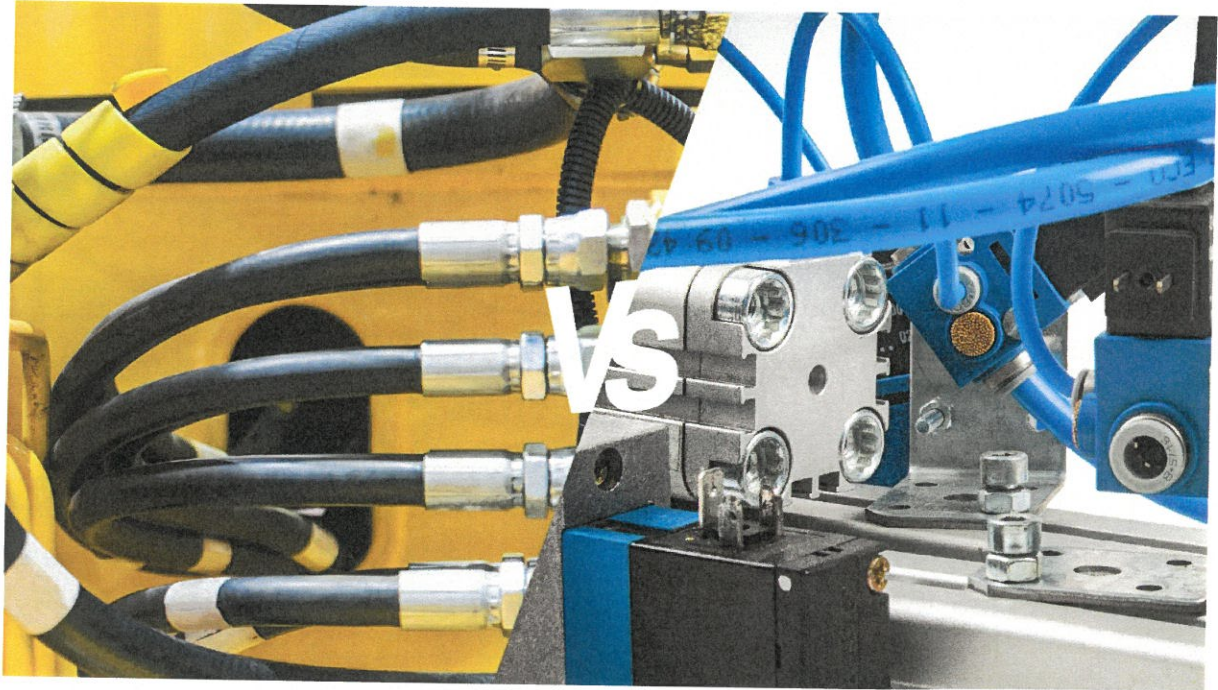


Marked 23/5/24  
J.M.

# Pneumatics and Hydraulics



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Course: Instrumentation Engineering

Module: Pneumatics and Hydraulics

Assignment: Pneumatics & Hydraulics Actuators and Design

*Programme title would  
be useful.*



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*Sub-headings may be useful  
for your report structure.*

*You do not have any  
page numbers to relate  
this information to 😊*

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*Numbered sub headings  
would be useful.*

*e.g.*

## 1. Task 1 – Actuator construction and operation

### 1.1 Introduction:

An actuator can be distinguished as an energy converter which translates sourced energy to mechanical energy in a controlled manner. Various energy input sources can be used to achieve the mechanical output (Gomis-Bellmun, 2010). ✓ An actuator can produce force, torque and displacement. The means of energy can be established from a range of sources such as pneumatic, hydraulic, electric, thermal and magnetic. These energy sources can be utilised to engage in linear motion and rotary motion driven by the actuator. ✓

Actuators have become an essential component in modern technology and engineering. They are utilised in all industries where movement of components are needed (Tameson, 2023). ✓

*+ proper use of  
Harvard referencing.*

### 1.2 Linear Actuators:

Linear actuators are actuators that convert energy into mechanical movement in the form of a pulling or pushing motion hence the linear naming. Depending on the type of energy form used depends on the mechanism to produce the linear movement (IDC Technologies, 2017). ✓

### 1.3 Construction of Linear Actuators:

An example of a linear actuator is a pneumatic or hydraulic piston. ✓ Due to similarity in construction both will be covered in the following segment.

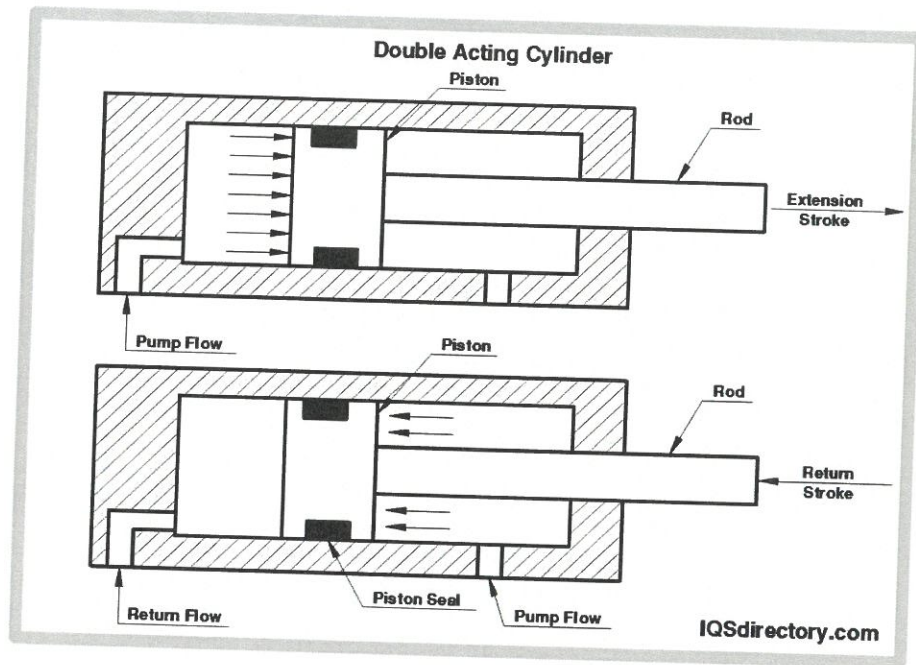
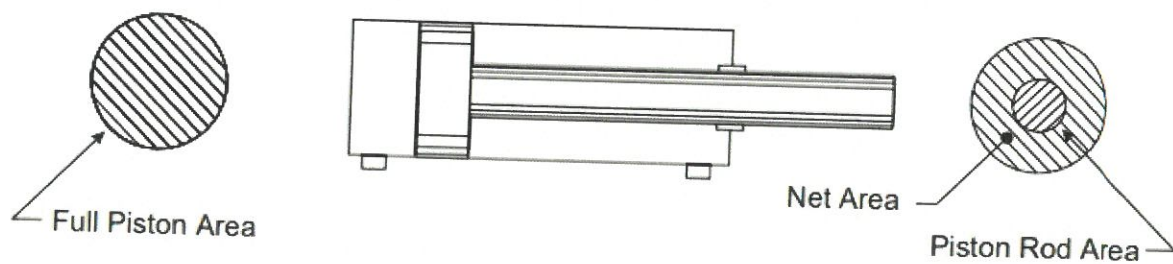


Figure 1. Double Acting Cylinder Piston (ref.?)

A piston type cylinder is a type of linear actuator commonly used in fluid power systems. The main components of a piston type cylinder are a cylindrical barrel, a piston and rod and seals. The cylindrical barrel is where the piston rod extends and retracts through. It is a sealed compartment where the pressurised fluid is maintained to perform the controlled movement of piston rod. Suitable seals are used on the hole and piston rod to maintain pressure of the sealed compartment but also to keep contaminants from entering the barrel which can affect the performance of the piston (United States Department of Defense, 2016). The piston rod is the component that performs the linear movement (extending or retracting) of the actuator to achieve the desired motion of equipment.



Significant Areas in a Double-Acting Cylinder, Single-End-Rod Type.

Figure 2. Exerted Force Surface Area

The standard double acting cylinder has three significant internal areas. On the extension when fluid enters the cylindrical chamber the full piston area is exposed to the force generated by the fluid and applies its force equally across the area to extend the piston rod. On the retraction stroke of the piston, less force is needed due to the piston rod occupying part of the area where the force is applied to cause retraction (Parker Hannifin, 2002). ✓

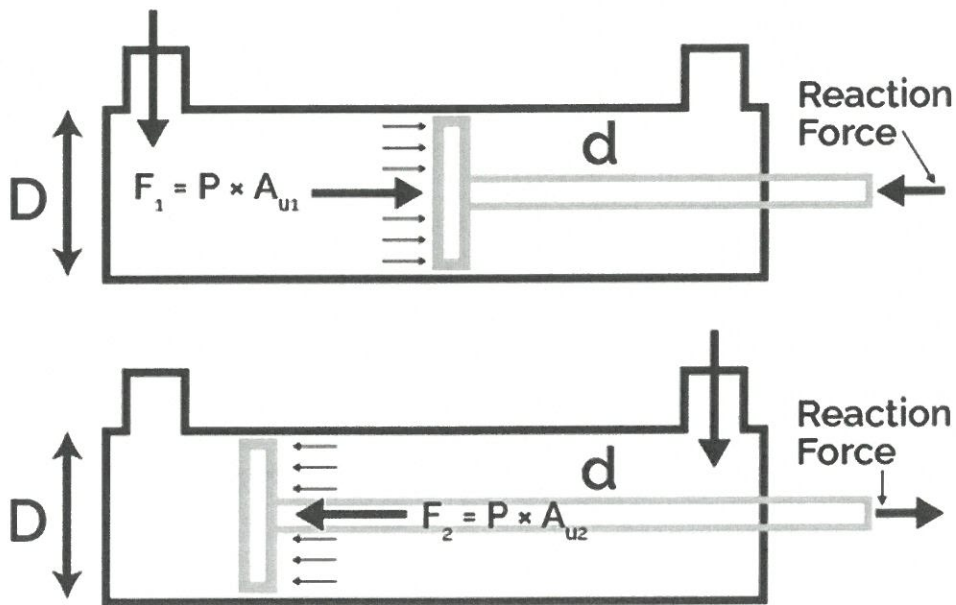


Figure 3. Equation for Force needed to move piston.

Electric linear actuators convert rotary motion of an electric motor to linear motion by three main components, the motor, which is driving force behind the actuator, the motor rotates a primary gear via a connected shaft or pulley. The output gear is connected to the lead screw and rotates in unison with the gears (Powerjacks, 2022). ✓ The nut of the screw moves progressively together with the rod it is fixed to. To alter between extending and retracting the rod the direction of the motor will need to be changed which can be done via a control panel. ✓

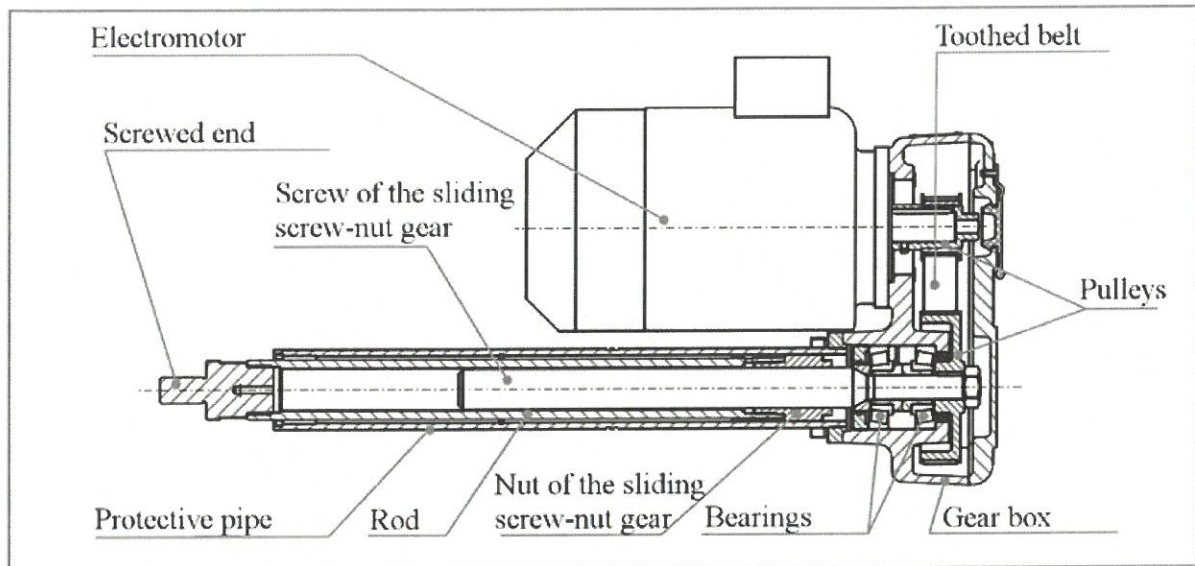


Figure 4. Electric Linear Actuator

#### Applications of Linear Actuators at Dragon LNG:

Linear actuators are utilised at the workplace of Dragon LNG, the system operates using an internal gear pump with a fixed displacement and an oil reservoir to pressurise the double acting cylinders to achieve the position needed. The hydraulics power functions such as slew right and left, extend or retract, or elevate or lower the gangway. ✓

*+ Good example, a photo would compliment your writing.*

#### Rotary Actuators:

Rotary actuators are actuators that convert energy into mechanical torque in the form of rotation, hence the rotary naming. Depending on the type of energy form used depends on the mechanism to produce the rotary movement (Firgelli Automations, 2023). The construction of rotary actuator depends on its function and the medium used to provide energy to the transducer. ✓

#### Construction of Rotary Actuators:

An example of rotary actuator is a rack and pinion actuator, it's a commonly used in fluid power systems to perform rotary motion. The medium used will depend on the function of the actuator as both pneumatic and hydraulic have different advantages and disadvantages. The operation of a rack and pinion is a linear gear 'rack' that is toothed and connected to the drive end of a sealed piston. The piston

is driven by fluid power and drives the gear rack forward or backwards depending on the entry point of pressure. ✓

## DZK-H dual piston rotary actuator

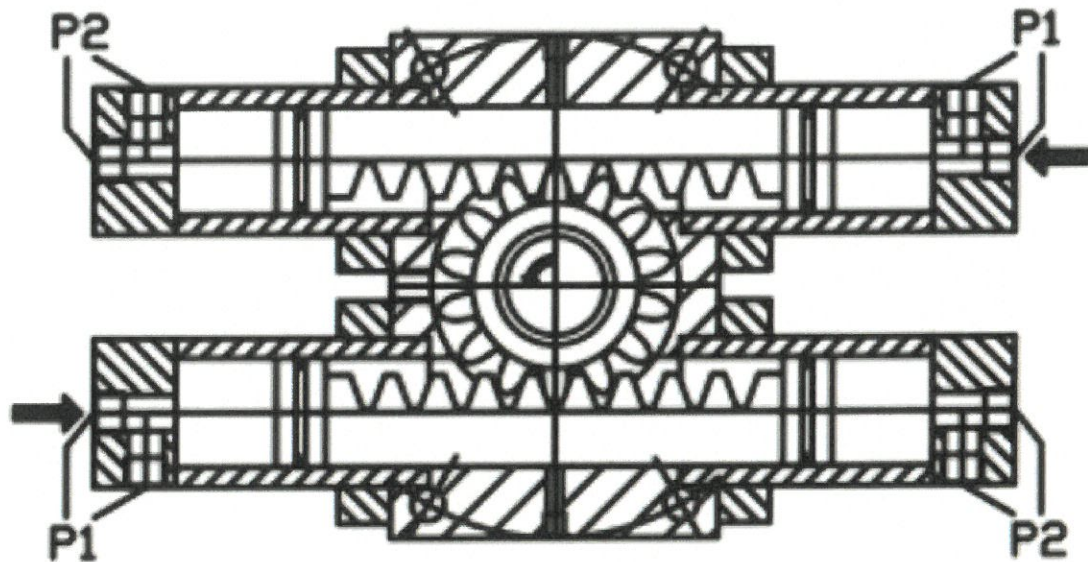
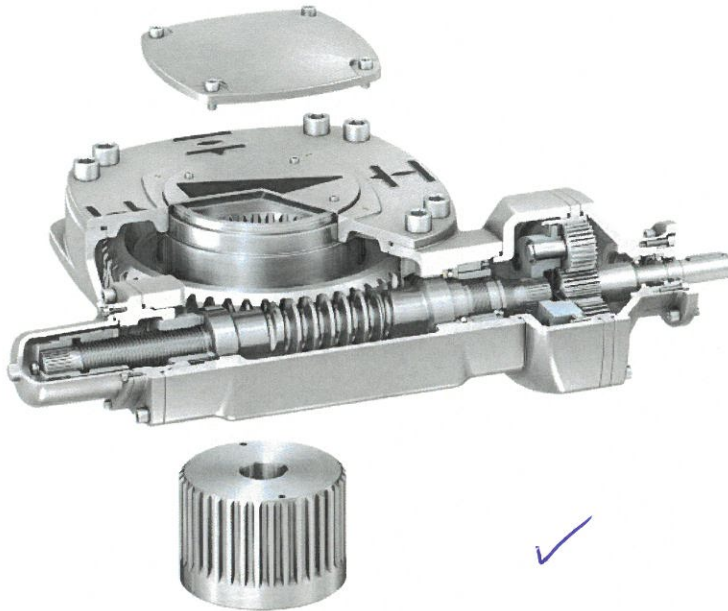


*Figure 5. Dual Piston Rotary Actuator*

The linear gear rack engages with the pinion which is a circular gear causing the two gears to mesh. The linear force exerted on the rack will drive the pinion gear which is connected to a shaft causing rotation. The design in figure 5. is utilised to ensure equal force is distributed across the pinion for more control and precision (Emerson, 2022). ✓

An example of electric rotary actuator is a motor operated quarter turn valve such as a ball or butterfly valve. ✓ This type of valve utilises an electric motor as the driving force of the shaft with teeth connecting to a gearing system that translates the motors energy into mechanical torque operating valve to rotate as needed on electrical input signals (ControlMatic, 2023). ✓



+ Ample examples  
of industrial  
applications provided.

Figure 6. Electric Rotary Actuation Gearbox

The rotating shaft will interlock with a keyway on the ball or butterfly valve to ensure the rotation of the valve. The motor's rotation direction will decide the direction of travel of the valve. However, modern process control systems will simplify operation of the valve to an open and closed signal and PLC will control the logic of the motor such as speed, rotation etc. ✓

#### Applications of Rotary Actuators at Dragon LNG:

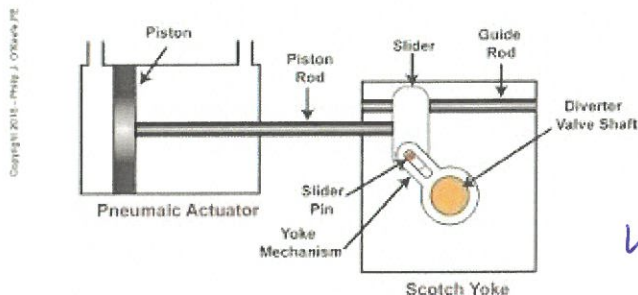


Figure 7. Scotch Yoke Valve

The actuator displayed is used at Dragon LNG for the emergency shutdown valves. The pneumatic actuator is where the pneumatic air is connected to the actuator. It works by the pneumatic air pressure force overcoming the spring force and driving the valve into its position. The piston rod extends which is connected to the slider. The slider moves along the guide rod causing the slider pin and yoke mechanism to move and rotate a certain angle which is connected to the shaft and

ball valve. This rotation and movement cause the ball valve to rotate 90 degrees either open or closed (Rotork, 2018). ✓

#### Conclusion:

Linear and rotary actuators are used in most of all industries in today's advancing technological world. They allow for the linear and rotary motion that is needed for wide ranges of applications to driven by fluid power, or electrical motors to lead to safer, efficient and precise outcomes when using these actuators. The construction of the devices is often similar due to effectiveness of the geared system and fluid power cylinder rams. The report highlights their application in the oil and gas industry and when intertwined with instrumentation and control can show of what actuators are capable of. ✓

## Task 2 – Actuator calculations

A double acting hydraulic cylinder has a bore diameter **D**. The rod diameter is 60mm and the stroke length is **S**. The rod must produce a pushing force of 50kN. The flow rate available in both directions is **Q**.

Calculate:

- The system pressure needed.
- The force with which it pulls, given the same pressure.
- The time taken to extend fully.
- The velocity on the outward stroke.
- The time taken to retract fully.
- The velocity on the inward stroke.
- The power transmitted on the outstroke given the cylinder is operating at capacity.

**Table 1 – Values for calculations**

| Student Number | Values        |               |                                 |
|----------------|---------------|---------------|---------------------------------|
|                | <b>D</b> (mm) | <b>S</b> (mm) | <b>Q</b> (dm <sup>3</sup> /min) |
| 1 (JC)         | 102           | 650           | 16                              |
| 2 (KC)         | 125           | 525           | 20                              |
| 3 (SD)         | 142           | 550           | 14                              |
| 4 (PP)         | 155           | 450           | 12                              |
| 5 (HR)         | 150           | 600           | 22                              |

a.)

$$A = \pi r^2$$

$$A = \pi \times (77.5 \times 10^{-3})^2$$

$$A = 18.86919 \text{ mm}^2$$

$$P = \frac{F}{A}$$

$$P = \frac{50 \times 10^3}{18.86919 \times 10^{-3}}$$

$$P = 2.64982 \text{ MPa} \quad \checkmark$$

b.)

$$A = 18.86919 \times 10^{-3} - (\pi \times (30 \times 10^{-3})^2)$$

$$A = 16.04176 \text{ mm}^2$$

$$F = P \times A$$

$$F = (2.64982 \times 10^6) \times (16.04176 \times 10^{-3})$$

$$F = 42.50778 \text{ KN} \quad \checkmark$$

c.)

$$V = A \times \text{stroke length}$$

$$V = (18.86919 \times 10^{-3}) \times (450 \times 10^{-3})$$

$$V = 8.49114 \times 10^{-3} \text{ m}^3$$

$$t = \frac{V}{Q}$$

$$t = \left( \frac{8.49114}{12} \right) \times 60$$

$$t = 42.4557 \text{ s} \quad \checkmark$$

d.)

$$C = \frac{\text{Stroke Length}}{t_{\text{out}}}$$

$$C = \frac{450 \times 10^{-3}}{42.4557}$$

$$C = 0.010599 \text{ m/s} \quad \checkmark$$

e.)

$$V = (16.04176 \times 10^{-3}) \times 0.45$$

$$V = 7.21879 \times 10^{-3}$$

$$t = \frac{7.21879}{12} \times 60$$

$$t = 36.0940s \quad \checkmark$$

f.)

$$C = \frac{\text{Stroke Length}}{t_{in} - \text{time?}}$$

$$C = \frac{450 \times 10^{-3}}{36.0940}$$

$$C = 0.01247m/s \quad \checkmark$$

g.)

$$W.D = (50 \times 10^3) \times 0.45 \quad \checkmark$$

$$W.D = 22500J \quad \checkmark$$

$$Power = \frac{22500}{42.4557}$$

$$Power = 529.96417 W \quad \checkmark$$

## Task 3 – Circuit analysis

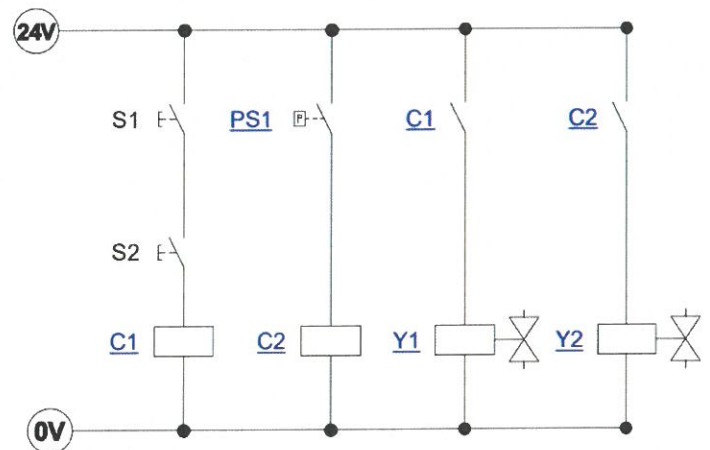
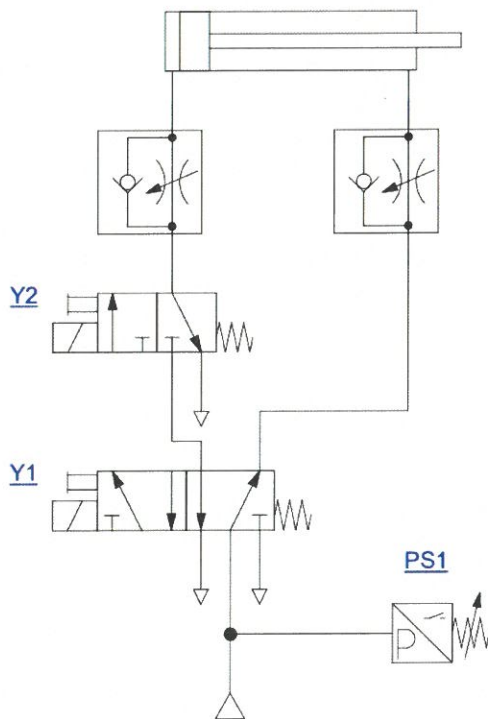
The figure below shows the circuit diagram of an electro-pneumatic system:

Produce a report explaining the full operation of the system which includes reference to each component and state the purpose of each component within the system.

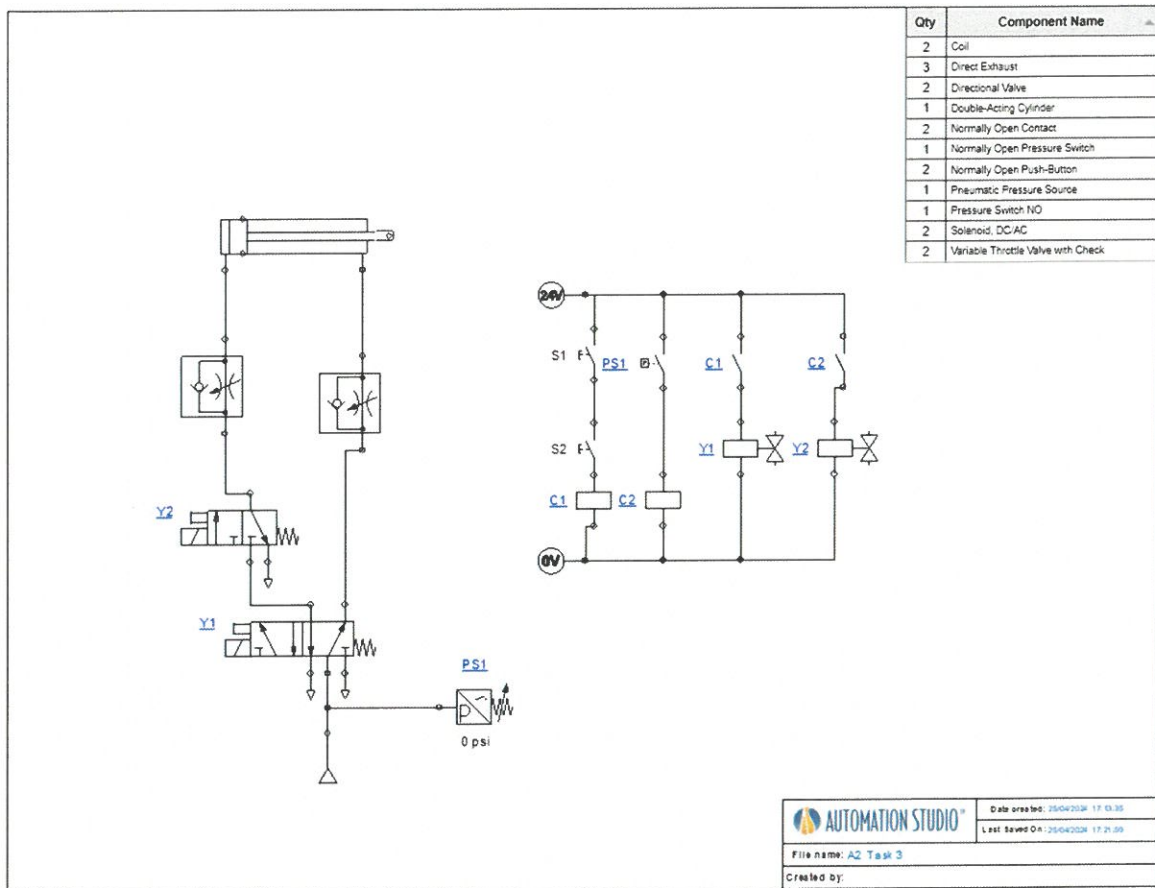
As part of the report include an explanation of the construction and operation of a relay.

*System supply pressure: 10bar*

*PS1 switching pressure: 9bar*



✓



### Function and Construction of a Relay:

A relay is <sup>an</sup> electromagnetic switch that opens and closes contacts by operating when receiving an electrical signal <sup>is</sup> this known as normally open or normally closed. The relay can either operate electromechanically or electrically depending on the type of relay used (Galco, 2023). For the system above electromechanical relays were used.

*Proofread.*

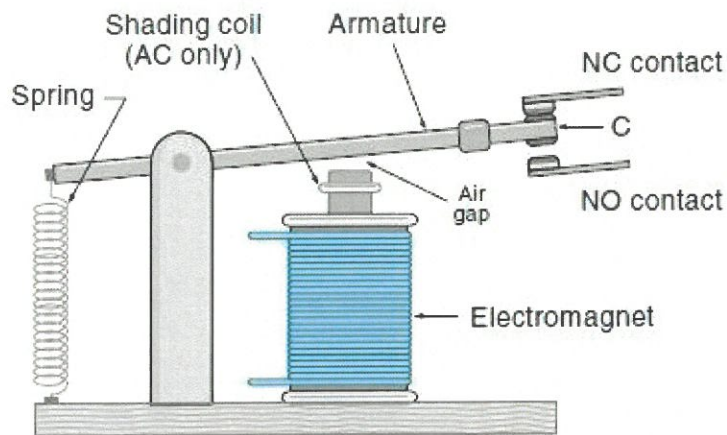


Figure 8. Components of an Electromechanical Relay (ref?)

A coil is wound around a permeable iron core known as the input coil and when energised generates a magnetic flux that operates the armature to the opposite position contact due to magnetism. When de-energised the armature returns to its starting position due the spring as the magnetic field is not present for the armature to overcome the springs force (Omron Industries, 2016). Once a contact is made the relay will output that electrical signal whether that be an on or off signal depends on the relay used (Normally Open, Normally Closed).

#### Full Operation of the Electro-Pneumatic Circuit:

##### Pneumatic Circuit Diagram:

Before starting the system and energising the system with pressure, understanding the function of the components will help gauge the purpose and operation of the system.

##### Pipework:

The solid black lines represent the pipework that is where the fluid power will transfer when the system is active.

##### Pneumatic Pressure Source:

A Pneumatic pressure source represents an ideal gas compressor that will maintain a specified pressure for the needs of the system regardless of the flow rate.

### Pressure Switch Normally Open:

A normally open pressure switch operates as safety or a control function. The normally open is regarding the pressure and that the designed pressure parameters need to be achieved for the switch to close and energise the circuit. ✓

### Direction valve (5/2-way single solenoid valve spring return):

The direction valve nearest the pneumatic pressure source is 5/2-way solenoid valve spring return. The purpose of this valve is to direct the fluid power to where it's needed. It has 5 ports that need to be connected and 2 positions. The position can be altered by the energising of a solenoid which in turn changes the direction of the fluid power. Once the solenoid is de-energised the spring return will return the position to its original state. ✓

### Exhaust:

The exhausts' purpose is to safely vent stored pneumatic pressure to a safe place. ✓

### Direction valve (3/2-way single solenoid valve spring return):

The second direction valve is 3/2-way solenoid valve spring return. Meaning it has 3 port connections and two positions. Operating with a solenoid to change position and a spring return to return to its original position. The position of the valve delegates the flow of fluid power. ✓

### Variable throttle valve with check:

A variable throttle valve purpose is to allow for the operator to maintain a control of the flow rate into the designated flow path. The check refers to a check valve only allowing the flow in one direction which can be identified with the direction of the arrow. ✓

### Double acting Pneumatic cylinder:

Is a cylinder that operates a piston which is driven pneumatically by the air pressure. The double acting means both outward and inward strokes of the piston need to be pneumatically energised for movement to occur. ✓

### Electric Circuit Diagram:

#### Push Button:

Push button purpose is to close the circuit when activated allowing for the circuit to be energised. ✓

#### Coil:

A coil is constructed of current-carrying wire designed to produce a magnetic field or to provide electrical resistance or inductance. ✓

#### Normally Open Contact:

A normally open contact is a switch that once energised the contact closes and carries on the current path. ✓

#### Solenoid:

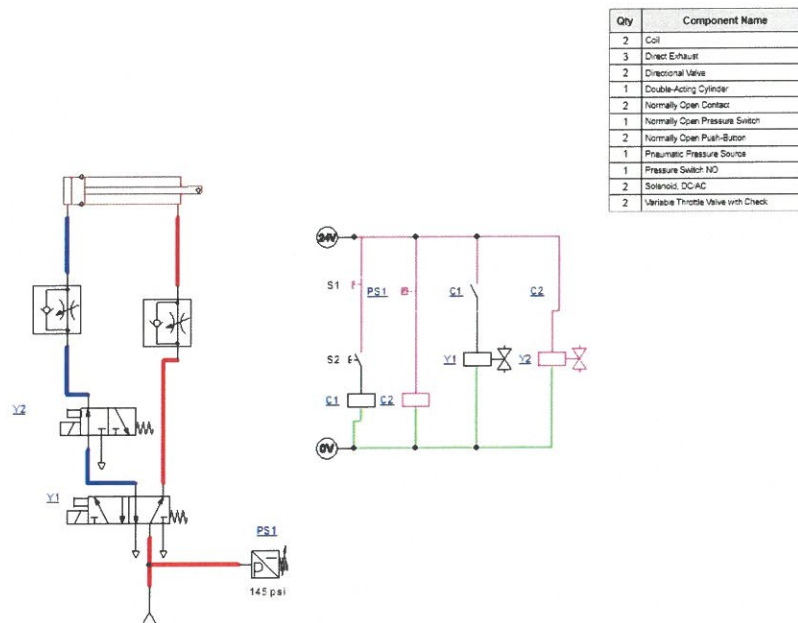
A solenoid is <sup>⚡</sup> device <sup>?</sup> an electromagnet formed by a cylindrical coiled wire that acts as a magnetic field when a current flows through. When energised the solenoid reacts to the magnetic field and turns electrical energy into mechanical motion and force. ✓

#### Pressure Switch Normally Open:

A normally open pressure switch operates as safety or a control function. The normally open is regarding the pressure and that the designed pressure parameters need to be achieved for the switch to close and energise the circuit. ✓

## Function of Electro-Pneumatic Circuit:

Firstly, when energised from the pneumatic pressure source the flow path can be

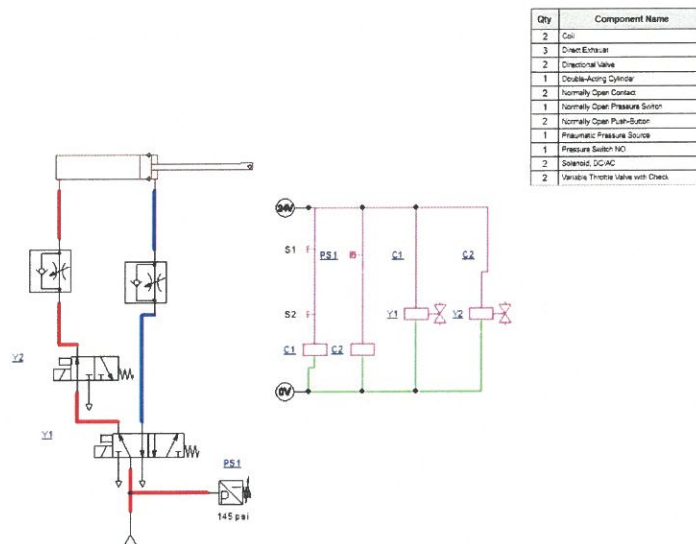


seen below in figure . The red represents the pressure in the pipework. The flow path energises the pressure switch and closes the contact due to the pressure exceeding 9 bar which is stated in the design regulations. This in turn energises coil '2' which closes the associated normally open switch labelled 'C2'. Furthermore, the solenoid 'Y2' is energised and alters the position of directional control valve 'Y2'. ✓

When the second push button is activated, a coil is energised 'C1' and after this solenoid 'Y1' is activated altering the position of the direction of the control valve. ✓

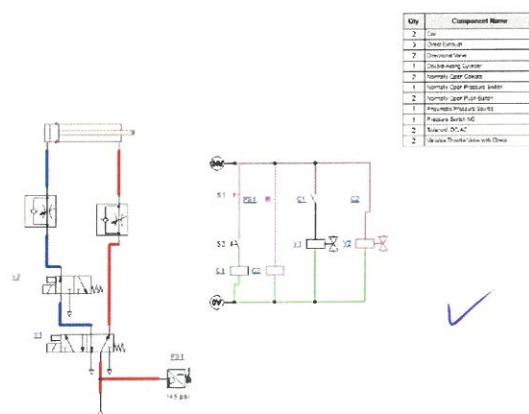
*When both S1 + S2 are activated.*

*Why would both need activating?*



The activation of 'Y2' solenoid associated with the direction control valve alters the flow path through the second position and through the next directional control valve to the variable throttle valve with check. The throttle valve can be altered to adjust the rate of double acting cylinders extension. ✓

For retraction to occur a push button will need to be released for the directional control valve to change position via the spring return and pressurise the retraction side of the cylinder. ✓



+ A great method of describing the system operation.

When testing the function of the system, it was noted that for a short while during a change of the piston extending or retracting, the pressure in the system would drop

below 9 bar opening the switch on the electric circuit and changing the position of 'Y2'. In this instance it didn't affect the function of the system but noted as a precaution. ✓

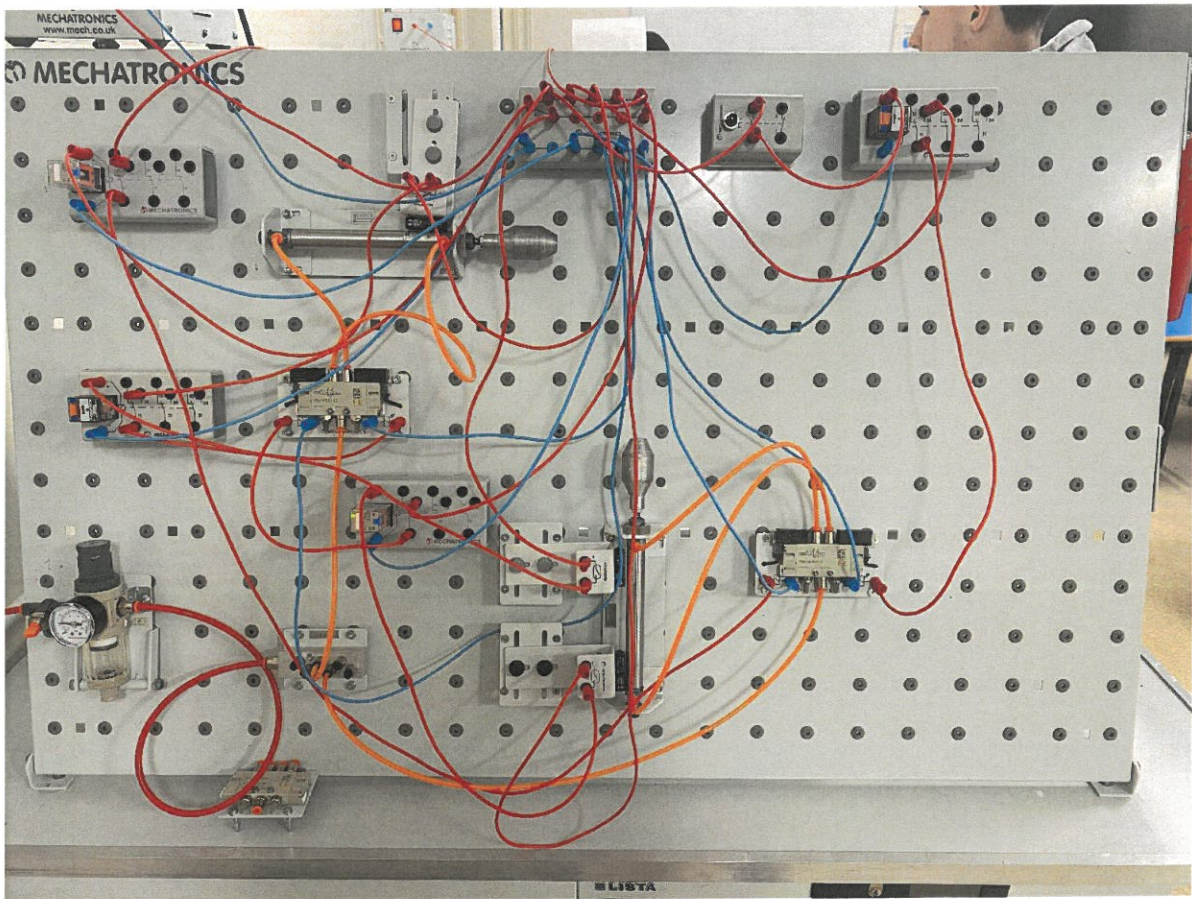
*Good observation -*

## Task 4 – Circuit design

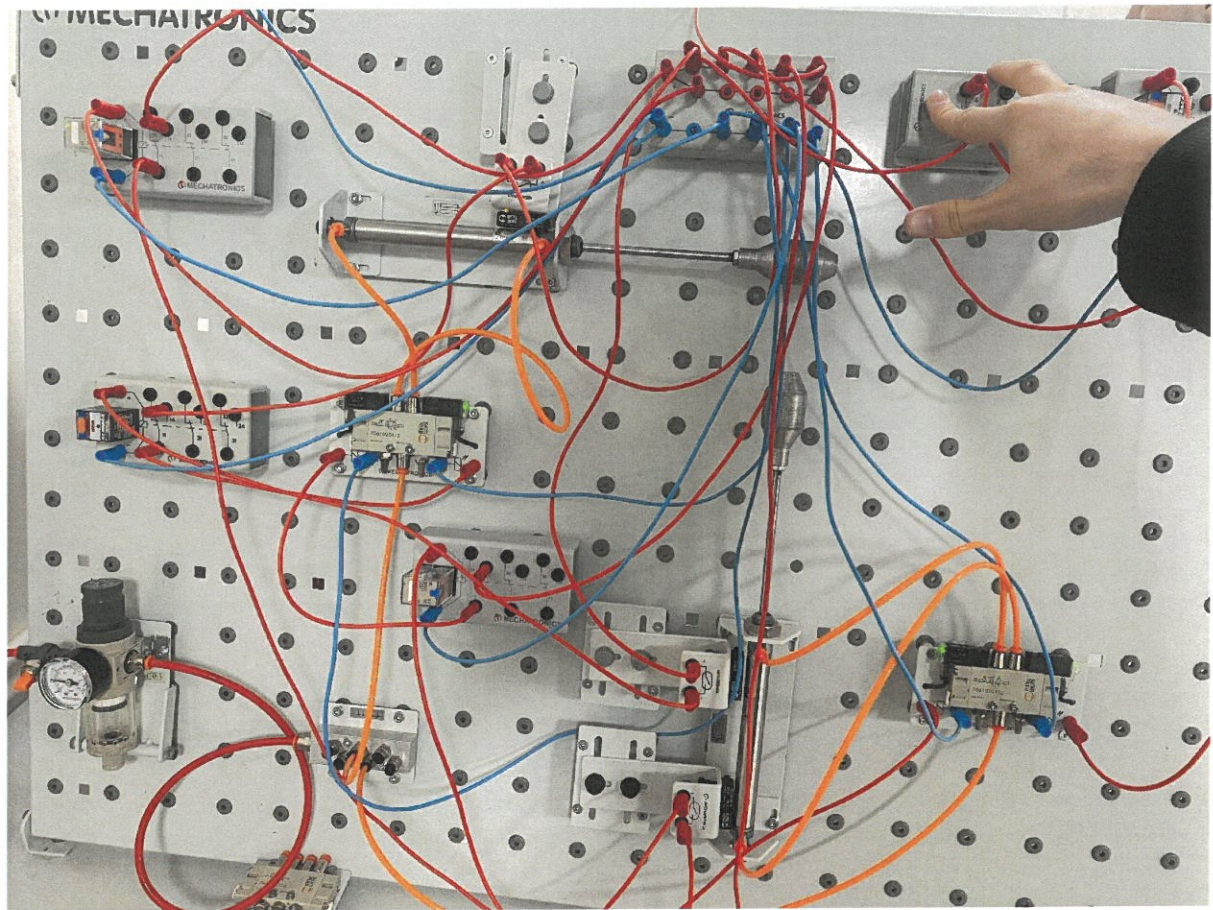
You are tasked with designing two fluid power circuits to meet the following requirements:

*Where are the requirements?*

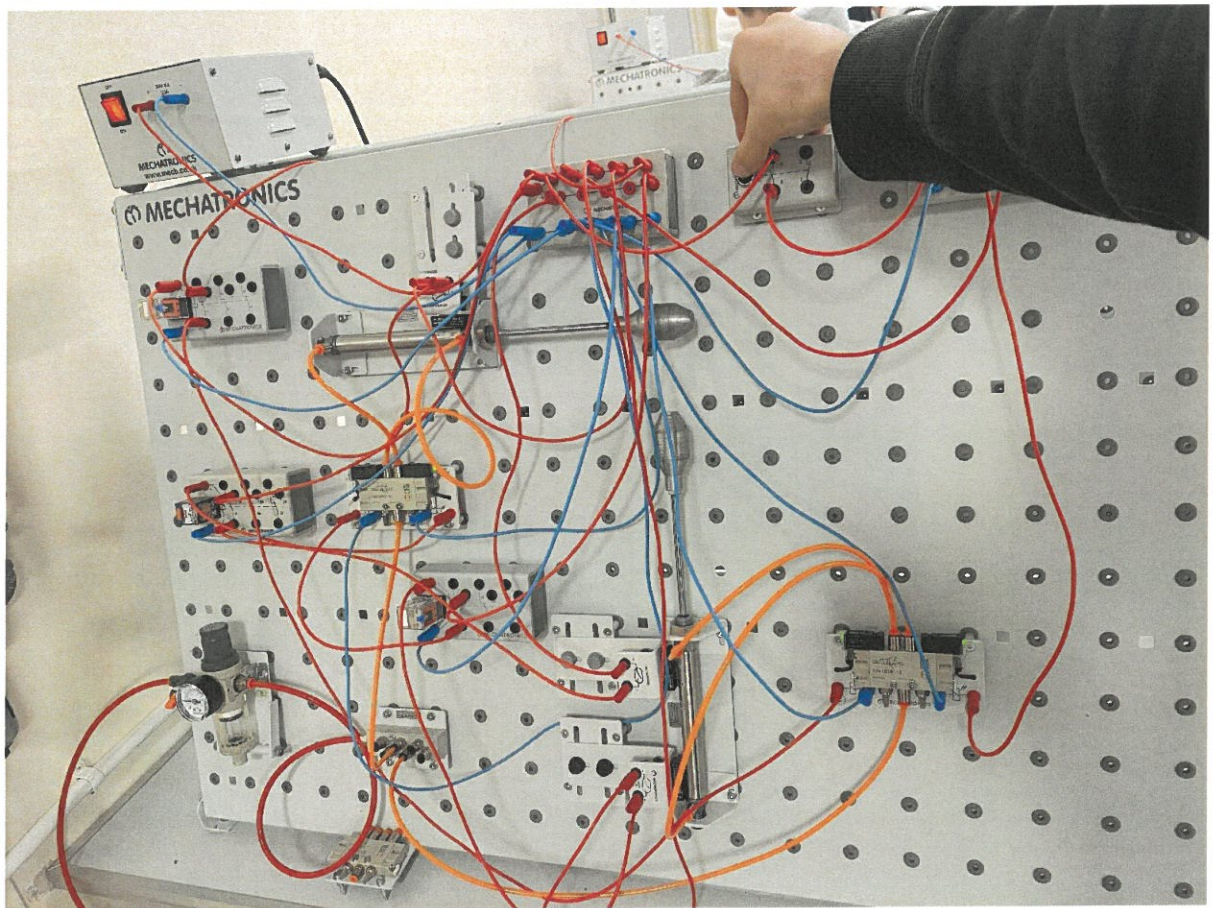
a) .



✓

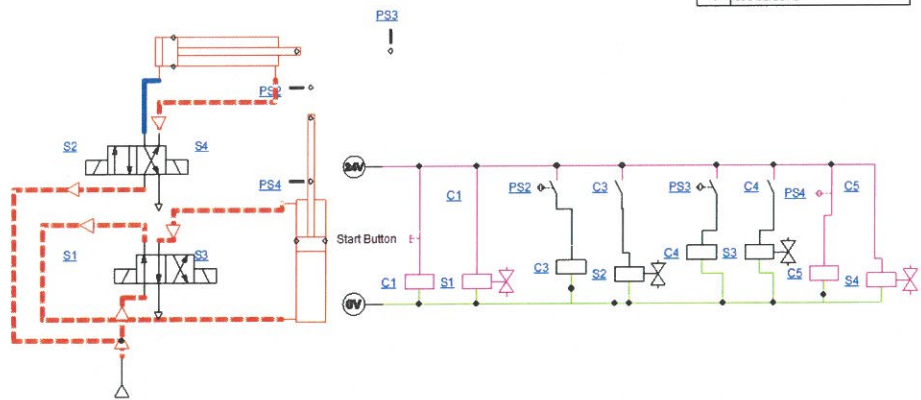


✓

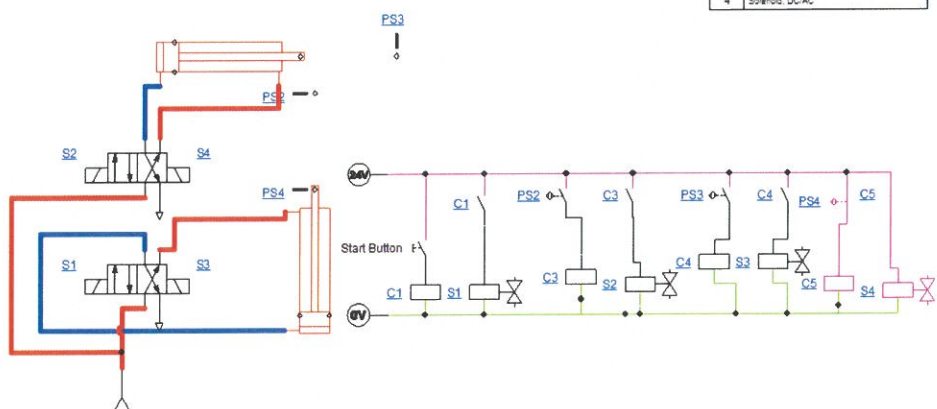


✓

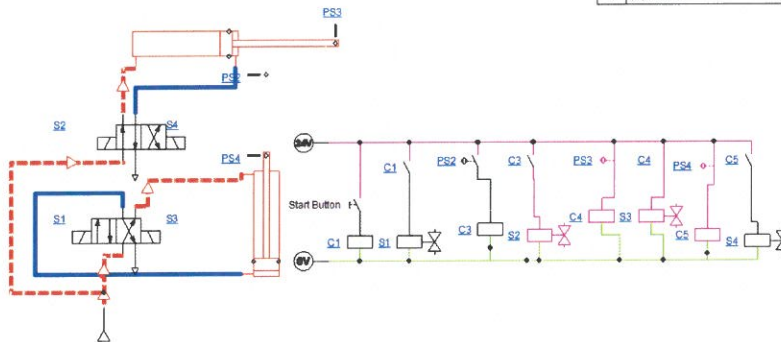
| Qty | Component Name                 |
|-----|--------------------------------|
| 4   | Coil                           |
| 2   | Direct Exhaust                 |
| 2   | Directional Valve              |
| 2   | Double-Acting Cylinder         |
| 4   | Normally Open Contact          |
| 3   | Normally Open Proximity Switch |
| 1   | Normally Open Push-Button      |
| 1   | Pneumatic Pressure Source      |
| 3   | Sensor Ref. (Bidirectional)    |
| 4   | Solenoid, DC/AC                |



| Qty | Component Name                 |
|-----|--------------------------------|
| 4   | Coil                           |
| 2   | Direct Exhaust                 |
| 2   | Directional Valve              |
| 2   | Double-Acting Cylinder         |
| 4   | Normally Open Contact          |
| 3   | Normally Open Proximity Switch |
| 1   | Normally Open Push-Button      |
| 1   | Pneumatic Pressure Source      |
| 3   | Sensor Ref. (Bidirectional)    |
| 4   | Solenoid, DC/AC                |



| Qty | Component Name                 |
|-----|--------------------------------|
| 4   | Coil                           |
| 2   | Direct Exhaust                 |
| 2   | Directional Valve              |
| 2   | Double-Acting Cylinder         |
| 4   | Normally Open Contact          |
| 3   | Normally Open Proximity Switch |
| 1   | Normally Open Push-Button      |
| 1   | Pneumatic Pressure Source      |
| 3   | Sensor Ref. (Bi-Directional)   |
| 4   | Solenoid DC/AC                 |



The task was simulated on Automation Studio and built in the pneumatic workshop to test the function and to check if it satisfied the criteria of the task. ✓

### Equipment List:

- 4x Coils
- 2x Exhausts
- 2x 4x2 directional control valve
- 2x Double acting cylinder
- 4x Normally open contact
- 3x Normally open Proximity Sensor
- 1x Normally Open push button
- 1x Pneumatic Pressure Source
- 3x Electrical Sensor Normally Open contacts
- 4x Solenoids

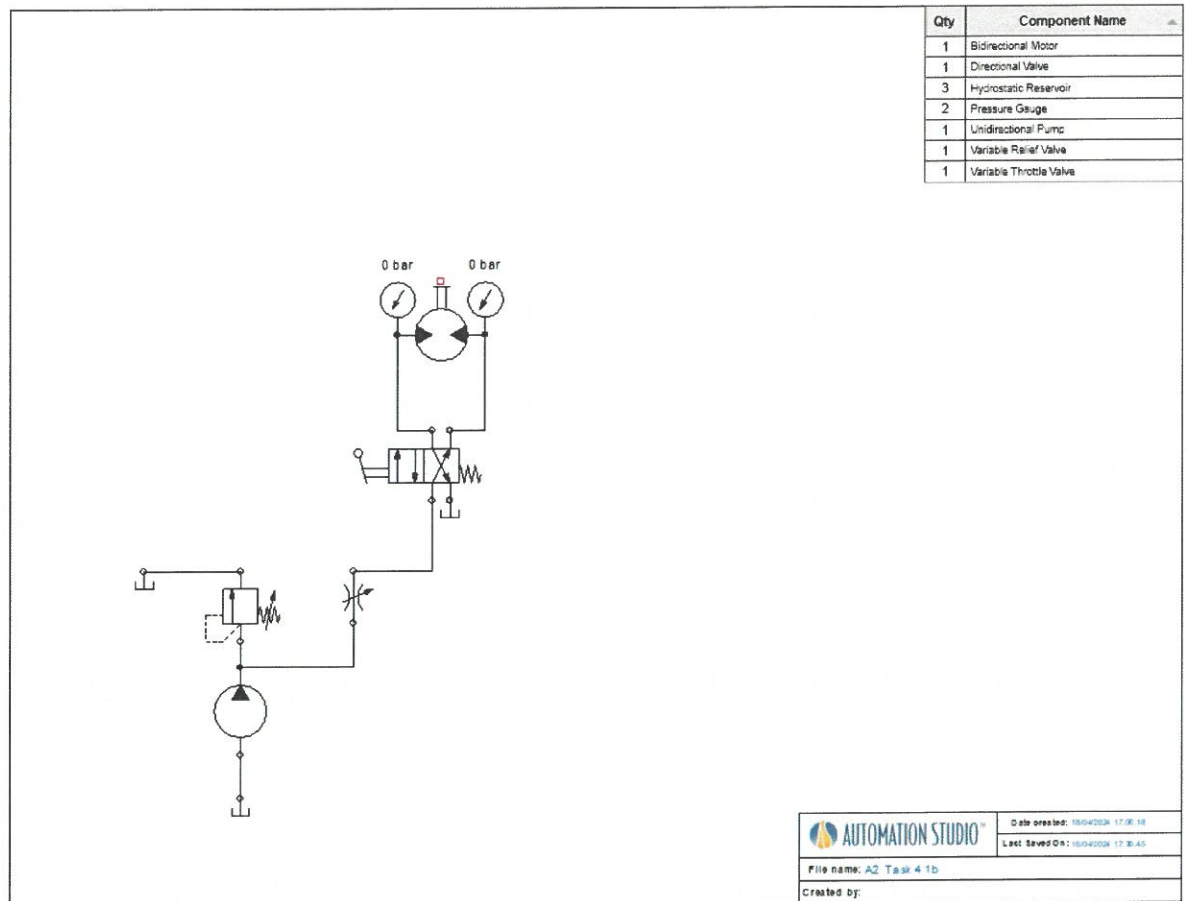
### Function:

Initially a start button is pressed to activate the sequence. The start button energises 'C1' which activates 'S1' solenoid. This changes the position of the solenoid

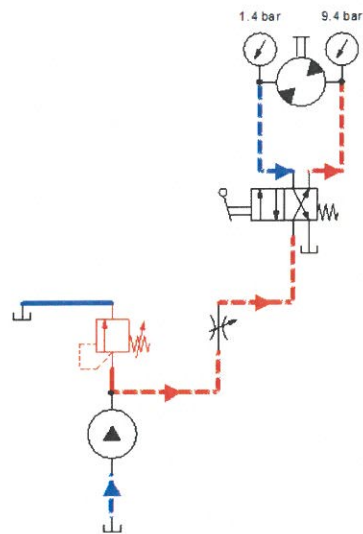
↙ In order to represent a box on the sensor.

operated 4x2 directional control valve. The air pressure is directed to the extension side of the first double acting cylinder. The piston rod extends out, due to magnet on the piston rod it activates the sensor 'PS2' closing the contact. This energises 'C3' closing the contact and energising 'S2' allowing for the flow to extend the top piston rod on the double acting cylinder. The magnet in the piston rod activates 'PS3' and energises 'C4'. The contact closes for 'C4' and energises the solenoid 'S3'. This alters the position of the bottom directional control valve to allow pneumatic pressure into the retraction of the piston rod. After the retraction of the piston rod the magnetic sensor activates 'PS4' this energises 'C5'. The contact closes on 'C5' and allows the current to flow to 'S4' which alters the position of the top directional control valve causing the retraction of the piston rod in the top cylinder. The start button will need to be activated for the sequence to occur again.

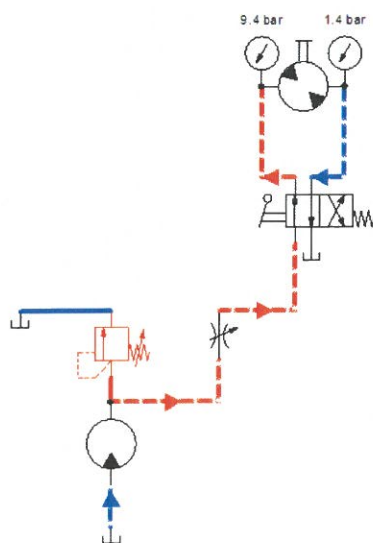
b) .

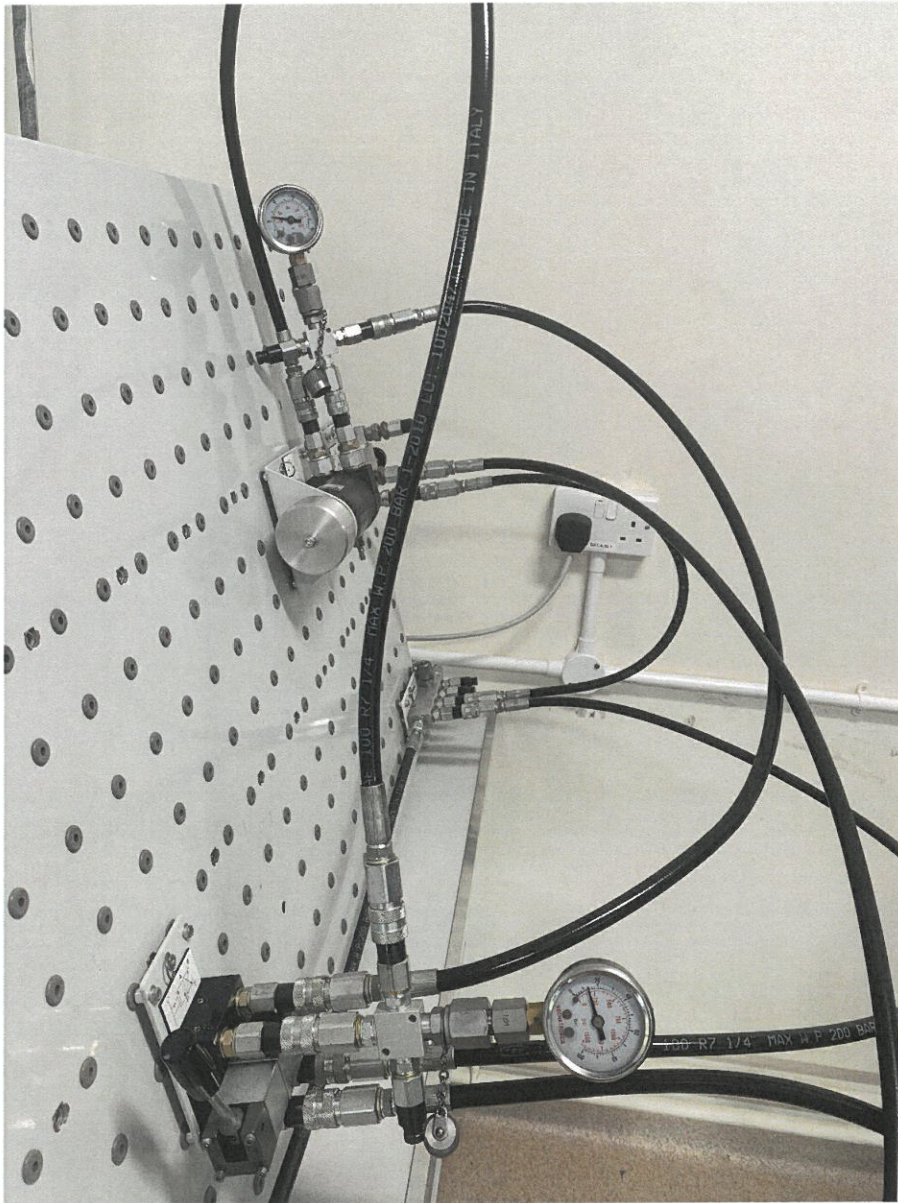


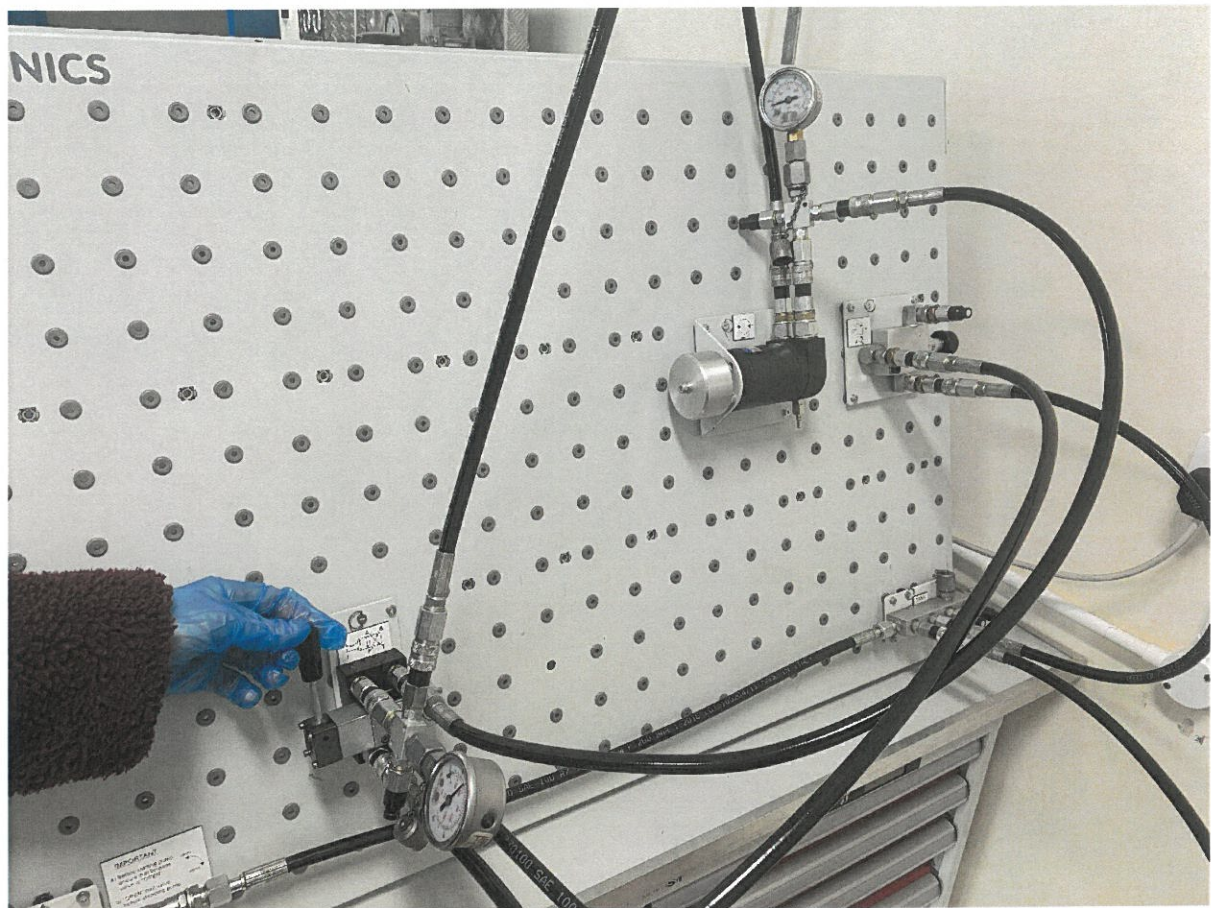
| Qty | Component Name          |
|-----|-------------------------|
| 1   | Bidirectional Motor     |
| 1   | Directional Valve       |
| 3   | Hydrostatic Reservoir   |
| 2   | Pressure Gauge          |
| 1   | Unidirectional Pump     |
| 1   | Variable Relief Valve   |
| 1   | Variable Throttle Valve |



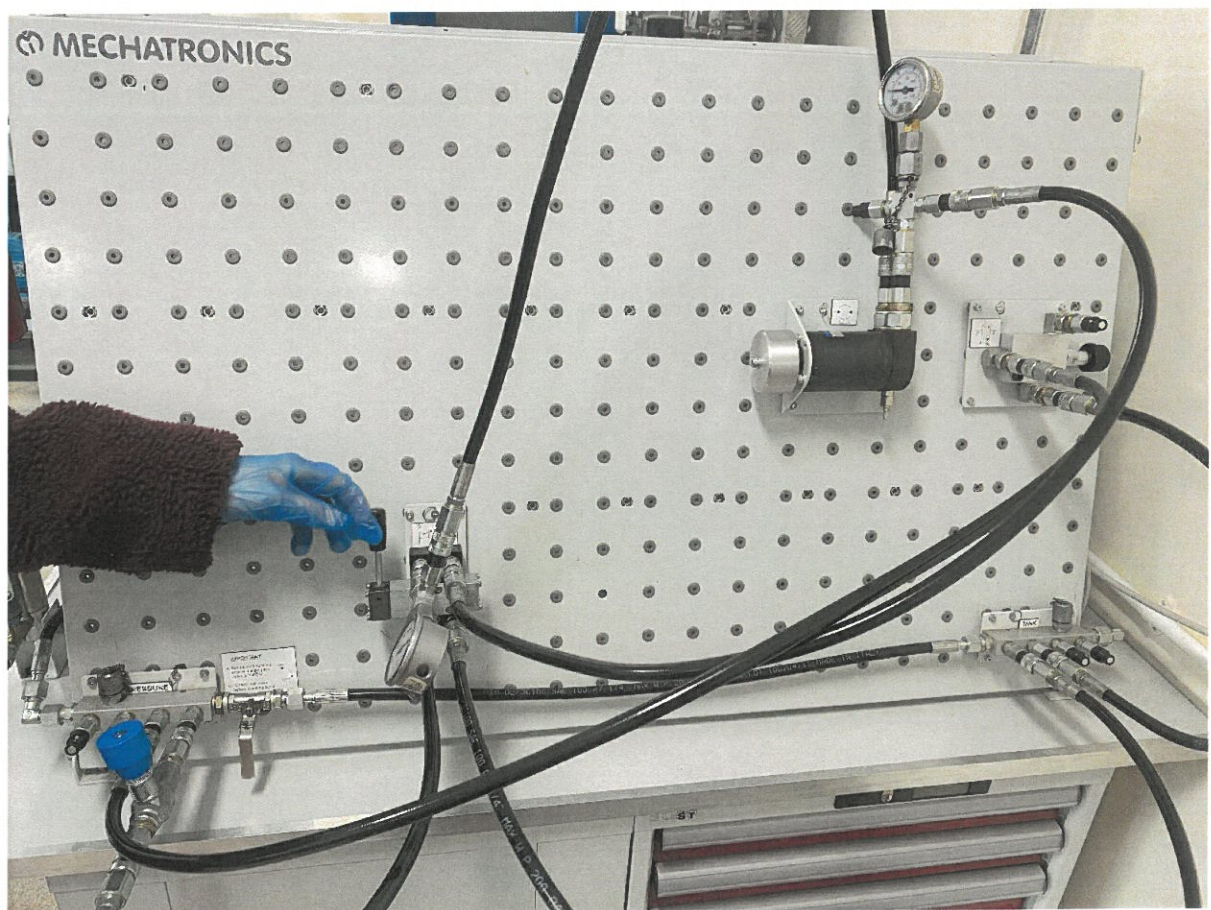
| Qty | Component Name          |
|-----|-------------------------|
| 1   | Bidirectional Motor     |
| 1   | Directional Valve       |
| 3   | Hydrostatic Reservoir   |
| 2   | Pressure Gauge          |
| 1   | Unidirectional Pump     |
| 1   | Variable Relief Valve   |
| 1   | Variable Throttle Valve |







✓



✓

### Equipment List:

1x Bi-Directional Pump

1x Directional Control Valve

1x Electric pump

1x Tank reservoir

2x Pressure gauges

1x Variable relief valve

### Function:

The tank reservoir stores the hydraulic oil which was used as the medium to pressurise the hydraulic system. The electric pump draws oil from the tank and pressurises the system. The variable relief valve can be adjusted to set a relief pressure for the hydraulic oil to return to the tank if an overpressure scenario occurs. ✓

The variable flow control valve can be altered to reduce flow of the hydraulic oil in turn reducing the revolutions of the bi-directional pump shaft. The direction of flow can be changed via the push button on the direction control valve which in turn will cause the pump to rotate in the opposite direction. <sup>Lever.</sup> The pressure gauges have been installed to each line connecting to bi-directional pump so that the pressure can be monitored. ✓

## References

- ControlMatic, 2023. *What Are Motor-Operated Valves and How Does It Work?*. [Online]  
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