ES2C5 Dynamics & Fluid Mechanics

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Pneumatics Laboratory Briefing

Pneumatics

An alternative to electrical powered devices is *fluid* powered devices.

These may be:

- hydraulics (liquid, usually oil)
- pneumatics (compressed air)

Why use pneumatics?

Widely used in automation for quick linear actuation where position and speed control during motion are not required,

e.g. bang-bang control or non-servo control.

- Cheap, reasonably safe, and easy to build into machinery and maintain.
- Compact but powerful and can be used in wet/hazardous/explosive environments.
- In robotics they are widely used for actuation of end effectors/pick up devices.

Pneumatic Circuit Design

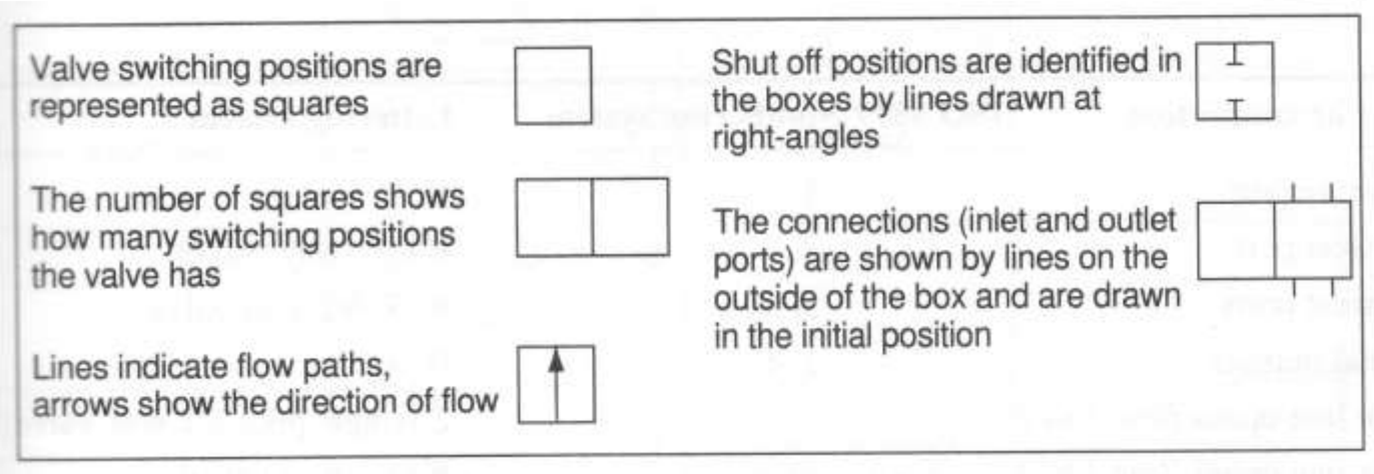
- Use symbols and lines to describe circuits just as for electrical.
- Lines represent pipes not wires!

- International Standards Organisation document ISO 1219 and the British Standard BS 2917 (1977) - Graphical symbols used on diagrams for fluid power systems and components.

Pneumatic Control - Valves

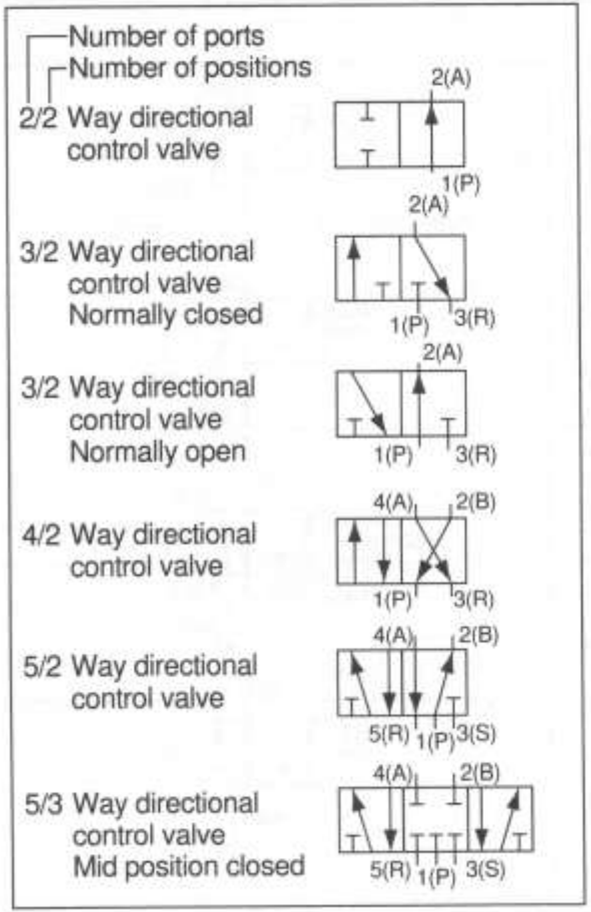
- Controllers such as PLCs produce electrical signals.
  - Solenoids are used to convert electrical to mechanical output to actuate valves.
- Valves switch air supplies between pipes and outlets according to the signals received.
  - They can be switched by (e.g.) physical motion (from a solenoid), spring, motor drive, hydraulics, pneumatics etc.
- Valves are the hardest part of a pneumatic circuit design to understand.

Valve ports & positions explained

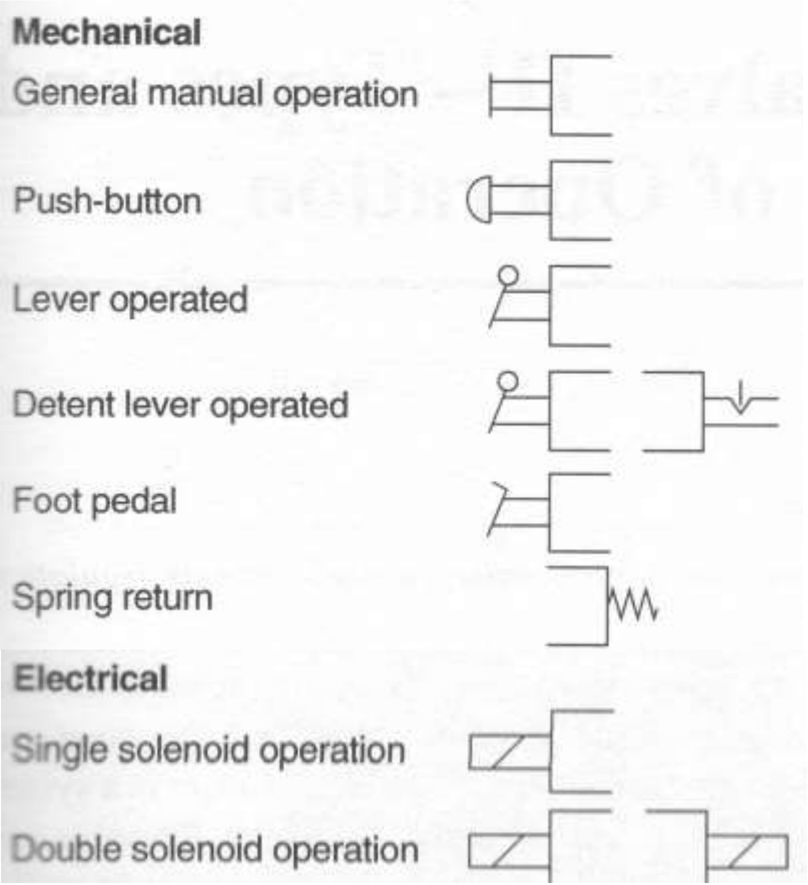


The directional control valve is represented by the number of ports and the number of positions. Each position is shown as a separate square.

Common Valves



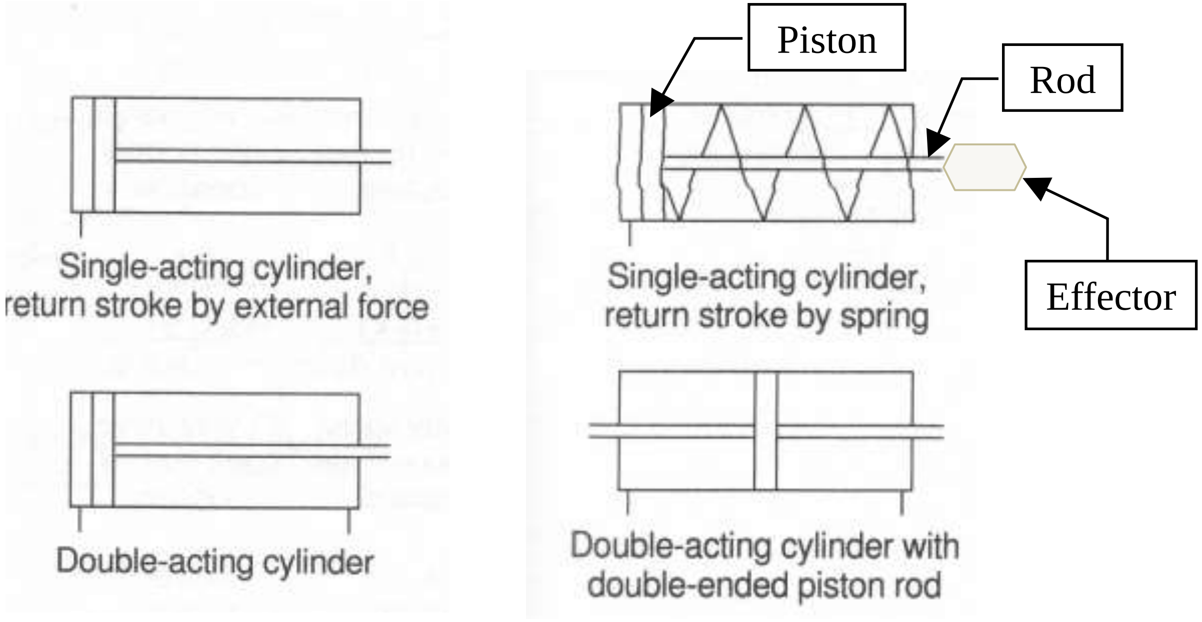
Valve actuation examples



Pneumatic Cylinders

- Single acting – the return is powered by a compressed spring. Use when return is not important e.g. reject pusher.
- Double acting – the return is powered pneumatically. Use when a quick or more controlled return is needed e.g. a gate.
- Rods (connected to cylinder pistons) have a female/male thread at the end to attach effectors which you buy or make.

Pneumatic symbols for converting pressure to linear force -Cylinders



Pneumatic Calculations

$$\text{Force} = \text{pressure}\,(p) \times \text{area}$$

Bernoulli's Equation:

$$\text{total pressure} = p + \frac{1}{2}\rho U^2 + \rho g z$$

p = static pressure

z = vertical displacement (m)

ρ = density of fluid (air) (kg/m^3)

U = velocity averaged over cross-section (m/s)

g = acceleration due to gravity = 9.81 m/s^2

Pneumatic Calculations

Efficiency of pneumatic cylinders

Friction work = $\tau.(\pi.d.s).(U.t)$ $(U.t)$ = stroke length

Work done = $P.(\pi.d^{2}/4).(U.t)$ = $P.\mathrm{d}V$ (V = volume)

Loss ratio = $4\,\tau.s/P.d$

τ = shear stress (N/m^2) P = Air pressure (N/m^2)

U = mean piston velocity (m/s) t = time (s)

d = piston/cylinder diameter (m) s = piston thickness (m)

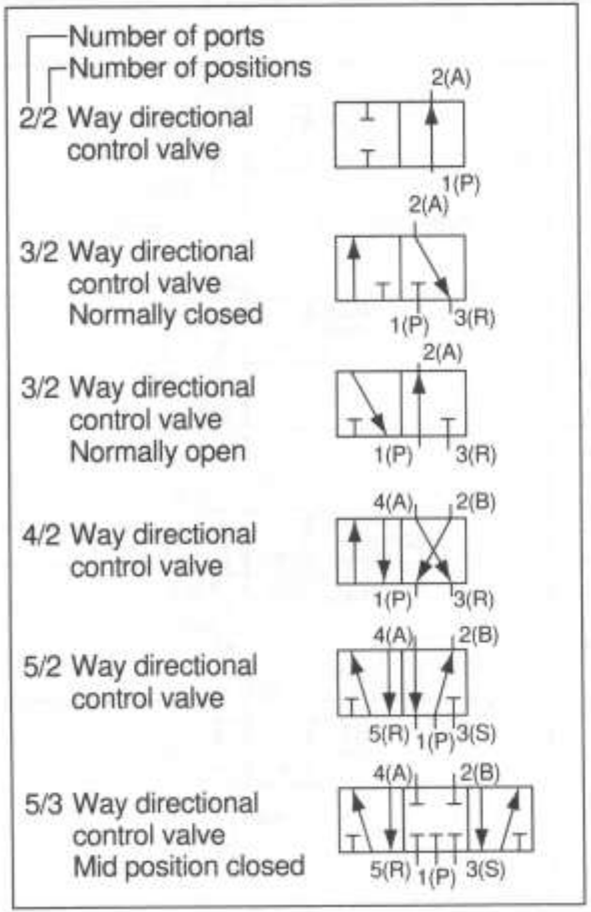
Actuator efficiency increases with $\boldsymbol{P}$ and $\boldsymbol{d}$ (See Fig B.1. last page of briefing sheet) –efficiency factor up to 80-90%

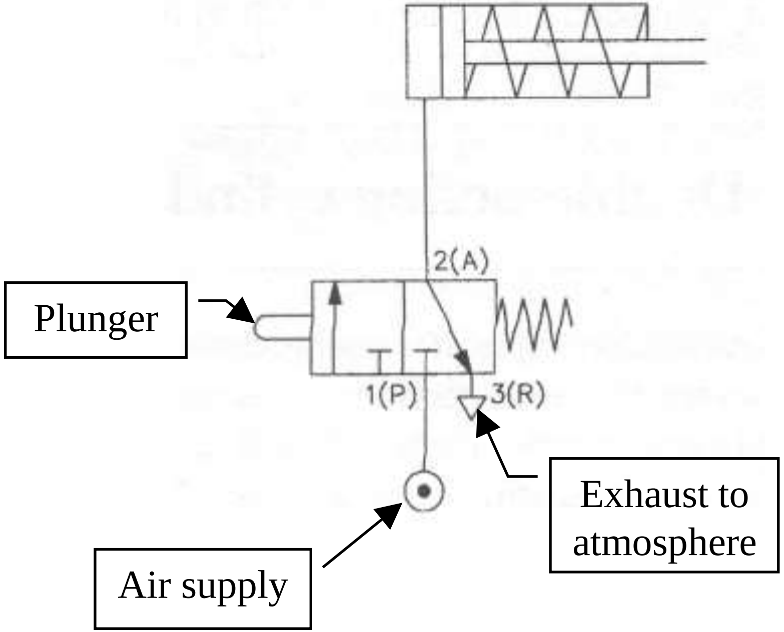
Pneumatic Valve connection

- Identification of ports is important when interpreting the circuit symbols and the valve as fitted to the physical system.
- To ensure that the correct lines, connections and valves are physically in place, symbols on the circuit are designated and the components used are labelled with the correct symbol and designations.
- A numbering system is used to designate directional control valves and is in accordance with ISO 5599, and BS2917.

Port or connection	ISO 5599 Numbering system
Pressure port	1
Exhaust port	3
Exhaust ports	5, 3
Signal outputs	2, 4
Pilot line opens flow 1 to 2	12
Pilot line opens flow 1 to 2	12
Pilot line opens flow 1 to 4	14
Pilot line flow closed	10
Auxiliary pilot air	81, 91

What is the circuit below showing?





Pneumatic control adjustment

- Problems in pneumatic systems arise from:
  - not having a good air supply (sufficient pressure)
  - lack of pressure/flow control in the circuit.
- Flow control can be helped by fitting valves which restrict or stop air flow in a certain direction at certain locations. Switching can cause brief air flow in undesirable directions.
- Cylinder inlet ports are often fitted with one-way flow regulators so the speed of the cylinder can be adjusted by simply adjusting the regulator.

Pneumatics for end-effectors

(A common application for pneumatics.)

- Grippers (e.g. robot hands) are created by using one or more pneumatic cylinders.
- Vacuum cups are created using a “Venturi” generator connected to a pneumatic supply. The evacuated volume should be minimised:
  - Locate the vacuum generator as close as possible to where it is needed.
  - Use an array of numerous small vacuum cups rather than one big single cup.

Learning Outcomes

By the end of the laboratory assignment you should be able to:

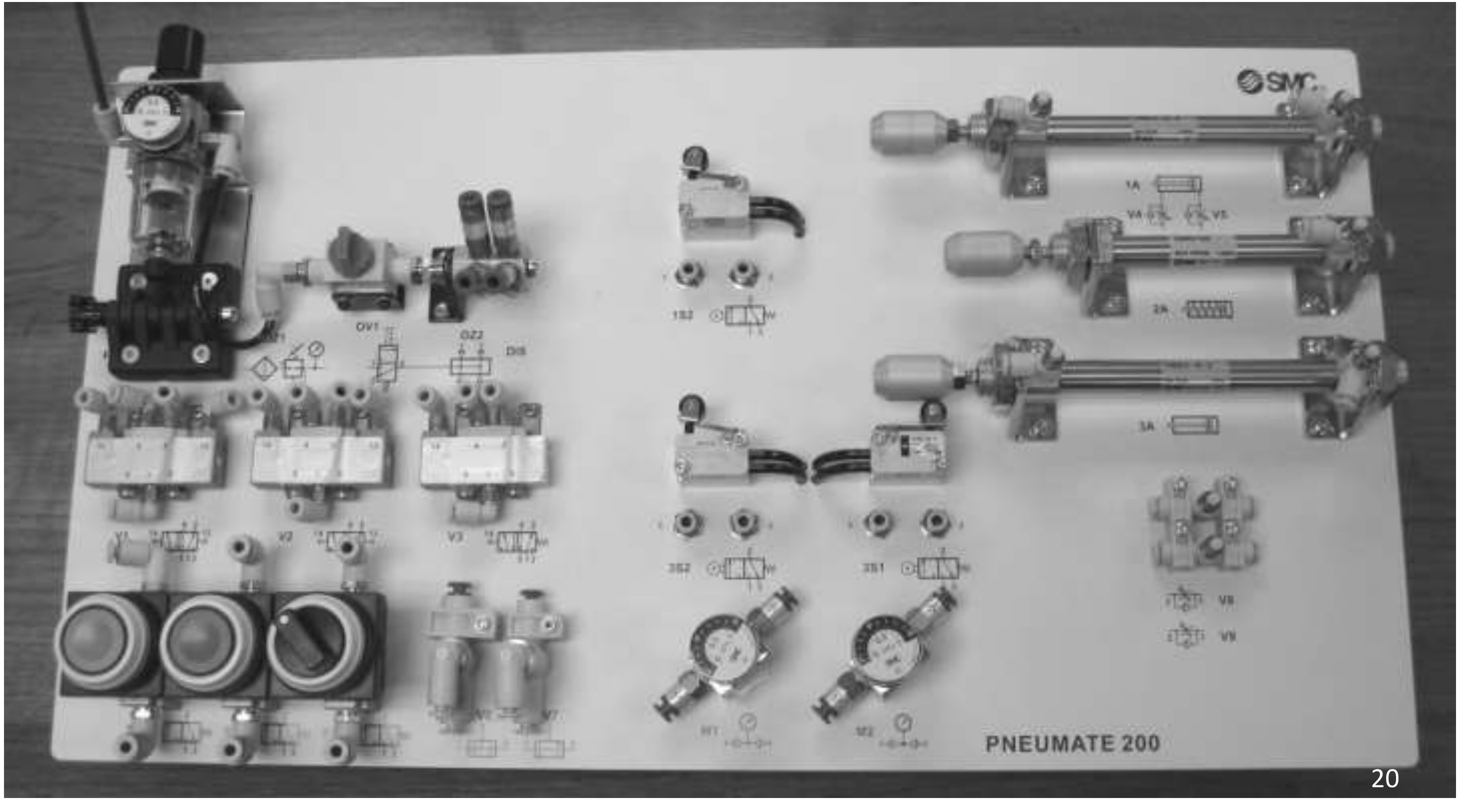
- Understand the basic principles for using pneumatics, the limitations and potential for practical applications.
- Create and test pneumatic circuits.
- Compare pneumatic actuation and control to similar mechanical and electrical systems.

Learning Outcomes

By the end of the laboratory assignment you should be able to:

- Apply theory studied in ES190 & ES193 (Dynamics & Maths) to carry out fluid calculations to predict speed and force of pneumatic actuators.
- Create pneumatic circuit diagrams by hand or by engineering drafting packages (MS Visio).

Pneumatic test board



Lab exercises

You will need to:

- Read and interpret (logic) phase diagrams.
- Use the test board to build and demonstrate pneumatic circuits.
- Compare these with electronic analogues.
- Draw correct system diagrams.
- Consider how well the circuits worked and how/why/where such systems might be implemented in practice.

Procedure

- Read the lab sheet *before* the lab to understand the symbols and functionality of valves, gates, cylinders, and phase diagrams etc.
- There are 6 exercises. Finish one experiment and draw the schematic of the apparatus before moving on to the next exercise.
  - If you don't know how to draw the schematic or don't understand the valves, you will lose time!

Notes:

- Do not expect to be pampered if you turn up unprepared (it is *your* responsibility to be prepared and to work safely; demonstrators are not there to do the work for you).
- All the exercises can be done at home, without the actual kit. The kit is there to gain practical experience and check whether the idea works or not. So, record the scheme that worked experimentally as well as your observations.

Safety

- There is a possibility of bruising if fingers are placed in the path of moving parts.
- Loose items such as long hair or jewellery could get caught. Hence it is advisable to ensure no one is in the vicinity of moving parts before the air supply is switched on.
- Take care when testing circuits: compressed air supply can cause injury if used in an unconventional manner.

Safety

- Do not push open pipes supplied with compressed air to any part of the body, particularly at eyes or on to the skin.
- Anyone seen to be behaving in a manner that jeopardises his or her safety or the safety of others will be removed from the lab immediately.