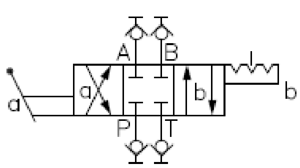
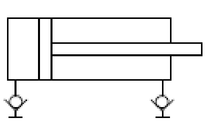
Diaphragm accumulator

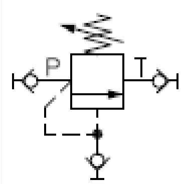
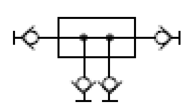
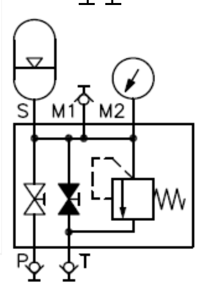
Description of experiment
Accumulators are used to store energy, damp pulsation's, maintain constant pressure, compensate oil leakage and for suspension of motor vehicles. In this experiment we are interested in oil storage. A diaphragm accumulator is used for this. The separating element of accumulators can be a diaphragm, a bladder or a piston. Diaphragms are commonly used for smaller accumulators. Diaphragms are manufactured from synthetic rubber materials such as NBR or FPM. The chemical composition and temperature of the oil determine the choice of the particular material. The physical principle of energy storage is in the compressibility of a gas.

Safety regulations
Since an accumulator is a pressure vessel it must be tested and comply with certain safety regulations. These regulations change from country to country and even within various areas of the country itself. The vessel should be certified and stamped for approval for installation in the area of final delivery. The manufacturer usually carries out the test and a test certificate should accompany the vessel.
Only nitrogen may be used as a gas for charging. Nitrogen is colourless, odourless and tasteless and is very inert at normal operating pressures. At temperatures below 600^0C it reacts only with lithium and above 600^0C with some other elements such as calcium and magnesium to form nitrides. Accumulators are typically supplied with isolation valving to allow safe discharge of the pressurized fluid when the system is shut off. Ensure that you open the bleed down valve after each experiment to ensure that there is no residual pressure in the system.

Description of exercise
The circuit on the following page allows the filling or charging and discharging of the accumulator. It is important to note that there is a check valve built into the P/T/X distributor manifold in the pressure line. The purpose of this check valve is to avoid the pump spinning backwards when the electric power is shut off.

Components:
You will require the following components:

	Hose assembly	
1x	Directional control valve DW5	
1X	Hydraulic cylinder	

2x	Pressure gauge DZ1.4	
1X	Pressure relief valve DD1.1	
1X	Connection piece DZ4.2	
1X	Accumulator with safety/shut-off block DZ3.2	

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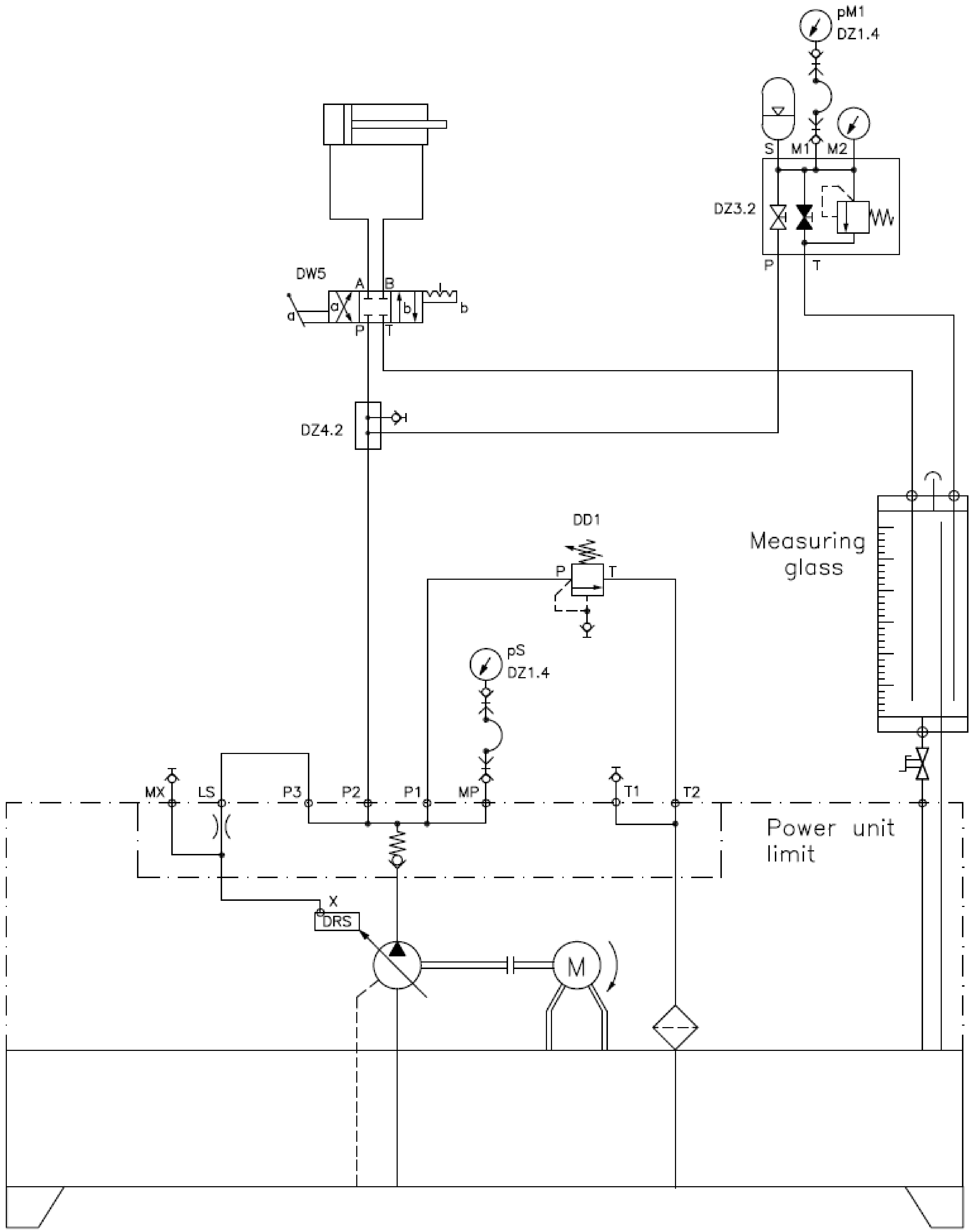


Before beginning the experiment read the **Rules for hydraulic trainer operation** sheet.

Setting up the experiment
Set up the circuit observing the following points:

1. Make sure the pump is switched off and the hydraulic circuit is not pressurized.
2. Mount the required components on the grid and lock them
3. Connect the separate units with pressure hoses according to the connection diagram. Take care that the connection hoses are not kinked or under undue stress.

Experimental procedure
Steps in the experimental procedure:

1. Has your instructor checked the constructed circuit?
2. Check again that all connection hoses are firmly coupled. (pull/turn to test)
3. Back out the setting (CCW) of loading relief valve DD1.1/L until a setting of zero. This will ensure minimum pressure at start-up.
4. Open the shut-off valve on the measuring glass to allow it to drain to tank.
5. Open the isolation ball valve (handle P) and close the bleed valve (rotary knob T) on the accumulator safety/shut-off block.
6. Ensure the red E-STOP button is not engaged on either of the starters. (rotate the button to reset)
7. Switch on the pump via the green START push button

Experiment

Part I – Checking the accumulator precharge

a) Set the system pressure to **600 psi** via the system pressure relief valve DD1.1. This pressure can be measured at gauge **M2** (on the accumulator manifold)
b) Close the isolation ball valve (handle P) on the accumulator safety/shut-off block. The system pressure is now isolated in the accumulator.
c) Switch the pump off.
d) Open the bleed valve (rotary knob T) until you see the pressure at gauge **M2 slowly** fall
e) The pressure will fall slowly while the oil is discharged from the accumulator.
f) Once the pressure reaches the precharge value this pressure will **rapidly** fall to **0 psi**
g) The pressure at which this changes from slowly to quickly changing pressure is the **nitrogen precharge pressure**

Precharge pressure __150__ psi

h) Switch off the pump.

Part II – Useable accumulator oil volume

a) Switch on the hydraulic pump again.
b) Open the isolation ball valve (handle P) and close the bleed valve (rotary knob T) on the accumulator safety/shut-off block
c) Set the pressure at pM1 to **150 psi** via the system pressure relief valve DD1.1
d) Extend and retract the cylinder by shifting 4/3-directional valve DW5 and mark the end of stroke positions on the cylinder base plate. The overall cylinder stroke should be 200mm≈ 8”
   or 400mm ≈ 16”
e) Retract the cylinder completely and centre the 4/3-directional control valve
f) Turn off the pump

g) Using the directional control valve, extend and retract the cylinder fully until it no longer moves. At this point all of the stored volume of oil has been discharged from the accumulator.
h) Note the number of strokes (extending and retracting) and also the partial stroke value and record these in the following table.
i) Turn on the hydraulic pump and set the pressure at pM1 to **200 psi** via the system pressure relief valve DD1.1
j) Repeat the above procedure from point e) for the different pressure settings listed in the table

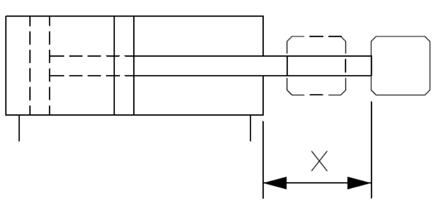
Once you have completed the experiment open the bleed valve (rotary knob T) on the accumulator safety/shut-off block and allow all pressure to bleed back to tank prior to disassembling the circuit.

Calculation of the useful volume of the accumulator

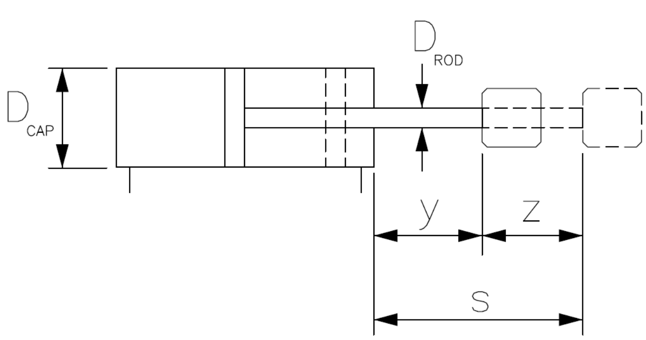
The following formula uses the travel of the hydraulic cylinder for calculation of the useful volume of the accumulator.

$$V = \frac{D_{CAP}{}^2 \bullet \pi}{4} \bullet (a \bullet S + x) + (D_{CAP}{}^2 - D_{ROD}{}^2) \bullet \frac{\pi}{4} \bullet (e \bullet S \bullet z)$$

V = useful volume of accumulator (in^3)
D_{CAP} = Bore of the hydraulic cylinder (in)
D_{ROD} = *Cylinder rod diameter (in)*
S = *Cylinder stroke (in)*
a = *Number of complete extension strokes*
e = *Number of complete retraction strokes*
x = *Partial stroke distance in extension*
z = *Partial stroke distance in retraction*



Cylinder comes to a stop while extending

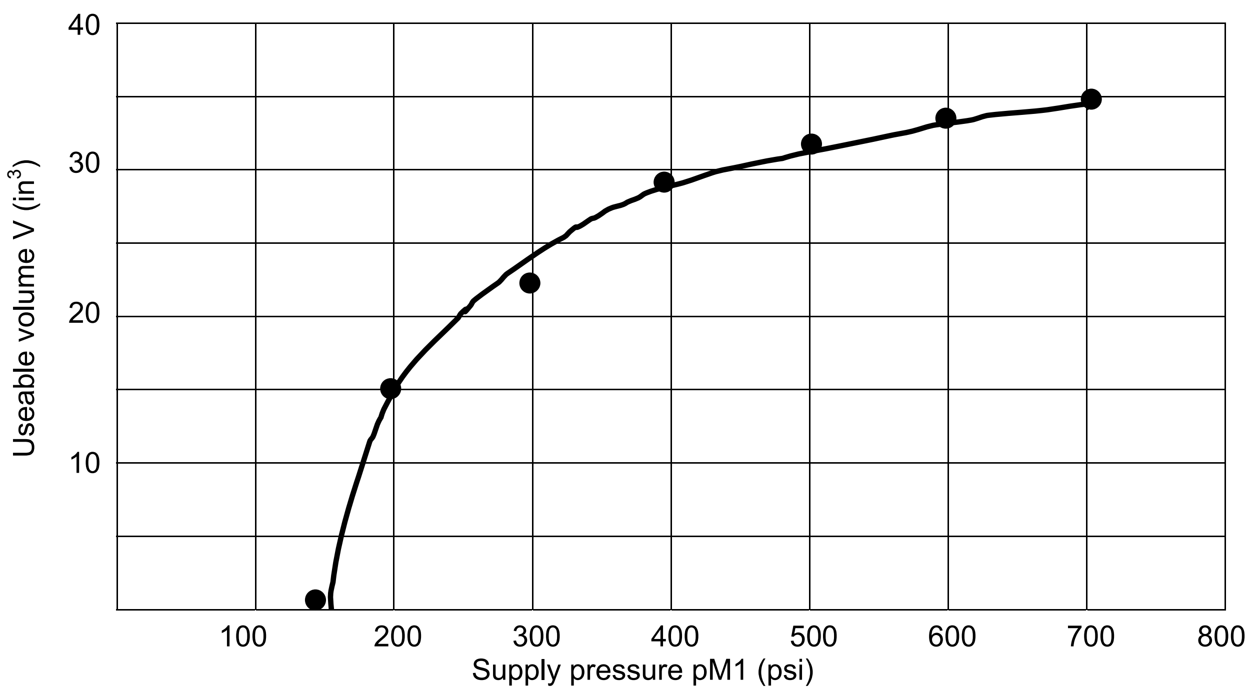


Cylinder comes to a stop while retracting
z=S-y

400 mm / 16” stroke (200 mm / 8” stroke)

Hydraulic supply pressure **pM1** p in psi	No. of complete strokes		Residual stroke (in)		Useable volume V (in^3)
	Extending **a**	Retracting **e**	Extending **x**	Retracting **z**	
150	0 (0)	0 (0)	0 (0)	0 (0)	0
200	1 (1)	0 (1)	6-1/2”	5-1/2”	15.24
300	1 (2)	1 (2)	2” (2”)	0	21.88
400	1 (3)	1 (2)	10-1/2”	4”	28.56
500	2 (3)	1 (3)	14-1/2” (1-1/2”)	0 (0)	31.70
600	2 (3)	1 (3)	4”	1-1/2”	33.60
700	2 (3)	1 (3)	6-1/2”	6”	35.57

Graph your results in the following space



Conclusions

- Due to the compressibility of the precharge gas, accumulators can be used to store energy.

- The volume of oil stored in the accumulator depends on the size of the accumulator, the gas precharge pressure and the maximum hydraulic pressure.

- The effective or useful volume of the hydraulic accumulator depends on the accumulator size, the gas pre-charge pressure and the difference between minimum and maximum working pressure.

- If the system pressure falls below the gas precharge pressure then the accumulator is completely drained.

- The hydraulic accumulator will be charged when the system pressure is higher than the gas precharge pressure

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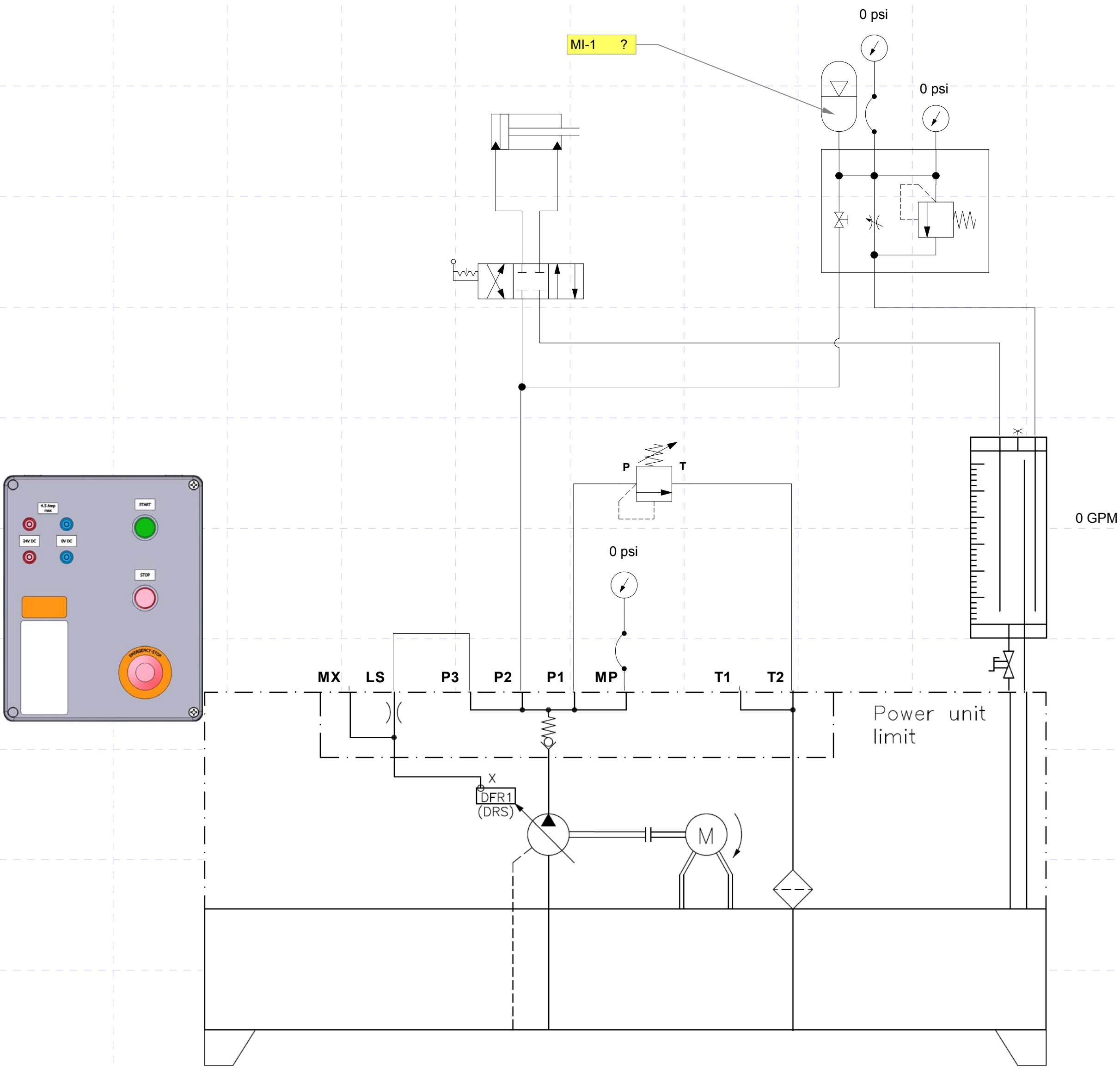
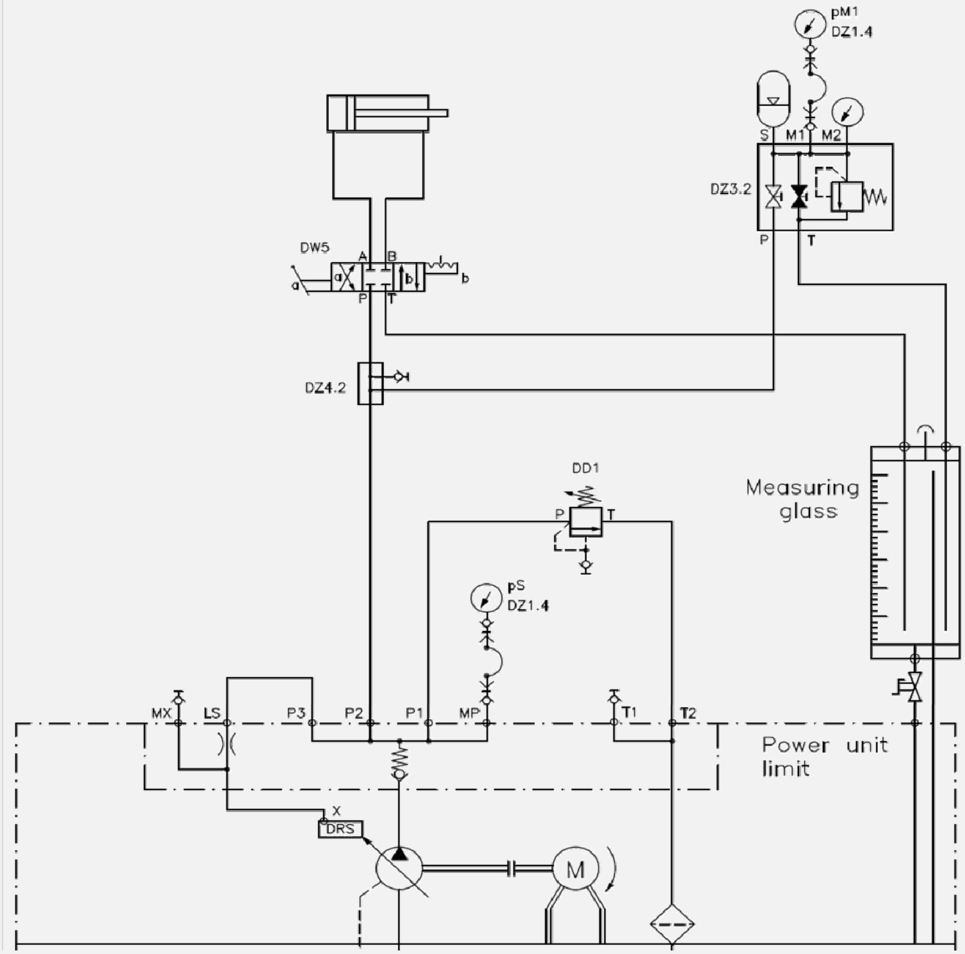
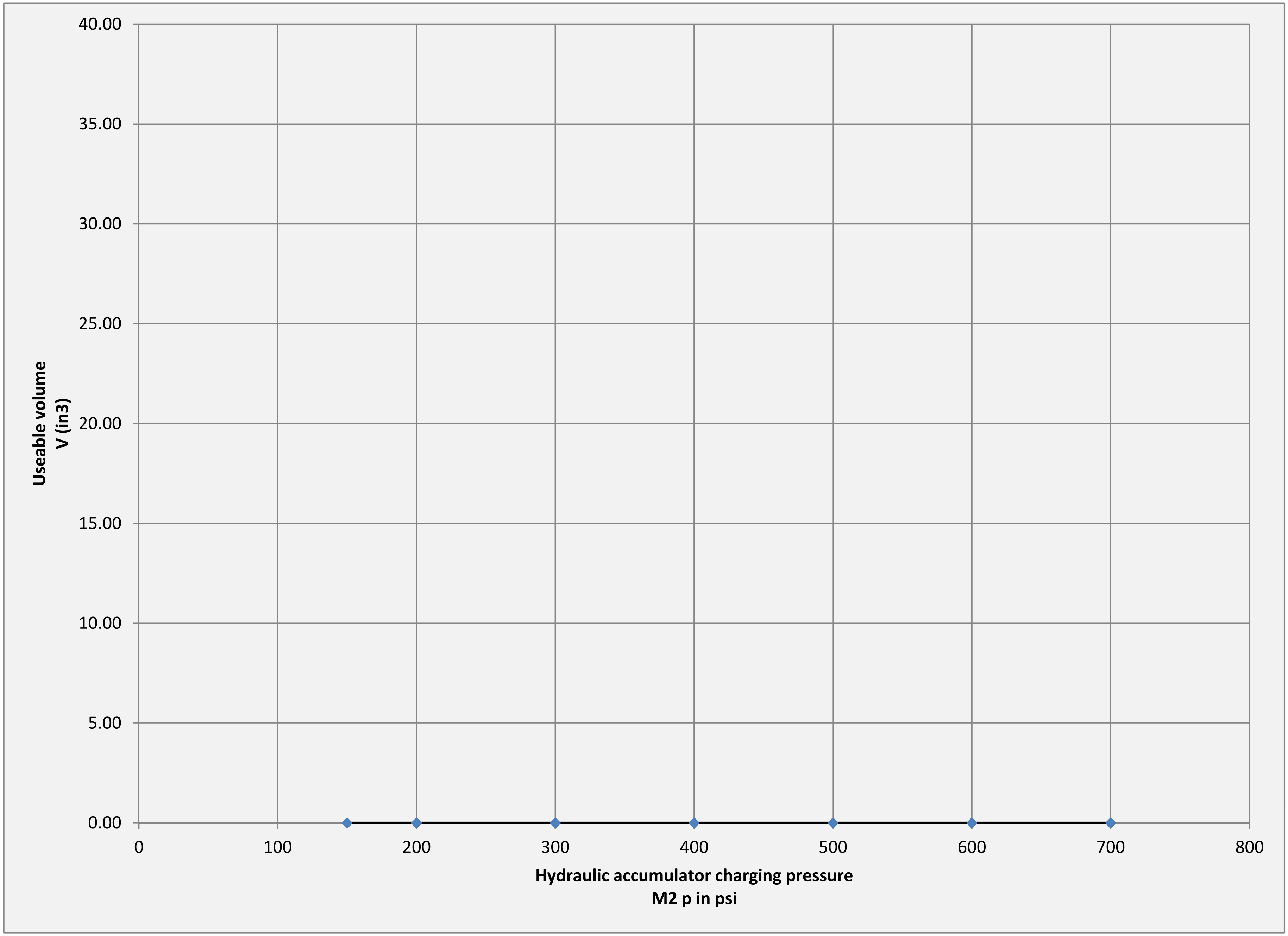


Diaphragm Accumulator

Hydraulic accumulator charging pressure **M2** p in psi	No. of complete strokes		Residual stroke (in)		Useable volume V (in^3)
	Extending **a**	Retracting **e**	Extending **x**	Retracting **z**	
150					0
200					0
300					0
400					0
500					0
600					0
700					0

Total cylinder stroke inches




40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Useable volume
V (in3)
0
100
200
300
400
500
600
700
800
Hydraulic accumulator charging pressure
M2 p in psi