# IOM Supplement IOMS011

## GAS-CHARGED HYDRAULIC ACCUMULATORS USED WITH ATI ACTUATORS

### SCOPE OF SUPPLEMENT

This supplement is intended to assist those who are involved with the installation, operation and maintenance of Gas-charged Hydraulic Accumulators with ATI Actuators. This supplement shall be used only in conjunction with a relevant ATI Installation, Operation & Maintenance Manual (IOM) and with any other applicable manuals and supplements that apply to a Product.

This supplement does not address weight-loaded, gravity-loaded or spring-loaded accumulators.

### APPLICABLE PRODUCT

This manual is intended as a guide for filling, charging and discharging Hydraulic Accumulators included with ATI actuators and hydraulic control systems. Failure to read and comply with installation, operation and maintenance instructions may result in bodily injury or equipment damage and will void the manufacturer's warranty.

### COMPANY CONTACT

For any questions or clarification, or for details on your nearest ATI Authorized Representative, contact ATI.


Email: Sales@ATIactuators.com

Web: http://www.ATIactuators.com/


### REFERENCE DOCUMENTS

This IOM Supplement is referenced in the following standard IOM's and may be referenced in additional documents.

- IOM 1004 ATI Hydraulic Spring-Return Extend (SRE) Actuator
- IOM 1005 ATI Hydraulic Spring-Return Retract (SRR) Actuator
- IOM 1006 ATI Hydraulic Double-Acting (DA) Actuator

### SAFETY WARNINGS

THIS SUPPLEMENT IS NOT A COMPLETE INSTALLATION, OPERATION AND MAINTENANCE MANUAL (IOM). USERS MUST FOLLOW INSTRUCTIONS AND GUIDELINES OF A COMPLETE IOM TO PREVENT PERSONAL INJURY, PROPERTY DAMAGE, AND DAMAGE TO THE PRODUCT.

DO NOT INSTALL, OPERATE, OR MAINTAIN AN ATI PRODUCT UNLESS TRAINED AND QUALIFIED IN PRODUCT AND ACCESSORY INSTALLATION, OPERATION AND MAINTENANCE.

### REVISION RECORD

| Rev # | Issue Date | Description | Reviewed By & Date | Approved By & Date |
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| A | 6/08/2017 | Initial Release | GAH | DPL |

## General Description

A hydraulic accumulator is a reservoir of incompressible fluid that is energized by an external source. The energy stored in the accumulator is a source of fluid power available for repositioning linear, part-turn and multi-turn hydraulic actuators.

## Product Operation

A gas-charged hydraulic accumulator stores potential energy of an incompressible fluid using pressurized gas as the compressible medium. The main use of an accumulator is to supplement pump flow. The accumulator enables the hydraulic system to cope with extremes of demand using a less powerful pump or to respond more quickly to a temporary demand with a smaller, more efficient pump. An accumulator may also be used to absorb pulsations from positive displacement pumps or to compensate fluid volume in the system due to temperature changes.

The accumulator consists of a pre-charged gas chamber and a fluid chamber. The chambers are separated by a gas-tight element – a bladder, a piston, or a diaphragm. The fluid chamber is connected to a hydraulic system. As the pressure at the accumulator fluid inlet becomes greater than the gas charge pressure, fluid enters the accumulator and compresses the gas. If pressure decreases at the accumulator fluid inlet, the gas will decompress and discharge the stored fluid into the hydraulic system.

During normal operations, the pressure in the gas chamber is equal to the pressure in the fluid chamber. Each accumulator is sized so that the fluid chamber provides enough fluid volume at the charge pressure and so that the gas chamber volume is always above zero. In some applications, the accumulator may include a supplemental gas cylinder (gas bottle) to increase the effective volume of the gas chamber. The supplemental gas cylinder is connected to the gas chamber, increasing the effective gas volume, which allows more of the original accumulator volume to be used as the fluid chamber.

If all of the working volume of fluid is discharged from the accumulator, the fluid chamber is effectively emptied and fluid pressure at the accumulator inlet will drop below the pre-charge gas pressure. Pressure in the gas chamber will then remain constant and equal to the pre-charge pressure, and the fluid pressure at the accumulator inlet will vary based on the dynamics of the hydraulic system. When the hydraulic system pressure at the accumulator inlet rises above the gas pre-charge pressure, hydraulic fluid will then enter and fill the accumulator, and pressure in the fluid chamber will again equal the pressure in the gas chamber.

### *Installation*

- Accumulators are typically discharged for shipment from the factory. There may be a low nitrogen charge remaining from the factory test.
- Each accumulator must be charged and inspected for proper pre-charge during hook-up and commissioning of the hydraulic system. When charging the accumulator, use dry nitrogen gas. The use of high pressure air or other gases is an explosion risk.
- The accumulator should be placed as near as practical to the source of shock or potential energy requirement.
- Normally an accumulator should be installed in a vertical position with the oil connection facing down. Mounting the accumulator horizontally can trap contaminants in the system and reduce its functional life.
- When installing an accumulator using “U” bolt type clamps, care should be exercised so as not to distort the accumulator with excessive tightening force.
- Do not weld or machine the accumulator shell. If hangers or mounting hardware is required that is not included with the accumulator, contact ATI for suitable recommendations.
- The hydraulic fluid must be kept clean and free of debris to prevent damaging the accumulator wall. For maximum seal life, the fluid should be filtered to 10 micron or less. Refer to actuator manuals (*e.g.* IOM 1006) for additional recommendations on fluid cleanliness.

## Pre-Charge Instructions

Review all safety precautions in all applicable manuals.  Only qualified personnel should perform any maintenance on accumulators.

- Pre-charge pressure should be inspected periodically to confirm that the accumulator is performing its intended pressure storage function.  Nitrogen gas pre-charge pressure should be checked at least once during the first week of operation to assure that no leak has developed.  The pre-charge pressure and ambient temperature should be recorded at installation.  If there is no loss of gas pre-charge pressure, it should be rechecked after 10 minutes and again per a Pre-charge Inspection procedure.
- The most accurate pre-charge readings are taken when fluid pressure is at "0 psig".
- Always observe the maximum working pressure and operating temperature ranges.
- Never use oxygen for pre-charging an accumulator!

Correct pre-charging involves accurately filling of the gas side of an accumulator with a dry, inert gas such as nitrogen, before admitting fluid to the hydraulic side.

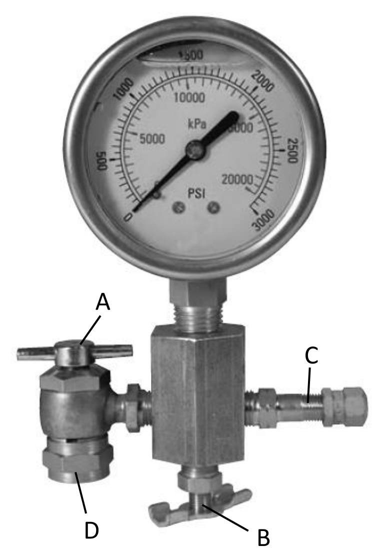
It is important to pre-charge an accumulator under the correct specified pressure.  Pre-charge pressure determines the volume of fluid retained in the accumulator at minimum system pressure.  In a power storage application, pre-charge is often around 50% of maximum system pressure; refer to order documentation or contact ATI for pre-charge requirements specific to the application.

Bladder accumulators are more susceptible to damage during pre-charging than piston types.  Before pre-charging, the inside of the shell should be lubricated with system fluid.  Before initial assembly of a bladder accumulator, it is advisable to pour some fluid into the accumulator inlet port and tilt it to coat the inside surfaces of the accumulator shell.  This fluid will lubricate the bladder as it expands.  When pre-charging, the charge gas (nitrogen) should be introduced slowly.  Failure to follow this precaution could result in immediate bladder failure as high-pressure nitrogen, expanding rapidly and thus cold, may concentrate at the bottom of the folded bladder, and the chilled, embrittled bladder can rupture.  The bladder could also be forced under the poppet, resulting in a cut.

Close attention should be paid to the operating temperature during pre-charging, as an increase in temperature will cause a corresponding increase in pressure which could then exceed the pre-charge limit.  For more information, refer to the Pre-charge Inspection Procedure and read the Special Note on Temperature Effects.

### *Pre-charge Procedure*

1. Isolate the accumulator from the system and make sure hydraulic fluid pressure is zero.
2. Remove gas valve protection guard and valve cap from the accumulator.
3. To charge the accumulator, use a charging hose and gauge assembly similar to Hydac Charging & Gauging Unit FPO 210 rated for 3,000 psi (or higher if required for conditions).
4. Before using the charging assembly, make sure that valve A is completely open (counter-clockwise), that bleed valve B is closed (clockwise).
5. Connect the Charging & Gauging Unit to the gas inlet on the accumulator by means of knurled cap D.
6. Connect the Charging & Gauging Unit to the gas supply (nitrogen bottle), ensuring that the gas valve on the supply is closed.  Remove the cap on non-return valve C to complete the hose connection from the gas supply.



7. SLOWLY open the valve at the gas supply (nitrogen bottle) and allow the gas to flow to the accumulator. Gauge should begin to register pressure. Do not exceed 120 psig (8 bar) during initial fill operation; it is recommended that a regulated nitrogen cylinder be used to limit the flow of gas. Ensure that accumulator charge is stable at approximately 120 psig (8 bar) before proceeding.
8. After pressure stabilizes 120 psig (8 bar), increase gas flow to reach the desired gas pre-charge pressure, then close the valve on the gas supply and close valve A (clockwise until it stops, DO NOT OVER TORQUE).
9. Open bleed valve B (turn counter-clockwise) until gauge reads 0 psi.
10. Remove hose from non-return valve C and replace cap.
11. Close the bleed valve B and wait a few minutes for temperature (and pressure) to stabilize.
12. After rest period per note below, open valve A so that pressure can be read on gauge. This should be slightly higher than the required pressure due to slight warming of the charge gas during the rest period.

    NOTE: Allow accumulator to rest approximately 10-15 minutes after gas pre-charging. This will allow gas temperatures to adjust and equalize. Recheck gas pre-charge pressure and adjust if necessary. Check accumulator gas valve for any leaks with soapy water. Always wear safety glasses.

13. If pressure is high, reduce pressure using bleed valve B, when desired pressure is attained, confirm that valve B is completely closed (clockwise). Close valve A completely (clockwise). Remove the charging unit at connection D.
14. Replace gas valve cap and protective guard on accumulator. Accumulator is now ready for operation.

## *MAINTENANCE*

Safety Warning: Hydraulic accumulators are pressurized vessels and only qualified technicians should perform maintenance. Drain all fluid completely from accumulator before performing any maintenance.

Precautions when performing maintenance on an Accumulator

- Always arrange some method to drain the accumulator at shut down.
- Never work on a circuit with an accumulator until it is depressurized.
- Discharge all fluid pressure from the accumulator before discharging gas pressure in the accumulator.
- Make sure accumulator flow is restricted to a reasonable rate during operation and shut down to avoid damage to the machine or piping. Accumulators will discharge fluid at the maximum rate allowed by the exit flow path. Such excessive flow at its uncontrolled maximum rate will be brief, but dangerous and damaging.
- Isolate the pump from the accumulator with a check valve, so fluid does not back flow and cause damage to the pump.

### Pre-Charge Inspection

Check the accumulator's pre-charge pressure at installation and again at least once before the 7th day of operation. If there is no noticeable loss of pressure during this time, check again one week later. If all is well: For non-cycling applications, do a routine check every three to six months thereafter; for high cycle applications that tend to result in more rapid gas loss, more frequent inspections are recommended (weekly or monthly depending upon the condition of the equipment and the criticality of accumulator performance to process quality or safety requirements).

Check the pre-charge if the system is acting sluggishly. Whenever the accumulator pre-charge drops below nominal pressure, the volume of available fluid is reduced and finally the cycle slows. If pre-charge is low, check the gas valve for leakage and recharge.

> **Note for Excessively Low Pre-charge**: Excessively low pre-charge pressure or an increase in system pressure without a corresponding increase in pre-charge pressure can also cause operating problems and subsequent accumulator damage. With no pre-charge in a piston accumulator, the piston will be driven into the gas end cap and will often remain there. Usually, a single contact will not cause any damage, but repeated impacts will eventually damage the piston and seal. With low or no pre-charge in a bladder accumulator, a single cycle can cause the bladder to be crushed into the top of the shell and can extrude into the gas stem and be punctured (condition known as "pick out").

**Note for Excessively High Pre-charge**: Excessive pre-charge pressure or a decrease in the minimum system pressure without a corresponding reduction in pre-charge pressure may cause operating problems or damage to accumulators. With excessive pre-charge pressure, the piston may cycle against the bottom cap at minimum system pressure, reducing output and eventually damaging the piston and the piston seal. The piston can often be heard bottoming, warning of impending problems. Excessive pre-charge is the most common cause of bladder failure in bladder accumulators, resulting from cycling the bladder into the poppet assembly, which can lead to fatigue failure of the poppet spring assembly or to a pinched and cut bladder.

## *Pre-charge Inspection Procedure*

1. Discharge all hydraulic fluid from the accumulator (pressure must be maintained at 0 psig through this inspection process).
2. To check or adjust pre-charge pressure, use a Charging & Gauging Unit similar to Hydac FPO 210.
3. Remove gas valve protection guard and valve cap as per pre-charge procedure instructions.
4. Attach gauge assembly to accumulator gas valve.
5. Make sure bleed valve B is closed, open gas valve core by turning valve A clockwise. Note the accumulator gas pre-charge pressure on gauge.
6. If charge pressure adjustments are required, refer to the Pre-charge Procedure. If charge is within range for the application, remove the charging unit at connection D and check the accumulator gas valve for leaks with soapy water.
7. Replace gas valve cap and protective guard on accumulator. Accumulator is now ready for operation.

NOTE: Allow accumulator to rest approximately 10-15 minutes after gas pre-charging. This will allow gas temperatures to adjust and equalize. Recheck gas pre-charge pressure and adjust if necessary. Check accumulator gas valve for any leaks with soapy water. Always wear safety glasses.

**Special Note on Temperature Effects**: Temperature variation has a substantial effect on the pre-charge pressure of an accumulator. As temperature increases, pre-charge pressure increases; as temperature drops, the pre-charge pressure will also drop. Temperature variation during pre-charge and variation during normal operational conditions must be considered to assure the accuracy of the accumulator pre-charge pressure. Consult original order documentation for more specific details, make adjustments to pre-charge pressure per the formula that follows, or Contact ATI for additional support.

| Variable | UoM | Formula | Definition |
|---|---|---|---|
| $\boldsymbol{P_{0,T_0}}$ | psi or bar | $\boldsymbol{P_{0,T_2}} \times \frac{(T_0+460)}{(T_2+460)}$ for °F<br>$\boldsymbol{P_{0,T_2}} \times \frac{(T_0+273)}{(T_2+273)}$ for °C | gas pre-charge pressure at pre-charge temperature |
| $\boldsymbol{P_{0,T_2}}$ | psi or bar | | required gas pre-charge pressure at maximum operating temperature |
| $\boldsymbol{T_0}$ | °F or °C | | pre-charge temperature |
| $\boldsymbol{T_2}$ | °F or °C | | maximum operating temperature |

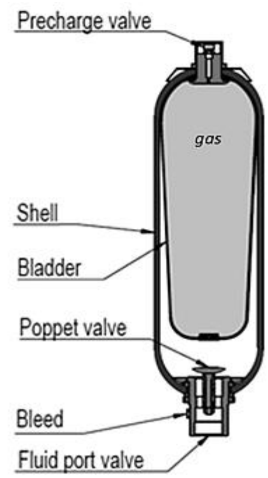
# APPENDIX A – ACCUMULATOR FAQ'S

## *Types of Accumulators*

Gas-charged accumulators consist of a fluid chamber, a gas chamber and a gas-tight element to separate the 2 chambers. Gas-charged accumulators are described by the type of element that separates hydraulic fluid from the gas. Gas accumulators without a separating element are rarely used in hydraulics due to the absorption of gas by the fluid.

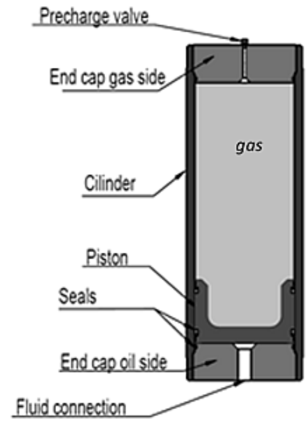
**Bladder accumulator**

The fluid chamber is separated from the gas chamber by a flexible bladder. The bladder is filled with nitrogen or another compressible gas until the designed pre-charge pressure is achieved. Hydraulic fluid is then pumped into the accumulator, thereby compressing the gas and increasing the pressure in the accumulator.



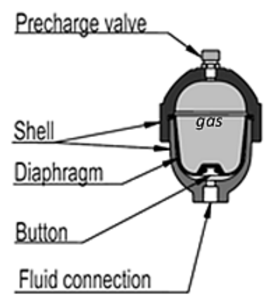

**Piston accumulator**

The fluid chamber is separated from the gas with a floating piston with gas-tight seals. The gas chamber is charged to a predetermined pressure using nitrogen or another compressible gas. This gas charge causes the piston to move down. After the pre-charge, hydraulic fluid is pumped into the hydraulic fluid port. As fluid enters the accumulator, the piston is pushed up, thereby compressing the gas and increasing its pressure. The gas pressure remains applied to hydraulic fluid through the piston. The piston moves freely between the lower end cap and its upper position, ensuring that pressure on the gas and the hydraulic fluid is always equal. (In practice, friction between the piston seals and the cylinder wall will create a small pressure differential, which is usually less than 1 bar with appropriate accumulator design and seal selection.)




**Diaphragm accumulator**

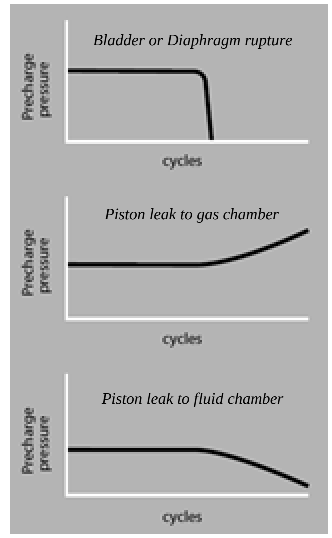
The fluid chamber and gas chamber are separated by a flexible diaphragm. Like the bladder accumulator, the diaphragm design has no sliding surface that requires lubrication and can therefore be used with fluids with poor lubricating qualities. They are also less sensitive to contamination due to fact that only the diaphragm moves, and it does not slide across any sealing surfaces.




Bladder and diaphragm accumulators have fewer elastomeric material options than piston designs, therefore piston accumulators are generally available in more sizes and for a wider range of temperature and fluid service requirements.

Bladder and diaphragm accumulators are generally less susceptible to damage caused by contamination of the hydraulic fluid than piston designs. While some risks exist from contaminants trapped between the bladder and the shell, a higher risk of failure exists from the same contaminants acting on the piston seal.




When a failure occurs, it is more likely to be a sudden failure in bladder and diaphragm designs, and more likely to be a gradual failure in piston designs. *Bladder and diaphragm accumulator failure occurs rapidly* due to rupture of the gas-tight element between the fluid and gas chambers; this rupture cannot be predicted because there will be no measurable gas or fluid leakage preceding the failure of the bladder or diaphragm.

Piston accumulator failure generally occurs in more gradual modes that can be detected by inspections on pre-charge pressure. *Piston seals that leak fluid to the gas chamber* will result in rising pre-charge while decreasing the amount of fluid available for discharge, eventually filling the gas chamber with fluid until pre-charge pressure equals maximum hydraulic system pressure. *Piston seals that leak gas into the fluid chamber* will result in a gradual decrease in pre-charge pressure.

In theory, bladder and diaphragm designs can respond more quickly to system pressure variations, because there is no static friction to overcome as with piston seals; though in practice, the difference due to static friction is rarely a design concern unless servo controls require response time under 25 ms. Systems with high-frequency pressure cycling can also cause a piston accumulator to “dither”, where the piston cycles rapidly back and forth over a distance less than its seal width, resulting in a lack of seal lubrication at that dithering point, which causes heat build-up that results in seal and bore wear.

Applications subject to high external forces (shock & vibration) should consider accumulator design and orientation. External forces along the axis of the accumulator shell normally have little effect on a bladder but may cause variation in gas pressure in a piston accumulator. Forces perpendicular to the shell of the accumulator should not affect a piston design, but fluid in a bladder may be thrown to one side of its shell, displacing the bladder and perhaps causing the poppet valve to pinch and cut the bladder.

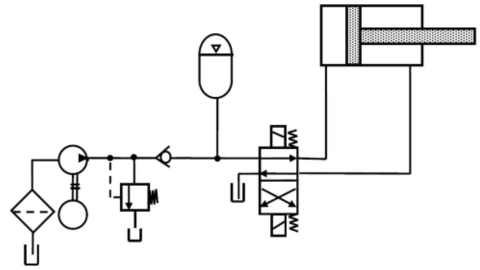
Accumulators are intended for vertical installation with the fluid inlet port at the bottom and the gas pre-charge valve at the top. Horizontal installations or installation at any inclination other than vertical should be discouraged. Bladder accumulators have an increased risk of the bladder bag floating in the horizontal position, which traps usable fluid inside, and a horizontal bladder can be pinched by the poppet valve closing, rupturing the bladder. While floating horizontally, the top of the bladder may wear unevenly as it rubs against its shell, reducing its service life. The horizontal position also requires more care when draining the fluid from the accumulator.

## *Typical Schematics using Accumulators*

**Accumulator as auxiliary power source**

The accumulator stores the fluid delivered by the pump and releases the stored fluid on demand, thereby serving as a secondary power source.

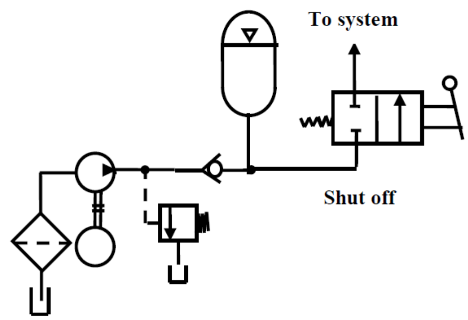
In the example, when the cylinder is at its end of travel position, the accumulator is being charged with fluid. With the pump motor turned off, when the four-way valve is switched, the accumulator releases stored fluid to reposition the actuator.



**Accumulator as hydraulic shock absorber**

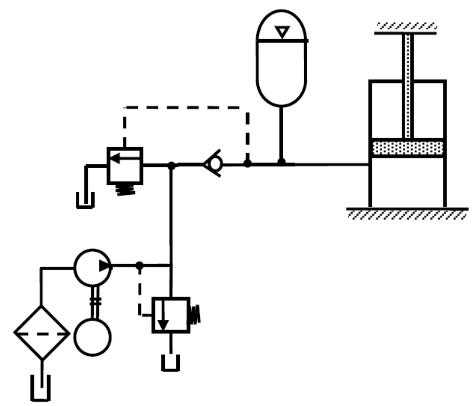
Hydraulic shock is caused by the sudden stoppage or deceleration of a fluid flowing at relatively high velocity in a pipe line. Rapidly closing a valve creates a compression wave in the fluid line that travels at the speed of sound upstream to the end of the pipe and back again to the closed valve, which can cause pressure to pulse or surge above nominal design pressures.

The resulting pressure pulsations or surges may damage hydraulic system components. An accumulator near the rapidly closing valve will suppress the pressure pulsations.




**Accumulator as thermal compensator**

When closed loop hydraulic systems are subjected to heat conditions, the pipe lines and the hydraulic fluid expand volumetrically. Because the coefficient of expansion of most fluids is higher than that for pipe materials, the change to liquid volume will increase system pressure. An accumulator of proper capacity that is pre-charged to the normal system working pressure will take up any increase in the system fluid volume, thus maintaining system pressure within safe limits. The accumulator also feeds the required volume back to the system if heat dissipates and as thermal contraction takes place.

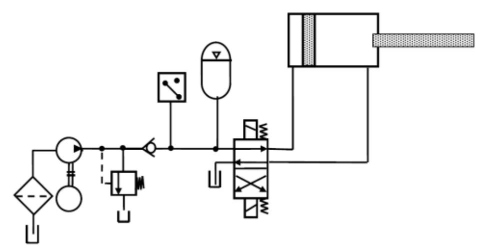


**Accumulator as leakage compensator**

An accumulator can be used as a compensator for internal and external leakage during an extended period during which the system is pressurized but not in operation. The pump charges the accumulator and the system until system pressure trips the maximum pressure setting on the power unit pressure switch.

The accumulator supplies fluid to the system to compensate for small leaks while the pump is off. A check valve is placed between the pump and accumulator so that fluid in the accumulator does not back flow to the pump and power unit reservoir when the pump is idle.

With this circuit, the power unit operates only when the pressure drops below the minimum pressure set point, which saves electric power and reduces the heat in the system.



## *General Calculations*

Within an accumulator, fluid is compressing a pre-charged gas or the pre-charged gas is expanding to push fluid into a hydraulic system. This compression or expansion brings about a status change in the gas, which is governed by the perfect gas equation,

$$PV = mRT$$

where P = absolute pressure, V = gas volume, *m* = mass of gas, R = universal gas constant, and T = absolute temperature.

For a particular gas and a known volume for the accumulator, the value of *mR* is constant and the equation reduces to PV/T or

$$\frac{P_0V_0}{T_0} = \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

For change over a long period of time, such as within an accumulator used as a volume compensator or as a pressure compensator, the temperature of the gas is assumed constant, and such a change is isothermal, resulting in the equation

$$P_0V_0 = P_1V_1 = P_2V_2$$

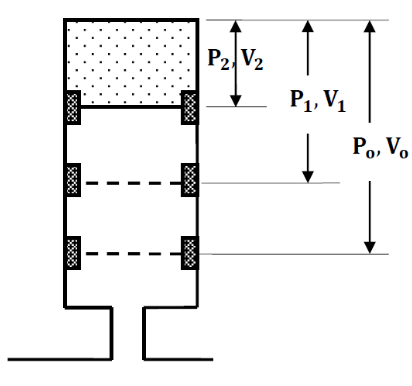
In theory*****, when the change occurs instantaneously (*i.e.* when the compression or expansion period is generally less than 3 minutes), there is no time for heat transfer from the work to the environment and such a change is called isentropic or reversible adiabatic. Such a condition should be considered if the accumulator is used for energy accumulation, pulsation damping, emergency power, dynamic pressure compensation, shock absorption, or a hydraulic spring, etc., and the equation is

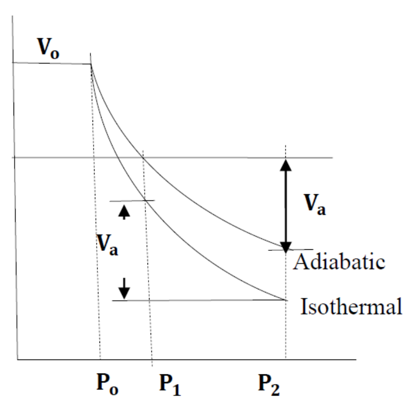
$$P_0V_0^n = P_1V_1^n = P_2V_2^n$$

**** In practice, for sizing and selection of accumulators for emergency power for valve actuator applications, isothermal expansion is usually assumed****, even in the case that the accumulator is discharging at a rate much faster than 3 minutes. For a given accumulator volume, isothermal compression stores more fluid than adiabatic, and isothermal discharge gives up more fluid than adiabatic, so isothermal calculations result in smaller, less expensive accumulators for a required volume of fluid. In most cases, hydraulic actuators with on-off valves are stroked only rarely. Although the charge cycle may be adiabatic, because it is idle for a long period, heat dissipates through the shell of the accumulator, transforming the charge to isothermal by the time the stored fluid is discharged. If sizing an accumulator for a high-speed actuator application that will be cycled frequently such that the motor may always run, the isothermal assumption must be re-evaluated and perhaps the adiabatic calculation applied.*

Changes between isothermal and isentropic are called polytropic. An ideal adiabatic process must occur very rapidly without any flow of energy in or out of the system. In practice, most expansion and compression processes are somewhere in between, or said to be polytropic.

The volumetric capacity of the accumulator is defined as volume of fluid in the accumulator at pressure P in operating range $P_1 \le P \le P_2$. ($P_0$ is the pre-charge pressure with no fluid in the accumulator.)




*for polytropic process* ($1 < n \le 1.4$)
*for adiabatic process* ($n = 1.4$)

$$V_a = V_1 - V_2 = V_0\left\{\left(\frac{P_0}{P_1}\right)^{\frac{1}{n}} - \left(\frac{P_0}{P_2}\right)^{\frac{1}{n}}\right\}$$

*for isothermal process* ($n = 1$)

$$V_a = V_1 - V_2 = V_0\left\{\left(\frac{P_0}{P_1}\right) - \left(\frac{P_0}{P_2}\right)\right\}$$