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Accumulator Sizing Data & Application

Sizing Accumulators

In selecting the proper accumulator size V1 (size of accumulator in cubic inches) when Vw (volume of fluid to be discharged from accumulator) is known.

$$V1 = \frac{(Vw)(E)}{f}$$

E in the above equation adjusts the equation due to the accumulator efficiency versus the gas pre-charge pressure. Use the following constants.

For Supplementing Pump
E = 1.24 for bladder accumulators.

For Auxiliary Power Source (No Pump)
E = 1.60 for bladder accumulators.

In the above equation the discharge coefficient "f" adjusts the equation for the change in the gas temperature due to heat gains and losses by expansion and compression of the gas (Calculate "f" as shown below).

Adiabatic Operation

In an adiabatic operation where the gas temperature is rapidly changing as a result of rapid compression and expansion of the gas:

$$f = 1 - \left(\frac{1}{a}\right)^{1/n}$$ (See Table 1, Page A63 for Calculations.)

Where:
$a = \frac{P_3}{P_2}$ = working pressure ratio
P_3 = Maximum system pressure
P_2 = Minimum system pressure
n = Polytropic exponent for adiabatic operation (See Charts on Page A64.)

Isothermal Operations

In an isothermal operation where the compression and expansion of the gas is very slow, allowing enough time for heat transfer resulting in little or no change in gas temperature.

$$f = 1 - \left(\frac{1}{a}\right)$$

Where:
$a = \frac{P_3}{P_2}$ = working pressure ratio
P_3 = Maximum system pressure
P_2 = Minimum system pressure

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Accumulator Sizing Data & Application (cont.)

Discharge Coefficient

$$f = 1 - \left(\frac{1}{a}\right)^{1/n}$$

Note: Use this formula if "a" is less than 1.1 or over 3.
If exact values of "a" are not shown, select the next higher value (See charts below).

How to Read Table 1

Locate "a" value in left-hand column and locate "n" value at top of Table 1. The point at which "n" and "a" intersect will be the "f" value.

Table 1

	"n" Values											
a Values	**1.40**	**1.45**	**1.50**	**1.55**	**1.60**	**1.65**	**1.70**	**1.75**	**1.80**	**1.85**	**1.90**	**1.95**
1.0	0	0	0	0	0	0	0	0	0	0	0	0
1.1	.0658	.0636	.0616	.0596	.0578	.0561	.0545	.0530	.0516	.0502	.0489	.0480
1.2	.1221	.1182	.1145	.1110	.1077	.1046	.1017	.0989	.0963	.0939	.0915	.0896
1.3	.1709	.1655	.1605	.1557	.1512	.1470	.1430	.1392	.1356	.1322	.1290	.1264
1.4	.2136	.2071	.2009	.1951	.1897	.1845	.1796	.1749	.1705	.1663	.1623	.1594
1.5	.2515	.2439	.2369	.2302	.2239	.2179	.2122	.2068	.2017	.1968	.1922	.1887
1.6	.2852	.2769	.2690	.2616	.2545	.2479	.2415	.2355	.2298	.2244	.2191	.2154
1.7	.3155	.3065	.2980	.2899	.2823	.2750	.2681	.2616	.2553	.2494	.2437	.2395
1.8	.3429	.3333	.3242	.3156	.3074	.2997	.2923	.2853	.2786	.2722	.2661	.2617
1.9	.3677	.3577	.3481	.3391	.3305	.3223	.3145	.3070	.2999	.2932	.2867	.2819
2.0	.3905	.3800	.3700	.3606	.3516	.3430	.3348	.3270	.3196	.3125	.3057	.3010
2.1	.4114	.4005	.3902	.3804	.3711	.3622	.3537	.3456	.3378	.3304	.3233	.3181
2.2	.4306	.4194	.4088	.3987	.3891	.3799	.3711	.3627	.3547	.3470	.3396	.3344
2.3	.4484	.4370	.4261	.4157	.4058	.3964	.3873	.3787	.3704	.3625	.3549	.3493
2.4	.4649	.4533	.442	.4315	.4214	.4117	.4025	.3936	.3851	.3770	.3692	.3634
2.5	.4803	.4684	.4571	.4463	.4360	.4261	.4167	.4076	.3989	.3906	.3820	.3766
2.6	.4947	.4826	.4711	.4601	.4496	.4396	.4300	.4207	.4119	.4034	.3952	.3891
2.7	.5081	.4959	.4843	.4731	.4625	.4523	.4425	.4331	.4241	.4154	.4071	.4010
2.8	.5207	.5084	.4966	.4854	.4746	.4642	.4543	.4448	.4356	.4268	.4184	.4120
2.9	.5326	.5226	.5083	.4969	.4860	.4755	.4654	.4558	.4465	.4376	.4290	.4226
3.0	.5438	.5337	.5193	.5078	.4967	.4862	.4760	.4662	.4568	.4478	.4391	.4326

Table 2

n	C3
1.41 - 1.45	.0300
1.46 - 1.49	.0318
1.50 - 1.53	.0336
1.54 - 1.57	.0352
1.58 - 1.62	.0371
1.63 - 1.67	.0389
1.68 - 1.73	.0410
1.74 - 1.79	.0429
1.80 - 1.85	.0447
1.86 - 1.91	.0464
1.92 - 1.94	.0472

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Accumulator Sizing Data & Application (cont.)

Instructions for Selection of Discharge Coefficient "n"

1. Determine Average System Pressure

$$\frac{P_2 + P_3}{2} = \text{Average System Pressure}$$

2. Determine the time in seconds to discharge the oil from the accumulator.

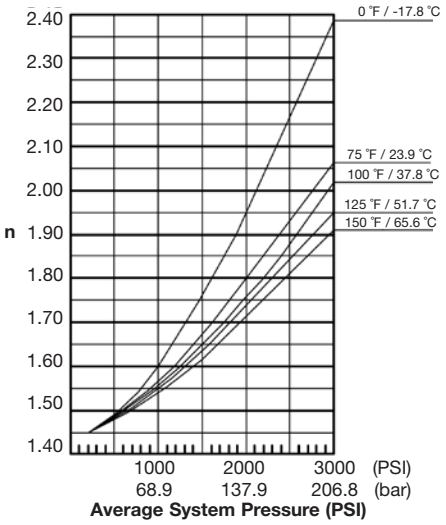
3. Select the graph which corresponds to the time (sec.) required to discharge the accumulator.

4. Select the curve on the graph which corresponds to the gas operating temperature (If gas temperature under operating conditions is not known assume *100 °F* / 38°C.)

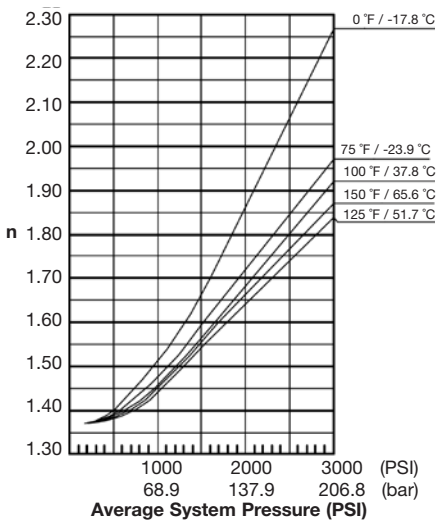
5. To use the graph, locate the average system pressure along the bottom portion of the graph. Move vertically along this column until you intersect the line corresponding to the gas temperature. Then move horizontally along this line and read the discharge coefficient to the left side of the graph.

Selection Charts for Discharge Coefficient "n"

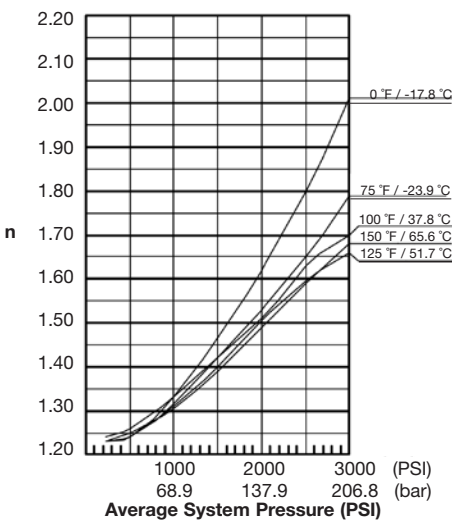
0 - 8 Seconds



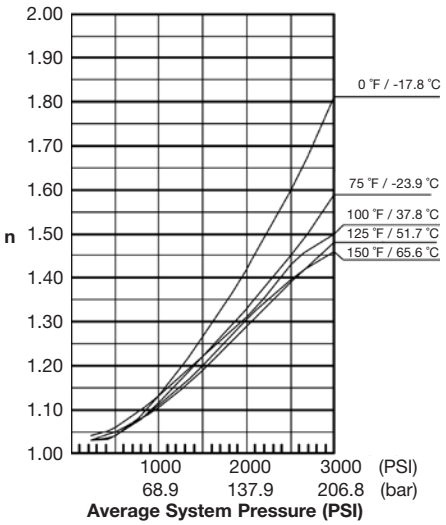
9 - 30 Seconds



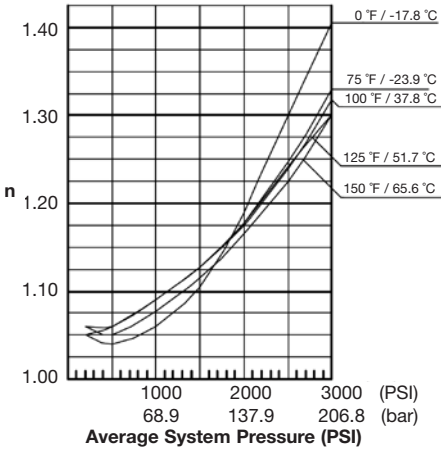
31 - 60 Seconds



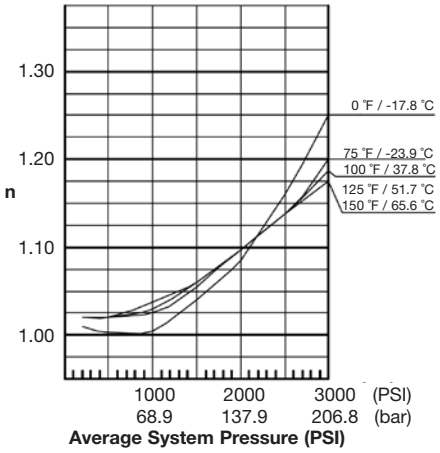
61 - 120 Seconds



121 - 500 Seconds



501 - 900 Seconds



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Accumulator Sizing Data & Application (cont.)

Problem #1 Supplementing Pump Flow

Given: A 4.5" bore x *10*" stroke cylinder with a *2*" diameter rod must extend and retract in 6 seconds. Minimum pressure required to cycle cylinder is *1000 PSI* (68 bar). Dwell time between cycles is 1.5 minutes. Gas temperature is *100 °F*. Maximum system pressure is *2000 PSI* (136 bar).

Information Required:

P_2 = 1000 PSI (68 bar) = Minimum system pressure
P_3 = 2000 PSI (136 bar) = Maximum system pressure
CT = 6 sec. = Cycle time of actuator
VC = 286.5 in^3 = Displacement of actuator per cycle
DT = 90 sec. = Dwell time between cycles
T = 100 °F. = Gas operating temperature

Solve For:

PC = 3.0 in^3/ sec. = $\frac{VC}{DT+CT}$ = minimum required output of pump (in^3 / sec)

Q = .78 GPM = .26 PC = pump output (GPM)

Vw = 269 in^3 = VC – (3.85) (Q) (CT) = cubic inches of fluid required from accumulator

a = 2 = $\frac{P_3}{P_2}$ = working pressure ratio

n = 1.65 = From Page A64

f = .3430 = From Page A63 (Table 1) (Based on values of "a" & "n")

Solution:

V_1 (in^3) = $\frac{(Vw)\ (E)}{f}$

E = 1.24 for bladder accumulator (See Page A62).

V_1 (in^3) = $\frac{269\ (1.24)}{.3430}$ = 973 in^3 or 4.25 Gallons

Where V_1 = Accumulator size required in cubic inches

Once V_1 has been determined, select the accumulator from Pages A47-A50 which has a gas volume equal to or greater then V_1. In this example a 5 gallon bladder accumulator would satisfy the system. P = gas pre-charge, which should be 80% of P_2 in bladder accumulators.

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Accumulator Sizing Data & Application (cont.)

Problem #2
Increasing Actuation Speed in an Existing Hydraulic System

Given: Present system has a 5 GPM pump capable of *3000 PSI* (207 bar), 6" bore x 12" stroke cylinder with a 2" rod. Minimum pressure to extend and retract cylinder is *1500 PSI* (103 bar). Gas temperature is 150 °F. Bladder accumulator to be used. Cylinder cycle time is to be reduced from 40 seconds to 8 seconds. Dwell time between cycles is 40 seconds.

Information Required:

P_2 = *1500 PSI* (103 bar) = Minimum system pressure
P_3 = *3000 PSI* (207 bar) = Maximum system pressure
CT = 8 sec. = Cycle time of actuator
VC = 640.5 in^3 = Displacement of actuator per cycle
DT = 40 sec. = Dwell time between cycles
Q = 5 GPM = Present pump flow
T = 150 °F. = Gas operating temperature

Solve For:

Vw = 486.5 in^3 = VC – (3.85) (Q) (CT) = oil required from accumulator

VR = 770 in^3 = (3.85) (Q) (DT) is the pump output during the dwell period. VR must be Greater than Vw to accomplish the new cycle rate. If not, cycle time (CT) or dwell time (DT) must be increased.

a = 2 = $\frac{P_3}{P_2}$ = Pressure ratio

n = 1.76 = From Page A66

f = .3196 = From Page A65 (Table 1) (Based on values of "a" & "n")

Solution:

$$V_1\ (in^3) = \frac{(Vw)\ (E)}{f}$$

E = 1.24 for bladder accumulator (See Page A64).

$$V_1\ (in^3) = \frac{486.5\ (1.24)}{.3196} = 1887.5\ in^3 \text{ or } 8.2 \text{ Gallons}$$

Where V_1 = Accumulator size required in cubic inches

Once V_1 has been determined, select the accumulator from Pages A47-A50 which has a gas volume equal to or greater then V_1. In this example a 10 gallon bladder accumulator would satisfy the system. P = gas pre-charge, which should be 80% of P_2 in bladder accumulators.

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Accumulator Sizing Data & Application (cont.)

Problem #3
Shock Suppression

Given: System has a 120 GPM pump operating at *2200 PSI* (152 bar). Shock is caused by rapidly closing the directional control valve. 80 feet of pipe is between the pump and valve causing shock. Internal area of pipe is 1.4 square inches. Gas operating temperature is 100°F (38°C). Using standard petroleum oil (54.3 lbs/ft^3). What size of accumulator (V1) would be required to limit shock pressure to 10% above system pressure P_2?

Information Required:

L	= 80 ft.	= Length of pipe between pump and valve causing shock.
A	= 1.4 in ^{2}	= Internal area of pipe
P_2	= *2200 PSI* (152 bar)	= Operating pressure
Q	= 120 GPM	= Rate of flow
T	= 100 °F	= Gas operating temperature

Solve For:

n = 1.80 = Discharge coefficient – See Page A64. Use 0-8 second curves.

VT = 0.78 ft^3 = $\frac{(L)\ (A)}{144}$ = Total volume of oil in pipe

WT = 54.3 lbs/ ft^3 = Weight of fluid per cubic foot

W = 42.2 lbs = (VT) (WT) = Total weight of liquid in pipe

V = 27.5 ft/ sec. = $\frac{(.3208)\ (Q)}{A}$ = Flow velocity

C3 = .0447 = From Page A63 (Table 2) (Opposite the "n" value selected)

Solution:

V_1 (in^3) = $\frac{(Vw)\ (E)}{f}$ = Size of accumulator required

$V_1 = \frac{(V)^2\ (W)\ (n\text{-}1)\ (.205)}{(P2)\ (C3)}$

$V_1 = \frac{(27.5)^2\ (42.2)\ (1.80\text{-}1)\ (.205)}{(2200)\ (.0447)}$ = 53.2 in^3 or .23 Gallons

A_1 Qt. accumulator would satisfy the system.

P_1 gas pre-charge pressure should normally be 60% of P_2, (in a shock suppression application).

ACCESSORIES