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An SAE International Group

AEROSPACE RECOMMENDED PRACTICE

SAE ARP4378 | REV. A

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Superseding ARP4378

(R) Aerospace - Accumulator, Hydraulic, Welded Bellows, Factory Precharged

RATIONALE

ARP4378 has been updated to Revision A for the following reasons:

a. New technical and test requirements have been introduced

b. Some technical and test requirements have been revised

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

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

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1. SCOPE

This Aerospace Recommended Practice (ARP) provides design and test requirements for factory precharged, welded bellows hydraulic accumulators.

1.1 Purpose

The requirements contained in this ARP are recommended for inclusion in a Procurement Specification for this type of accumulator.

NOTE: 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 also provided to permit a consistent approach for testing to be conducted for the different applications of this type of hydraulic accumulator.

1.2 Field of Application

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

a. Type I: -65 to +160 °F (-54 to +71 °C) hydraulic fluid temperature

b. Type II: -65 to +275 °F (-54 to +135 °C) hydraulic fluid temperature

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

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

ARP1383 Impulse Testing of Hydraulic Actuators, Valves, Pressure Containers and Similar Fluid System Components

ARP4386 Terminology and Definitions for Aerospace Fluid Power, Actuation and Control Technologies

AS4059 Aerospace Cleanliness Classification for Hydraulic Fluids

AS4941 Aerospace - General Requirements for Commercial Aircraft Hydraulic Components

AS5440 Hydraulic Systems, Aircraft, Design and Installation, Requirements for

AS8775 Hydraulic System Components, Aircraft and Missiles, General Specification for

2.1.2 U.S. Government Publications

Available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, http://assist.daps.dla.mil/quicksearch/

MIL-PRF-27401 Propellant Pressurizing Agent, Nitrogen

MIL-PRF-27407 Propellant Pressurizing Agent, Helium

MIL-STD-130 Identification Marking of U.S. Military Property

MIL-STD-810 Environmental Engineering Constraints and Laboratory Tests

2.1.3 Code of Federal Regulations (CFR)

Available from the U.S. Government Printing Office, 732 N. Capitol Street, NW Washington, DC 20401, Tel: 202-512-0000, http://www.gpoaccess.gov

49CFR.173.306 Code of Federal Regulations – Transportation – Shippers – General Requirements for Shipments and Packaging – Limited Quantities of Compressed Gases

2.2 Related Publications

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

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

ARP4379 Aerospace - Accumulator, Hydraulic, Cylindrical, Piston Separated

ARP4553 Aerospace - Accumulator, Hydraulic, Self-Displacing

ARP4752 Aerospace - Design and Installation of Commercial Transport Aircraft Hydraulic Systems

ARP4925 Aerospace Design and Installation of Commercial Transport Helicopter Hydraulic Systems

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 ARP.

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, for example). The Purchaser should provide the procurement specification for the accumulator.

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

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

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)

NOTES:

1. For military aerospace applications, Rated System Pressure is equivalent to the Pressure Class

2. For commercial aerospace applications, Rated System Pressure is equivalent to the Design Operating Pressure (DOP)

PRECHARGE: The precharge is the factory sealed gas charge within the accumulator with the separator bottomed at the fluid end (usually specified as a pressure at a specific temperature).

SEPARATOR: The separator is the part of the accumulator that separates the gas and the hydraulic system fluid. The separator comprises a welded bellows assembly and other devices to permit the separator to smoothly move within the accumulator body as hydraulic fluid is ingressed or expelled.

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

FILLING OIL VOLUME: The filling oil volume is the fluid that is stored in the accumulator fluid part when the accumulator separator is moved from the position at either zero pressure or a designated return pressure to where the separator is at the rated system pressure and at a prescribed temperature.

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 system pressure and at a prescribed temperature to either zero pressure or a designated return 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 either proof pressure or the system relief pressure at cold temperature, for example –40 °F (–40 °C). 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 of an accumulator is the capability of the accumulator to expel the volume of hydraulic fluid with which it has been filled. This is expressed as an efficiency using the equation:

Volumetric efficiency = (Swept (Expelled) Oil Volume/Filling Volume) x 100%

ENDURANCE TEST: The endurance test is the test that is intended to determine the wear characteristics of the accumulator in order to determine if the element 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 an 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 an appropriate test rig.

3. TECHNICAL REQUIREMENTS

3.1 General

The accumulator shall be designed to meet the requirements of Federal Regulation 49CFR.173.306, Para.(f)(3).

Factory precharged, welded bellows hydraulic accumulators that are intended to be used in military flight vehicle hydraulic systems shall conform to the general hydraulic components' requirements of AS8775.

Factory precharged, welded bellows 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.

3.2 Functional Requirements

3.2.1 Dynamic Performance Requirements

3.2.1.1 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 the:

a. Response rate for filling the accumulator

b. Response rate for discharging the accumulator

c. Optimization of charge pressure/accumulator volumes, including whether the gas pressure changes are considered to be adiabatic or isothermal, etc.

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 dynamic operation of the hydraulic system.

3.2.1.2 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 pressures generated by any combination of dynamic flow rate and fluid temperature permitted by this ARP or the Procurement Specification.

3.2.1.3 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 welded bellows and resistance within any fluid passages

b. The responsiveness of the accumulator during a rapid pressure decay at the pressure port

3.2.2 Precharge Pressure

The Procurement Specification shall specify the required precharge pressure, the associated tolerance range and the corresponding temperature.

3.2.3 Swept (expelled) Oil Volume

The Procurement Specification shall specify the swept (expelled) oil volume and the corresponding temperature.

NOTE: Careful consideration should be given to the start and finish pressures, temperatures and fluid flow rates since these are significant factors that affect accumulator design and sizing.

3.2.4 Maximum Swept Oil Volume

The Procurement Specification shall state the relief valve pressure (either the system relief valve or the dedicated thermal relief valve pressure) and the corresponding temperature in order to enable the maximum swept oil volume to be determined.

3.2.5 Volumetric Efficiency

The volumetric efficiency shall be such that the fluid expelled as the hydraulic pressure is reduced from the rated system pressure to 0 psi (0 kPa) shall be in excess of 97% of the total oil volume of the fluid stored in the accumulator at the rated system pressure. The expelled volume shall be as specified in 3.2.3.

The Procurement Specification should state the temperature range over which this volumetric efficiency is to be achieved.

3.2.6 Separator Friction

The hydraulic fluid pressure at which the separator begins to move shall not be greater than 25 psi (172 kPa) above the precharge pressure. This requirement shall be met over the total stroke of the accumulator, and over the specified temperature range.

NOTE: This value should be independent of the precharge pressure and the rated system pressure. If this is not the case, then the Supplier and the Purchaser should agree where the requirement can be exceeded.

3.2.7 Leakage Requirements

3.2.7.1 Gas Leakage

A new precharged accumulator shall have a total gas leakage, internal and external, not greater than 1×10^{-7} standard cubic centimeters of helium per second at atmospheric pressure. The precharge pressure shall not reduce more than 3% in ten years with any combination of storage or operation.

3.2.7.2 Fluid Leakage

There shall be no evidence of external fluid leakage over the lifetime of the accumulator.

3.2.8 Operating Temperature

3.2.8.1 Ambient Temperature

In accordance with AS4941 or AS8775, as applicable or as specified in the Procurement Specification.

3.2.8.2 Hydraulic Fluid Temperature

In accordance with AS4941 or AS8775, as applicable or as specified in the Procurement Specification.

3.3 Pressure Monitoring

The accumulator may have a readout device (i.e. pressure gage or transducer), which senses the precharge pressure. If used, the pressure readout device shall be considered part of the pressure vessel and therefore must meet the proof pressure, leak test, vibration and burst pressure requirements specified herein as well as the endurance and pressure impulse requirements.

Alternatively, dependent upon the accumulator construction, the precharge pressure may be measured by an indirect means. If this is required, the Procurement Specification should state the required accuracy. The means to measure the precharge pressure should be achieved in a consistent and robust manner.

3.4 Construction

3.4.1 Fluid Port and Gas Charging Point

The accumulator shall be designed with a fluid port and a gas charging point.

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

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

The gas side of the accumulator shall be precharged using the gas charging point and then hermetically sealed prior to delivery.

Means should be provided to release the gas precharge at the gas charging point prior to the unit being scrapped. If required by the Procurement Specification, a means shall also be provided to visually indicate that the accumulator gas precharge has been discharged, either deliberately or inadvertently.

3.4.2 Fragmentation

If required by the Procurement Specification, the accumulator, when struck by gunfire as specified in 6.7.2, 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.

3.4.3 Materials

In accordance with AS4941 or AS8775, as applicable.

3.4.4 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.

The effect of welding and any post-weld heat treatment on the corrosion resistance of the metals should be evaluated.

3.4.4.1 Internal Surfaces

If the internal surfaces exposed to the precharge gas are coated with a film of oil in order to meet the corrosion resistance requirements, the oil used shall be compatible with the precharge gas.

3.4.4.2 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 topcoat that meets the humidity, fungus, sand and dust and salt fog requirements. The fluid boss spot face and threads, the face of the pressure indicator and the associated electrical connector (if fitted) shall be free of primer and paint.

The use of any protective coating that will crack, chip, scale or erode shall be avoided. Any assembly of parts 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 hydraulic fluid as specified in 3.4.7 and shall meet the requirements stated in the applicable specifications.

3.4.5 Electro-conductive Bonding

If required by the Procurement Specification, the accumulator shall have a facility to enable it to have an effective electro-conductive bond to the airframe.

The electrical resistance between any point on the mounting facilities and specified points on the accumulator shall not be greater than 300 milliohms, unless otherwise stated in the Procurement Specification.

3.4.6 Precharge Gas

The accumulator shall be precharged with nitrogen conforming to MIL-PRF-27401 and/or helium per MIL-PRF-27407. The precharge shall contain 5% minimum by pressure of helium for leak detection, using a helium mass spectrometer. The choice of gas to be used is dictated by the accumulator performance requirements. The Supplier should propose the choice of gas to be used for agreement by the Purchaser.

3.4.7 Hydraulic Fluid

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

3.4.7.1 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)

3.4.7.2 Seals

The seals contained within the accumulator shall be compatible with the operating fluid as specified in 3.4.7 and the operating temperature as specified in 3.2.8.2.

3.5 Installation Requirements

3.5.1 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

In accordance with AS4941 or MIL-STD-130, as applicable.

3.5.2.2 Warning Label

Each accumulator shall be permanently marked with a legible warning in red letters stating:

PRESSURIZED VESSEL, DO NOT PUNCTURE OR INCINERATE

This container meets the requirements of 49CFR, Sect. 173.306. Para.(f)(3)

3.5.2.3 Nameplate

In addition to the requirements of 3.5.2.1, each accumulator shall be furnished with a nameplate that shall include the following information as a minimum:

a. Rated System Pressure (or equivalent term)

b. Proof Pressure

c. Precharge Pressure at Room Temperature

d. Precharge Gas Volume

3.6 Strength

3.6.1 Separator

The separator shall be designed to operate with a pressure differential equal to the precharge pressure at the maximum rated temperature. These conditions exist in operation when a precharged accumulator exhausts all the expellable hydraulic fluid and the hydraulic port is open to atmospheric pressure.

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 1.5 times the maximum precharge pressure on the gas side.

3.6.2.2 Vessel Proof Pressure

This requirement is for the accumulator pressure vessel only and does not include the internal separator.

The accumulator shall be designed to withstand a proof pressure of:

a. For commercial applications, three times the rated system pressure

b. For military applications, two times the rated system pressure

3.6.2.3 Accumulator Proof Pressure

The precharged accumulator shall be designed to withstand a hydraulic proof pressure that is the larger of:

a. 1.5 times the rated system pressure

b. Three times the precharge pressure (49CFR.173.306 Para.(f)(2) requirement)

The accumulator shall be designed such that the separator shall not bottom on the gas end of the accumulator during accumulator proof pressure testing throughout the entire temperature range.

3.6.3 Burst Pressure

NOTE: This requirement is for the accumulator pressure vessel only and does not include the separator.

The accumulator shall be designed to withstand a burst pressure that is the larger of:

a. Four times the rated system pressure or as specified in the Procurement Specification.

b. Five times the precharge pressure (49CFR.173.306 Para.(f)(3) requirement)

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 Pressure Impulse

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 Temp (°F (°C))	Hydraulic Fluid Pressure Lower Limit Maximum	Hydraulic Fluid Pressure Upper Limit Minimum	Cycle Rate (CPM)
1	12 500	50-90 (10-32)	10 psi (69 kPa)	117% of rated pressure	10.0 to 50.0
2	50 000	275 min (135 min)	7% of rated pressure	Rated pressure	10.0 to 50.0
3	1 000 000	50-90 (10-32)	67% of rated pressure	Rated pressure	10.0 to 50.0

3.6.5 Vibration

The accumulator shall be designed to withstand the vibration levels as stated in AS4941 or AS8775 (as applicable), or as stated in the Procurement Specification.

The precharge pressure of the accumulator shall be within the acceptable tolerance range of 3.2.2 and shall meet gas leakage requirements of 3.2.7.1 after being exposed to these vibration levels

3.6.6 Maximum Wrenching Torque

The accumulator shall withstand 250 percent of the maximum wrench torque required for making the tubing connection without any permanent deformation of the accumulator (in particular the area around the connection port).

3.7 Weight

The accumulator weight should be the minimum possible weight that is consistent with the performance requirements 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

3.9 Operational and Safety Requirements

3.9.1 Storage

The accumulator shall be constructed of materials that 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

In accordance with AS4941 or AS8775, as applicable.

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

3.9.3 Endurance Cycling

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

TABLE 2 - ENDURANCE CYCLING

Step Number	Number of Cycles	Fluid Temperature (°F (°C))	Hydraulic Fluid Pressure Lower Limit Maximum (1)	Hydraulic Fluid Pressure Upper Limit Minimum	Cycle Rate (CPM)
1	500	-65 max (-54 max)(2)	7% of Rated Pressure	Rated Pressure	0.2 to 2.0
2	62 000	275 min (135 min)(3)	7% of Rated Pressure	Rated Pressure	3.0 to 20.0
3	12 000	50-90 (10-32)	7% of Rated Pressure	Rated pressure	3.0 to 20.0

NOTES:

1. If the accumulator includes a device to limit the separator differential pressure when there is no system pressure, the cycling shall start at 0 psi (0 kPa) in order to check that there is no wear in the device as a result of the endurance cycling.

2. The minimum operating temperature stated in the Procurement Specification should be the maximum test temperature used for step 1 if the Purchaser specifies a minimum operating temperature lower than -65 °F (-54 °C).

3. The maximum operating temperature stated in the Procurement Specification should be the minimum test temperature used for steps 2 and 3 if the Purchaser specifies a maximum operating temperature higher than 275 °F (135 °C).

4. The ambient temperature to be used at each of the steps should be agreed between the Purchaser and the Supplier. It should ideally be such that the gas temperature equals or exceeds the fluid temperature at the end of each compression stroke.

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 charge pressure

b. External leakage

c. Internal leakage

d. Jamming of the separator

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspection

Unless otherwise specified in the contract or purchase order, the Supplier:

a. Is responsible for the performance of all inspection requirements as specified herein

b. May use his own facilities or the services of any industrial laboratory that has the necessary approvals

The Purchaser should reserve the right to perform any of the inspections contained in this ARP or in the Procurement Specification, where such inspections are deemed necessary to ensure that the supplies and services conform to the stipulated requirements.

4.2 Physical Defect Inspection

All detail parts of the accumulator shall be subjected to non-destructive inspection prior to assembly, as follows:

a. All magnetic highly stressed parts shall be subjected to magnetic particle inspection

b. Nonmagnetic highly stressed parts shall be subjected to liquid penetrate inspection

During and after the accumulator assembly, it shall be subjected the following inspections:

c. Final assembly welds shall be magnetic or penetrant inspected

d. Full penetration electron beam or laser closure welds shall be subjected to ultrasonic inspection

e. In process inspection of the separator welded bellows assembly shall also be performed

There shall be no evidence of leakage, cracks, excessive porosity or other injurious defects.

4.3 Classification of Tests

For the purpose of demonstrating compliance of factory precharged, welded bellows hydraulic accumulators with this ARP and the applicable Procurement Specification, two distinct test programs shall be conducted, hereinafter referred to as follows:

a. Acceptance Tests (see 5.)

b. Qualification Tests (see 6.)

Table 3 provides the listing of the qualification tests for the factory precharged, welded bellows hydraulic accumulators, together with a recommendation of the test accumulators that the tests should be conducted on.

4.4 Test Stand Requirements

These shall be in accordance with AS4941 or AS8775, as applicable.

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

4.4.1 Test Medium

The test medium shall be the system hydraulic fluid.

4.5 First Article Inspection

The First Article Inspection shall consist of the examinations specified in 4.5.1 below 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 Supplier's quality organization shall 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

The failure of any factory precharged, welded bellows hydraulic accumulators to successfully comply with any of the requirements of the First Article Inspection or the quality conformance inspections shall be the cause for rejection of that accumulator.

TABLE 3 - TEST PROGRAM

Requirement	Test Paragraph	Test #1 Accumulator	Test #2 Accumulator	Test #3 Accumulator	Test #4 Accumulator
First Article Inspection	4.5	X			
Production Acceptance Tests	5	X		X	X
Immersion Test	6.2(1)	X			
Functional Tests	6.3(1)				
Gas Volume Verification	6.3.1	X			
Volumetric Efficiency	6.3.2	X			
Endurance Test	6.3.3	X			
Additional Tests	6.3.4	X			
Electrical Tests	6.4				
Magnetic Effect	6.4.1	X (If required)			
Power Inputs	Not required (2)				
Voltage Spikes	Not required (2)				
Audio frequency conducted susceptibility	Not required (2)				
Induced signal susceptibility	Not required (2)				
High intensity radiated fields	Not required (2)				
Radio frequency susceptibility (radiated and conducted)	6.4.2	X (If required)			
Emission of radio frequency energy	6.4.3	X (If required)			
Environmental Tests	6.5				
Low temperature	6.5.1.1	X			
High temperature	6.5.1.3	X			
Humidity	6.5.2	X			
Fluids susceptibility	6.5.3	X			
Fungus	6.5.4	X			
Salt spray	6.5.5	X			
Fire Resistance (3)	6.5.6				X (If required)
Structural Tests	6.6				
Proof test	6.6.1	X (4)	X		
Fatigue (pressure impulse)	6.6.2		X		
Vibration	6.6.3			X	
Handling loads	6.6.4		X		
Wrench loads	6.6.6		X		
Destructive Tests	6.7				
Burst pressure	6.7.2(5)		X		
Fragmentation	6.7.1(6)			X	
Post Qualification Tests	6.8				
Post qualification acceptance test	6.8.1	X			
Disassembly and inspection	6.8.2	X			

NOTES:

a. Tests conducted in Sections 6.2 and 6.3 can be conducted on Test #3 Accumulator if time scales and/or availability of equipment are critical.

b. Specific tests (if required) will be conducted at sub-assembly level.

c. A fire resistance test will be required if the accumulator is used for specific applications in a fire zone, for example, a thrust reverser actuation system.

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

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

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

5. ACCEPTANCE TESTS

Each welded bellows, factory precharged accumulator submitted for delivery under a Procurement Contract shall be subjected to the following acceptance test requirements:

a. Visual and dimensional examination (see 5.1)

b. A test program to determine product conformance to the functional and performance requirements of this ARP and the Procurement Specification. The test program is specified in 5.2. Unless otherwise specified in the Procurement Specification, the fluid and ambient temperatures shall be between 60 °F (16 °C) and 120 °F (49 °C)

The tests shall comprise the following:

c. Proof pressure (see 5.2.2)

d. Precharge verification (see 5.2.3)

e. Separator friction (see 5.2.4)

f. Volumetric efficiency test (see 5.2.5)

g. Helium leak test (See 5.2.6)

h. Electro-conductive bonding – if required (see 5.2.7)

5.1 Visual and Dimensional Examination

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.

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.

NOTE: Care should be taken to ensure that there are no particulates on either the fluid or gas side of the metal bellows which could be detrimental to the bellows if the particulate is large enough in size and of sufficient hardness to get wedged in a bellows convolution during the bellows retraction or extension.

5.2.2 Proof Pressure

The accumulator shall be proof pressure tested using one of the two following methods. There shall be no sign of distortion or failure in any part of the accumulator. Then, after the accumulator precharge has been set, conduct the conduct the precharge proof test to demonstrate compliance with or 49CFR.173.306.

The accumulator shall pass the helium leak test of 5.2.6 after being subjected to either of these proof pressure tests.

5.2.2.1 Method 1

Fluid pressure shall be applied to the fluid port of precharged accumulator until the proof pressure specified in 3.6.2.2 is obtained. Maintain the proof pressure for 5 minutes minimum.

5.2.2.2 Method 2

Prior to final precharge of the accumulator, it is acceptable to fill the gas cavity with hydraulic fluid or to precharge the accumulator at a pressure greater than the shipping precharge pressure. Apply the proof pressure specified in 3.7.2.2 to the fluid port for 5 minutes minimum.

5.2.2.3 49CFR.173.306 Proof Test

After the final precharge of the accumulator, apply the proof pressure specified in 3.7.2.3 to the fluid port for 5 minutes minimum.

5.2.3 Precharge Pressure Verification

The precharge pressure shall be verified that it is in accordance with 3.2.2 by using the following procedure:

a. If the pressure read out device described in 3.3 is fitted, use the device to record the precharge pressure with no hydraulic supply to the accumulator.

b. If the pressure read out device described in 3.3 is not fitted, then conduct the following:

    1. Install a pressure transducer in the hydraulic supply pipeline to the accumulator

    2. Pressurize the accumulator to the system rated pressure

    3. Slowly decrease the hydraulic pressure from the system rated pressure to ambient pressure while monitoring the fluid pressure decrease rate

    4. The precharge pressure is established as the pressure at which the pressure decay rate changes from a gradual decrease rate to a rapid decrease rate (knee of the curve)

5.2.4 Separator Friction

Starting with the hydraulic pressure at 0 psi (0 kPa), increase the pressure until the separator begins to move. The pressure at which the separator begins to move shall not be greater than 25 psi (172 kPa) above the precharge pressure.

5.2.5 Volumetric Efficiency

Record the quantity of hydraulic fluid required to fill the accumulator, with the hydraulic pressure increasing from 0 psi (0 kPa) to rated system pressure. Record the quantity of hydraulic fluid that the accumulator expels as the accumulator starts at rated system pressure and decays to 0 psi (0 kPa). Check that the volumetric efficiency is greater than 97% and that the expelled volume meets the requirement as specified in 3.2.3.

Conduct 50 cycles of refilling/depleting the accumulator. Then repeat the volumetric efficiency test to verify that there has not been any fluid migration into the gas chamber.

There should be a check that the accumulator bellows assembly exhibits no binding or seizure during the fluid ingress and expulsion testing.

5.2.6 Helium Leak Test

The precharge leak rate of the separator and of the pressure vessel shall be determined by using a Helium Mass Spectrometer. A one atmosphere differential pressure shall be used for mass spectrometer leak detection. The total leak rate of a new accumulator shall not exceed 1×10^{-7} standard cubic centimeters per second of helium. After the completion of the acceptance testing, the helium content of the precharge gas shall be verified and the total leak rate shall not exceed 1×10^{-6} standard cubic centimeters per second of helium.

5.2.7 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 10 milliohms, unless otherwise stated in the Procurement Specification.

5.3 Preparation for Shipment

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

5.4 Storage and Packing

The method of storage, packing and marking, shall be in accordance with the requirements of 49CFR.173.306 Para.(f)(3) together with any other specific requirements defined in the Procurement Specification.

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. State 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 to the production standard, and have passed the acceptance tests. The Purchaser, prior to the commencement of testing, shall approve any discrepancies between the test and production units.

Prior to the commencement of the accumulator qualification tests, the pressure-monitoring device (if fitted to the accumulator) shall have completed its qualification test.

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).

6.2 Fluid Immersion Test

6.2.1 Fluid Immersion

The fluid immersion test shall be in accordance with AS4941 or AS8775, as applicable.

NOTES:

a. The seal compound and hydraulic fluid used shall be that which, when combined, has the highest swell.

b. This test does not apply to elastomeric seals used in the hydraulic port of the accumulator

6.2.2 Electrical Components

Where electrical components are part of the pressure indication system for accumulator assembly (if fitted), and are in contact with the system hydraulic fluid (partially or completely), they shall be separately subjected to a fluid immersion test. This shall consist of continuous immersion for 72 hours in the hydraulic fluid at rated temperature. After the soak period, the component shall remain in the fluid at the normal temperature until ready for further tests.

6.3 Function Tests

6.3.1 Gas Volume Verification

The gas volume shall be verified. An acceptable method of gas volume verification is an expulsion volume measurement between a known temperature and pressure condition and the precharge condition. The gas volume is calculated as:

$V_G = \Delta V \times (P_1 Z_G T_G / P_G Z_1 T_1) / ((P_1 Z_G T_G / P_G Z_1 T_1) - 1)$

Where:

V_G = Gas Volume to be determined

P_1 = Arbitrary pressure above the precharge pressure

T_1 = Temperature at which P_1 is measured

Z_1 = Compressibility factor or “Gas Constant” of the gas at P_1 and T_1

P_G = Precharge gas pressure

T_G = Temperature at which P_G is measured

Z_G = Compressibility factor or "gas constant" of the gas at P_G and T_G

ΔV = Volume of expelled fluid between condition 1 and condition G

6.3.2 Volumetric Efficiency

The volume efficiency over the temperature range shall be verified. Repeat the test called up in 5.2.5 over the temperature range specified in the Procurement Specification.

6.3.3 Endurance Cycling

Unless otherwise specified in the Procurement Specification, the accumulator shall be cycled as specified in Table 2, Steps 1 through 3. After each step the accumulator shall be helium leak tested, and shall have the precharge verified per 5.2.4 and 5.2.6.

One cycle is defined as the pressure starting at the lower limit, rising to the upper limit and dropping to the lower limit.