THE ENVIRO ENGINEER
SCIENCE, ENGINEERING & TECHNOLOGY
CALCULATION SHEET

Power and Motion Control Systems: Hydro-pneumatic Accumulators

A sample of a calculation to determine the size of a hydro-pneumatic accumulator required to store additional hydraulic fluid and avoid the need for a larger pump for the system. Since the gas change is very rapid there will be adiabatic expansion.

Calculations based on Boyle's gas law.

The additional hydraulic fluid volume needed to be supplied from the accumulator: $V_H = 1.25\ \text{L}$

Adjustment for Adiabatic gas condition: $n = 1.4$

The maximum hydraulic fluid operating pressure: $P_3 = 172.4\ \text{bar}$

The minimum hydraulic fluid system pressure: $P_2 = 138\ \text{bar}$

The pre-charge pressure of the nitrogen gas: $P_1 = 0.9 \cdot P_2 = 124.2\ \text{bar}$

From boyle's law: $P_1 \cdot V_1 = P_2 \cdot V_2$ $P_1 \cdot V_1 = P_3 \cdot V_3$

The equation is adjusted for Adiabatic gas conditions: $P_1 \cdot V_1^{\,n} = P_2 \cdot V_2^{\,n}$ $P_1 \cdot V_1^{\,n} = P_3 \cdot V_3^{\,n}$

In order to find the fluid volume at the pre-charge pressure the equations are transposed: $V_1 = V_2 \left(\frac{P_2}{P_1}\right)^{\frac{1}{n}}$ $V_1 = V_3 \left(\frac{P_3}{P_1}\right)^{\frac{1}{n}}$

The hydraulic fluid volume needed can be written as: $V_H = V_2 - V_3$

The above equations can now be combined to obtain the maximum nitrogen gas volume required:

$$V_1 = \frac{V_H}{\left(\frac{P_1}{P_2}\right)^{\frac{1}{n}} - \left(\frac{P_1}{P_3}\right)^{\frac{1}{n}}} = 9.1692\ \text{L}$$

Selected accumulator is a Bosch Rexroth AG bladder-type accumulator type HAB series 4X

From the manufacturers specification sheets the nearest size is a 10 litre accumulator

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An alternative option to determine the size of accumulator required

A sample of a calculation to determine the size of a hydro-pneumatic accumulator required to store additional hydraulic fluid and avoid the need for a larger pump for the system. Since the gas change is very rapid there will be adiabatic expansion.

Calculations based on Boyle's gas law.

Selected accumulator is a Bosch Rexroth AG bladder-type accumulator type HAB series 4X

The additional hydraulic fluid volume needed to be supplied from the accumulator:

$V_H = 1.25\ \text{L}$

Assumption of size of accumulator needed.
Adjust the size to get answer nearest fluid vol. req.:

$V_1 = 10.0\ \text{L}$

Adjustment for Adiabatic gas condition:

$n = 1.4$

The maximum hydraulic fluid operating pressure:

$P_3 = 172.4\ \text{bar}$

The minimum hydraulic fluid system pressure:

$P_2 = 138\ \text{bar}$

The pre-charge pressure of the nitrogen gas:

$P_1 = 0.9 \cdot P_2 = 124.2\ \text{bar}$

From boyle's law:

$P_1 \cdot V_1 = P_3 \cdot V_3$

The equation is adjusted for Adiabatic gas conditions:

$P_1 \cdot V_1^{\,n} = P_3 \cdot V_3^{\,n}$

In order to find the fluid volume at the maximum operating pressure the equation is transposed

$V_3 = V_1 \cdot \sqrt[n]{\frac{P_1}{P_3}}$

This can now be simplified to obtain the gas volume
The nitrogen gas volume at maximum operating pressure:

$V_3 = V_1 \cdot \left(\frac{P_1}{P_3}\right)^{\frac{1}{n}} = 7.9118\ \text{L}$

The same transpose of the equation can be used for the nitrogen gas volume at minimum system pressure:

$V_2 = V_3 \cdot \left(\frac{P_3}{P_2}\right)^{\frac{1}{n}} = 9.275\ \text{L}$

Since this is greater than the hydraulic fluid volume needed to be supplied by the accumulator V1 is correct:

answer should be either ≥ VH

$answer = V_2 - V_3 = 1.3633\ \text{L}$