Pearson BTEC Levels 4 Higher Nationals in Engineering (RQF)

Unit 29: Electro, Pneumatic and Hydraulic Systems

Unit Workbook 2

in a series of 4 for this unit

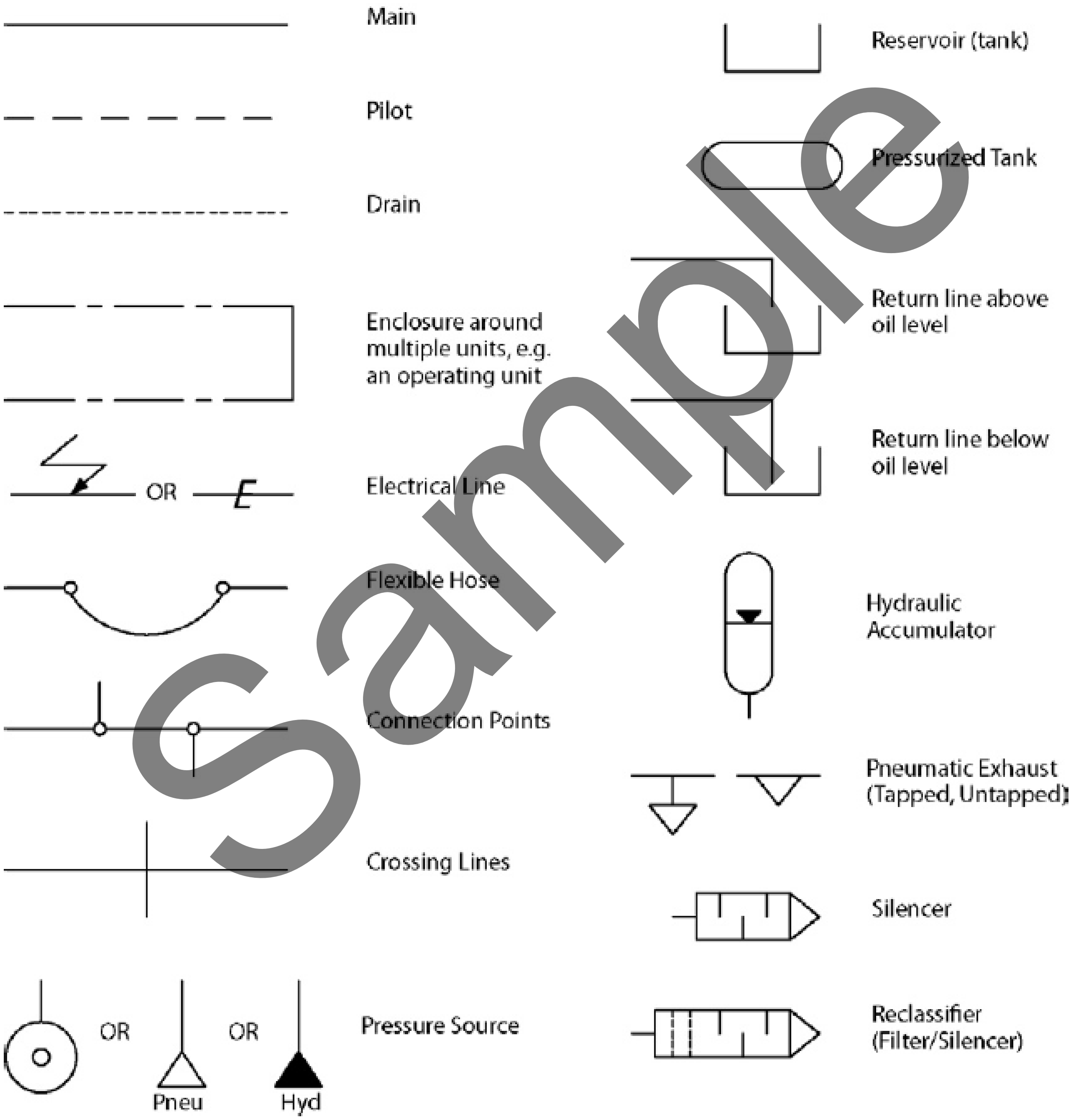
Learning Outcome 2

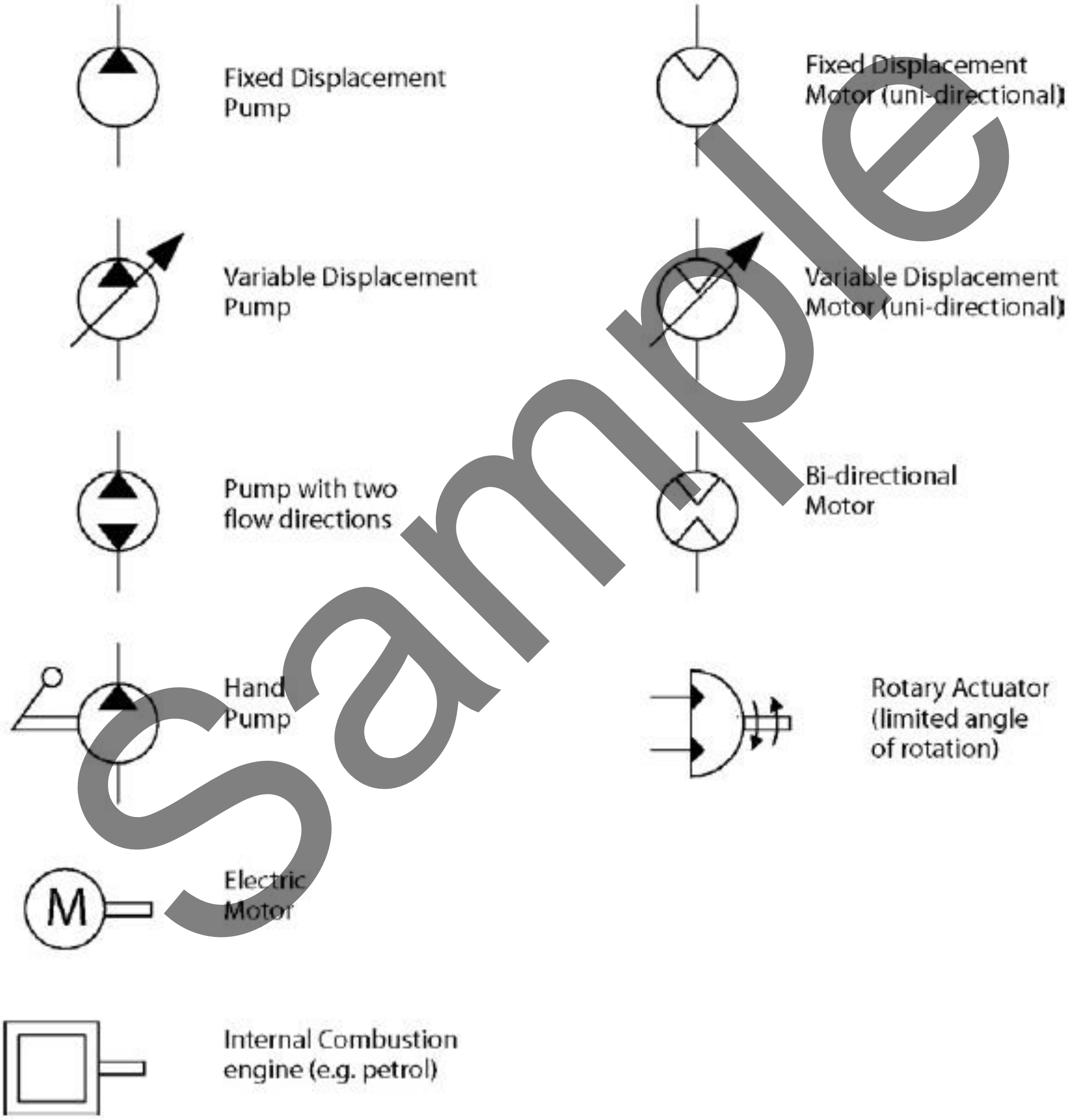
Pneumatic and Hydraulic Notation and Symbols

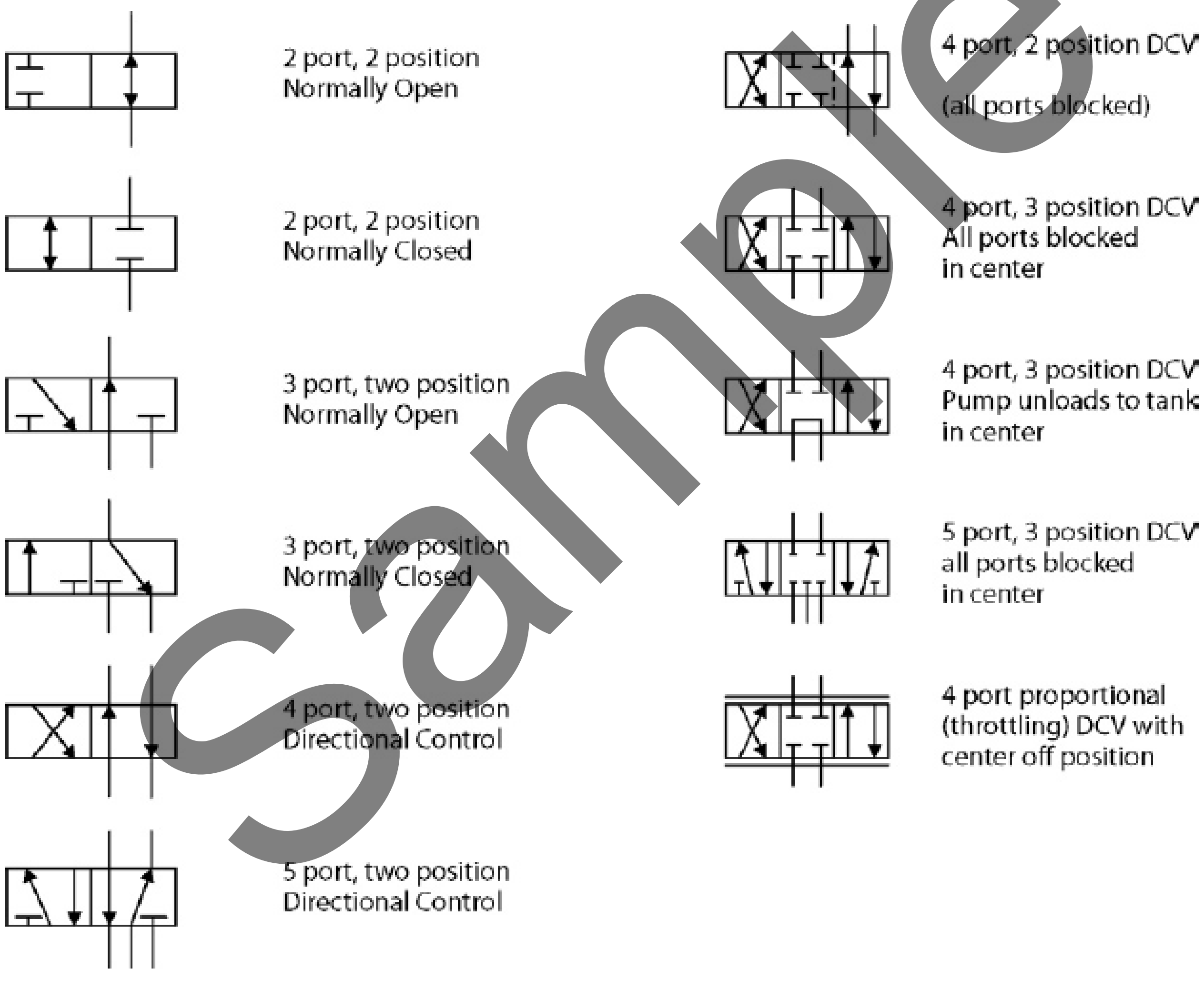
Performance of hydraulic and pneumatic components

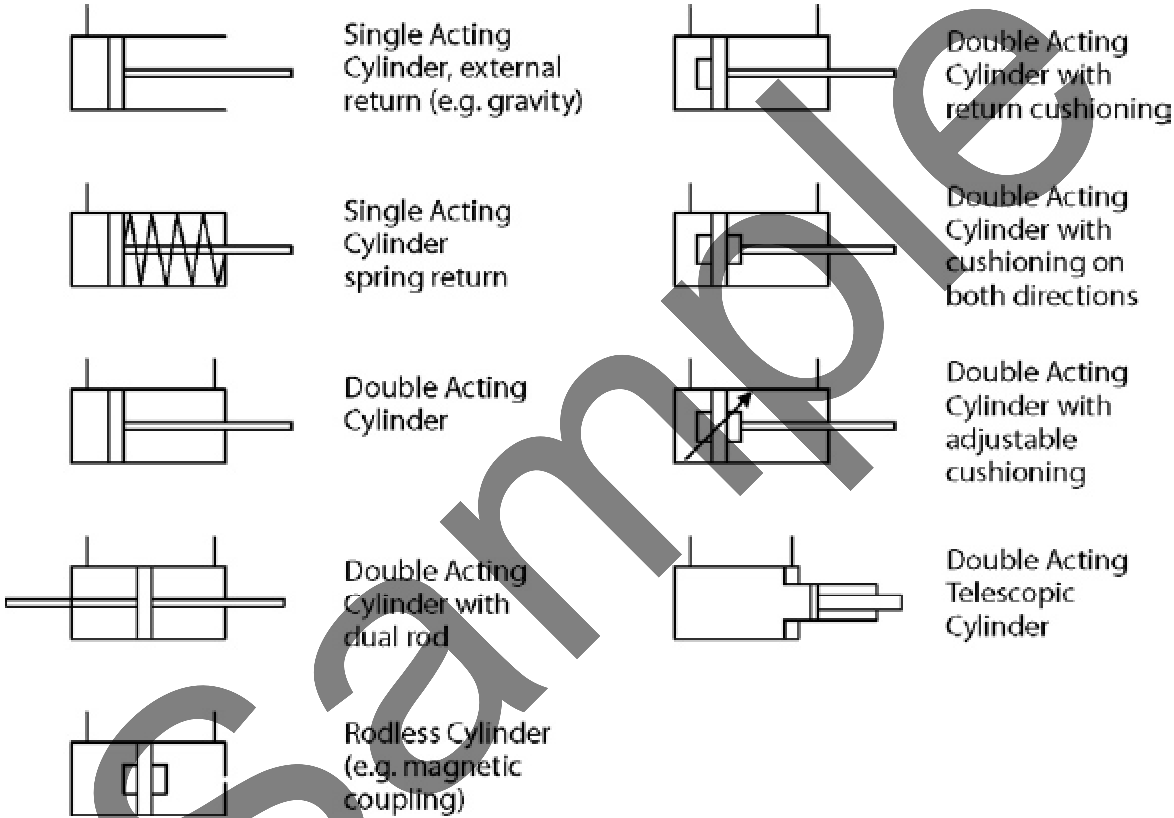
Symbols

The symbols below correspond to the ISO 1219 international standard. Similar symbols are used for both pneumatics and hydraulics. Energy triangles may be found on pumps and motors, and these triangles are coloured black for hydraulic systems and clear for pneumatic systems.




Fixed Displacement
Pump
Fixed Displacement
Motor (uni-directional)
Variable Displacement
Pump
Variable Displacement
Motor (uni-directional)
Pump with two
flow directions
Bi-directional
Motor
Hand
Pump
Rotary Actuator
(limited angle
of rotation)
M
Electric
Motor
Internal Combustion
engine (e.g. petrol)


2 port, 2 position
Normally Open
2 port, 2 position
Normally Closed
3 port, two position
Normally Open
3 port, two position
Normally Closed
4 port, two position
Directional Control
5 port, two position
Directional Control
4 port, 2 position DCV
(all ports blocked)
4 port, 3 position DCV
All ports blocked
in center
4 port, 3 position DCV
Pump unloads to tank
in center
5 port, 3 position DCV
all ports blocked
in center
4 port proportional
(throttling) DCV with
center off position


Single Acting Cylinder, external return (e.g. gravity)
Single Acting Cylinder spring return
Double Acting Cylinder
Double Acting Cylinder with dual rod
Rodless Cylinder (e.g. magnetic coupling)
Double Acting Cylinder with return cushioning
Double Acting Cylinder with cushioning on both directions
Double Acting Cylinder with adjustable cushioning
Double Acting Telescopic Cylinder

Fluid Power Diagrams

These may be drawn with AutoCAD, a free version of which is available here.

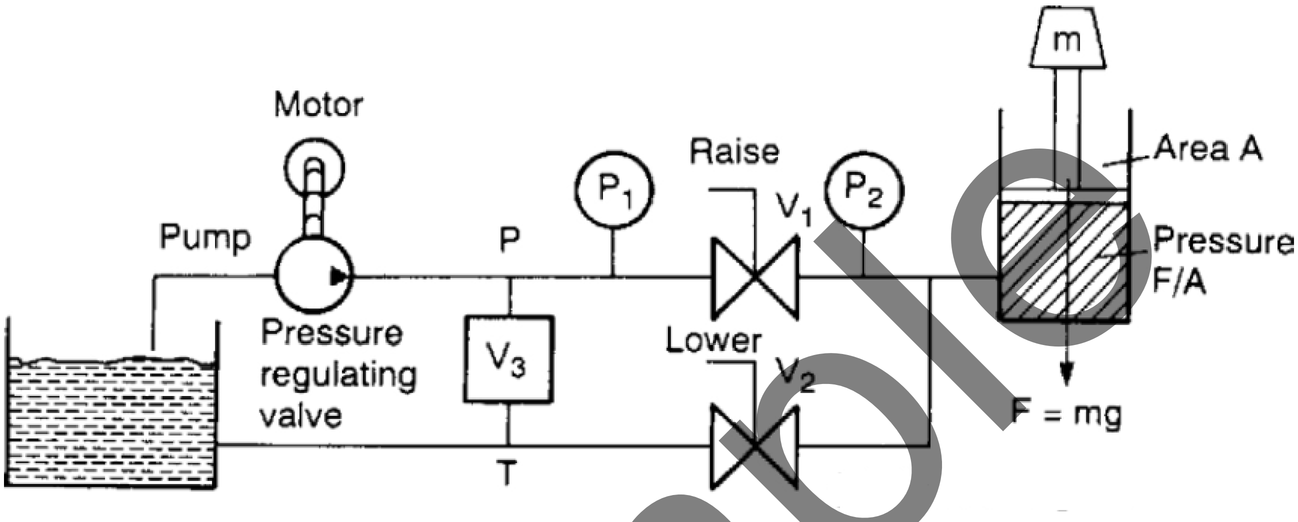


Figure 2 *Fluid power diagram of a hydraulic cylinder lifting system*

Figure 2 shows a system whereby a load 'm' can be elevated or lowered by a hydraulic cylinder. Here's how it works;

- When valve V_1 is open and valve V_2 closed, the hydraulic fluid enters the pump P_2 and into the cylinder. The load is raised.
- Pressure gauges P1 and P2 indicate the pressure at the inlet and outlet to the valve, respectively.
- When valve V_1 is closed and valve V_2 open, the hydraulic fluid returns to the tank, lowering the load.

A problem arises when the load is falling. The pump (driven by the motor) still keeps delivering hydraulic fluid at the point where P1 is sited, causing a build-up in pressure, due to V_1 being closed. Some means must be found to limit pressure P_1 to a safe level. A pressure-regulating valve V_3 is therefore included to limit the pressure at P_1. Valve V_3 is normally-closed, but once the pressure at P_1 hits a preset level (the 'cracking level') it will open. With V_3 open, hydraulic fluid is returned from the pump to the tank.

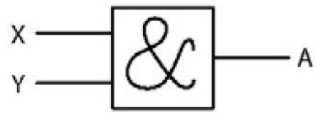
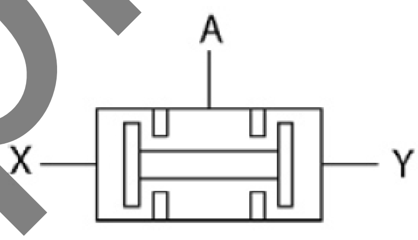
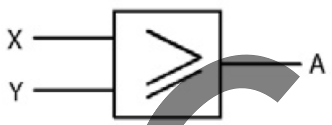
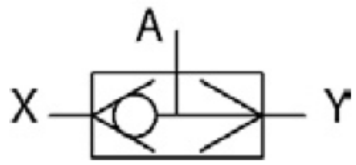
Logic Functions

When we wish for motors, pumps, valves, actuators etc, to operate given certain conditions, we need to employ logic functions.

Consider the requirement;

IF (A is in position AND B is in position AND C is NOT in position) OR (D is in position) then operate valve X.

The key terms here are; AND, OR, NOT. We may use logic elements to represent these terms. Figure 3 shows the symbols for these functions, their Truth Tables (how they work), along with their representations on many fluid power diagrams (FPD).

<table>
<tr><th>Logic Symbol</th><th>Truth Table</th><th>FPD Symbol</th></tr>
<tr><td>AND Gate

</td><td><table><tr><th>X</th><th>Y</th><th>A</th></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>1</td></tr></table></td><td>
</td></tr>
<tr><td>OR Gate

</td><td><table><tr><th>X</th><th>Y</th><th>A</th></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>1</td></tr></table></td><td>
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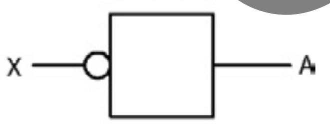
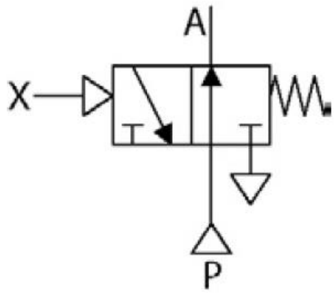
<tr><td>Inverter

</td><td><table><tr><th>X</th><th>A</th></tr><tr><td>0</td><td>0</td></tr><tr><td>0</td><td>0</td></tr><tr><td>1</td><td>0</td></tr><tr><td>1</td><td>1</td></tr></table></td><td>
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Figure 3 *Logic functions used in fluid systems*

Let's now draw the logic function which represents the requirement mentioned earlier…

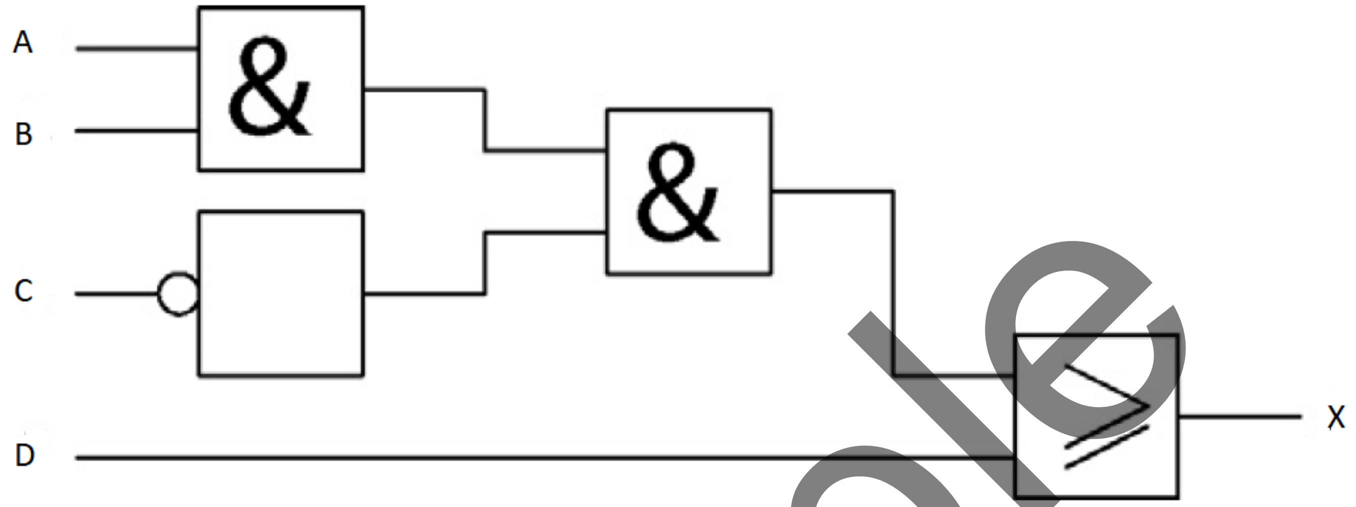

Figure 4 *Example logic functions used to operate a valve*

Again, let's examine that function mentioned earlier…

IF (A is in position AND B is in position AND C is NOT in position) OR (D is in position) then operate valve X.

A and B are inputs to an AND gate on the left. We would like 'NOT C' to be a third input to this AND gate, but first of all need to invert C (make it NOT C), which is performed by the NOT gate. The outputs from the leftmost AND gate and the NOT gate are then presented to the inputs of the central AND gate. The output from this central AND gate is effectively ***(A is in position AND B is in position AND C is NOT in position).***

This last statement in brackets needs to be OR'ed with D, as shown. The output at X then represents to full requirement.

That was just an example, of course. It is important to note that just by using AND, OR, NOT function combinations it is possible to construct **ANY** desired logic function for a fluid system.

Actuators

Linear Actuator

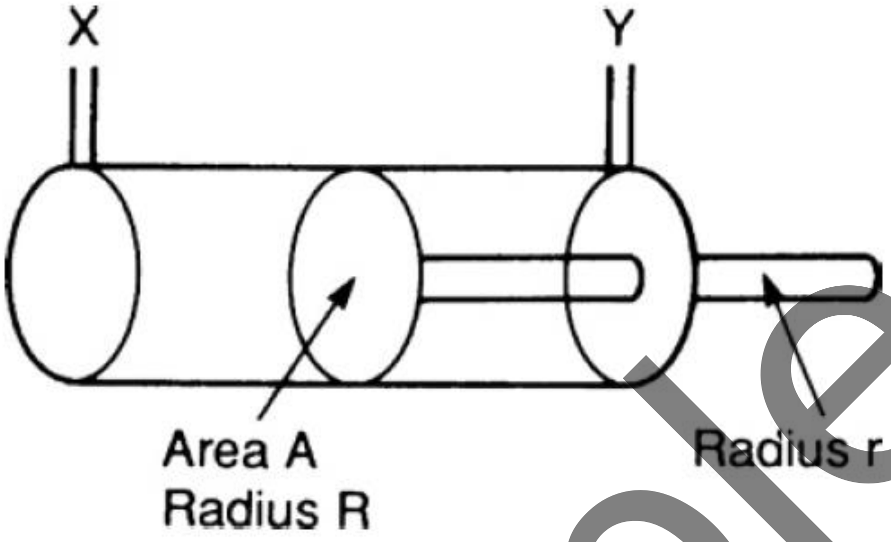

Figure 5 *Linear Actuator*

The basic linear actuator is, of course, the cylinder, as shown in figure 5. Here, a cylinder moves inside a bore. The cylinder is connected to a rod. If fluid pressure is applied to X then the piston will extend. If pressure is applied to Y then the piston will retract.

The force applied to the load is proportional to both the fluid pressure P and the area of the piston…

$$F = P\pi R^2 \quad [1]$$

From equation 1 it is clear that more force can be exerted if the radius of the piston/bore is increased and/or the fluid pressure is increased.

The construction of pneumatic and hydraulic cylinders is quite similar. The main difference is that a hydraulic cylinder may exert a pressure of, perhaps, 100 bar, whereas a typical pressure exerted by a pneumatic cylinder might be around only 10 bar.

Rotary Actuator

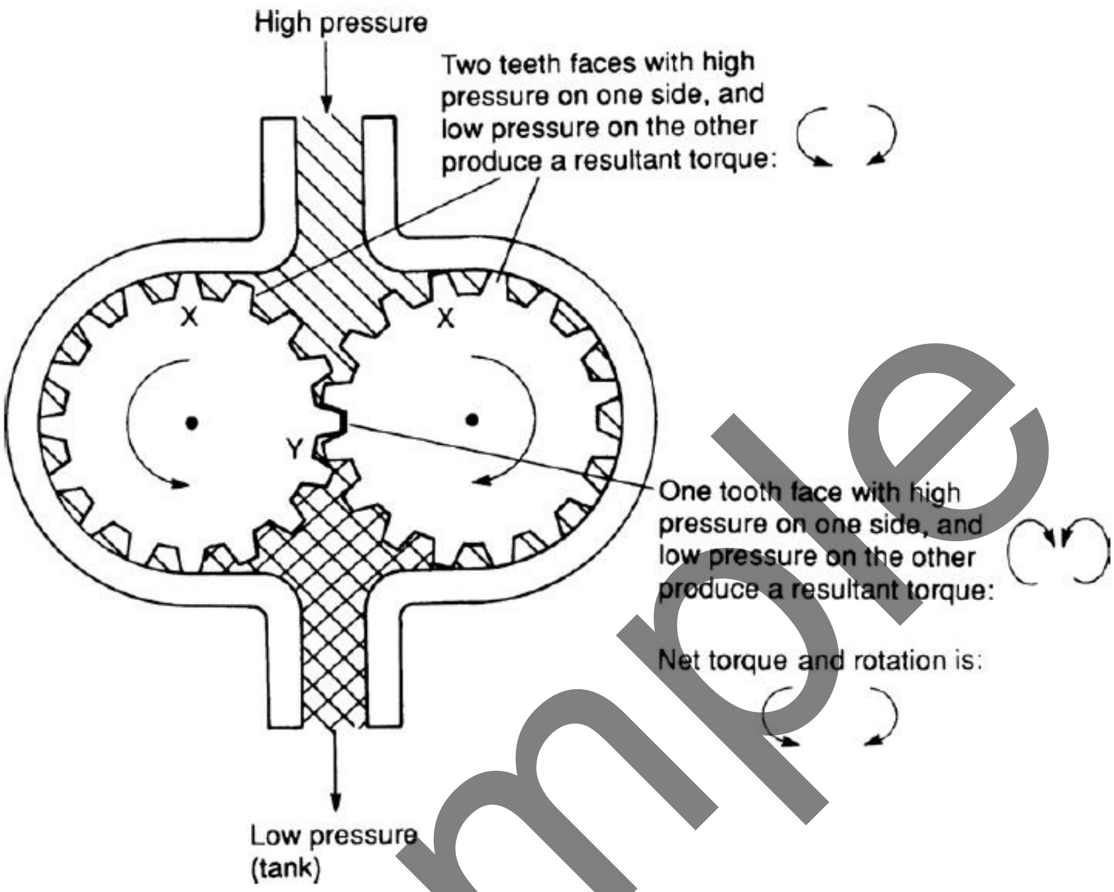

Figure 6 *Rotary Actuator*

A gear motor type of actuator is shown in figure 6. Here, fluid enters from the top and exerts pressure on the top chamber above the gear teeth. The gear faces exposed to the top chamber will experience a greater force than those which face the bottom chamber. This differential in force causes a rotational torque.

Such gear motors tend to leak fluid when operated at low speed and high torque. Therefore, these devices tend only to be used in medium-speed low-torque situations.

Bellows Actuator

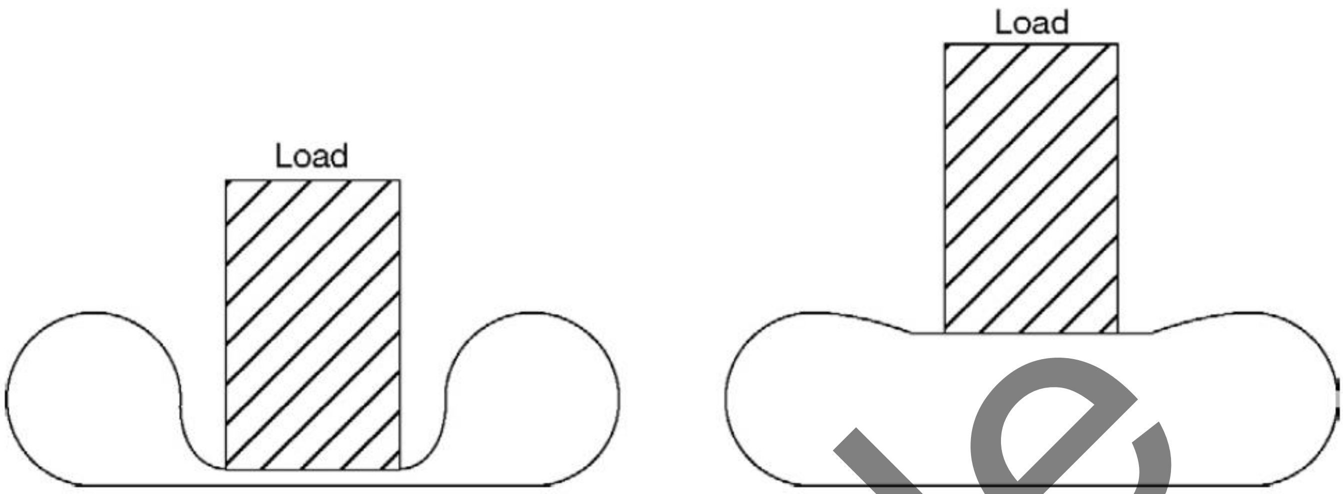

Figure 7 *Bellows Actuator*

The bellows actuator shown in figure 7 has a very simple operational principle. The load is placed onto the bellows and falls due to gravity. When air is pumped into the bellows they begin to inflate, raising the load. To lower the load the air pressure is reduced.

Advanced Functions

Timers

When tasks need to be performed in sequence (sequencing), there is often the need to utilise time as part of the sequence. Usually a 'timer' is employed to perform such a delay. Usually, there are three types of timer in use;

- Delay-on (TON)
- Delay-off (TOF)
- One-shot (PULSE)

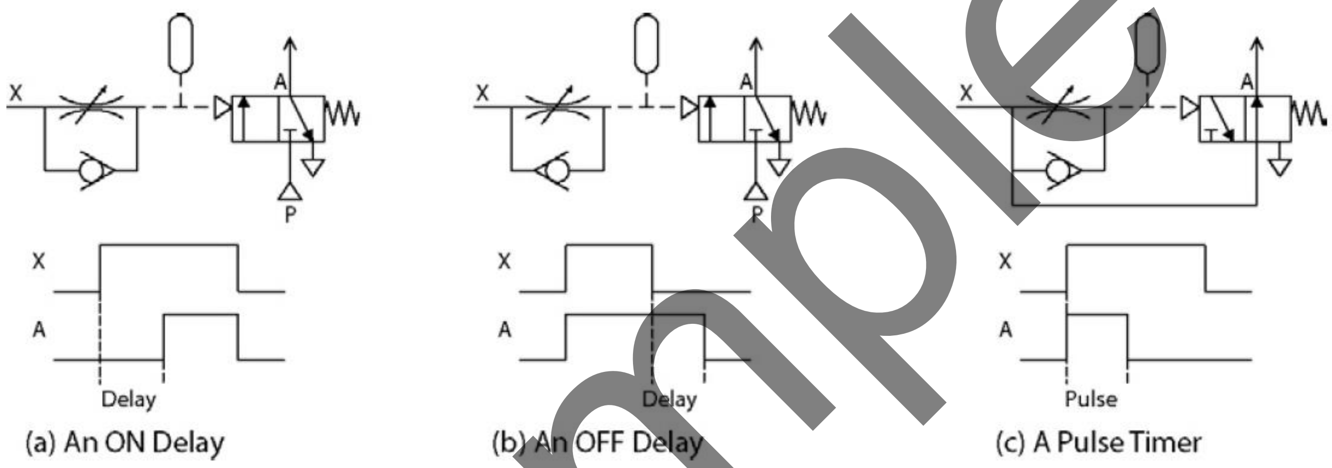

Figure 8 *Timers used in a fluid system*

Each of these timers function on the principle of charging or discharging a small reservoir of fluid, where the timing period is set by an adjustable restrictor.

Pneumatic Limit Switches

Limit switches allow pneumatic pressure to be passed or blocked. They are usually shown in the 'rest' state on circuit diagrams. Limit switches have many uses in industrial process control. They can be connected to a cylinder which moves the position of an object on a conveyor, as shown in figure 9, thus allowing the object to be moved into the correct position ready to be stamped or labelled.