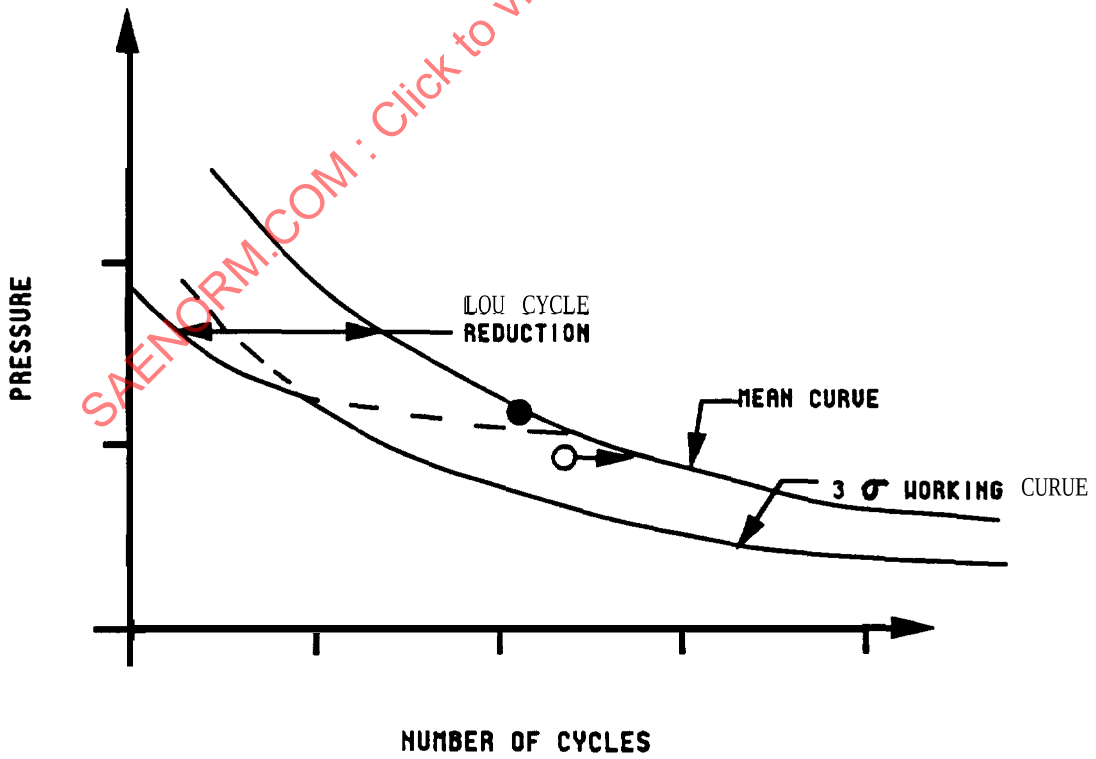
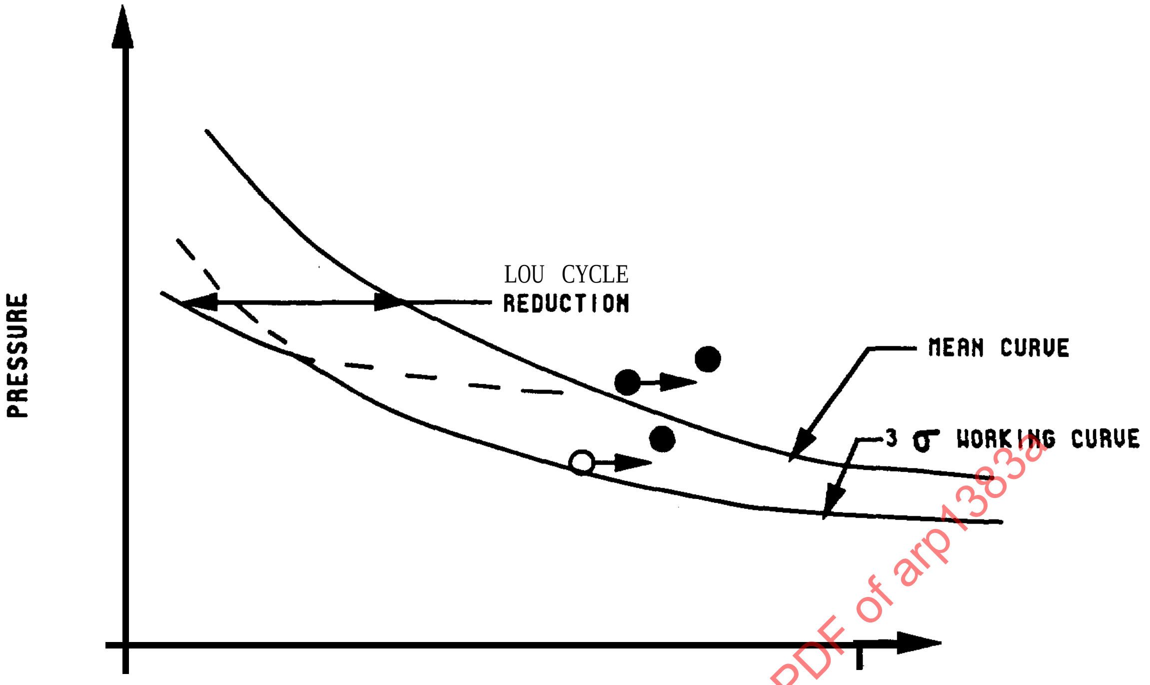
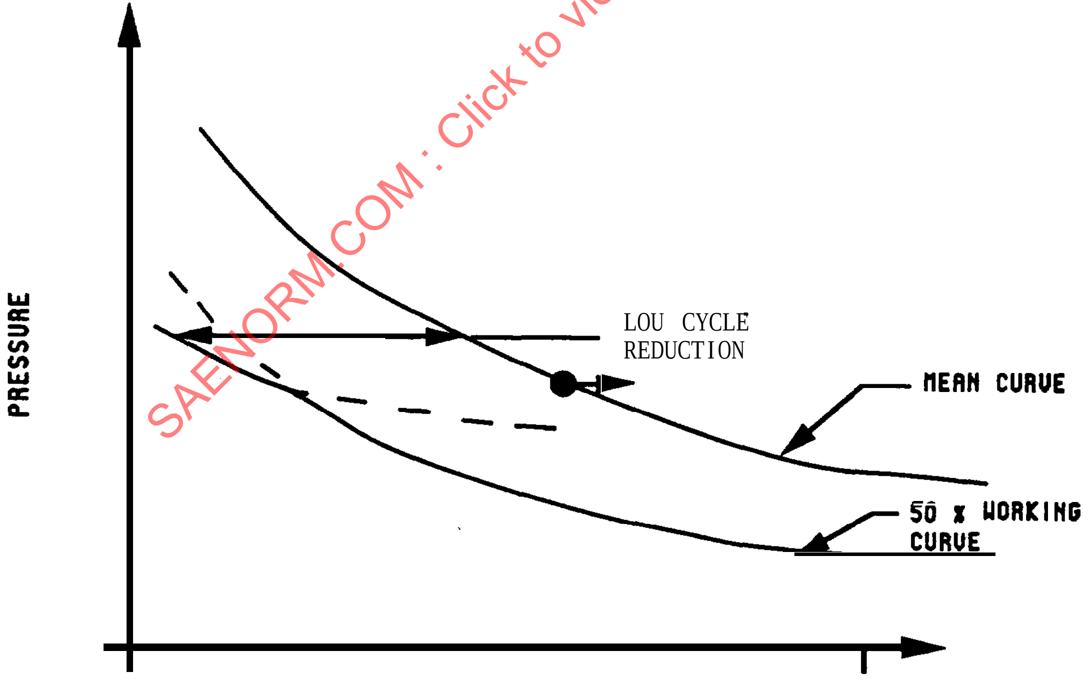


FIGURE A2 - S-N Curves



NUMBER OF CYCLES

FIGURE A3 - S-N Curves



NUMBER OF CYCLES

FIGURE A4 - S-N Curves

APPENDIX B
DETERMINATION OF TEST CYCLE REQUIREMENTS USING PROCEDURE III

B.1 SCOPE:

This appendix presents an example to show how the number of test cycles applicable to 3.5.1 Procedure III can be determined for an application. This appendix is not a mandatory part of the document.

B.1.1 To use Procedure III 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 method recommended. 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. The actuator manifold and cylinder barrel are pressure vessels for which the duty cycle is defined by pressure limits between zero and operating pressure. 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 **B1** shows a summary of the determination of the test cycle requirements for this actuator. The following text describes the procedure for defining test cycles and applies it to **the** example.

B.2 APPLICABLE DOCUMENTS:

B.2.1 U.S. Government Publications:

Available from- Standardization Documents Order Desk, Building **4D,** 700 **Robbins** Avenue, Philadelphia, PA **19111-5094.**

MIL-HBDK-5 Metallic Materials and Elements for Aerospace **Vehicle** Structures

B.3 REQUIREMENTS:

B.3.1 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 B1 - Determination of Fatigue Test Cycles Typical Aileron Actuator, 62 000 Flights - 1 Life
(References to procedure steps in text are indicated by <x>)

<1> Flight Segment	<1> Flight Segment ~/flt n/flt	<1> Flight Segment n cycles in 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