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AEROSPACE RECOMMENDED PRACTICE

SAE ARP4553

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Accumulator, Hydraulic, Cylindrical Aircraft, Self-Displaciing

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1. SCOPE:

1.1 Purpose:

This SAE Aerospace Recommended Practice (ARP) is intended as a guide in defining the requirements for aircraft hydraulic self-displacing accumulators, including details pertinent to the design, fabrication, and performance of the accumulator. This type of accumulator has a piston separator and contains a low pressure chamber and a high pressure chamber for actuating a self-displacing piston. For use in aircraft hydraulic systems of the following types as defined in MIL-H-5440 with rated operating pressures to 8000 psi (55,160 kPa).

a. Type I: -65 to +160 °F (-54 to +71 °C) fluid temperature
b. Type II: -65 to +275 °F (-54 to +135 °C) fluid temperature

For commercial aircraft applications, the information and guidelines of ARP4752 are considered.

1.2 Classification:

The accumulators shall be classified per the rated system pressure and return pressure as follows:

a. Class 1500: Hydraulic system, rated pressure 1500 psi (10,345 kPa)
b. Class 3000: Hydraulic system, rated pressure 3000 psi (20,685 kPa)
c. Class 4000: Hydraulic system, rated pressure 4000 psi (27,580 kPa)
d. Class 5000: Hydraulic system, rated pressure 5000 psi (34,475 kPa)
e. Class 8000: Hydraulic system, rated pressure 8000 psi (55,160 kPa)

In addition to the above system pressure classification, the low pressure (return system), must be stated or classified to the particular application. The basic classification number above will have a dash number added to specify the return pressure as follows:

Each 100 psi (700 kPa) will be designated by a two digit number:

a. 01: Hydraulic system, rated return pressure 100 psi (700 kPa)
b. 02: Hydraulic system, rated return pressure 200 psi (1400 kPa)

Each additional 100 psi (700 kPa) will be a corresponding increase in dash number.

The accumulator will be identified with a number as shown in Figure 1 for a hydraulic system, rated pressure of 3000 psi (20,685 kPa) and hydraulic system rated return pressure of 1000 psi (7000 kPa).

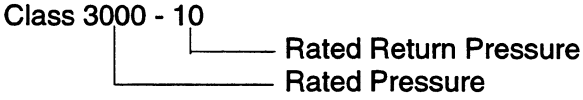

FIGURE 1

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, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AIR4543	Aerospace Hydraulics and Actuation Lessons Learned
ARP598	Procedure for Determination of Particulate Contamination in Liquids by the Particle Count Method
ARP1288	Placarding of Aircraft Hydraulic Equipment to Identify Required Fluid Suitability
ARP1383	Impulse Testing of Hydraulic Actuators, Valves, Pressure Containers and Similar Fluid System Components
ARP4150	Inspection of In-Service Airborne Accumulators
ARP4752	Aerospace, Design and Installation of Commercial Transport Aircraft Hydraulic Systems
AS1241	Fluid Fire Resistant Phosphate Ester, Hydraulic, for Aircraft
AS4059	Aerospace, Cleanliness Classification for Hydraulic Fluids
AS4716	Gland Design, O-Ring and Other Elastomeric Seals
AS4941	Aerospace, General Requirements for Commercial Aircraft Hydraulic Components
MA2012	Port Connection, Internal Straight Thread (Metric)

2.1.2 U.S. Government Publications: Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-P-116	Preservation, Methods of
MIL-H-5440	Hydraulic System, Aircraft, Design and Installation
MIL-C-5501	Caps and Plugs, Protective Dust and Moisture Seal
MIL-H-5606	Hydraulic Fluid, Petroleum Base, Aircraft, Missile and Ordinance
MIL-H-8775	Hydraulic System Components, Aircraft and Missiles, General Specification for
MIL-P-27401	Propellant Pressurizing Agent, Nitrogen
MIL-H-83282	Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Aircraft
MIL-P-83461	Packing, Preformed, Petroleum Based Hydraulic Fluid Resistant
MIL-H-87257	Hydraulic Fluid, Fire Resistant, Low Temperature, Synthetic Hydrocarbon Base, Aircraft and Missile
MIL-STD-810	Environmental Test Methods
MIL-STD-129	Marking for Shipment and Storage
MIL-STD-130	Identification Marking of U.S. Military Property
MS 33649	Boss, Fluid Connection, Internal Straight Thread

2.1.3 NAS Publications: Available from Aerospace Industries Association, 1250 Eye Street, NW, Washington, DC 20005.

NAS 1613	Packing, Preformed, O-Ring, Ethylene Propylene Rubber
NAS 1638	Cleanliness Requirements of Parts Used in Hydraulic Systems

2.1.4 FAA Publications: Available from the Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591.

FAR Part 25	Federal Aviation Regulations Airworthiness Standards

2.1.5 Joint Aviation Authorities Committee Documents: Available from the Civil Aviation Authority, Printing and Publications Services, Grenville House, Cheltenham, Glos., GL50 2BN.

JAR Part 25	Transport Category Airplanes Joint Airworthiness Requirements

2.1.6 RTCA Publications: Available from RTCA Secretariat, 44 Suite 500, 1425 K Street, Washington, DC 20005.

RTCA/DO-160	Environmental Conditions and Test Procedures for Airborne Equipment (Radio Technical Commission of Aeronautics)

2.2 Definitions:

The following terms used in this document are defined as follows:

EXTERNAL GAS LEAKAGE: External leakage is the leakage of the precharge gas from within the vessel as evidenced by free gas bubbles when the accumulator is immersed in a test fluid.

INTERNAL GAS LEAKAGE: Internal leakage of gas across the piston head seal. If a vent is incorporated into the piston seal design leakage will be to atmosphere.

PRECHARGE GAS VOLUME: The gas contained within the accumulator and separated from the hydraulic fluid, with the separator bottomed at the fluid end.

RATED PRESSURE: Rated pressure is the maximum operating fluid pressure of the accumulator, as defined and classified in 1.2.

SEPARATOR: The part of the accumulator (the interconnected tandem piston) that isolates the precharge gas from the high pressure hydraulic fluid, and the low pressure hydraulic fluid from the atmosphere.

VESSEL: The portion of the accumulator that contains the hydraulic fluid and the precharge gas.

VOLUMETRIC EFFICIENCY: The capability of the accumulator to expel the hydraulic volume with which it has been filled, (Expulsion Volume/Filling Volume) x 100.

3. TECHNICAL REQUIREMENTS:

3.1 General:

The requirements of MIL-H-5540 and MIL-H-8775 (military specifications) or ARP4752 and AS4941 (commercial applications) shall apply as requirements of this document, with the exceptions specified herein. When this document and the applicable above referenced specifications conflict, this document shall govern.

3.2 Qualification Test:

The accumulator furnished under this document shall be a product that has been tested and has passed the qualification tests specified in Section 4.

3.3 Design and Fabrication:

The materials and processes used in the design and fabrication of components shall be of high quality, suitable for the purpose and shall conform to the applicable specifications. Materials conforming to the supplier's material specifications can be used provided the specifications are acceptable to the procurement specification and contain provisions for adequate tests. For commercial applications, materials shall conform to FAR/JAR PART 25, sections 25.603 and 25.613.

3.3.1 Construction: Accumulators shall be designed and constructed to contain gas and hydraulic fluid under pressure. The accumulator will contain a high pressure fluid chamber and a low pressure fluid chamber of equal volume as specified by the procurement specification. The accumulator will be provided with two fluid ports and a gas port per 3.3.3 and shown schematically in Figure 2.

3.3.2 Dimensions and Mounting Provisions: Dimensions and mounting provisions shall conform to the requirements as defined in the procurement specification.

3.3.3 Ports:

3.3.3.1 Fluid Ports: Two fluid ports shall be provided. The fluid ports shall be designed to give a minimum restriction to fluid flow. One port will be connected to the high pressure chamber and the other to the low pressure chamber. The ports will be per MS 33649 (or MA2012) or as defined in the procurement specification. It is recommended that the two fluid ports be different sizes to prevent inadvertent cross connection on the installation.

3.3.3.2 Gas Port: A gas port per MS 33649 (or MA2012) shall be provided unless otherwise specified by the procurement specification.

3.3.4 Weight: The accumulator weight shall be a minimum consistent with the performance and requirements of this document and the procurement specification.

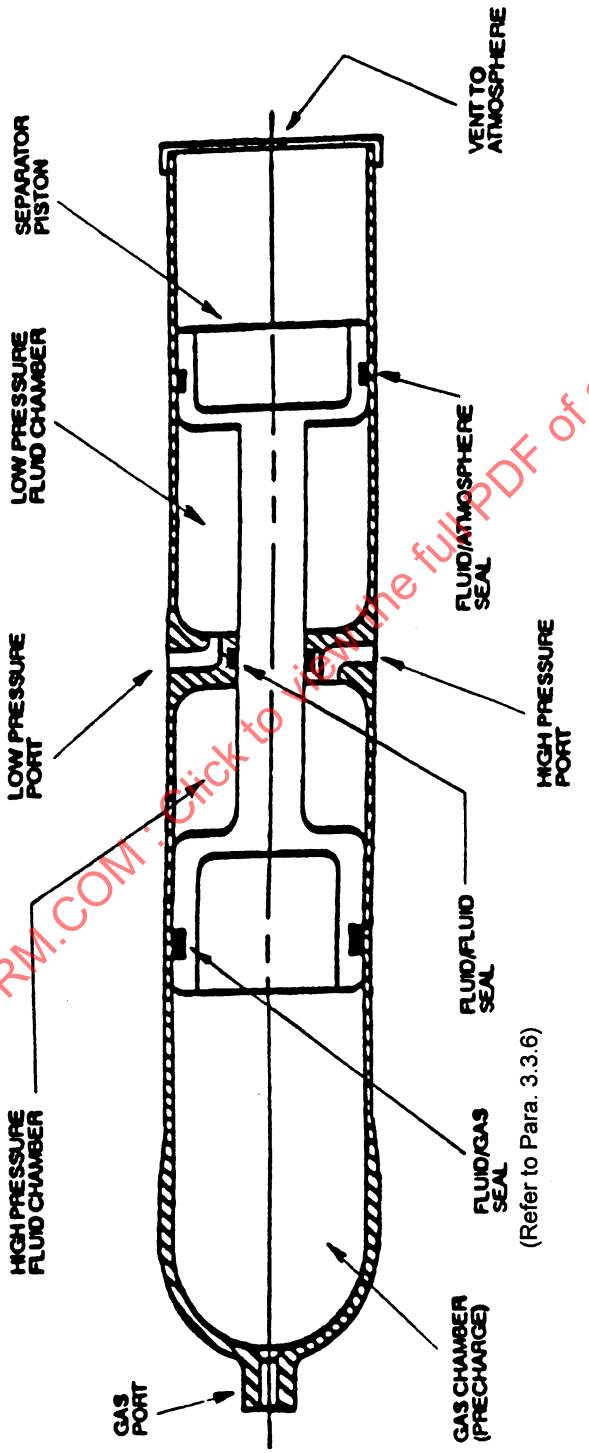

FIGURE 2 - Accumulator Schematic

3.3.5 Fluid: The accumulator will be designed to operate and be compatible with the fluid specified by the procurement specification (for example: MIL-H-5606, MIL-H-87257, MIL-H-83282, or AS1241).

3.3.6 Seals: The seals contained within the accumulator shall be compatible with the operating fluid per 3.3.5 (such as MIL-P-83461 or NAS 1613) and the operating temperatures of 3.4.10. The seal gland design shall be per AS4716 (commercial application) or MIL-G-5514 (military application) unless otherwise specified by the procurement specification.

NOTE: In Figure 2 a single seal is shown on the separator piston between the fluid and gas chambers. This configuration could be modified to allow dual sealing with a vent to atmosphere between the seals. This configuration provides additional protection to prevent leakage of gas into the hydraulic fluid.

3.3.7 Corrosion Protection: Materials subject to deterioration when exposed to the climatic and other environmental conditions specified shall be protected. The method of protection shall not prevent compliance with other requirements. The use of any protective coating that will crack, chip, scale or erode during life or as a result of climatic or other environmental conditions shall be avoided. Assembly requiring the contact of dissimilar metals shall be adequately protected against galvanic interaction in service by the use of an appropriate finish system. Protective coatings shall be compatible with the operating fluid of 3.3.5 and shall meet the requirements stated in the applicable specifications.

3.3.8 Storage: The accumulator shall be constructed of materials which shall not degrade during the life of the accumulator. The accumulator shall be designed for a shelf life of ten years after delivery.

3.3.9 Marking:

3.3.9.1 Warning Label: Each accumulator shall be permanently marked with a legible warning in red letters stating: RELEASE GAS AND FLUID PRESSURE BEFORE DISASSEMBLING, STORING OR SHIPPING ACCUMULATOR.

3.3.9.2 Nameplate: Each accumulator shall be furnished with a nameplate and shall provide the following data unless otherwise specified:

a. Accumulator, Hydraulic, Self-Displacing
b. ARP Classification Number per 1.2
c. Manufacture Date
d. Manufacturer's Serial Number
e. Manufacturer's Name
f. Manufacturer's Part Number
g. Oil Swept Volume
h. Operating Fluid

3.3.10 Workmanship: Workmanship shall be defined by the supplier process standards. The levels of workmanship shall be defined such that they ensure that each accumulator complies with all the requirements including proper operation and personnel safety.

3.4 Performance:

The accumulator shall be capable of all the performance requirements specified below unless otherwise specified by the procurement specification.

3.4.1 Rated Pressure: The accumulator shall be designed and constructed to have a high pressure chamber and a low pressure chamber, as shown in Figure 2, and rated pressure as classified in 1.2.

3.4.1.1 High Pressure Chamber: The high pressure chamber shall be designed to meet the requirements for the rated pressure of 1.2.

3.4.1.2 Low Pressure Chamber: The low pressure chamber shall be designed to meet the requirements for the rated return pressure of 1.2.

3.4.1.3 Precharge Pressure: The procurement specification shall specify the required precharge pressure of the accumulator. The accumulator shall be precharged with inert gas only, per MIL-P-27401 or equivalent, as specified by the procurement specification.

NOTE: The precharge pressure is specified at a specific temperature such that when the high pressure fluid chamber is filled with fluid per 3.4.6, and stabilized at that temperature, the gas pressure will be at the rated system pressure of 3.4.1.

3.4.1.4 Vessel Proof Pressure: The high and low pressure chambers of the vessel shall be subjected to a proof pressure of two times the applicable maximum rated pressure defined by 3.4.1.1 and 3.4.1.2.

3.4.1.5 Vessel Burst Pressure: The high and low pressure chambers of the vessel shall be subjected to a burst pressure four times the rated pressure defined by 3.4.1.1 and 3.4.1.2 respectively or as specified by the procurement specification, and shall be designed to withstand this pressure at maximum rated temperature of the accumulator per 3.4.10.

NOTE: The Figure 2 accumulator schematic shows a conventional design wherein the high pressure fluid chamber and high pressure gas chamber share a common barrel structure. In some designs the high pressure chamber is a separate structure, or the vessel maximum pressure is controlled by a relief valve or rupture disk. In these cases lower proof and burst factors may be considered to reduce the accumulator weight. The reduced factors must be specified by the procurement specification.

3.4.2 Separator: The separator that isolates the hydraulic fluid and the gas shall be designed to operate with the maximum precharge pressure as defined by the procurement specification. Means shall be provided to prevent sealing off the fluid ports when the piston is bottomed adjacent to the fluid port(s).

3.4.2.1 Proof Pressure: The separator shall be designed to withstand a differential pressure of two times the rated pressure per 3.4.1.1 in the high pressure chamber and 3.4.1.2 in the low pressure chamber.

3.4.2.2 Burst Pressure: The separator shall be designed to withstand a differential pressure of four times the rated pressure per 3.4.1.1 in the high pressure chamber and 3.4.1.2 in the low pressure chamber, and shall be designed to withstand this pressure at the maximum operating temperature of the accumulator per 3.4.10.

NOTE: The high pressure chamber burst pressure may be modified as noted in 3.4.1.5 if specified in the procurement specification.

3.4.2.3 Separator Friction: The hydraulic fluid differential pressure at which the separator begins to move shall not be greater than 150 psid (1050 kPa) when pressure is varied at the high pressure port within the rated pressure of 3.4.1.1. This condition shall be met with the gas chamber precharged per 3.4.1.3 and the low pressure chamber pressurized to rated return pressure per 3.4.1.2. This requirement shall be met over the total stroke of the accumulator.

3.4.3 Internal Cleanliness: The accumulator shall meet all the requirements of this specification when operating in hydraulic fluid continuously filtered to 5 µm absolute (class 6 per AS4059) or as specified by the procurement specification.

A maximum "in service" cleanliness level classification can be specified by the procurement specification.

3.4.4 Leakage:

3.4.4.1 Gas Static Leakage: A new accumulator shall have no external leakage and an internal leakage of not more than specified below, or as specified by the procurement specification.

a. 2 ml per hour of free gas for volumes up to 50 in^3 (0.8 L)
b. 3 ml per hour of free gas for volumes from 50 to 200 in^3 (3.3 to 6.6 L)
c. 10 ml per hour of free gas for volumes from 200 to 400 in^3 (3.3 to 6.6 L)

3.4.4.2 Gas Dynamic Leakage: The accumulator internal dynamic gas leakage shall be less than 1% of the gas volume for each 500 charge/discharge cycles as measured in the change in the gas charge pressure.

3.4.4.3 Fluid Static Leakage: A new accumulator shall have no external static leakage at the rated pressures specified. Internal leakage shall not exceed two drops in 1 h or as specified in the procurement specification.

3.4.4.4 Fluid Dynamic Leakage: Leakage shall not exceed one drop per 100 charge/discharge cycles per seal or as specified in the procurement specification.

3.4.5 Endurance Cycling: The accumulator shall be designed to withstand pressure cycling as defined in Table 1, Step 1 through 6. Accumulator performance during testing shall be verified as noted during testing.

NOTE: Table 1 is a typical endurance test cycle for an accumulator. Self Displacing Accumulators can be used for many applications such as a power storage device for engine start systems. A device of this type can have a different duty cycle and additional or modified endurance cycling should be considered.

3.4.6 Swept Oil Volume: The total oil volume (swept oil volume) of the high pressure and the low pressure chambers of the accumulator shall be specified in the procurement specification.

3.4.7 Volumetric Efficiency: The volumetric efficiency shall be such that the fluid expelled shall be in excess of 95% of the total oil volume of the fluid chambers. The expelled volume shall be as specified in 3.4.6.

3.4.8 Pressure Impulse Cycling: The accumulator shall be designed to withstand pressure impulse cycling as defined in Table 1, Step 7 or ARP1383, Procedure III or as specified in the procurement specification. Typical impulse curves are shown in ARP1383 Figure 1.

3.4.9 Immersion: The accumulator shall meet all test requirements per Table 2 after being immersed in the operating fluid for a period of 72 h at the maximum operating temperature per 3.4.10.

3.4.10 Operating Temperature: The accumulator shall be designed to operate at temperatures as specified in 1.1 for Type I or Type II systems, or as specified by the procurement specification.

3.4.11 Vibration: The accumulator shall be installed in a test setup to simulate the aircraft installation. The accumulator will be vibrated in accordance with the applicable test procedure of MIL-STD-810, Method 514.2 or the equivalent section of RTCA/DO-160. There shall be no mechanical failure of any part resulting from this test. On completion the accumulator shall meet the functional test of 4.5.

3.4.12 Additional Testing: Additional testing, based on the use and environment of the accumulator, should be considered and specified as required by the procurement specification. For example, additional testing could include extreme temperature, temperature shock, humidity, sand, and dust. These tests should be accomplished per the applicable sections of MIL-H-8775 for military applications and AS4941 may be used for commercial applications. In the case of a military application fragmentation testing (gun fire) may be specified.

3.4.13 Reliability: As a part of the design process, every effort shall be made to achieve the best possible reliability for the accumulator. The procurement specification will specify the required reliability for the application.

Reviewing the in-service history of similar components and consulting AIR4543 to determine the lessons learned and thereby minimize the possibility of in-service problems. ARP4150 should be reviewed for in-service history and inspection for accumulators.

TABLE 1 - Cycling Endurance Tests
(See Note 1)

Step	Total Cycles	Cycling Rate (CPM)	Gas Charge % of Rated Pressure	Fluid Pressure Cycling Limits % Rated Presuure Lower Limit Max	Cycling Limits % Rated Pressure Upper Limit Min	Temperature (°F ± 10 °F) Fluid	Temperature (°F ± 10 °F) Ambient Air	Leakage of Fluid to Gas Side (% Accumulator Volume) (See Note 5)	Leakage of Gas (% drop in Gage Pressure)
1	2,000	0.2 to 2	35	7	100	Note 7	Note 2	2	1
2	Gas Leakage Test	Gas Leakage Test	Paragraph 4.7.3.1						
3	50	Note 3	17	7	100	-65 °F (-54 °C)	Note 3	0.5	5
4	500	0.2 to 2	17	7	100	-40 °F (-40 °C)	Note 2	1	3
5A	2,500	3 to10	33	7	100	Note 7	Note 2	3	3
5B	7,500	3 to 10	33	7	100	Note 8	Note 2	3	3
6A	12,000	3 to 10	33	87	100	Note 7	Note 2	2	3
6B	37,500	3 to 10	33	87	100	Note 8	Note 2	2	3
7A	12,500	Optional	N/A Note 4	10 psi (70 kPa)	117	100 °F (38 °C)	Note 2 & 6	N/A	N/A
7B	500,000	Optional	N/A	7	100	Note 7	Note 2	N/A	N/A
7C	1,000,000	Optional	N/A Note 4	67	100	100 °F (38 °C)	Note 2	N/A	N/A

NOTES:

1. During all cycle tests, the gas side of the accumulators shall be lubricated with an amount of fluid equal to approximately 0.50% of accumulator volume. Fluid leakage shall be determined by draining fluid through the gas port without disassembling the accumulator. Gas pressure shall be determined at stabilized and identical temperature before each step af Table 1.
2. Ambient temperature shall be maintained such that the gas temperature equals or exceeds the fluid temperature at the end of each compression stroke.
3. The accumulators shall be charged to minimum rated fluid pressure. Accumulators shall be maintained in this condition for 24 h at the temperature specified in Step 3 of Table 1. The 50 cycles shall be fast discharged followed immediately by recharging with oil at the specified temperature. A 2 h minimum interval shall elapse between the end of each of the cycles, or until the unit and ambient temperature is stabilized.
4. The piston may be removed and an optional plug applied during high pressure chamber testing. The piston must be replaced during low pressure chamber testing to check the integrity of the piston on the separator. This test is intended to prove design of the accumulator shell construction and end cap construction. The rate of pressure build-up and the peak pressures shall be recorded at the start and the finish and at least 10 equally spaced intervals during the test. The pressure build-up rate shall be as specified in 3.4.8.
5. Be sure not to count the lubrication fluid on the gas chamber as leakage.
6. After completion of Step 6 in Table 1, the leakage tests specified in 4.7.3 shall be performed. After completion of these tests, the accumulator shall be disassembled and the accumulator piston removed. A new set of packing gland seals may be installed at this time. Step 7 of Table 1 will then be accomplished.
7. The temperature shall be the maximum operating temperature as specified in 3.4.10.
8. The temperature shall be 80% of the maximum operating temperature as specified in 3.4.10.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility of Inspection:

Unless otherwise specified in the procurement specification, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified, the supplier may utilize their own facilities or any commercial laboratory acceptable to the customer. The procuring activity reserves the right to perform any of the inspections set forth in this specification whenever it is deemed necessary to assure that the accumulator conforms to the prescribed requirements.

4.2 Classification of Tests:

The inspection and testing of the accumulators shall be classified as:

a. Qualification Test (4.4)
b. Acceptance Tests (4.5)

4.3 General Testing Requirements:

The accumulator shall be subjected to the qualification testing stated herein to demonstrate compliance with this specification. Acceptance of items under the qualification provisions specified herein shall not relieve the supplier of the responsibility to meet all other requirements of this specification.

4.4 Qualification Tests:

Two qualification samples shall be subjected to the testing as specified and in the order listed in Table 2.

TABLE 2 - Qualification Testing

Test	Required Paragraph	Test Method Paragraph	Unit A	Unit B
1. Acceptance Test		4.5	X	X
2. Fluid Immersion	3.4.9	4.7.5	X	
3. Volumetric Efficiency	3.4.7	4.7.6	X	
4. Separator Friction	3.4.2.3	4.7.4	X	X
5. Proof pressure	3.4.1.4	4.7.1	X	X
6. Leakage	3.4.4	4.7.3	X	X
7. Endurance Cycling	3.4.5	4.7.7	X	
8. Impulse	3.4.8	4.7.8	X	
9. Vibration	3.4.11	4.7.9		X
10. Additional Testing	3.4.12	4.7.10		X
11. Burst	3.4.1.5	4.7.11		X
12. Fragmentation	3.4.12	4.7.10	X	