SAE Aerospace
An SAE International Group

AEROSPACE RECOMMENDED PRACTICE

SAE ARP4553A

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Superseding ARP4553

(R) Aerospace - Accumulator, Hydraulic, Self-Displacing

RATIONALE

ARP4553 has been updated to Revision A for the following reasons:

a. New and revised technical and test requirements have been introduced

b. The references called up in the document have been updated

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

TABLE OF CONTENTS

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1. SCOPE

1.1 Purpose

This SAE Aerospace Recommended Practice (ARP) is intended to provide design and qualification requirements for self-displacing hydraulic accumulators.

These requirements are intended be included in the Procurement Specification for the accumulator. Those requirements identified by the use of “shall” are considered to be essential requirements; those requirements identified by the use of “should” are considered to be optional requirements for inclusion in the Specification at the discretion of the Purchaser.

In addition, test methods for production acceptance and qualification purposes are provided.

The accumulator is intended for use in military aerospace hydraulic systems with rated pressures of up to 8000 psi (55 158 kPa) and of the following types as specified in AS5440:

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

The accumulator is also intended for use in commercial aerospace and helicopter hydraulic systems.

1.2 Classification

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

a. Class 1500 Hydraulic system, rated system pressure 1500 psi (10 342 kPa)

b. Class 3000 Hydraulic system, rated system pressure 3000 psi (20 684 kPa)

c. Class 4000 Hydraulic system, rated system pressure 4000 psi (27 579 kPa)

d. Class 5000 Hydraulic system, rated system pressure 5000 psi (34 473 kPa)

e. Class 8000 Hydraulic system, rated system pressure 8000 psi (55 158 kPa)

In addition to the above system pressure classification, the rated return pressure shall be stated or classified for the particular application. The basic classification number above has a dash number added to specify the return pressure as follows:

Each 100 psi (689 kPa) shall be designated by a two digit number, for example:

- 01 Hydraulic system, rated return pressure 100 psi (689 kPa)

Each additional 100 psi (689 kPa) will be a corresponding increase in dash number, for example:

- 05 Hydraulic system, rated return pressure 500 psi (3447 kPa)

1.2.1 Accumulator Identification

Each accumulator shall be identified as Class XXXX – YY, where:

a. XXXX is the rated system pressure

b. YY is the rated return pressure

For example. an accumulator that is identified as Class 3000-10 means that it is to be used in a hydraulic system where:

a. The rated system pressure is 3000 psi (20 684 kPa)

b. The rated return pressure is 1000 psi (6894 kPa)

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification 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.

AS1241	Fire Resistant Phosphate Ester Hydraulic Fluid for Aircraft
ARP1288	Placarding of Aircraft Hydraulic Equipment to Identify Phosphate Ester Fluid Compatibility
ARP1383	Impulse Testing of Aerospace Hydraulic Actuators, Valves, Pressure Containers, and Similar Fluid System Components
AS4059	Aerospace Fluid Power - Cleanliness Classification for Hydraulic Fluids
ARP4150	Procedure for Inspection of Inservice Airborne Accumulators for Corrosion and Damage
ARP4386	Terminology and Definitions for Aerospace Fluid Power, Actuation and Control Technologies
AIR4543	Aerospace Hydraulics and Actuation Lessons Learned
AS4716	Gland Design, O-ring and Other Elastomeric Seals
AS4941	Aerospace - General Requirements for Commercial Aircraft Hydraulic Components
AS5440	Hydraulic Systems, Aircraft, Design and Installation, Requirements for
AS5857	Gland Design, O-ring and Other Elastomeric Seals, Static Applications
AS8775	Hydraulic System Components, Aircraft and Missiles, General Specification for

2.1.2 ASTM Publications

Available from ASTM International, 100 Bar Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM E 1417	Liquid Penetrant Examination
ASTM E 1444	Standard Practice for Magnetic Particle Examination

2.1.3 US Government Publications

Available from the Document Automation and Production Service (DAPS), 5450 Carlisle Pike Building. 09, P.O. Box 2020, Mechanicsburg, PA 17055-0788, Tel: 717-605-2362, http://assist.daps.dla.mil/quicksearch.

MIL-STD-810 Environmental Test Methods and Engineering Guidelines

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Aerospace Technical Report.

2.2.1 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.

ARP4378 Accumulators, Hydraulic, Cylindrical, Aircraft, Maintenance Free, Factory Precharged

ARP4379 Accumulator, Hydraulic, Cylindrical, Piston Separated

2.2.2 FAR Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

Order 8300.10. Appendix 3, Bulletin Type HBAW 02-01B: Flight Standards Handbook Bulletin for Airworthiness. Maintenance of Pressure Cylinders in use as Aircraft Equipment.

2.3 Definitions

Refer to ARP4386 for general hydraulic system terms that are used in this Aerospace Recommended Practice.

SELF-DISPLACING HYDRAULIC ACCUMULATOR: A self-displacing accumulator is a tandem type piston accumulator that is designed to maintain a constant volume of active fluid in the hydraulic circuit. Figure 1 illustrates the accumulator concept.

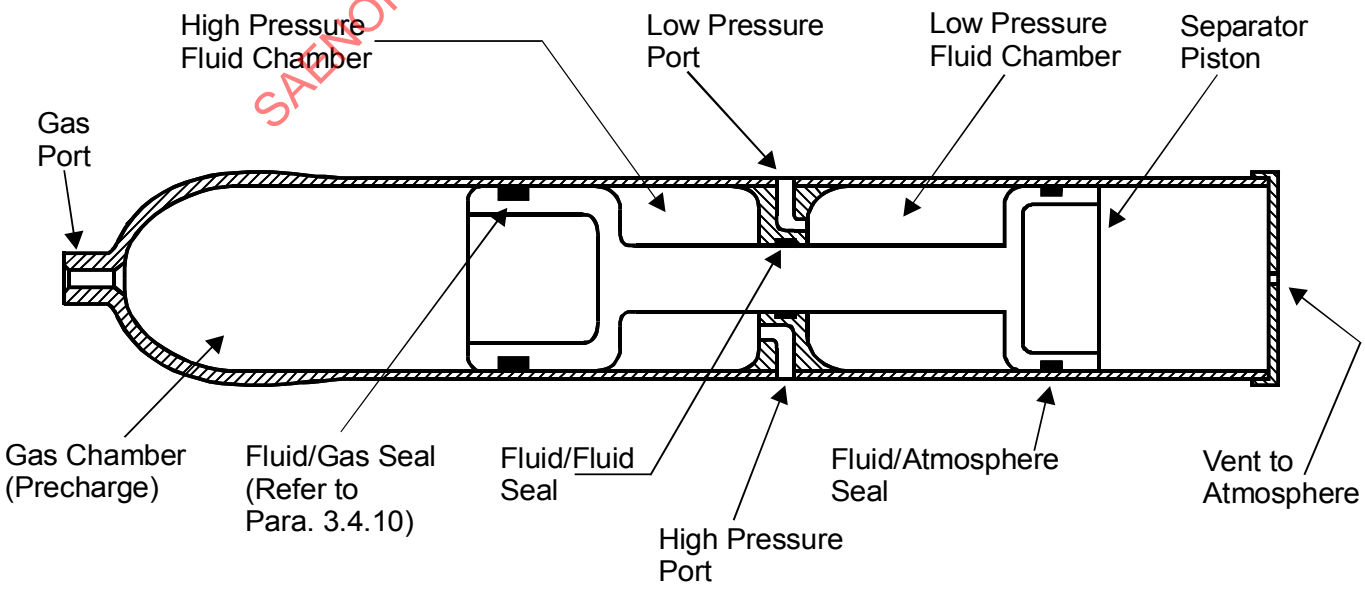

FIGURE 1 - ACCUMULATOR SCHEMATIC DIAGRAM

A self-displacing accumulator essentially comprises an accumulator combined with a pressurized reservoir. The gas precharge displaces the tandem piston and the low pressure fluid chamber is filled with fluid from the low pressure side of the hydraulic system. When the system is pressurized, the high pressure fluid chamber is filled with fluid from the high pressure side of the hydraulic system and the gas compressed. This results in the separator moving and causes fluid from the low pressure chamber to be returned to the low pressure side. With the system working, any fluid then withdrawn from the high pressure side is simultaneously replaced on the low pressure side, thus maintaining a constant volume of fluid both in the system and the accumulator.

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

VESSEL: The vessel is the portion of the accumulator that contains the pressurized hydraulic fluid and gas and separates both from the atmosphere.

GAS PORT: The gas port is the connection in the accumulator where the gas precharge is supplied into the accumulator.

HIGH PRESSURE PORT: The high pressure port is the connection in the accumulator where high pressure fluid is supplied into/out from the accumulator.

LOW PRESSURE PORT: The low pressure port is the connection in the accumulator where fluid from low pressure side of the hydraulic system is supplied into/out from the accumulator.

RATED SYSTEM PRESSURE: The rated system pressure is the nominal steady state pressure that is achieved:

a. From the output pressure of the hydraulic system pumps - for an accumulator used in the power generation system

or

b. Due to thermal effects at the point of the actuation of a thermal relief valve - for an accumulator used to provide stored energy (for example, a brake accumulator)

RATED RETURN PRESSURE: The rated return pressure is the maximum pressure that can be generated in the hydraulic system return network due to fluid returning to the hydraulic reservoir as a result of the operation of hydraulic services.

MAXIMUM RATED PRESSURE: The maximum rated pressure is the maximum steady state pressure that could be generated in the accumulator due to, for example, a failure in the power generation system such that the system pressure reaches the system relief pressure, or a sustained high transient pressure that occurs during the operation of the system.

NOTE: The maximum rated pressure and the rated system pressure could be the same for an accumulator that is used to provide stored energy. For this type of application, the value of the maximum rated pressure/rated pressure would the thermal relief valve opening pressure.

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

SWEPT (EXPELLED) OIL VOLUME: The swept (expelled) oil volume is the fluid that is expelled from the accumulator fluid port when the accumulator separator is moved from the position where the fluid stored in the accumulator is at the rated pressure and at a prescribed temperature to being fully bottomed against the fluid end of the accumulator. It should be noted that the swept oil volume is a function of the precharge pressure.

MAXIMUM SWEPT OIL VOLUME: The maximum swept oil volume is the maximum volume of hydraulic fluid that can be stored in the accumulator at the maximum pressure (either the thermal relief pressue or the system relief pressure) at cold temperature. To determine the maximum swept volume, the volume at both conditions must be calculated. The difference in gas volume between the precharge volume and the smaller of the proof pressure volume and the cold temperature relief pressure volume is the maximum swept oil volume. Real gas laws, including compressibility, should be used to calculate these volumes.

VOLUMETRIC EFFICIENCY: The volumetric efficiency is the capability of the accumulator to expel the volume of hydraulic fluid with which it has been filled as the hydraulic pressure is reduced from the maximum pressure to 0 psi (0 kPa). This is expressed as an efficiency using the equation:

Volumetric efficiency = (Expulsion Volume/Filling Volume) x 100%

STATIC LEAKAGE: Static leakage is the fluid or gas leakage with the unit statically pressurized.

DYNAMIC LEAKAGE: Internal leakage, across the separator piston fluid/gas, fluid/fluid and fluid/atmosphere seals, which occurs during operation (cycling)

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

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

ENDURANCE TEST: The endurance test is the test that is intended to determine the wear characteristics of the accumulator in order to determine if it will operate satisfactory throughout its operational lifetime. The endurance test comprises the realistic simulation of the operation of the accumulator over the life that has been declared for it, using the appropriate test rig.

FATIGUE TEST: The fatigue test is the test that is intended to determine the fatigue strength of the accumulator. The fatigue test comprises the repeated application of pressure impulses, using the appropriate test rig.

PURCHASER: The Purchaser is the organization that is responsible for providing the Procurement Specification for the accumulator. The Purchaser is typically an aircraft manufacturer, a modification center, or a system supplier (hydraulic or braking systems, for example).

SUPPLIER: The Supplier is the manufacturer of the accumulator who will be responsible for the design, production and qualification of the component.

PROCUREMENT SPECIFICATION: The Procurement Specification is the document that includes the following:

a. Specific performance and technical criteria

b. Acceptance and qualification test requirements

c. Reliability requirements

d. Quality requirements

e. Packaging requirements

3. TECHNICAL REQUIREMENTS

3.1 General

Self-displacing hydraulic accumulators that are intended to be used in military flight vehicle hydraulic systems shall conform to the general hydraulic components' requirements of AS8775.

Self-displacing hydraulic accumulators that are intended to be used in commercial aircraft or helicopter hydraulic systems shall conform to the general hydraulic components' requirements of AS4941.

This document shall govern whenever there is a conflict between any requirements contained within it and the above referenced specifications.

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 6.

3.3 Functional Requirements

3.3.1 Dynamic Performance Requirements

3.3.1.1 General

The Purchaser should identify if there are any important accumulator dynamic behavior requirements depending on the accumulator design and the hydraulic system characteristics, such as:

a. Response rate for filling the accumulator

b. Response rate for discharging the accumulator

c. Optimization of charge pressure/accumulator volumes

d. Performance at operating temperature extremes

The Purchaser and the Supplier should work together to ensure that the accumulator will meet these requirements. If required, the Supplier should provide a detailed hydraulic model to be used in the Purchaser's hydraulic simulation program to ensure that the accumulator is compatible with the hydraulic system dynamic operation.

3.3.1.2 Maximum Pressure Limitation

The design of the accumulator, including, but not limited to, the effects of friction and inertia of moving elements and flow passage restrictions, shall be such that it can withstand the pressues generated by any combination of dynamic flow rate and fluid temperature permitted by this specification.

3.3.1.3 Extreme Pressure Rise or Decay Rates

The Supplier and the Purchaser should determine if there are any necessary application-specific detail requirements related to extreme pressure rise or decay rates at the interface between the system and the accumulator, considering for example:

a. High pressure within the accumulator due to inertia of the moving parts and resistance within its fluid passages

b. High pressure within the accumulator due to inertia of the fluid in system return circuit

c. Potential for cavitation within the low-pressure section of the accumulator

d. Responsiveness of the accumulator during rapid pressure decay at the pressure port

3.3.2 Precharge Pressure

The Procurement Specification shall specify the accumulator required precharge pressure for the corresponding temperature.

3.3.3 Swept (expelled) Oil Volume

The Procurement Specification shall specify the swept oil volume (expelled oil volume) of the high pressure and low pressure chambers of the accumulator. The volumes of these chambers shall be equal.

3.3.4 Maximum Swept Oil Volume

The Procurement Specification shall state the maximum rated pressure (either the system relief valve or the dedicated thermal relief valve pressure, as applicable) in order to enable the maximum swept oil volume to be determined.

3.3.5 Volumetric Efficiency

The volumetric efficiency shall be in excess of 95% of the total oil volume of the fluid stored in the accumulator fluid chambers at the rated pressure. The expelled volume shall be as specified in 3.3.3.

3.3.6 Separator Friction

The hydraulic fluid pressure at which the separator begins to move shall not be greater than 150 psid (1034 kPad) when the pressure is varied at the high pressure port within the rated pressure of 3.6.1.1. This condition shall be met with the gas chamber precharged per 3.3.2 and the low pressure chamber pressurized to rated return pressure per 3.6.1.2. This requirement shall be met over the total stroke of the accumulator, and over the specified temperature range.

3.3.7 Leakage Requirements

3.3.7.1 Gas Static Leakage

Each accumulator shall have no external leakage of gas over the lifetime of the application.

Each accumulator shall have an internal leakage of gas of not more than specified below, or as specified by the Procurement Specification, over the lifetime of the application:

a. 0.5 ml per hour for accumulators with precharge gas volumes up to 50 in^3 (0.8 L)

b. 1.0 ml per hour for accumulators with precharge gas volumes from 51 to 200 in^3 (0.8 to 3.3 L)

c. 3.0 ml per hour for accumulators with precharge gas volumes from 201 to 400 in^3 (3.3 to 6.6 L)

3.3.7.2 Gas Dynamic Leakage

The accumulator internal dynamic gas leakage shall be less than 0.5% of the gas volume for each 500 precharge/discharge cycles as measured in the change in the gas precharge pressure.

3.3.7.3 Hydraulic Fluid Static Leakage

An accumulator shall have no external static leakage at the rated pressures specified over the lifetime of the application.

Internal leakage shall not exceed two drops in 1 hour or as specified in the Procurement Specification, for new build.

The Procurement Specification should stated the maximum internal leakage degradation over the lifetime of the application.

3.3.7.4 Hydraulic Fluid Dynamic Leakage

Leakage shall not exceed one drop per 100 precharge/discharge cycles per seal or as specified in the Procurement Specification, for new build.

The Procurement Specification should stated the maximum internal leakage degradation over the lifetime of the application.

3.3.8 Operating Temperature

3.3.8.1 Ambient Temperature

The accumulator shall be designed to function correctly over the range of ambient temperature of -65 to +194 °F (-54 to +90 °C) or as specified in the Procurement Specification.

3.3.8.2 Hydraulic Fluid Temperature

The accumulator shall be designed to function correctly over the range of hydraulic fluid temperature as specified in 1.1 for Military Type I or Type II systems. For commercial applications, accumulator shall be designed to function correctly over the range of hydraulic fluid temperature of -65 to +275 °F (-54 to +135 °C) or as specified in the Procurement Specification.

3.4 Construction

3.4.1 Ports

3.4.1.1 Hydraulic Fluid Ports

Two hydraulic fluid ports shall be provided. One port shall be connected to the high pressure chamber and the other to the low pressure chamber. The Procurement Specification shall define the type and size of the fluid ports. It is recommended that the two fluid ports be different sizes to prevent inadvertent cross connection on the installation.

The passages from the fluid ports into the accumulator structure should be designed to give a minimum restriction to hydraulic fluid flow.

3.4.1.2 Gas Port

The Procurement Specification shall define the type and size of the gas port.

3.4.2 Vent

If the vent is open to atmosphere, means shall be provided to prevent the ingress of external contaminants into the accumulator.

3.4.3 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).

3.4.4 Fragmentation

If required by the Procurement Specification, the accumulator, when struck by gunfire as specified in 6.6.1, shall remain in one piece. The greatest dimension of the opening (cut or tear) created by the projectile shall not exceed the dimensions of the hole (cut) created by the projectile by more than 3.0 in (76.2 mm) in any direction.

3.4.5 Materials and Processes

The general requirements for materials and processes used in the design and fabrication of the accumulator components shall be in accordance with AS4941 or AS8775, as applicable.

3.4.6 Corrosion Resistance

All metals shall possess corrosion resistance characteristics or shall be protected by use of permanent coatings to resist corrosion, in accordance with AS4941 or AS8775, as applicable.

Hydraulic fluid contacting interior surfaces of the accumulator shall not be considered as corrosion protection.

3.4.6.1 Internal Surfaces

All internal surfaces exposed to the precharge gas shall be coated with a film of oil that is compatible with the precharge gas and the piston seals.

3.4.6.2 External Surfaces

The external surfaces of the accumulator shall comply with the corrosion protection requirements as specified in AS4941 or AS8775 (as applicable) or be painted with a suitable primer and top coat, which meets the humidity, fungus, sand and dust, and salt fog requirements as specified in AS4941 or AS8775. The fluid bosses' spot faces and threads shall be free of primer and paint.

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 as specified in 3.4.9 and shall meet the requirements stated in the applicable specifications.

3.4.7 Electro-conductive Bonding

The accumulator should have a facility to enable it to have an effective electro-conductive bond to the airframe.

The value of the the electrical resistance between any point on the mounting facilities and specified points on the accumulator should be specified in the Procurement Specification.

3.4.8 Gas Precharge

The Procurement Specification shall specify the gas and the pressure that is used for the gas precharge.

NOTES:

1. The gas precharge shall be an inert gas only.

2. The gas precharge pressure shall be specified at a specific temperature such that when the high pressure fluid chamber is filled with fluid per 3.4.9, and stabilized at that temperature, the gas pressure will be at the rated system pressure of 3.6.1.

3.4.9 Hydraulic Fluid

The Procurement Specification shall specify the hydraulic fluid to be used for the application.

3.4.9.1 Hydraulic Fluid Cleanliness

The Procurement Specification shall state the hydraulic fluid cleanliness limits for:

a. Aircraft at new build

b. In-service (typical and maximum)

3.4.10 Seals

The seals contained within the accumulator shall be compatible with the operating fluid as specified in 3.4.9 and the operating temperature as specified in 3.3.8.2. Unless otherwise specified by the Procurement Specification, the seal gland design shall be per AS4716 for dynamic applications and AS5857 for static applications.

NOTE: In Figure 1, 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.

3.5 Installation Requirements

3.5.1 Dimensions and Mounting Requirements

The dimensions and mounting provisions of the accumulator shall conform to the requirements of the Procurement Specification.

3.5.2 Marking

3.5.2.1 General

The nameplate and part number shall be in accordance with AS4941 or AS8775 as applicable.

The requirements of ARP1288 shall also be incorporated if the hydraulic fluid used is according to AS1241.

3.5.2.2 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.

3.5.2.3 Nameplate

Each accumulator shall be furnished with a nameplate that shall include the following information as a minimum:

a. Accumulator, Hydraulic, Self-Displacing

b. ARP Classification Number as per 1.2, for example: “ARP4553 Class 3000-05”

c. Manufacture Date

d. Manufacturer’s Serial Number

e. Manufacturer’s Name

f. Manufacturer’s Part Number

g. Oil Swept Volume

h. Operating Fluid

3.6 Strength

The strength requirements shall be in accordance with AS4941 or AS8775, as applicable.

3.6.1 Rated Pressure

The Procurement Specification shall state the rated pressure for the high and low pressure chambers, as classified in 1.2.

3.6.1.1 High Pressure Chamber

The high pressure chamber shall be designed to meet the requirements for the rated pressure of its respective classification in 1.2.

3.6.1.2 Low Pressure Chamber

The low pressure chamber shall be designed to meet the requirements for the rated return pressure of its respective classification in 1.2.

3.6.2 Proof Pressure

NOTES:

1. The accumulator shall be designed to ensure that it can sustain the proof pressure being applied at the maximum rated temperature of the accumulator for 5 minutes minimum.

2. For production, the proof pressure should be applied at the room temperature for 5 minutes.

3.6.2.1 Separator Proof Pressure

The separator shall be designed to withstand a differential pressure of two times the rated pressure per 3.6.1.1 in the high-pressure chamber and per 3.6.1.2 in the low pressure chamber.

3.6.2.2 Vessel Proof Pressure

The high and low pressure sides of the accumulator shall be designed to withstand a burst pressure of four times the rated pressure for the high and low pressure sides respectively.

a. Three times the rated pressure for the high and low pressure sides respectively for commercial applications

b. Two times the maximum rated pressure for the high and low pressure sides respectively for military applications

3.6.3 Burst Pressure

3.6.3.1 Separator Burst Pressure

The separator shall be designed to withstand a differential pressure of four times the rated pressure per 3.6.1.1 in the high pressure chamber and per 3.6.1.2 in the low pressure chamber.

The accumulator shall be designed to ensure that the separator can sustain the burst pressure being applied at the maximum rated temperature of the accumulator for 5 minutes minimum.

3.6.3.2 Vessel Burst Pressure

The high and low pressure sides of the accumulator shall be designed to withstand a burst pressure of

a. For commercial applications, four times the maximum rated pressure for the high and low pressure sides respectively

b. For military applications, four times the maximum rated operating pressure for the high and low pressure sides respectively

The accumulator shall be designed to ensure that the vessel can sustain the burst pressure being applied at the maximum rated temperature of the accumulator for 5 minutes minimum.

3.6.4 Fatigue

Unless specified in the Procurement Specification, the accumulator shall be designed to withstand pressure impulse cycling as specified in Table 1.

TABLE 1 - IMPULSE CYCLING

Step Number	Number of Cycles	Fluid Temperature	Hydraulic Fluid Pressure Lower Limit Rated Maximum	Hydraulic Fluid Pressure Upper Limit Rated Minimum
1	12 500	50-90 °F (10-32 °C)	10 psi (69 kPa)	117% of Rated Pressure
2	500 000	275 °F min (135 °C min)	7% of Rated Pressure	Rated Pressure
3	1 000 000	50-90 °F (10-32 °C)	67% of Rated Pressure	Rated Pressure

3.6.5 Vibration

The accumulator shall be designed to withstand the vibration levels as stated in 6.5.3, or as stated in the Procurement Specification.

3.6.6 Maximum Wrenching Torque

The accumulator should have ample strength and rigidity to withstand 250% of the maximum wrench torque required for making the tubing connections without any permanent deformation of the accumulator.

3.7 Weight

The accumulator weight shall be the minimum weight consistent with the performance and requirements of this ARP and the Procurement Specification.

3.8 Environmental Requirements

Unless otherwise specified in the Procurement Specification, the accumulator should comply with the following environmental requirements as detailed in the applicable paragraphs of AS4941 or AS8775:

a. Humidity

b. Fluids Susceptibility

c. Fungus

d. Salt Spray

e. Sand and Dust*

f. Waterproofness*

g. Icing*

*If the vent is open to atmosphere

3.9 Operational and Safety Requirements

3.9.1 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 minimum shelf life of ten years after delivery.

3.9.2 Reliability

The Procurement Specification should specify the required reliability for the application of the accumulator.

The following documents should be reviewed, and lessons incorporated during the design process in order to achieve the best possible reliability for the accumulator:

a. AIR4543 to determine the lessons learned and thereby minimize the possibility of in-service problems

b. ARP4150 should be reviewed for in-service history and inspection requirements for accumulators

In addition, in-service history of similar components should be reviewed to determine if any lessons-learned can be incorporated into the accumulator design or qualification testing.

3.9.3 Endurance

Unless otherwise specified in the Procurement Specification, the accumulator shall be designed to withstand endurance cycling as specified in Table 2.

TABLE 2 - ENDURANCE CYCLING

Step	Total Cycles	Cycle Rate (CPM)	Gas Precharge % of Rated Pressure	Fluid Pressure Cycling Limits % Rated Pressure Lower Limit Max	Cycling Limits % Rated Pressure Upper Limit Min	Fluid Temp (°F (°C))	Ambient Air Temp (°F (°C))	Leakage of Fluid to Gas Side (% Accumu-lator Volume	Leakage of Gas (% Drop In Gage Pressure)
1	2000	0.2 to 2	35	7	100	Note 2	Note 3	2	1
2	Gas Leakage Test	Not applicable	Paragraph 5.2.4.1						
3	50	Note 4	17	7	100	-65 (-54)	Note 4	0.5	5
4	500	0.2 to 2	17	7	100	-40 (-40)	Note 3	1	3
5A	2500	3 to 10	33	7	100	Note 2	Note 3	3	3
5B	7500	3 to 10	33	7	100	Note 5	Note 3	3	3
6A	12 000	3 to 10	33	87	100	Note 2	Note 3	2	3
6B	37 500	3 to 10	33	87	100	Note 5	Note 3	2	3

NOTES:

1. Table 2 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.

2. The temperature shall be the maximum operating temperature as specified in 3.3.8.2.

3. The ambient temperature shall be maintained such that the gas temperature equals or exceeds the fluid temperature at the end of each compression stroke.

4. The accumulator shall be pressurized to the rated pressure. The accumulator shall be maintained in this condition for 24 hours at the temperature specified in Step 3 of Table 2. The 50 cycles shall be fast discharged (equivalent to that resulting from a quick operating of a directional control valve of comparable port size) followed immediately by normal recharge rate with hydraulic fluid at the specified temperature. A 2 hour minimum interval, during which time the accumulator is maintained at the specified temperature, shall elapse between each of the 50 cycles, or until the accumulator and the ambient temperature is stabilized. The 50 cycles shall be conducted consecutively.

5. The temperature shall be 80% of the maximum operating temperature as specified in 3.3.8.2.

3.9.4 Safety

The Procurement Specification shall specify the required safety objectives for the application of the accumulator, including the failure rates for the following events:

a. Loss of accumulator gas precharge pressure

b. External leakage

c. Excessive internal leakage

d. Jamming of the separator

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

The requirements for the Supplier and the Purchaser shall be in accordance with the applicable requirements of AS4941 or AS8775.

4.2 Physical Defect Inspection

All detail parts of the accumulator shall be subjected to Non-Destructive Inspection prior to assembly. All magnetic highly stressed parts shall be subjected to magnetic particle inspection in accordance with ASTM E 1444. Nonmagnetic highly stressed parts shall be subjected to liquid penetrate inspection in accordance with ASTM E 1417. Cracks or other injurious defects disclosed by the inspection shall be cause for rejection.

In process inspection of the separator shall also be performed. There shall be no evidence of leakage, cracks or other injurious defects.

4.3 Classification of Tests

For the purpose of demonstrating compliance of self-displacing hydraulic accumulators with this ARP and the applicable Procurement Specification, two distinct test programs should be conducted, hereinafter referred to as follows:

a. Acceptance Tests (see 5.)

b. Qualification Tests (see 6.)

Table 3 provides the listing of the tests for the self-displacing hydraulic accumulators, together with the nomination of the test accumulators that the tests should be conducted on.

TABLE 3 - TEST PROGRAM

Requirement	Test Paragraph	All Accumulators	Test #1 Accumulator	Test #2 Accumulator
First Article Inspection	4.5		X	X
Production Acceptance Tests	5	X	X	X
Immersion Test	6.2		X	
Functional Tests	6.3		X	
Volumetric Efficiency	6.3.1		X	
Endurance Test	6.3.2		X	
Environmental Tests	6.4			
Low temperature	6.4.1.1		X	
Intermediate temperature	6.4.1.2		X	
High temperature	6.4.1.3		X	
Humidity	6.4.2		X	
Fluids susceptibility	6.4.3		X	
Fungus	6.4.4		X	
Salt spray	6.4.5		X	
Sand and dust	6.4.6(2)		X	
Waterproofness	6.4.7(2)		X	
Icing	6.4.8(2)		X	
Structural Tests	6.5			
Proof pressure	6.5.1	X	X(3)	X
Fatigue	6.5.2			X
Vibration	6.5.3		X	
Handling loads	6.5.4			X
Wrench loads	6.5.5			X
Destructive Tests	6.6			
Burst pressure	6.6.1(4)			X
Fragmentation	6.6.2(5)			
Post Qualification Tests	6.7			
Acceptance tests	6.7.1		X	
Disassembly and inspection	6.7.2		X	

NOTES:

1. This table assumes that all the tests listed in Section 6 will be conducted on the test accumulators. If not all the tests are required, the table can be adapted as required.

2. Only required if the accumulator vent is open to atmosphere.

3. The proof test of the accumulator separator shall be conducted on Test #1 Accumulator.

4. The burst test is to follow the fatigue test.

5. The test may be conducted on the specimen that has been subjected to the fatigue and burst test or on another specimen.

6. Tests conducted in 6.2 and 6.3 can be conducted on Test #2 Accumulator if time scales and/or availability of equipment are critical.

4.4 Test Stand Requirements

These shall be in accordance with AS4941.

NOTE: AS4941 contains tolerances' requirements for steady state test conditions, including temperature and pressure.

4.4.1 Test Medium

The hydraulic fluid test medium shall be the system hydraulic fluid.

The gas test medium shall be that as used for the application.

4.5 First Article Inspection

The First Article Inspection should consist of the examinations specified in 4.5.1 and the tests specified in 5.

4.5.1 First Article Samples

The Supplier should make available at least one hydraulic accumulator for review by the Purchaser's quality organization. The sample(s) should be representative of the design and construction, workmanship, integral components and materials to be used during production.

4.5.2 First Article Inspection Report

Upon completion of the First Article Inspection, the Purchaser's quality organization should submit to the Purchaser the following:

a. The results of the inspection and the test programs

b. The recommendation if the Qualification Test Program can commence or not.

4.5.3 Rejection

Failure of any hydraulic accumulators to successfully comply with any of the requirements of the First Article Inspection or quality conformance inspection should be the cause for rejection of that accumulator design.

5. ACCEPTANCE TESTS

Each accumulator submitted for delivery under a Procurement Contract should be subjected to the following acceptance test requirements as a minimum, in the order listed

a. Visual and dimensional examinations (see 5.1)

b. A test program to determine product conformance to the dimensional, workmanship, functional and performance requirements of this ARP and the Procurement Specification. The test program is specified in 5.2.

The tests shall comprise the following:

a. Proof pressure (see 5.2.2)

b. Cycling (see 5.2.3)

c. Leakage test (see 5.2.4)

d. Separator friction (see 5.2.5)

e. Electro-conductive bonding - if required (see 5.2.6)

5.1 Examination of the Product

Prior to testing, each accumulator should be inspected for quality of workmanship and to determine compliance with this ARP and referenced Procurement Specifications and drawings. Inspection records should be retained by serial number so that failure and reliability studies may be conducted using these records as reference. Any defective parts found during the inspection should be cause for rejection of the accumulator.

5.2 Test Program

5.2.1 General

All tests shall be conducted at ambient and fluid temperature of 70 °F ± 10 °F (21 °C ± 5 °C). The fluid cleanliness shall be to AS4059 Class 6 maximum throughout these tests, unless otherwise specified in the Procurement Specification.

5.2.2 Proof Pressure

The accumulator shall be proof pressure tested as stated below. There shall be no leakage of fluid or permanent deformation or failure in any part of the accumulator. The pressure shall be applied at a maximum rate of 25 000 psi/min (172 MPa/min).

5.2.2.1 Vessel High Pressure Chamber

With the separator in approximately mid position, completely fill the high pressure fluid and gas chambers with hydraulic fluid and plug the gas port. With the low pressure port open, fluid pressure shall be applied at the high pressure fluid port until a pressure per 3.6.2.2 is obtained and maintained for 5 minutes.

5.2.2.2 Vessel Low Pressure Chamber

With the high pressure fluid port and the gas port open to atmosphere completely fill the low pressure chamber with fluid and apply pressure to the low pressure port until a pressure per 3.6.2.2 is obtained and maintained for 5 minutes.

5.2.2.3 Separator Proof Pressure

a. With the accumulator mounted in a vertical position and with the gas port down and the gas and low pressure ports open to the atmosphere, the accumulator separator shall withstand a fluid pressure per 3.6.2.1 applied at the high pressure fluid port for 2 minutes without leakage or damage.

b. With the accumulator mounted in a vertical position and with the vent port down and the gas and high pressure ports open to the atmosphere, the accumulator separator shall withstand a fluid pressure per 3.6.2.2 applied at the low pressure fluid port for 2 minutes without leakage or damage.

c. With the accumulator mounted in a vertical position and with the high pressure fluid port down and the port open to the atmosphere, the accumulator separator shall withstand a fluid pressure per 3.6.2.1 applied to the gas port for 2 minutes without leakage or damage.

5.2.3 Cycling

The accumulator should be cycled for a minimum of 25 full stroke cycles or as specified in the Procurement Specification. The cycling should be accomplished with:

a. The gas chamber precharged per 3.3.2

b. The low pressure chamber maintained at rated return pressure per 3.6.1.2

c. The pressure increased at the high pressure port up to the rated pressure per 3.6.2.1

5.2.4 Leakage Test

5.2.4.1 Gas Leakage

With the accumulator mounted in a vertical position with gas port up (unless otherwise specified in the Procurement Specification), and the high pressure port connected to a calibrated sight tube or cylinder open to atmosphere, gas pressure shall be applied to the gas port at both 7% and 67% of rated pressure. There shall be no evidence of external leakage. This can be detected by the use of bubble-detecting fluid at the gas port. Internal leakage shall be no greater than specified in 3.3.7.1.

A recommended test setup (Figure 2) and a method to measure gas leakage is as follows:

a. Partially fill the fluid side of the accumulator with fluid and connect a tube to the outlet port. Connect the other end of the tube to a calibrated sight tube or cylinder.

b. Place the accumulator in a vertical position with the fluid side down.

c. Charge the gas side of the accumulator to the required pressure.

d. Adjust the fluid level such that the level is in the calibrated portion of the sight glass that will permit measurement of air leakage by a rise in the fluid level.

e. Obtain the required test temperature

f. The fluid volume displaced during the specified test time will be a measure of the gas leakage.

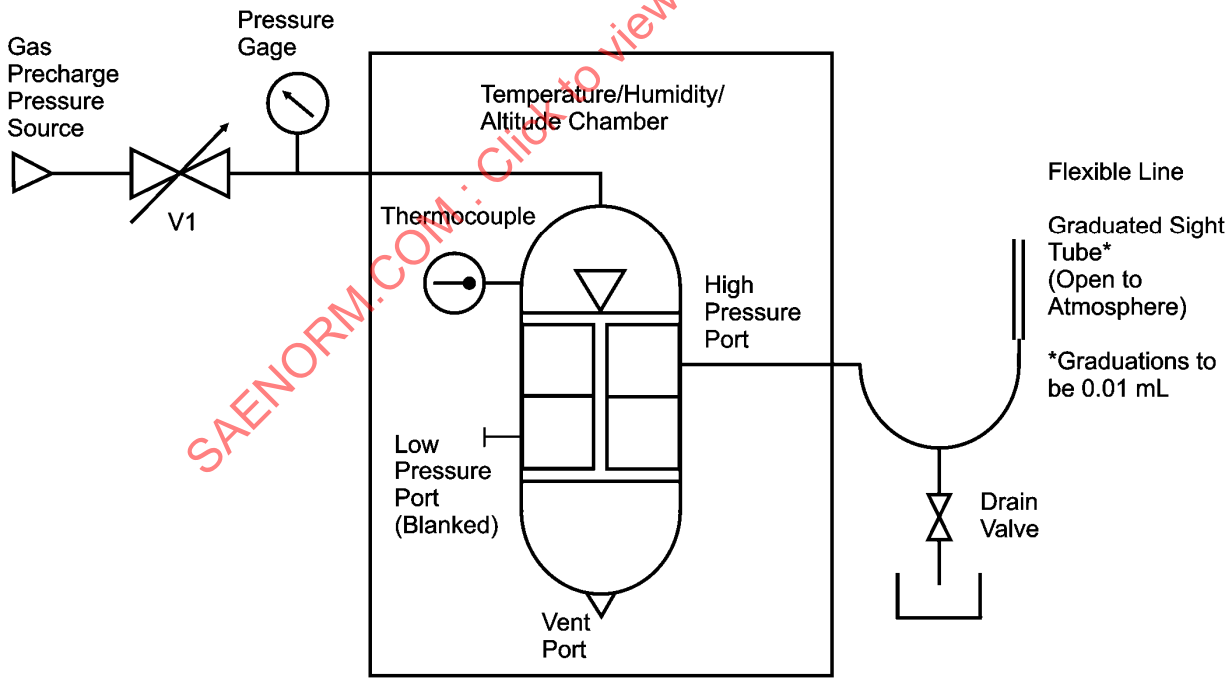

FIGURE 2 - RECOMMENDED GAS LEAKAGE TEST SETUP

5.2.4.2 Hydraulic Fluid Leakage

5.2.4.2.1 High Pressure Side

With the accumulator mounted in a vertical position with the gas port down and open to the atmosphere, rated pressure per 3.6.2.2 shall be applied to the high pressure fluid port for a period of 1 hour, or as specified in the Procurement Specification. There shall be no evidence of external leakage. Internal Leakage shall not exceed leakage per 3.3.7.3.

5.2.4.2.2 Low Pressure Side

With the accumulator mounted in a vertical position with the vent port down and open to the atmosphere, rated pressure per 3.6.2.2 shall be applied to the low pressure fluid port for a period of 1 hour, or as specified in the Procurement Specification. There shall be no evidence of external leakage. Internal Leakage shall not exceed leakage per 3.3.7.3.

5.2.5 Separator Friction

With the accumulator gas chamber precharged per 3.3.1, and pressure maintained at the low pressure port per 3.6.1.2, pressure shall be gradually increased at the high pressure port until the separator is approximately in mid position. Gradually decrease the pressure at the high pressure port until the separator begins to move. The differential pressure at which the separator begins to move should be per 3.3.5.

NOTE: This test should be repeated with the separator at various position of the stroke to ensure compliance with this requirement over the full stroke.

5.2.6 Electro-Conductive Bonding

If required by the Procurement Specification, the electrical resistance between any point on the mounting facilities and specified points on the accumulator shall be measured (for example, at the fluid connection). The resistance shall not be greater than 300 milliohms, unless otherwise stated in the Procurement Specification.

5.3 Preparation for Delivery

After testing, the accumulator shall be prepared for delivery (including packaging and marking) in accordance with AS4941 or AS8775, as applicable.

6. QUALIFICATION TESTS

6.1 General

Qualification tests, for the purposes of checking whether the accumulator design conforms to the requirements of this ARP and the Procurement Specification, should consist of the tests specified herein.

If tests additional to those detailed in Table 3 are required, then the Procurement Specification should:

a. Provide the test requirements

b. Define which test accumulator(s) shall be used for these additional tests

The qualification tests should be conducted on accumulators that are identical to the accumulators to be manufactured. The Purchaser, prior to the commencement of testing, shall approve any discrepancies between the test and production units.

All tests shall be conducted at ambient and fluid temperature of 70 °F ± 10 °F (21 °C ± 4 °C) unless otherwise specified The fluid cleanliness shall be to AS4059 Class 6 maximum throughout these tests (unless otherwise specified in the Procurement Specification), except for endurance cycling (6.3.2).

For the proof and burst tests, pressure shall be applied at a maximum rate of 25 000 psi/min (172 MPa/min).