How to Size an Accumulator

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Conversion for Metric

Pressure 145 psi = 1 MPa
Absolute temperature 0° Kelvin = -273.15° below 0° Celsius
Absolute Temperature 0° Rankine = = -459.67° below 0° Fahrenheit
Degrees C = °F - 32 x 5/9
Degrees F = °C x 1.8 + 32
3.7854 liters = 1 gallon
3785.4 cm^3 = 1 gallon
16.39 cm^3 = 1 in^3

$p_1 \times V_1 = p_2 \times V2$ (Gas Laws) (US Customary)
$V_2 - V_1$ = Usable volume of oil

Use these formulas if you use all of the oil in the accumulator

Given: 1 Gallon working between 3000 and 1000 psi

Use absolute values

p_1 =1000 psi + 14.7 (1014.7) Precharge

p_2 = 3000 psi + 14.7 (3014.7) Maximum working pressure

V_1 = 231 cubic inches Volume of accumulator

V_2 = Volume of gas

$1014.7 \times 231 = 3014.7 \times V_2$

$V_2 = 77.75$

$V_1 - V_2$ = Volume of useable oil

231 – 77.75 = 153.25 Useable oil

p_1 x V_1 = p_2 x V2 (Gas Laws)

(Metric)

V_2 - V_1 = Usable volume of oil

Use these formulas if you use all of the oil in the accumulator

Given: 3785.4 cm^3 working between 20.6897 and 6.8955 MPa

Use absolute values

p_1 = 6.8955 MPa + .1013 (6.9979) Precharge

p_2 = 20.6879 MPa + .1013 (20.7910) Max. working pressure

V_1 = 3785.4 cm^3 Volume of accumulator

V_2 = Volume of gas

6.9979 x 3785.4= 20.7910 x V_2

V_2 = 1274.09 cm^3

V_1 - V_2 = Volume of useable oil

3785.4 – 1274.09 = 2511.31 cm^3 useable oil

2511.31 / 16.39 = 153.22 in^3

$$p_1 \times V_1 = p_2 \times V_2 = p_3 \times V_3$$

$$V_3 - V_2 = \text{Useable volume of oil}$$

Use these formulas if you are working between maximum system pressure and minimum system pressure

p_1 = Pre-charge pressure

p_2 = Minimum working pressure

p_3 = Maximum working pressure

V_1 = Volume of gas in accumulator (empty)

V_2 = Volume of gas at minimum working pressure

V_3 = Volume of gas at maximum working pressure

All pressures are in absolute pressure

Solving for an Accumulator with the Following Specifications:

(US Customary)

$p_1 = 900 + 14.7$ PSI (914.7) Pre-charge
$p_2 = 1000 + 14.7$ PSI (1014.7) Minimum working pressure
$p_3 = 3000 + 14.7$ PSI (3014.7) Maximum working pressure
$V_1 = 1$ Gallon or 231 cubic inches

$p_1 \times V_1 = p_2 \times V_2$

$914.7 \times 231 = 1014.7 \times V_2$ $(914.7 \times 231) / 1014.7 = V_2$
$V_2 = 208.23$ Cubic inches

$p_2 \times V_2 = p_3 \times V_3$

$1014.7 \times 208.23 = 3014.7 \times V_3$ $(1014.7 \times 208.23) / 3014.7 = V_3$
$V_3 = 70.09$ Cubic inches

$V_2 - V_3 =$ Volume of Oil
208.23 – 70.09 = 138.15 Cubic inches of useable oil

Solving for an Accumulator with the Following Specifications:

(Metric)

$p_1 = 6.2069 + .1013$ MPa (6.3082) Pre-charge
$p_2 = 6.8966 + .1013$ MPa (6.9979) Minimum working pressure
$p_3 = 20.6897 + .1013$ (20.7913) Maximum working pressure
$V_1 = 3785.4 \text{ cm}^3$
$p_1 \times V_1 = p_2 \times V_2$

$6.3082 \times 3785.4 = 6.9979 \times V_2$ $6.3082 \times 3785.4 / 6.9979 = V_2$
$V_2 = 3412.3180 \text{ cm}^3$

$p_2 \times V_2 = p_3 \times V_3$

$6.9979 \times 3412.3180 = 20.7913 \times V_3$ $(6.9979 \times 3412.0180) / 20.791 = V_3$
$V_3 = 1148.67$

$V_2 - V_3$ = Volume of Oil
$3412.3180 – 1148.67 = 2263.65 \text{ cm}^3 / 16.39 = (138.11 \text{ in}^3)$

Sizing an Accumulator with a Temperature Change over a Period of One Minute or Greater. (Isothermal) (US Customary)

$p_1 \times V_1 \times T_2 = p_2 \times V_2 \times T_1$ (Use Absolute Values)

Example:

p_1 = Precharge pressure (1000 + 14.7)

p_2 = Maximum system pressure (3000 + 14.7)

V_1 = Initial volume of gas (231)

V_2 = Final volume of gas (Unknown)

T_1 = Initial temperature (70°F + 460) = 530

T_2 = Final temperature (100°F +460) = 560

$1014.7 \times 231 \times 560 = 3014.7 \times V_2 \times 530$

$V_2 = \dfrac{(1014.7 \times 231 \times 560)}{(3014.7 \times 530)}$ $V_2 = 82.15$ in^3 of gas

$V_1 - V_2 = 231 - 82.15 = 148.85$ in^3 of oil

Sizing an Accumulator with a Temperature Change over a Period of One Minute or Greater. (Isothermal) (Metric)

$p_1 \times V_1 \times T_2 = p_2 \times V_2 \times T_1$ (Use Absolute Values)

Example:

p_1 = Precharge pressure 6.8966 + .1013 (6.9979 MPa)

p_2 = Maximum system pressure 20.6897 + .1013 (20.791MPa)

V_1 = Initial volume of gas (3785.4 cm^3)

V_2 = Final volume of gas (Unknown)

T_1 = Initial temperature (21°C + 273) = 294° Kelvin

T_2 = Final temperature (38°C +273) = 311° Kelvin

$6.9979 \times 3785.4 \times 311 = 20.79 \times V_2 \times 294$

$V_2 = \left(\frac{6.9979 \times 3785.4 \times 311}{(20.791 \times 294)}\right)$ $V_2 = 1347.77\ cm^3$

$V_1 - V_2 = 3785.4 - 1347.77 = 2437.63\ cm^3$ ($148.73\ in^3$)

Solving for a Change in Temperature Occurring $\geq$ One Minute

Isothermal

(US Customary)

$P_1 \times V_1 \times T_2 = P_2 \times V_2 \times T_1$

$P_1 = 1000$ psi + 14.7 (1014.7)

$P_2 = 3000$ psi + 14.7 (3014.7)

$V_1 = 231\ in^3$

$V_2 = 100\ in^3$

$T_1 =$ 70°F Initial temperature + 460° (530°Rankine)

$T_2 =$ Final temperature + 460° (Rankine)

$1014.7 \times 231 \times T_2 = 3014.7 \times 100 \times 530$

$$T_2 = \frac{(3014.7 \times 100 \times 530)}{(1014.7 \times 231)}$$

$T_2 = 681.66°$ Rankine – 460 = 221.66°F

Solving for a Change in Temperature Occurring $\geq$ One Minute

Isothermal

(Metric)

$P_1 \times V_1 \times T_2 = P_2 \times V_2 \times T_1$

$P_1 = 6.8966$ MPa $+ .1013 = (6.9979\}$

$P_2 = 20.6897$ MPa $+ .1013 = (20.7910)$

$V_1 = 3785.4\ cm^3$

$V_2 = 1637\ cm^3$

$T_1 =$ 21°C Initial temperature + 273 = (294 Kelvin)

$T_2 =$ Final temperature + 273 (Kelvin)

$6.8966 \times 3785.4 \times T_2 = 20.7910 \times 1637 \times 294$

$$T_2 = \frac{20.7910 \times 1637 \times 294}{6.9979 \times 3785.4}$$

$T_2 = 377.74°$ Kelvin – 273° = 104.739°C

104.739 x 1.8 +32 = (220.5°F)

Sizing an Accumulator with a Change in Temperature of Less Than One Minute

(Adiabatic)

$$V_u = V_1 \times \left[\left(\frac{p_1}{p_2} \right)^{\frac{1}{n}} - \left(\frac{p_1}{p_3} \right)^{\frac{1}{n}} \right]$$

V_1 = Initial accumulator volume
V_u = Available liquid volume
p_1 = Pre-charge pressure
p_2 = Minimum system pressure
p_3 = Maximum system pressure
$\frac{1}{n}$ = Polytropic exponent (n = 1.4 for nitrogen gas; 1/n = 0.714)

Adiabatic

US Customary

$$V_u = V_1 \times \left[\left(\frac{p_1}{p_2}\right)^{\frac{1}{n}} - \left(\frac{p_1}{p_3}\right)^{\frac{1}{n}}\right]$$

$V_1 = 231\ in^3$
Vu = Unknown useable volume of oil
$P_1 = 900 + 14.7$ psi
$P_2 = 1000 + 14.7$ psi
$P_3 = 3000 + 14.7$ psi
$n = 1.4$

$$V_u = 231 \times \left[\left(\frac{914.7}{1014.7}\right)^{.714} - \left(\frac{914.7}{3014.7}\right)^{.714}\right]$$

Vu = 231 x [.93 - .43]
Vu = 231 x .5 = 115.93 in^3 useable oil

Metric

Adiabatic

$$V_u = V_1 \times \left[\left(\frac{p_1}{p_2} \right)^{\frac{1}{n}} - \left(\frac{p_1}{p_3} \right)^{\frac{1}{n}} \right]$$

$V_1 = 3785.4\ \text{cm}^3$

Vu = Unknown useable volume of oil

$P_1 = 6.2069 + .1013 = (6.3082)\ \text{MPa}$

$P_2 = 6.8966 + .1013 = 6.9979\ \text{MPa}$

$P_3 = 20.6897 + 1013 = 20.7910\ \text{MPa}$

$n = 1.4$

$$V_u = 3785.4 \times \left[\left(\frac{6.308}{7} \right)^{.714} - \left(\frac{6.308}{20.79} \right)^{.714} \right]$$

Vu = 3785.4 x [.9285 - .4267]

Vu = 3785.4 x .5018 = 1899.34 cm^3 115.91 in^3 useable oil

HAD ENOUGH?

QUESTIONS?

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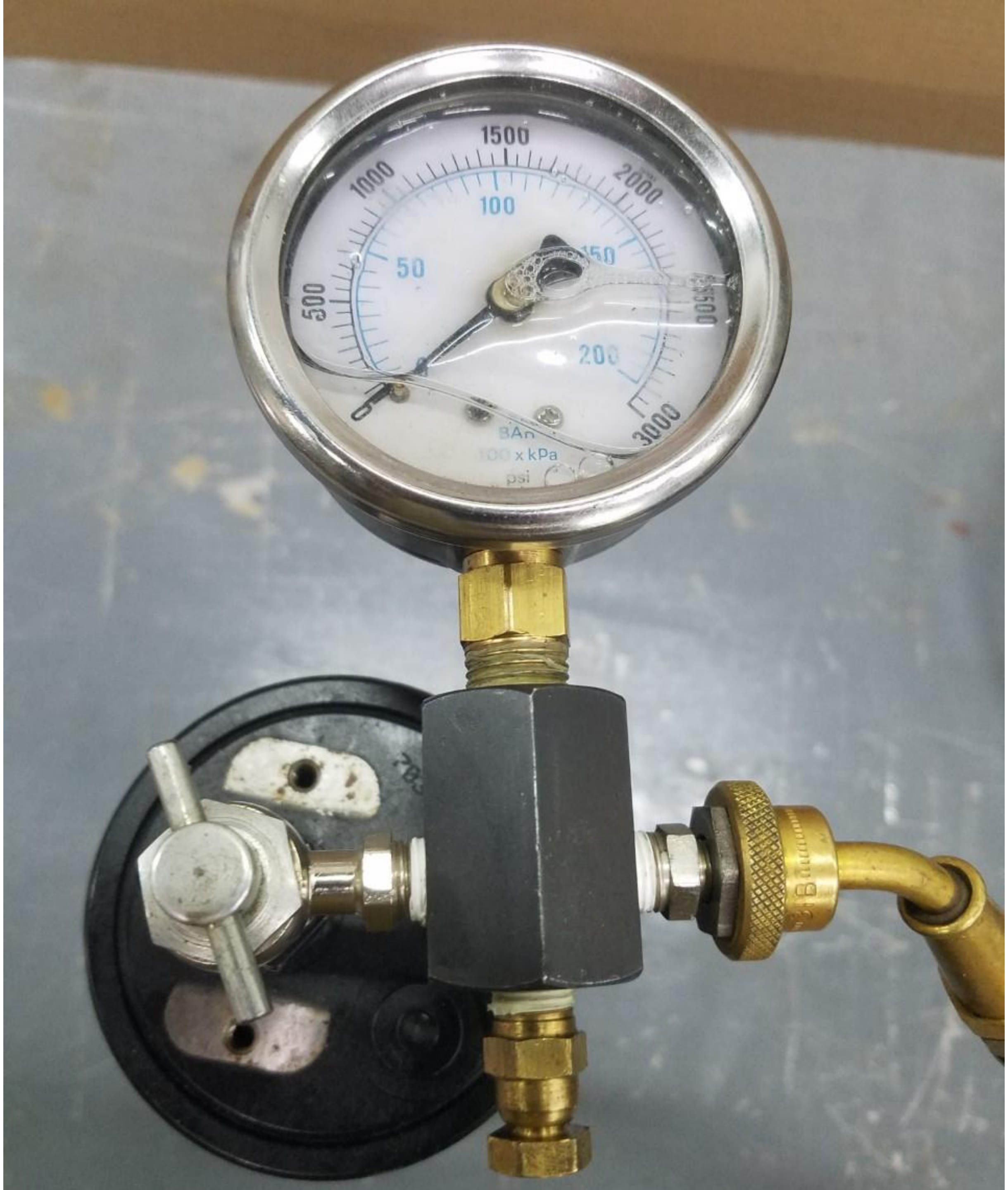

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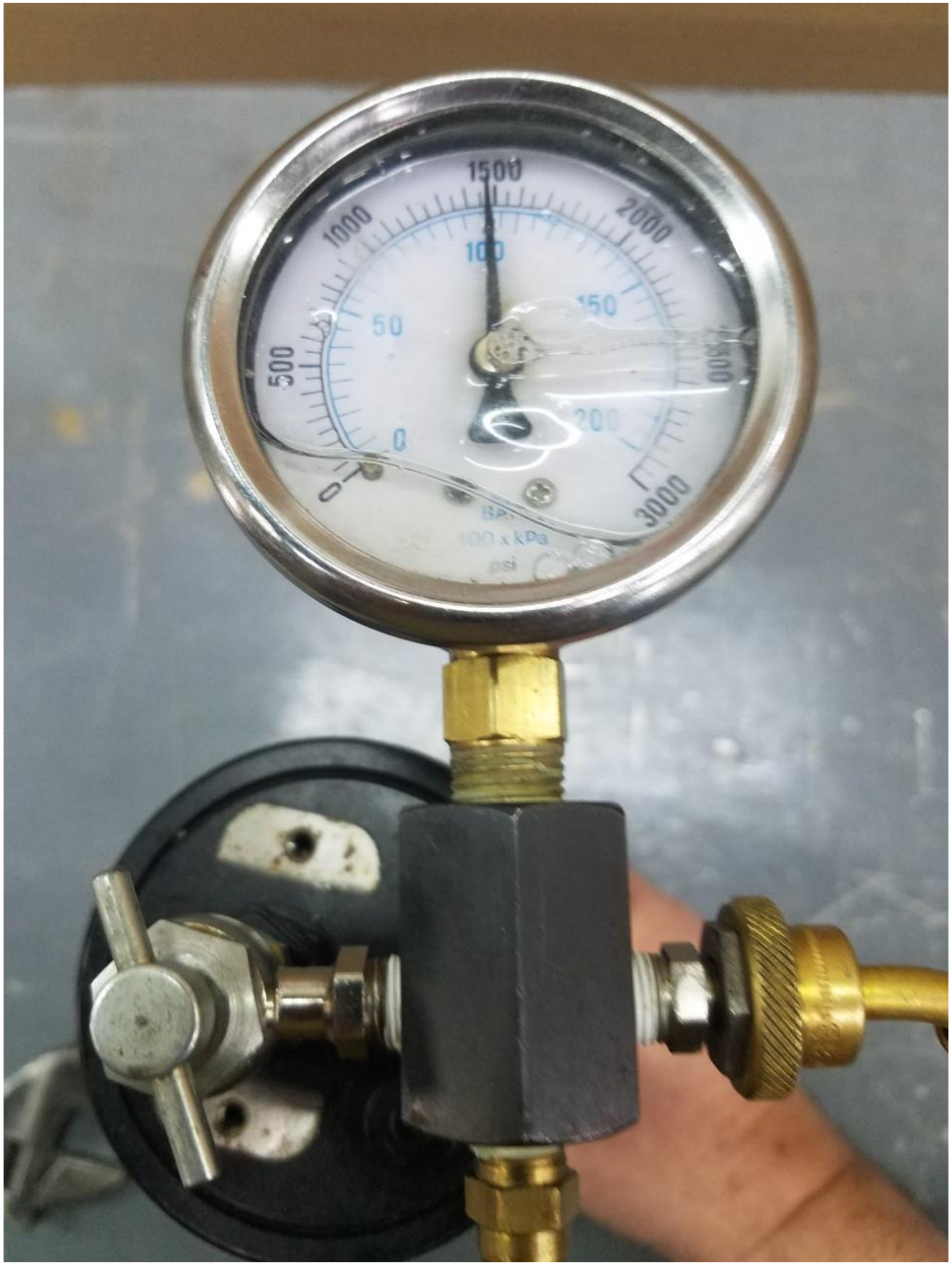

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