



AEROSPACE RECOMMENDED PRACTICE

ARP4553™

REV. B

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Superseding ARP4553A

(R) Self-Displacing Hydraulic Accumulator

RATIONALE

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

- To introduce recommendations for new and revised technical and test requirements
- To delete the classification of accumulators as this is not used by the industry
- To update the references
- To include editorial improvements

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1. SCOPE

This SAE Aerospace Recommended Practice (ARP) provides recommendations for design and test requirements for self-displacing hydraulic accumulators.

1.1 Purpose

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

NOTES:

1. The recommended requirements in this ARP should be reviewed by the procuring activity and only those requirements that are applicable for a specific application should be incorporated in the Procurement Specification.
2. In the event of a conflict between the recommended requirements in this ARP and the Procurement Specification, the Procurement Specification shall take precedence.

1.2 Field of Application

The accumulator is intended for use in commercial and military aircraft hydraulic systems with rated pressures up to 5000 psi (34474 kPa).

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

ARP1383	Aerospace - Impulse Testing of Hydraulic Components
ARP4386	Terminology and Definitions for Aerospace Fluid Power, Actuation and Control Technologies
AS478	Identification Marking Methods
AS4716	Gland Design, O-Ring and Other Seals
AS4941	Aerospace - General Requirements for Commercial Aircraft Hydraulic Components
AS5857	Gland Design, O-Ring and Other Elastomeric Seals, Static Applications
AS8775	Hydraulic System Components, Aircraft and Missiles, General Specification for

2.1.2 U.S. Government Publications

Copies of these documents are available online at <http://quicksearch.dla.mil>.

A-A-59503 Nitrogen, Technical

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

MIL-STD-810 Environmental Engineering Constraints and Laboratory Tests

MIL-DTL-5498 Accumulators, Hydraulic, Cylindrical, 3000 PSI, Aircraft

2.2 Related Publications

The following publications are provided for information purposes only, and are not a required part of this SAE 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 +1 724-776-4970 (outside USA), www.sae.org.

ARP4378 Aerospace - Accumulator, Hydraulic, Welded Bellows, Factory Pre-Charged

ARP4379 Aerospace - Accumulator, Hydraulic, Cylindrical, Piston Separated

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

ARP4925 Aerospace Design and Installation of Commercial Transport Helicopter Hydraulic Systems

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

2.3 Definitions

Refer to ARP4386 for the fluid power terms that are used in this ARP.

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.

NOTES:

1. Figure 1 illustrates the accumulator concept.

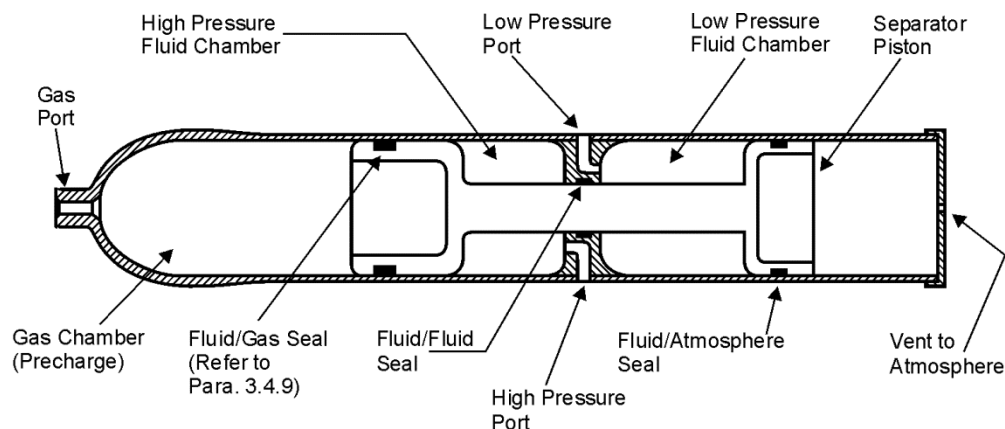


Figure 1 - Accumulator schematic diagram

2. A self-displacing accumulator essentially comprises an accumulator combined with a pressurized reservoir. The gas pre-charge displaces the tandem piston and the low-pressure fluid chamber is filled with fluid from the low-pressure side of the hydraulic system.
3. 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 piston moving and causes fluid from the low-pressure chamber to be returned to the low-pressure side of the hydraulic system. 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: This is the part of the accumulator (the interconnected tandem piston) that isolates the gas pre-charge from the high-pressure hydraulic fluid, and the low-pressure hydraulic fluid from the atmosphere.

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

GAS PORT: This is the connection in the accumulator where the gas pre-charge is supplied into the accumulator.

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

LOW-PRESSURE PORT: This 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: This 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
- 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. Rated System Pressure is equivalent to the Design Operating Pressure (DOP)
2. All pressures referred to in this document are gauge pressures

RATED RETURN PRESSURE: This 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: This 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 be the thermal relief valve opening pressure.

PRE-CHARGE GAS VOLUME: This is the gas volume contained within the accumulator and separated from the hydraulic fluid, with the separator piston bottomed at the fluid end.

DISPLACED FLUID VOLUME: This is the fluid that is expelled from the accumulator fluid port when the accumulator separator piston 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 DISPLACED FLUID VOLUME: This is the maximum volume of hydraulic fluid that can be stored in the accumulator at either proof pressure or the system/thermal relief pressure at cold temperature, for example -40 °F (-40 °C).

NOTE: To determine the maximum displaced volume, the volume at the proof pressure condition or the system/thermal relief pressure at cold temperature condition is required to be calculated. The difference in gas volume between the pre-charge volume and the smaller of the proof pressure volume and the cold temperature relief pressure volume is the maximum displaced fluid volume. Real gas laws, including compressibility, should be used to calculate these volumes.

VOLUMETRIC EFFICIENCY: This is the capability of the accumulator to expel the volume of hydraulic fluid with which it has been filled from 0 psi (0 kPa) to the maximum pressure and then the pressure is reduced back to 0 psi (0 kPa).

NOTE: This is expressed as an efficiency using the equation:

$$\text{Volumetric efficiency} = (\text{Expulsion Volume} / \text{Filling Volume}) \times 100\% \quad (\text{Eq. 1})$$

STATIC LEAKAGE: This is the fluid or gas leakage across the separator piston fluid/gas, fluid/fluid, and fluid/atmosphere seals, with the unit statically pressurized.

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

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

INTERNAL GAS LEAKAGE: This is the leakage of gas pre-charge across the separator piston fluid/gas seal.

NOTE: If a vent is incorporated into the piston seal design, the gas leakage will be to atmosphere. Leakage of gas into this vent is considered to be internal leakage.

ENDURANCE TEST: This is the test or series of tests that is intended to determine the wear and fatigue characteristics of the accumulator separator piston in order to determine if it will operate satisfactorily throughout its design lifetime.

NOTE: The endurance test comprises the realistic simulation of the accumulator operation in the specific application on the aircraft over the lifetime that has been declared for it. The test comprises the repeated application of hydraulic pressure cycles using an appropriate test rig.

PRESSURE IMPULSE TEST: This is the test or series of tests that is intended to determine the fatigue characteristics of the accumulator pressure vessel in order to determine if it will maintain its strength throughout its operational lifetime.

NOTE: The pressure impulse test comprises the realistic simulation of the operation of the accumulator in the specific application on the aircraft over the life that has been declared for it. The test comprises the repeated application of pressure impulses using an appropriate test rig.

CHARGE/DISCHARGE CYCLE: This is the test cycle starting with the accumulator with the fluid pressure at the Rated System Pressure, then dropping the pressure to bottom the separator on the fluid side and then returning to the Rated System Pressure.

PURCHASER: This is the organization that is responsible for providing the Procurement Specification for the accumulator.

NOTE: The purchaser is typically an aircraft manufacturer, a modification center, or a system supplier (hydraulic or braking, for example).

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

PROCUREMENT SPECIFICATION: This 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. RECOMMENDED REQUIREMENTS

3.1 General

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

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

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

In addition, mis-servicing events should be considered, such as:

- The potential for charging from the high-pressure port without gas pre-charge or the pre-charge pressure port open to atmosphere
- The potential for rapid pressure applied to the gas port with the high- and low-pressure open and the separator piston starting towards to the gas chamber as may be encountered during bench servicing prior to test

The purchaser and the supplier should work together to ensure that the accumulator will meet these requirements.

If required, the supplier should provide the necessary data to the purchaser to enable a detailed hydraulic model to be generated in a 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 should be such that it can withstand the pressures generated by any combination of dynamic flow rate and fluid temperature permitted by this recommended practice.

NOTE: This should include, but not limited to, the effects of friction and inertia of moving elements and any flow passage restrictions.

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 the 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 the system return circuit
- c. Potential for cavitation within the low-pressure section of the accumulator
- d. Responsiveness of the accumulator during the rapid pressure decay at the pressure port

3.2.2 Pre-Charge Gas Requirements

The Procurement Specification should specify the gas and the pressure that is used for the gas pre-charge.

NOTES:

- 1. The gas pre-charge should only be an inert gas; for example, Nitrogen to A-A-59503.
- 2. The gas pre-charge pressure should be specified at a specific temperature such that when the high-pressure fluid chamber is filled with fluid per 3.4.8, and stabilized at that temperature, the gas pressure will be at the rated system pressure of 3.7.1.

3.2.3 Displaced Oil Volume

The Procurement Specification should specify the displaced oil volumes of the high-pressure and low-pressure chambers of the accumulator.

3.2.4 Maximum Displaced Oil Volume

The Procurement Specification should specify the maximum displaced oil volume at either the proof pressure or the system relief valve or the dedicated thermal relief valve pressure, as applicable.

3.2.5 Volumetric Efficiency

The volumetric efficiency should be in excess of 95% of the filling oil volume in the accumulator fluid chambers at the rated pressure. The displaced volume should be as specified in 3.2.3.

NOTE: The Procurement Specification should define the rate of expulsion of fluid from the accumulator.

3.2.6 Separator Piston Friction

The hydraulic fluid differential pressure at which the separator piston begins to move should not be greater than 150 psi (1034 kPa) when the pressure is varied at the high-pressure port within the rated pressure of 3.7.1.1. This condition should be met with the gas chamber pre-charge per 3.2.2 and the low-pressure chamber pressurized to rated return pressure per 3.7.1.2.

NOTES:

- 1. This differential pressure is between the high-pressure port and the gas pressure port.
- 2. The differential area between the high-pressure area and the gas pressure area (separator rod diameter) may have an effect on the differential pressure as the accumulator size increases. The supplier and the purchaser should agree on the differential pressure requirements if the differential pressures as detailed above cannot be achieved by design.
- 3. The differential pressure requirement applies in both the filling and emptying directions.
- 4. The polarity of the differential pressure depends on whether the accumulator is being filled or being emptied.

This requirement should be met over the total stroke of the accumulator, and over the specified temperature range.