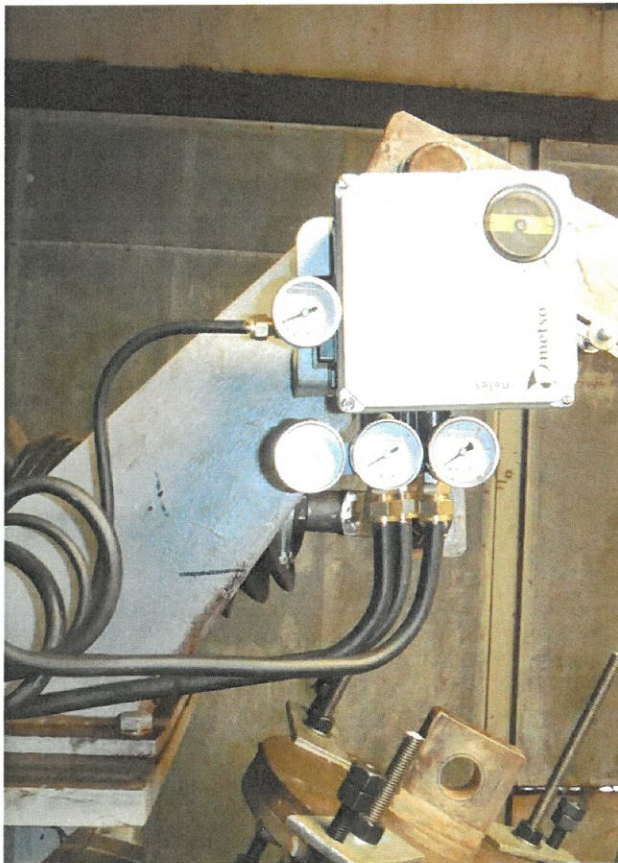




Marked 23/5/24
J.M.



PCEE4010

Assignment 2- Pneumatics &
Hydraulics Actuators and Design

Heather Raymond

95699@pembrokeshire.ac.uk

Course name would be
useful alongside PCEE4010



LEVEL 4 ASSESSMENT SPECIFICATION

Student name:	Heather Raymond	Student ID number:	95699
Programme:	HNC Instrumentation Engineering		
Module:	Pneumatics and Hydraulics		
Module code:	PCEE4010	Contribution to Overall Module Assessment (%):	50%
Lecturer:	J Mowbray	Internal Verifier:	Jason Pointer
Assignment Title:	Pneumatics & Hydraulics Actuators and Design	Word count (or equivalent):	2000
Submission deadline:	09/05/24	Return date of provisional marks & written feedback:	07/06/24
Submission method:	All written assessments, where practical and possible, must be submitted via Turnitin unless otherwise instructed by the Lecturer. (Please DO NOT put this assessment specification into Turnitin or it will match many similarities with other students' submissions.) Alternative submission method (if applicable): Late submission of the assessment will result in a late penalty mark. Penalties for late submission: Up to one week late, maximum mark of 40%. Over one week late, 0%. Only the Extenuating Circumstances Panel may approve a change to submission dates.		
Academic honesty / referencing:	Academic honesty is required. In the main body of your submission you must give credit to authors on whose research and ideas your work is based. Append to your submission a reference list that indicates the books, articles, etc. that you have used, cited or quoted in order to complete this assessment.		

Module Learning Outcomes (from module syllabus)
1. Demonstrate an understanding of the construction, function and operation of pneumatic and hydraulic components, equipment and plant. 2. Demonstrate the skills to analyse, design pneumatic and hydraulic circuits.



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✓
Concise TOC -



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TASK DESCRIPTION

Introduction

The aim of this assignment is to provide an introduction of the key aspects of pneumatics and hydraulics actuators along with the designing of systems. The assignment will cover the following areas of pneumatics and hydraulics – construction of actuator, speed calculations and system design. This will be achieved through a calculations, research and design work.



Task 1 – Actuator construction and operation

Produce a report explaining the construction and operation of the following types of actuators:

- Linear
- Rotary.

Linear Actuators

Linear Actuator Diagram

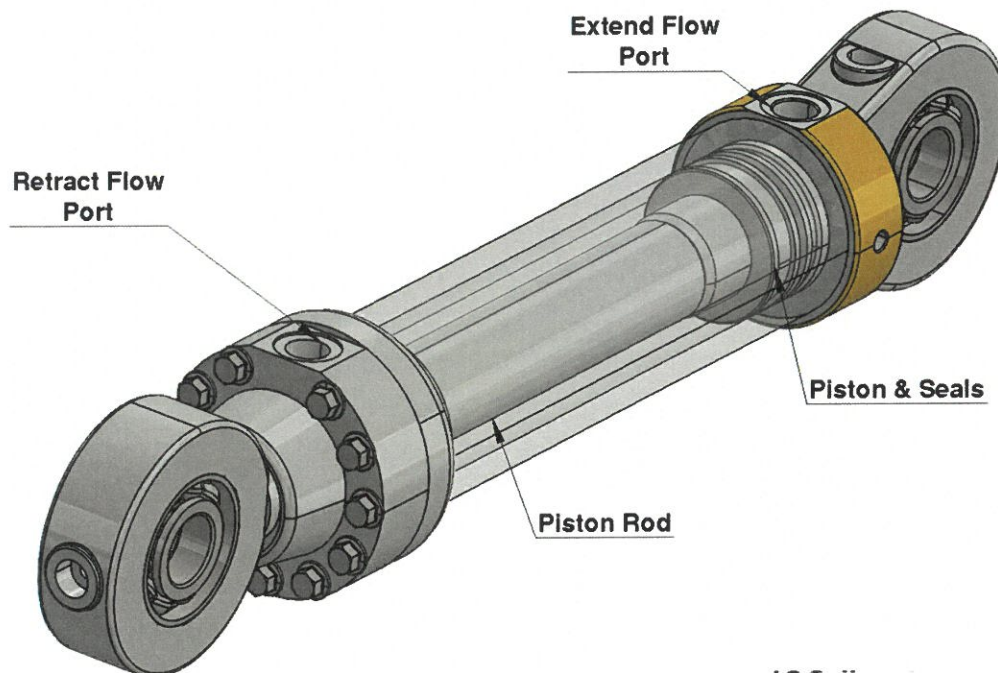


Figure 1, Linear Actuator diagram Source: <https://www.iqsdirectory.com/articles/linear-actuator/12-volt-linear-actuators.html>

A linear actuator is a means for converting rotational motion into push or pull linear motion. Static and dynamic are the load capacity variables for linear actuators, dynamic load capacity being the amount of force being applied when the actuator is in motion. Thus, static load capacity being when the actuator is motionless and holding a load in place (Simpson, 2022). Please see figure 1 as an example of the construction of a linear actuator piston/ rod.

Correct use of Harvard referencing.

As shown in *figure 1*, page 6, a basic linear actuator consists of a cylinder or ram, with a piston moving within a bore. The piston is connected to a rod which drives the load. If pressure is applied to the extend flow port, the piston will extend. Thus, the opposite is true when force is applied to the retract flow port. 'The maximum force available from the cylinder depends on fluid pressure and cross-sectional area of the piston' (Parr, A, 2011). Equations and forces at work are given in Task 2, where calculations are required for various pressures, forces and speeds with regards to a double acting hydraulic linear actuator.

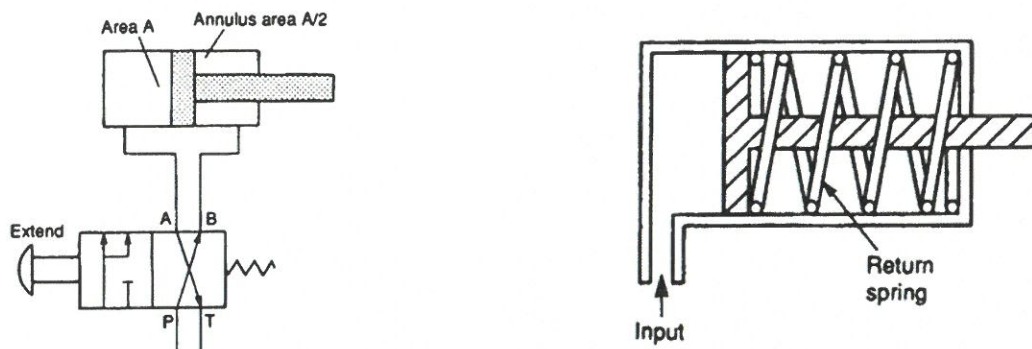


Figure 2, Example of double acting and single acting actuators, source: Parr, A, 2011, *Hydraulics and Pneumatics: A Technician's and Engineer's Guide*, 3rd Edition.

Hydraulic linear actuators can be both single and double acting, as shown in the schematic drawings in *figure 2*. With double acting cylinders, fluid pressure is used to extend and retract the piston. Single acting actuators are typically used for applications where a high extend force is required, but the retract force is minimal. This can be seen on some types of control valve actuators with spring return on refinery sites. Single acting cylinders are simple to drive and can be both hydraulically or pneumatically controlled (Parr, A, 2011).

On the following pages are some industrial examples where both single and double acting actuators are used to control valves, as well as, a fluid coupling on a compressor. *Figure 3*, page 8, shows a positioner requiring replacement on a single acting pneumatic positioner at Valero refinery, unit 3. The 2nd photo shows how one would set up the positioner if air was used to open or close a valve using the actuator. This actuator would be spring return for the opposing movement.

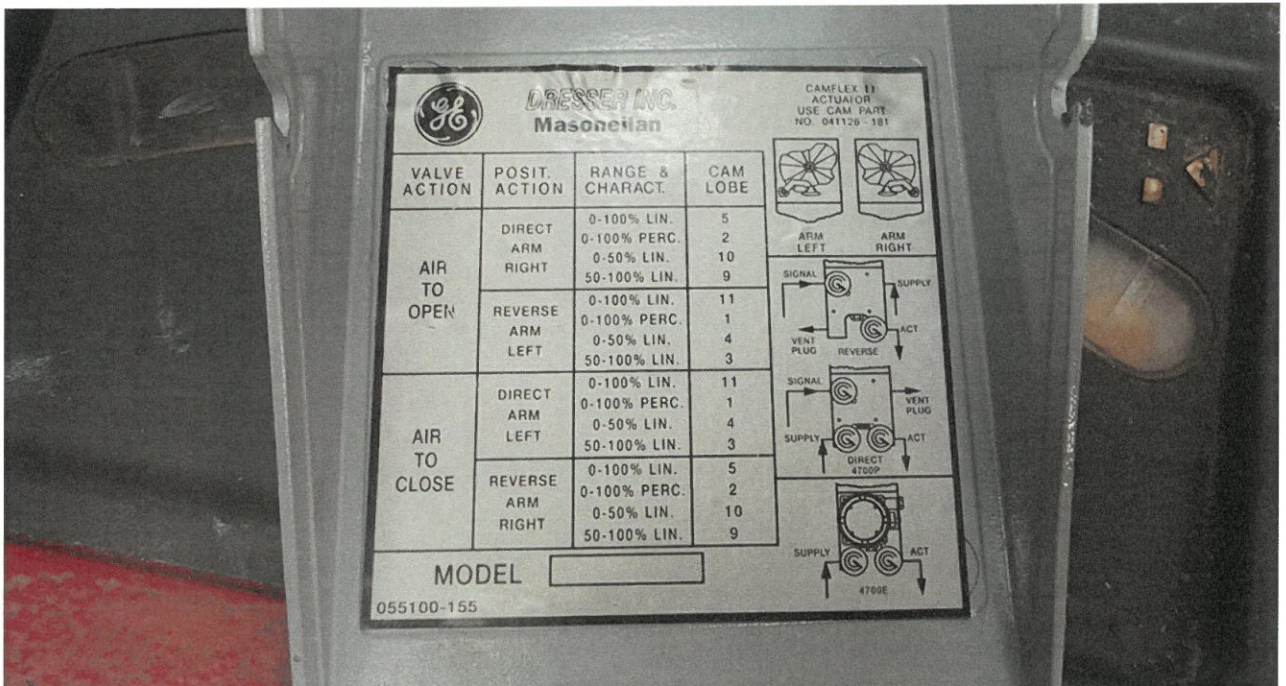


Figure 3, Source: Heather Raymond, Valero, 2022. Example of a single acting pneumatic actuator with positioner control. The first photo shows a positioner requiring replacement. The 2nd photo shows the new positioner and how it can be set up with a cam to suit different actuator/ valve actions.

+ Excellent evidence of industrial application.

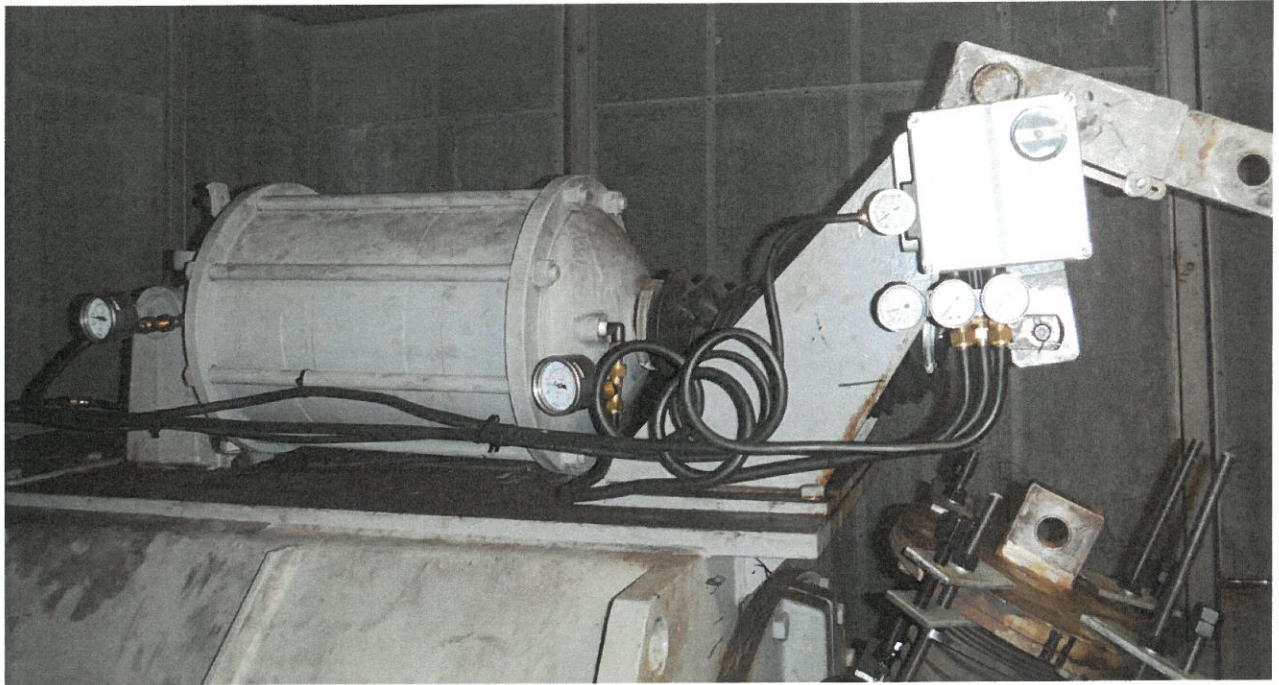


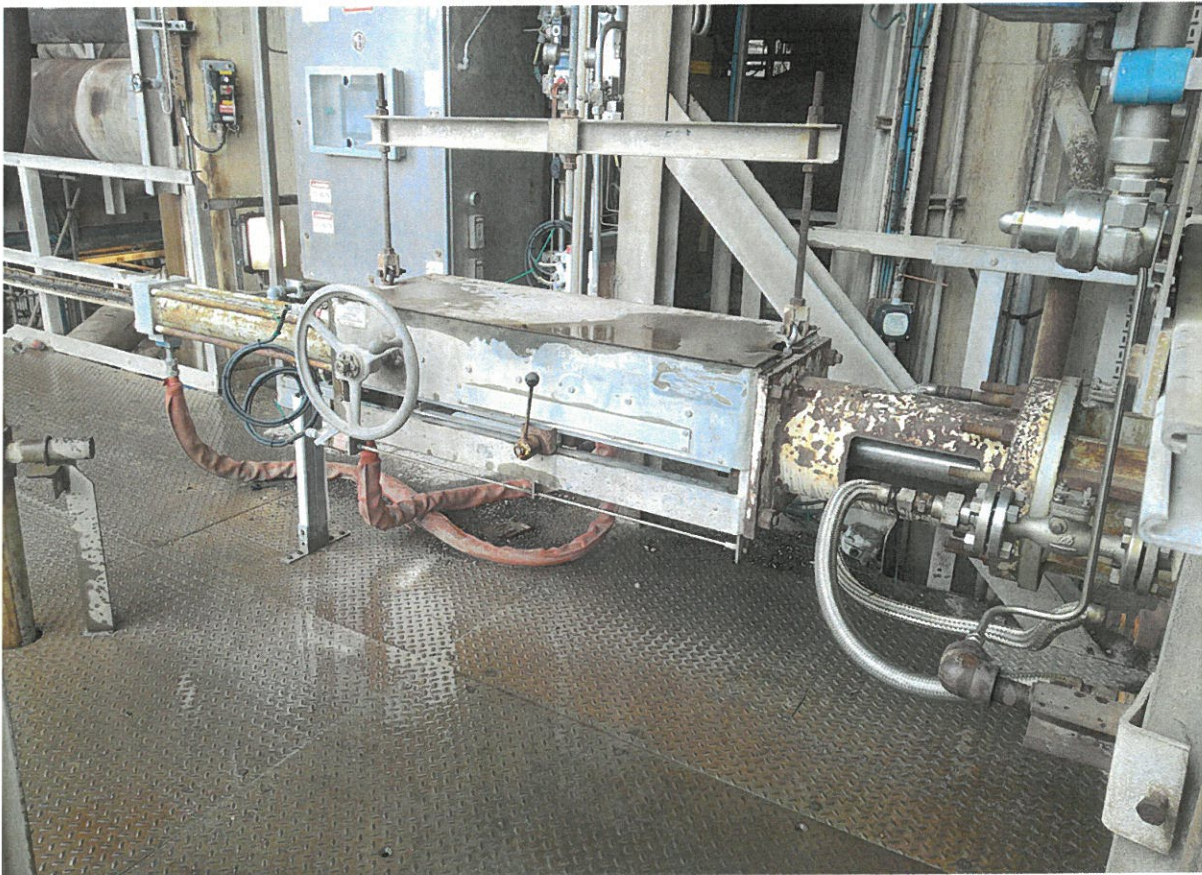
Figure 4, Source: Marc Goode, Valero, 2022. An example of a double acting pneumatically controlled actuator, used on a compressor to move the fluid coupling position (hence adjusting machine speed under load).

Figure 4 is a good example of a double acting pneumatic actuator. At Valero Refinery, this actuator is part of the speed control of the primary hydrogen compressor 7-C-301. The speed is adjusted on the machine via movement of the fluid coupling (which has been clamped for maintenance in figure 4.) The actuator air supply on either end of its cylinder is controlled via the use of the positioner pictured. Internal seals are used to prevent leaking. For actuation, air is applied to one side and vented the other, until the desired position is obtained. Quite often this style of actuator can be made to fail in current position. ✓ + Well explained.

Figures 5 and 6 on pages 10 and 11, are industrial examples of hydraulic actuation of slide valves, used on the FCCU unit at Valero Refinery. These operate under the same principles as pneumatic linear actuators, only with much higher pressures and with the use of fluid acting on either end of a cylinder. This is high criticality control, as these massive slide valves control the level of catalyst in the riser, reactor and Power recovery train inlet sections of the Catalyst cracking conversion unit. The actuators pictured have the option to hand jack control for maintenance purposes. ✓



✓



✓

Figure 5, source: Heather Raymond, Valero, 2024. 2 out of 3 of the Cat Slide valves used at Valero Refinery site.

+ Good.

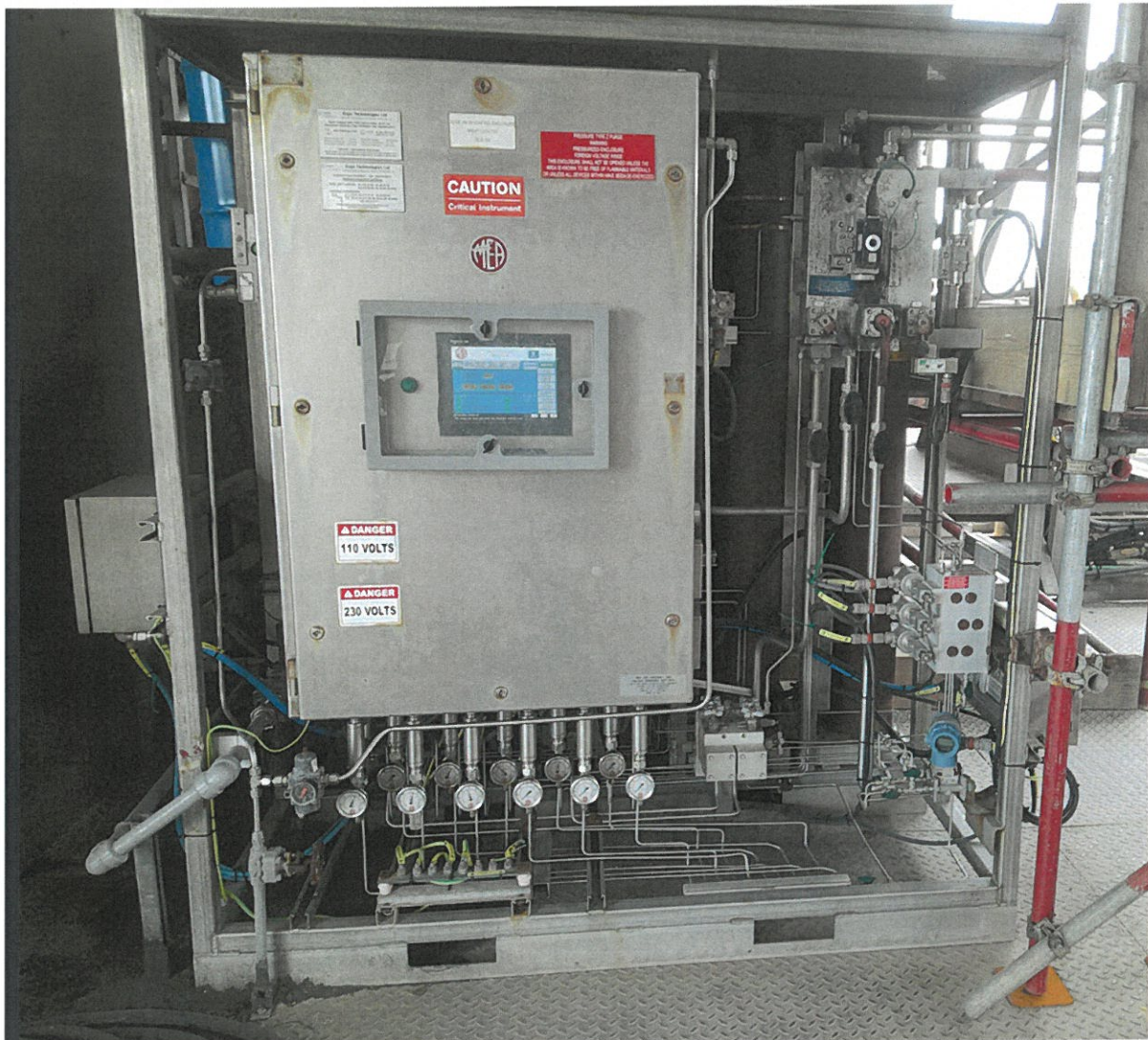


Figure 6, Source: Heather Raymond, Valero, 2024. Hydraulic unit controlling the cat slide valve and actuator.

Rotary Actuators

This type of actuator transforms pneumatic and hydraulic energy to mechanical rotation. Two of the most common configurations of pneumatic rotary actuators are rack and pinion/ vane configurations. With the rack and pinion style, a piston and rack move linearly and cause a pinion gear and output shaft to rotate. A vane actuator consists of a vane mounted on a shaft enclosed in a cylindrical chamber. This vane will rotate upon pressurization and will continue to rotate until it reaches the end of the stroke. Air pressure can be applied to the other side of the vane to force the shaft to rotate in the opposite direction (M.B. Popovic, 2014).

The hydraulic version of a rotary actuator has design configurations including the piston type, vane type or gear type. *'In vane-type actuators, the operating principle is similar to that of a pneumatic rotary actuator. Pressurized fluid is used to produce rotation of the vane which produces rotational motion of the central shaft. In a gear-type configuration, pressurized fluid moves meshed gears to generate rotary motion of the shaft connected to the gears.'* (M.B. Popovic, 2014). Examples of all three types of hydraulic rotary actuators can be observed in figures 7, 8 and 9.

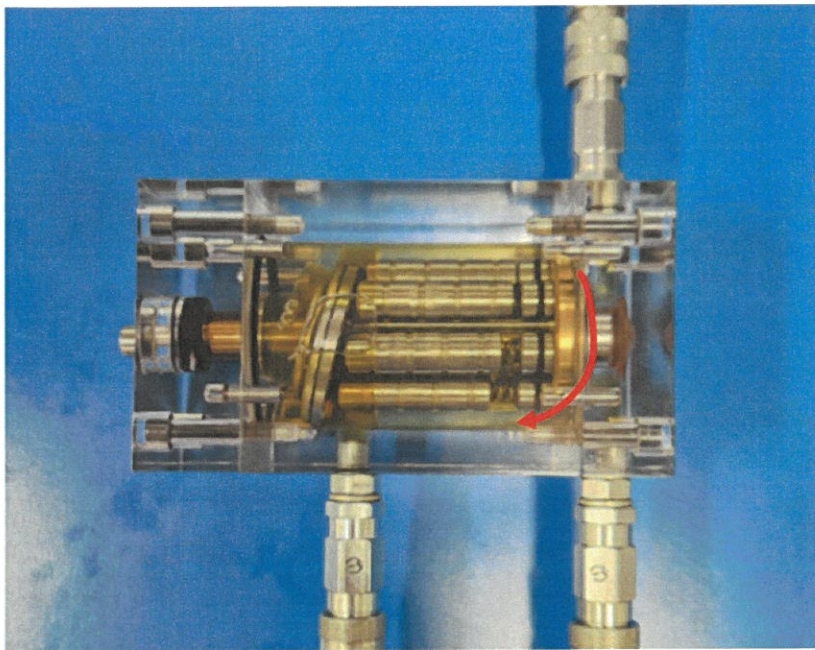


Figure 7, Source: Pembrokeshire college, 2023, piston type hydraulic actuator

Figure 7 shows a piston-type actuator, in this example pressurized hydraulic fluid is used to displace a piston and generate rotational motion.

See the red arrows on figures 7, 8 and 9 for the direction of motion of the actuators, used to drive shafts in rotation.

Not to forget pneumatic rotary actuators, these 'may have fixed or adjustable angular strokes, and can include such features as mechanical cushioning, closed-loop hydraulic dampening (by oil), and magnetic features for reading by a switch.' (P Zhang, 2010).

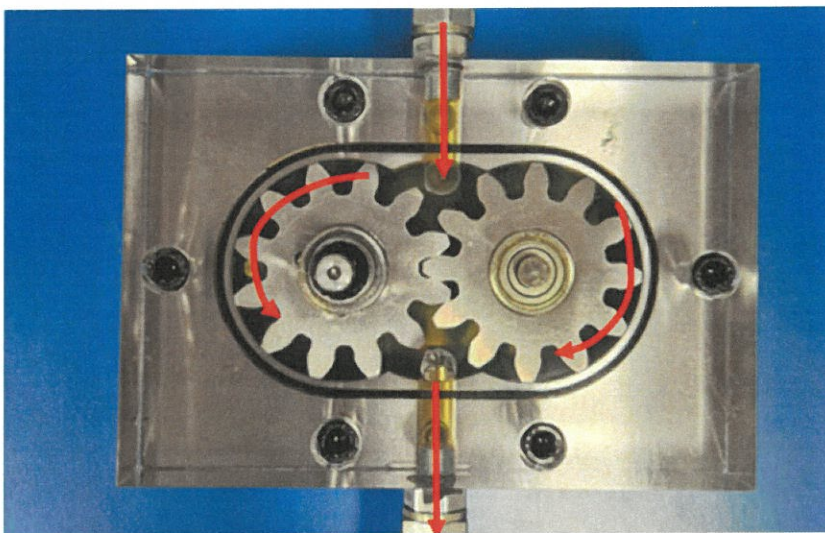


Figure 8, Source: Pembrokeshire college, 2023, gear type hydraulic actuator

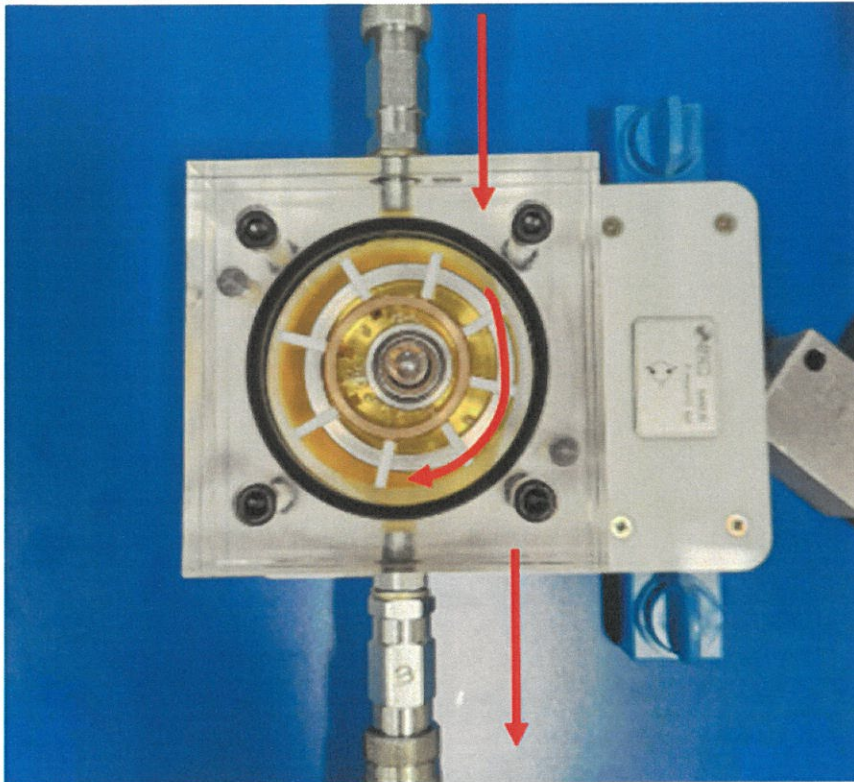


Figure 9, Source: Pembrokeshire college, 2023, rotary vane type actuator

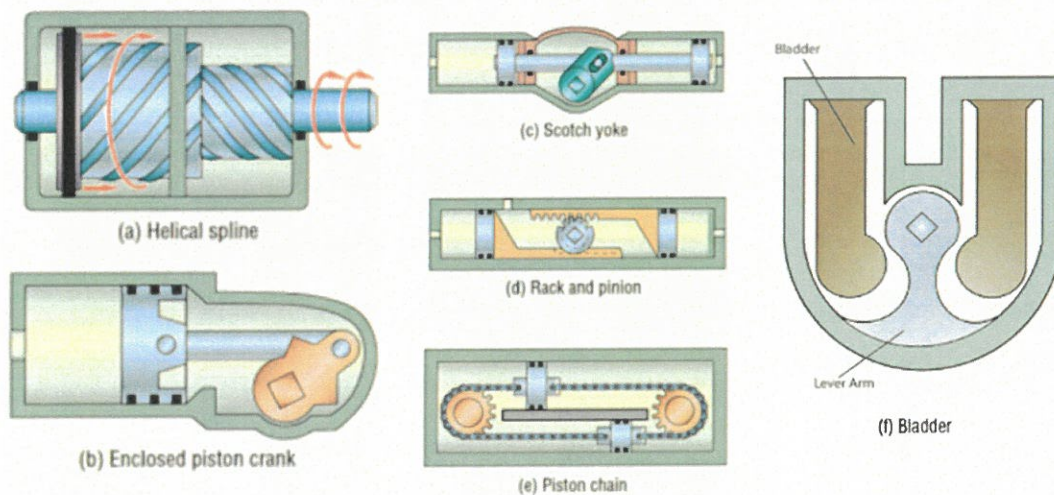


Figure 10, Source: <https://fluidpowerjournal.com/test-your-skills-size-a-rotary-actuator/> types of rotatory actuators

Various types of rotary actuators are shown in figure 10, these styles of actuator can be pneumatically driven. Choice of actuator would depend on torque required for the output shaft. At Valero Refinery site, we do not have many hydraulic or pneumatic examples of rotary type actuators. Limit switches on valves operate in a rotary motion. There are also electrical type MOVs with rotationary action on the fuel gas supplies to some of the boilers, the RTW and mainline pipeline.

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		
	D (mm)	S (mm)	Q (dm ³ /min)
5 (HR)	150	600	22

Please see Appendix A at the end of the report for the hand written calculations for this task. The shorthand answers are given as follows,

- The system pressure needed= 2.83MPa ✓
- The force with which it pulls, given the same pressure= 42.01kN ✓
- The time taken to extend fully= 28.9 seconds ✓
- The velocity on the outward stroke= 0.021 m/s ✓
- The time taken to retract fully= 24.29 seconds ✓
- The velocity on the inward stroke= 0.025 m/s ✓
- The power transmitted on the outstroke given the cylinder is operating at capacity= 1.038kW ✓

Construction and operation of a relay

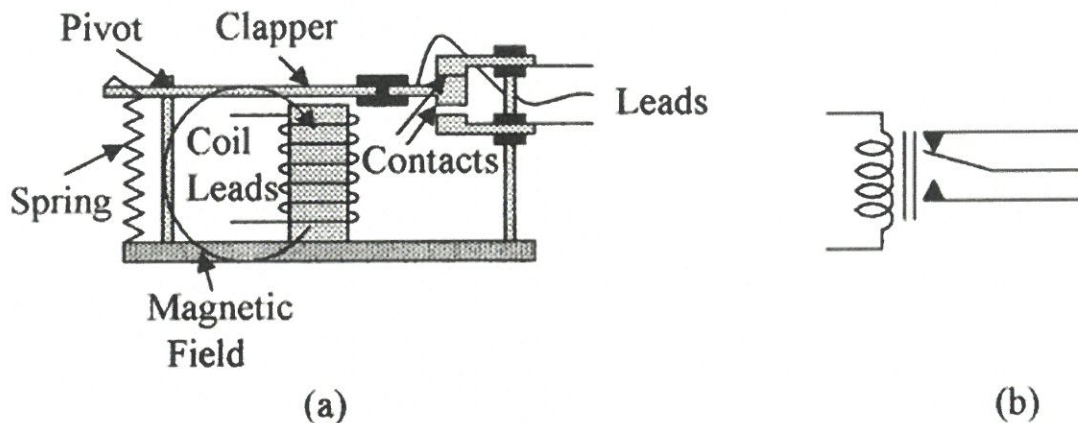
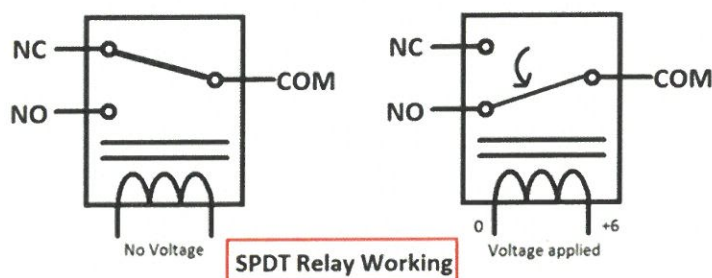


Figure 12, source: Bolton, W, 2021, cross section (a) electromagnetic relay, (b) schematic of a relay

Figure 12 is a drawing of an electromagnetic relay. When the coil is not energized the centre lead is held in contact with the top lead by a spring. When a current is present in the coil, it energizes it and a magnetic field is established. The clapper attracts towards the coil and moves the contact arm downwards breaking the contact between the upper and centre leads- thus establishing a contact between the centre and lower leads (Bolton, W, 2021).

The main purpose of a relay is to make or break a contact, without any manual operating of the switch. Relays are mainly used to control a high-powered circuit using a low power signal. As shown in figure 13, Electromagnetic relays also have two pins, normally closed and normally open (NC and NO). The NC pin is connected to the armature or the common terminal. The NO pin is left free when the coil is not energized (Thonti, 2017).



Materials used to construct a relay include copper windings around a conductor metal. Conductive metals as contacts. And suitable materials for the armature, spring and casings. (Thonti, 2017).

Figure 13, source: <https://circuitdigest.com/article/relay-working-types-operation-applications>, general wiring arrangement of a relay

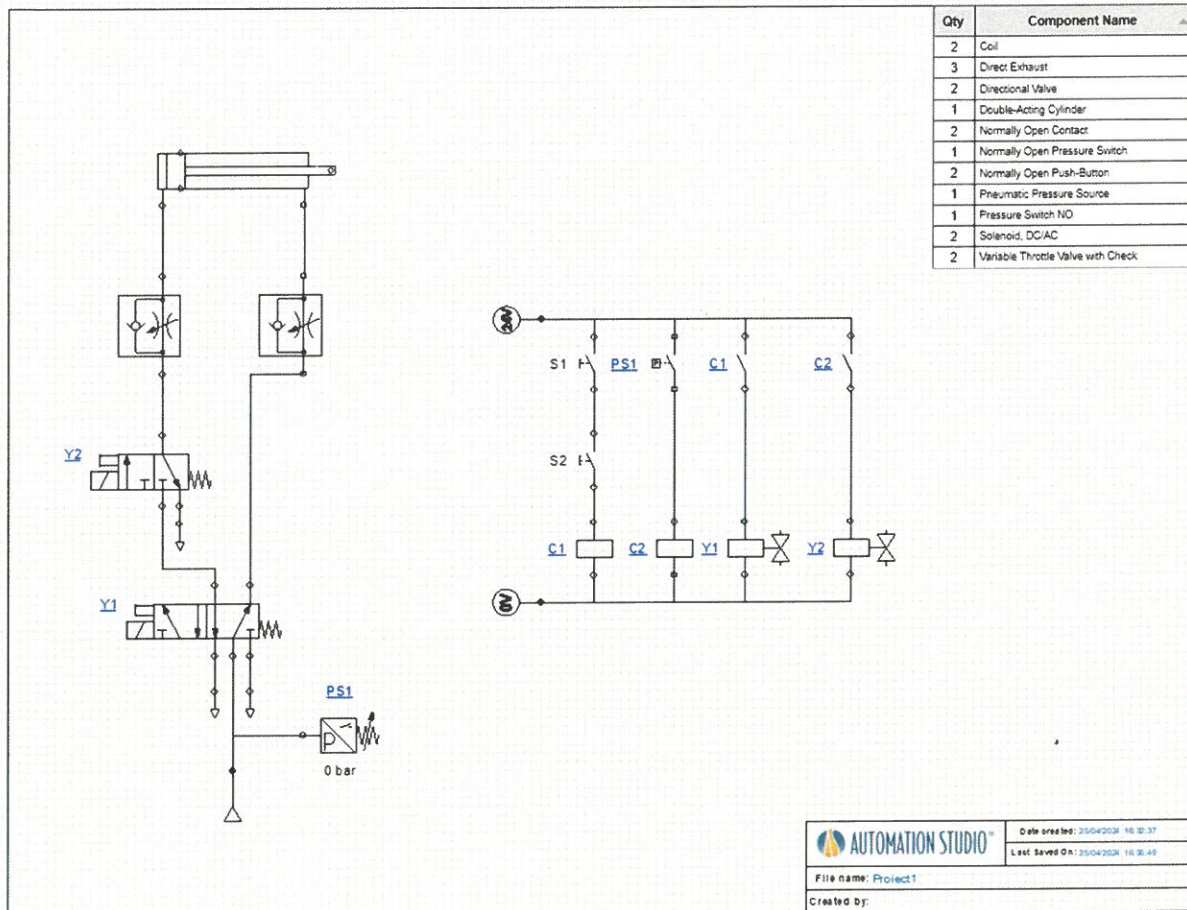


Figure 14, circuit built in automation studio, with electrical components included, Heather Raymond, 2024

To gain an understanding of the circuit, it has been initially built in automation studio and simulated there, as is shown in Figures 14 to 17. Firstly, the circuit is pneumatically powered, as given, the system supply pressure is 10 bar. The pneumatic power source is represented by a triangle symbol in the schematic. This would be an air supply with an air regulator setup in practice. The purpose of the circuit is to drive the double acting cylinder outwards when both start buttons are pressed. The variable throttles have been included to presumably control the speed of actuation. The directional control valves allow for movement both ways. The pressure switch is there to switch the air to the cylinder if a pressure drop below 9 bar is sensed. The directional control valves are electronically actuated through the use of solenoids and coils. If the 2nd switch S2 is not held on, the cylinder retracts.

The components of the system are as follows,

- Coils/ relays with normally open contacts (C1 & C2)
- Solenoids (on directional valves) (Y1 & Y2)
- Pressure switch (PS1)
- Push buttons (S1 & S2)
- Directional valves
- Variable throttle with check
- Double acting cylinder
- Pneumatic air lines
- Air regulator

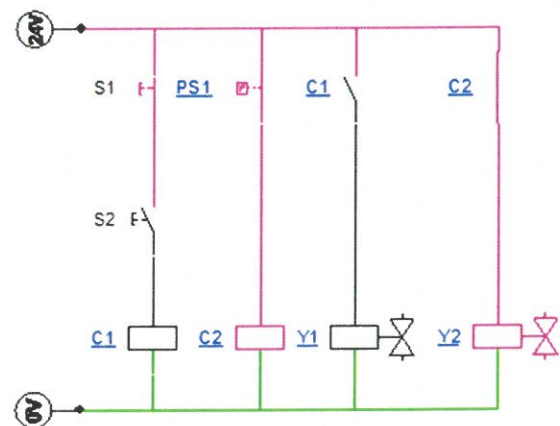
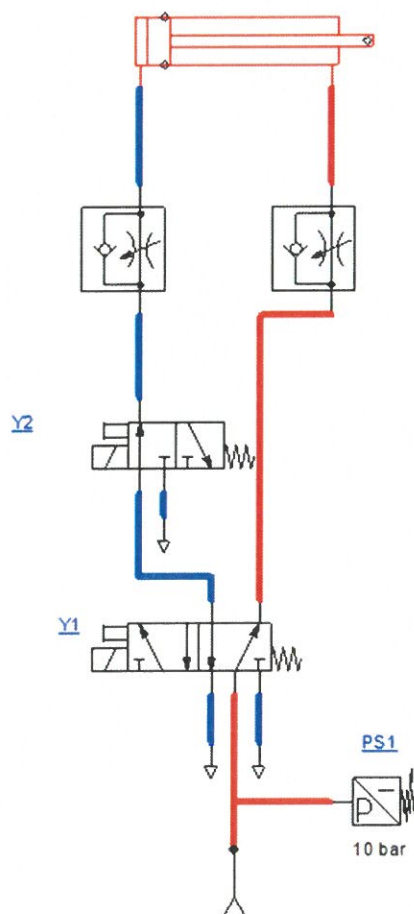


Figure 15, initial start up of the circuit- via a simulation tool

The initial circuit position is given in *figure 15*. The directional valves will switch when the circuit is activated. Air will be supplied to one side of the cylinder and exhausted through the other. When initially starting the circuit, 2 switches need to be activated- this is a safety modification, one will latch and the other push button will require holding down during operations. The switches depressed create a current flow through C1, which closes the open contact- thus energizing solenoid operated valve Y1. If a pressure drop is sensed within the system, to 9 Bar or below, PS1 will activate and relay C2 will open. Thus, breaking the circuit and switching the air to the cylinder, which would cause it to retract.

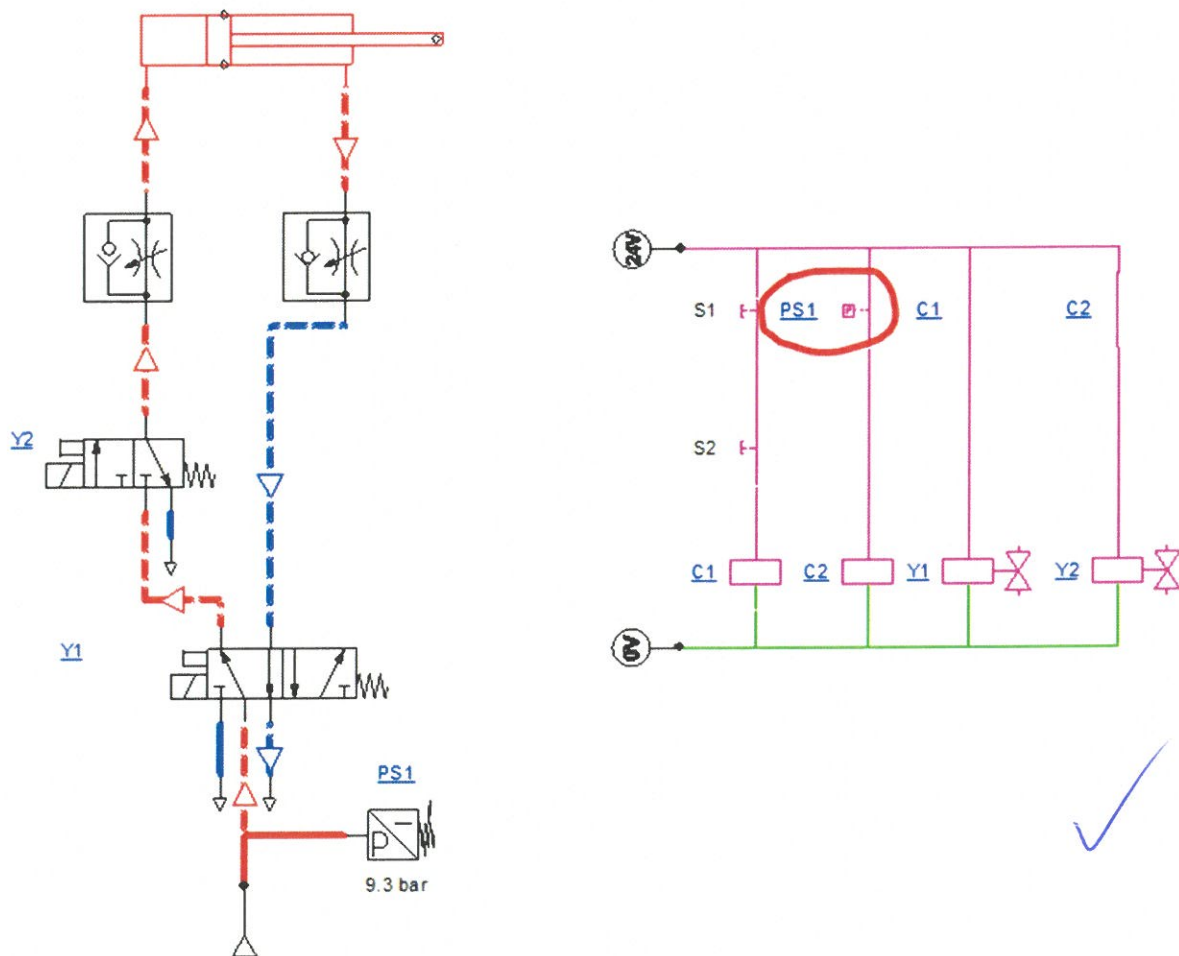
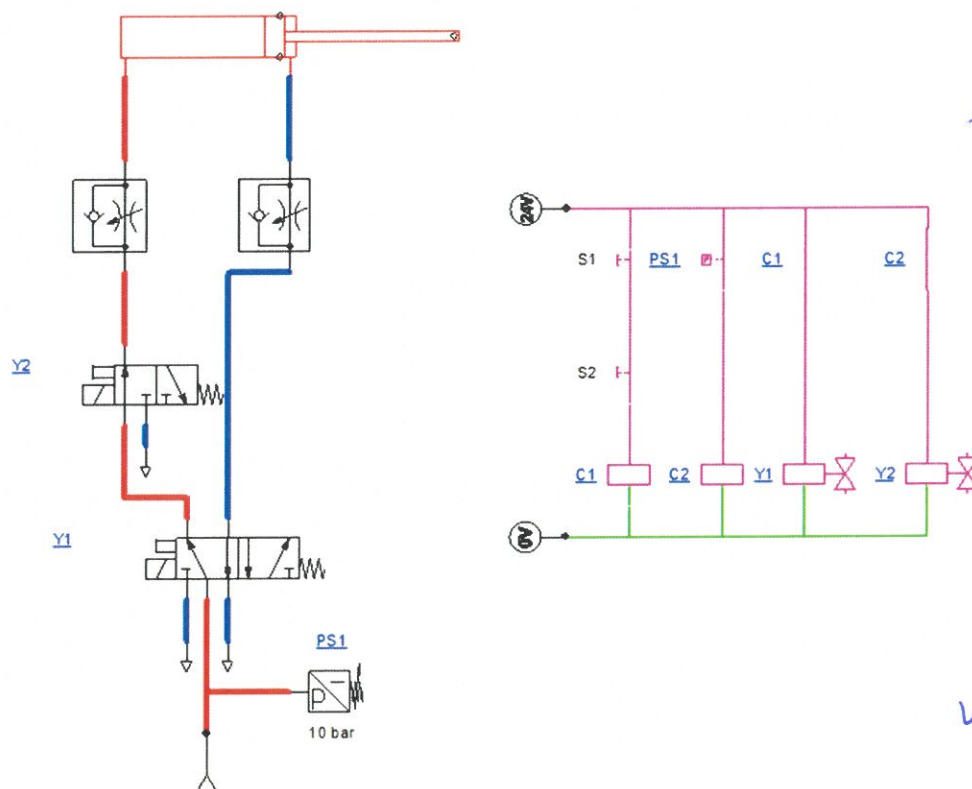


Figure 16, issues with PS1 activating when air enters the cylinder, creating a pressure drop



The system in motion is shown in *figure 16*. There is a fault present within the system, PS1 temporarily gets triggered when the cylinder extends, due to the system dropping in output pressure at that point of travel. The system supply pressure drops when air initially enters the cylinder. To fix this, it is possible to drop the trigger point of PS1 to 8 bar, to make the pressure switch less sensitive to pressure changes when the double acting cylinder is extending outwards. When S2 is released, this opens the contact C1 and causes the solenoid operated directional valves to switch position, causing the cylinder to retract.



+ Well explained
with consideration
for reducing
sensitivity of
pressure switch.

Figure 17, circuit condition after cylinder has been extended

Figure 17 shows the circuit layout after the cylinder has extended, see how the directional valves have switched as compared to their positions in *figure 16*. Please see Appendix B for photographs of the circuit built in practice and a video link of the circuit being activated. This has been done to supplement this report and to gain a greater understanding of how the circuit works in principle.

Good effort. i



Task 4 – Circuit design

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

For both systems you are to produce electro-pneumatic and hydraulic circuit diagrams, prove the designs using simulations and finally, build the systems to demonstrate correct operation.

Document your design and testing of the design in a written report.

- a) At the end of a conveyor section, boxes are to be detected then lifted by a pneumatic cylinder, then pushed onto a second conveyor by a second cylinder. On this installation it is vital that the second cylinder should not return until the first one has fully retracted.

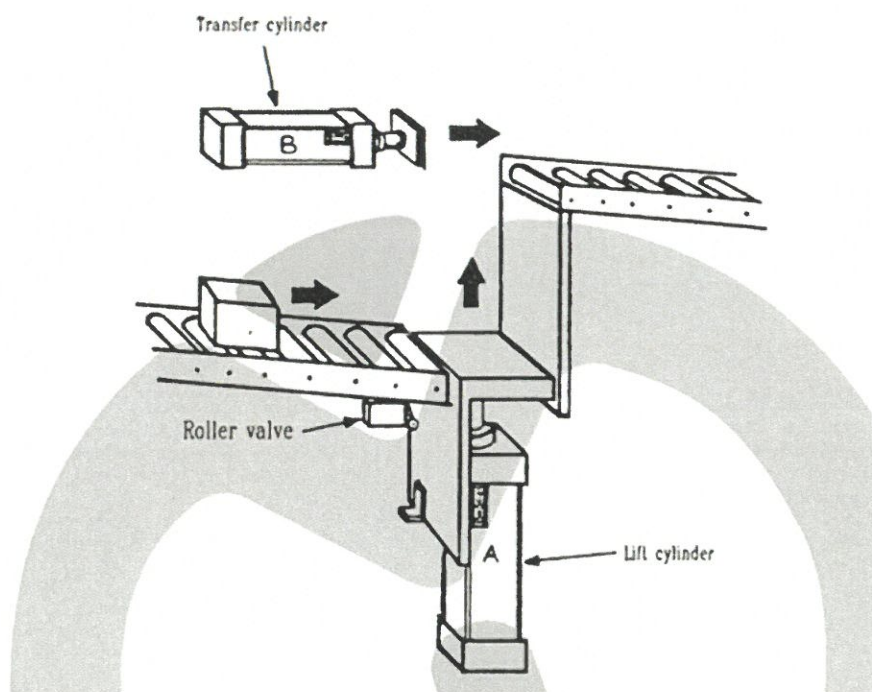
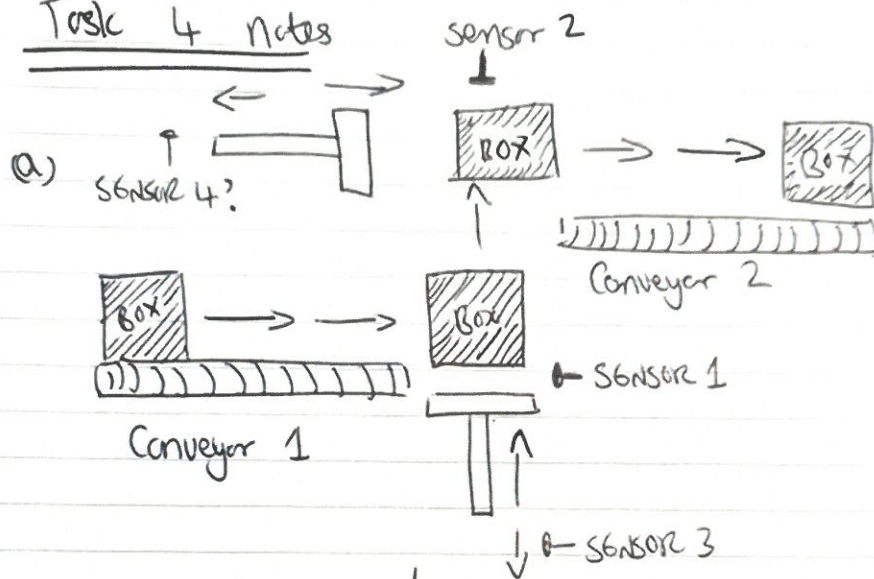


Figure 18, pneumatic circuit requirements



Pneumatics & Hydraulics Assignment 2

Task 4 notes



pneumatic source  (has its own pressure relief valve built in).

- 2 x cylinders (double acting)
- Directional control valves - solenoid operated?
- Coils / relay contacts (normally open).
- 4th sensor not required

Figure 19, notes to design pneumatic circuit, Heather Raymond, 2024.

As shown in figure 19, some thought has been given to the components required by Task (a). A sensor is required to detect a box on a conveyor belt, which then should be lifted by a pneumatic cylinder and further pushed onto a second conveyor belt by another pneumatic cylinder. It has been determined by the brief that the second cylinder should not retract until the first has fully returned to its starting position. This is to ensure boxes are conveyed safely, without possibly damaging the boxes due to the timing being off with the cylinder actuation. Two sensors will be required to trigger the second cylinder movement initially and after the first has returned fully.

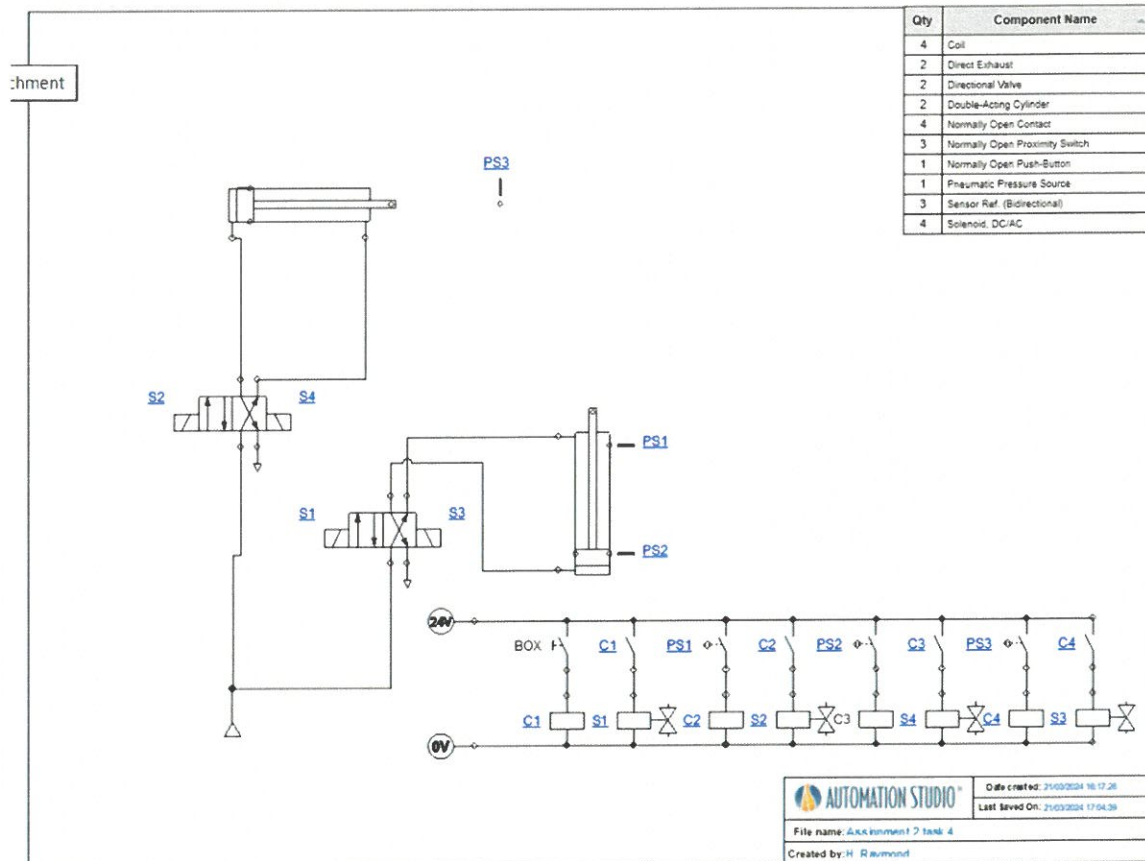


Figure 20, circuit designed in Automation Studio

As per the initial instructions given for this report, the pneumatic circuit has been designed in Automation Studio and a schematic drawing produced, as shown in figure 20. Solenoid triggered directional valves were selected for this task, with 4 open contact relays, 2 exhausts, 2 double acting cylinders, 3 proximity switches and a button to initiate the sequence. This software allows for a digital simulation of the circuit prior to building, as shown in figures 21-22.

At the start of the sequence, a button (BOX) is pressed to close the contact (C1), which energises Solenoid (S1). This extends the first cylinder, which in practice would raise the box on the conveyor to the next level. The proximity sensor (PS1) activates when the first cylinder extends. This causes contact (C2) to close, energising solenoid S2. This causes the directional valves to put air onto the 2nd cylinder to extend. Thus pushing the box forward in theory.

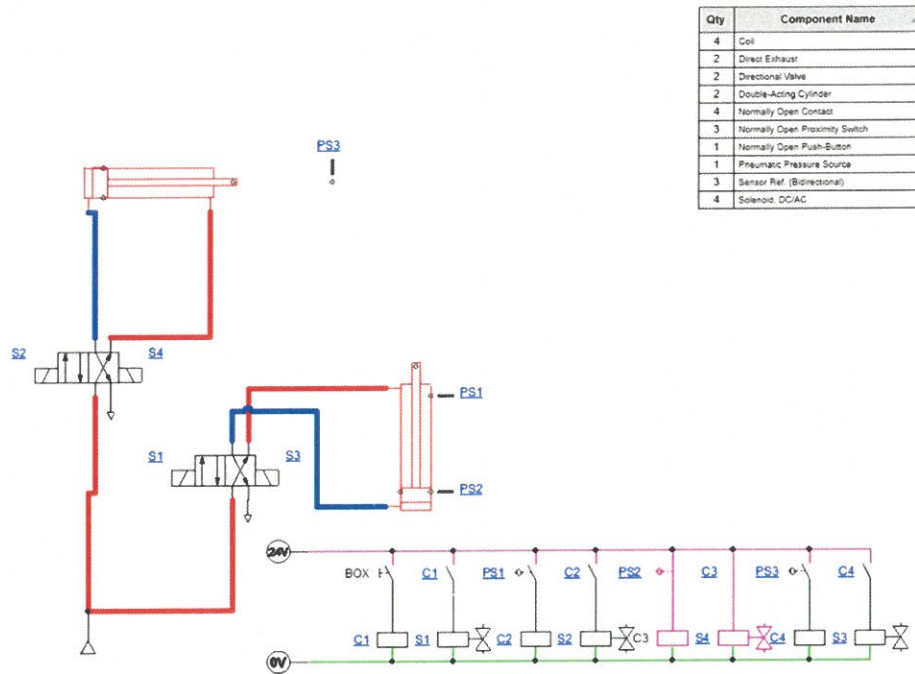


Figure 21, initial simulation of the circuit

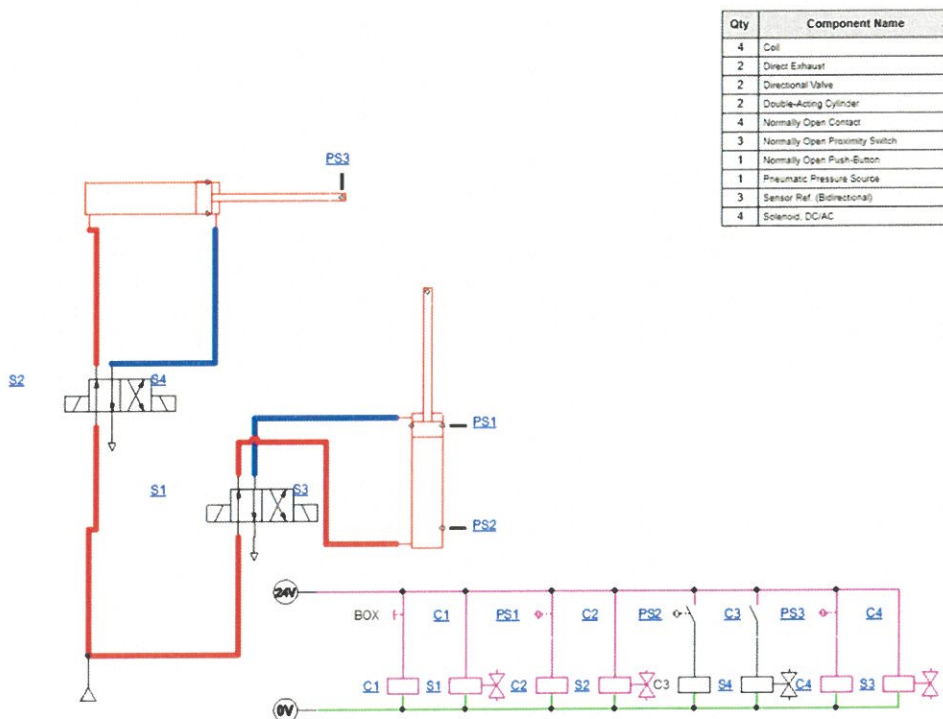


Figure 22, circuit simulation with cylinders extended

When the button (BOX) is released, it breaks the contact C1, causing the directional valve with solenoids (S1) and (S3) to switch air onto the first cylinder, causing it to retract. The proximity switch on the first cylinder (PS2) activates when the cylinder is fully retracted. This closes the contact which will energise the coil (C3), which in turn switches on Solenoid (S4). This causes the air direction to switch on cylinder 2, causing it to retract once cylinder 1 has fully retracted. Thus, the sequence is complete. Please see *figures 23 and 24* showing the pneumatic circuit built and used successfully to demonstrate how the system would work in practice. ✓

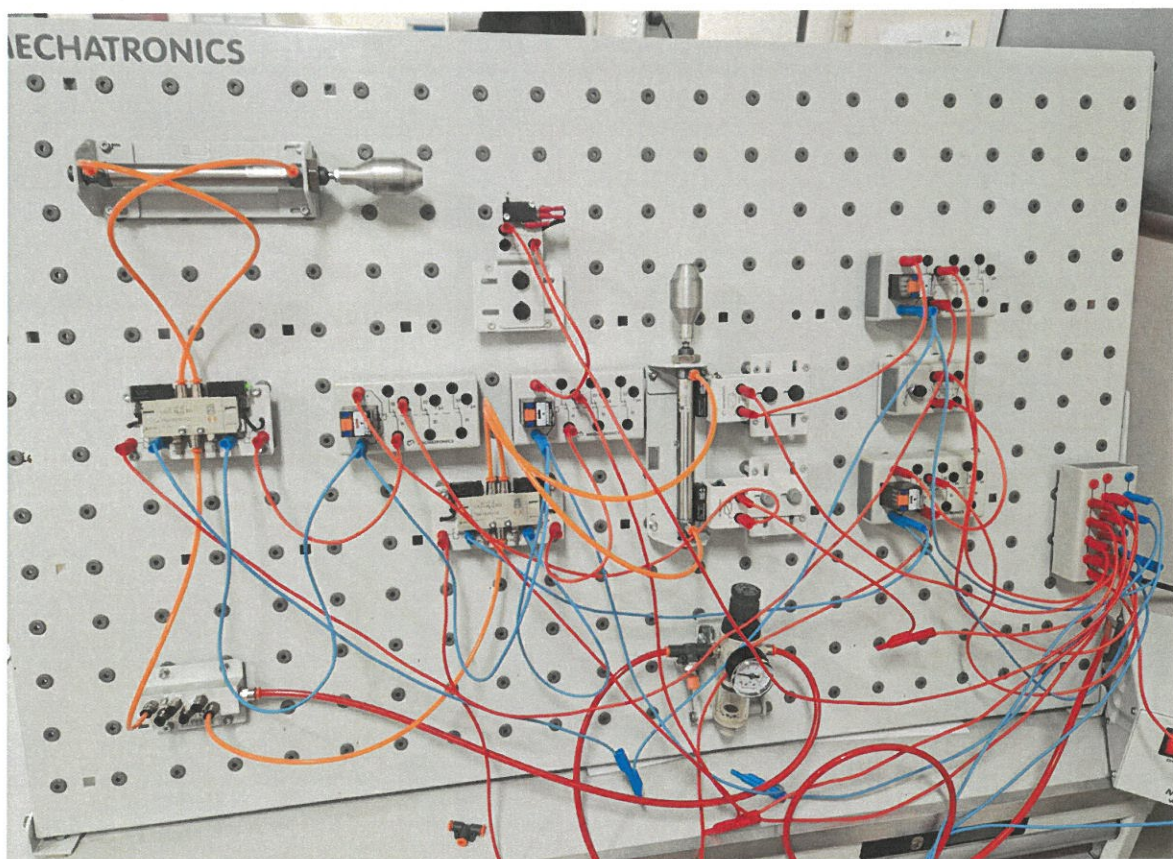


Figure 23, circuit built ✓

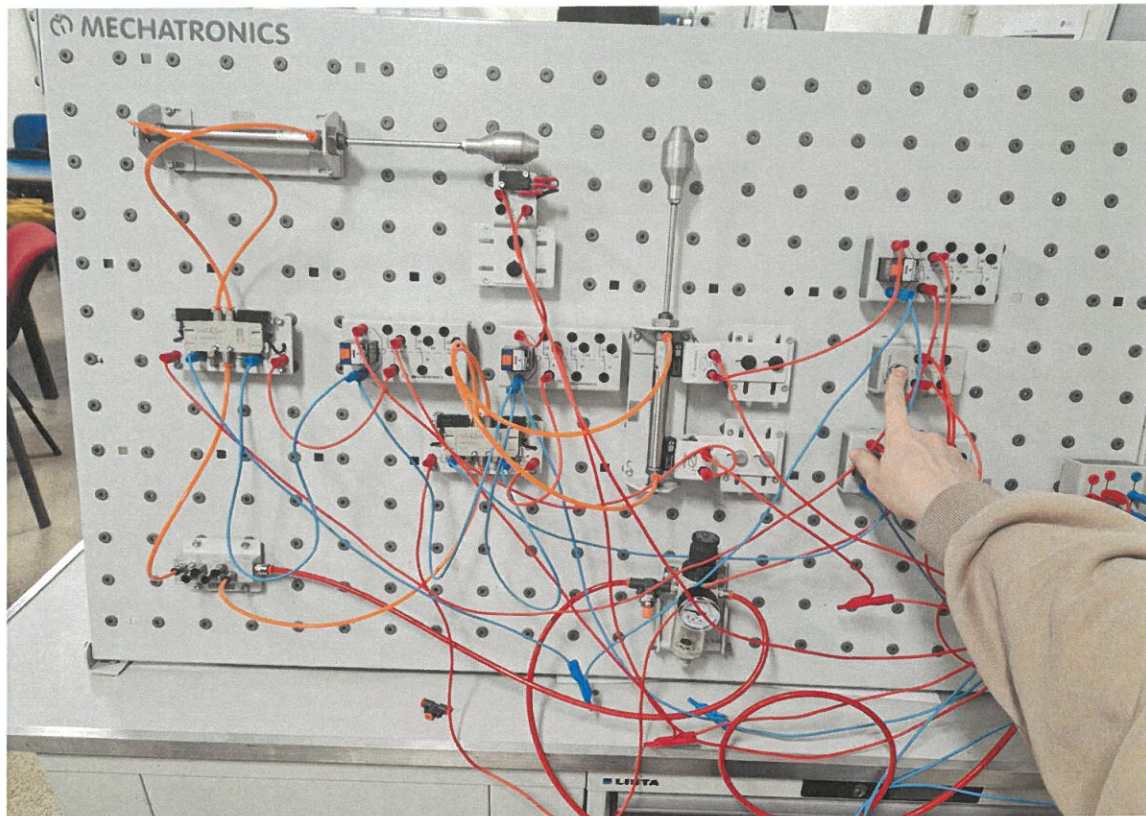


Figure 24, circuit in use, proving function

A link to a video of the circuit in motion is given in Appendix C.



- b) A power winch is to be driven by means of bi-directional hydraulic motor the rotation speed of the motor is to be controllable (adjustable) in both directions of travel.

As per the initial instructions given for this report, the hydraulic circuit (b) has been designed in Automation Studio and a schematic drawing produced, as shown in *figure 25*. This software allows for a digital simulation of the circuit prior to building, as shown in *figures 26-27*. The componentry of this circuit includes a Bidirectional motor, hydraulic directional valve with a lever, electric motor, hydrostatic reservoir, relief valve, unidirectional pump with shaft and a variable pressure reducing valve. A power winch can be driven in 2 different directions by this system. The system also allows for the rotational speed to be adjusted in both directions of travel. The circuit is shown simulated in *Figures 26 and 27*.

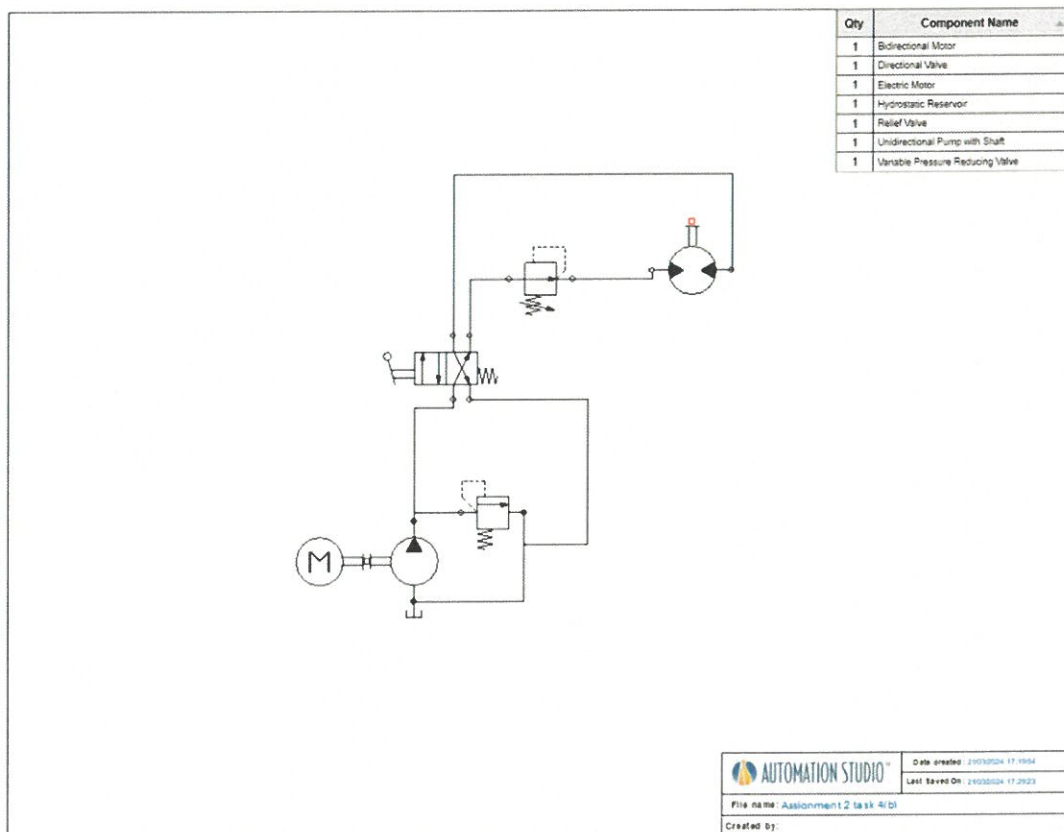


Figure 25, hydraulic circuit built in automation studio

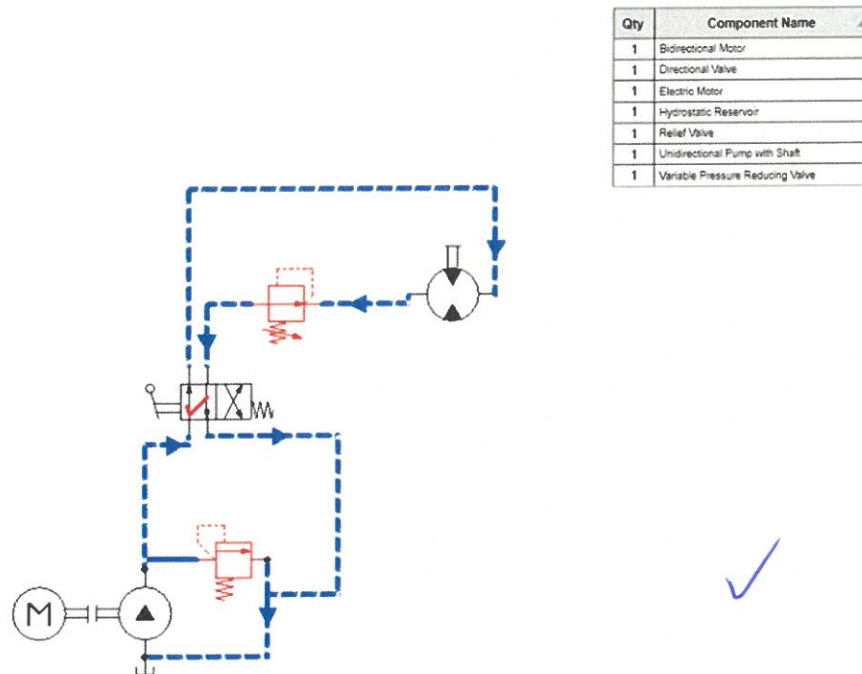


Figure 26, circuit simulated in clockwise direction

Figure 26 shows the circuit being driven in a clockwise rotation. The speed at which the bidirectional motor will turn can be controlled by restricting the flow of hydraulic oil to that part of the system. The settings of the variable pressure reducing valve can be adjusted to obtain different speeds in both directions of rotation. The relief valve is in place to ensure over pressurising of the system cannot happen. The oil is allowed to circulate back to a hydrostatic reservoir, thence back through the rest of the system. Figure 27 shows the circuit working in the opposite direction. Figure 28 is a photo of the circuit built physically. A link to a video of the circuit in motion is given in Appendix D.

This concludes this report on Hydraulic and Pneumatic systems. Please see the following pages for the citations/ references list, bibliography section and appendices referenced throughout the report.



Qty	Component Name
1	Bidirectional Motor
1	Directional Valve
1	Electric Motor
1	Hydrostatic Reservoir
1	Relief Valve
1	Unidirectional Pump with Shaft
1	Variable Pressure Reducing Valve

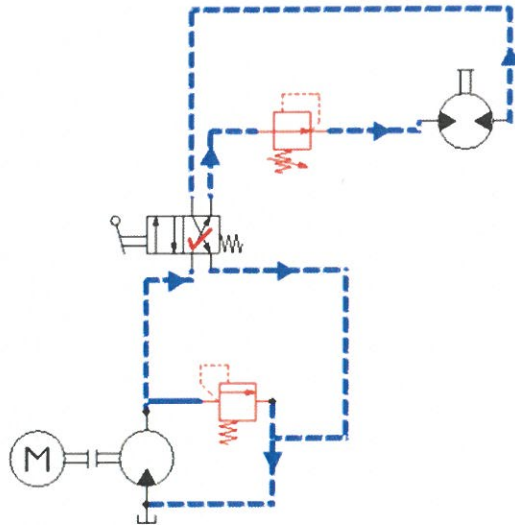


Figure 27, circuit simulation in anti-clockwise direction

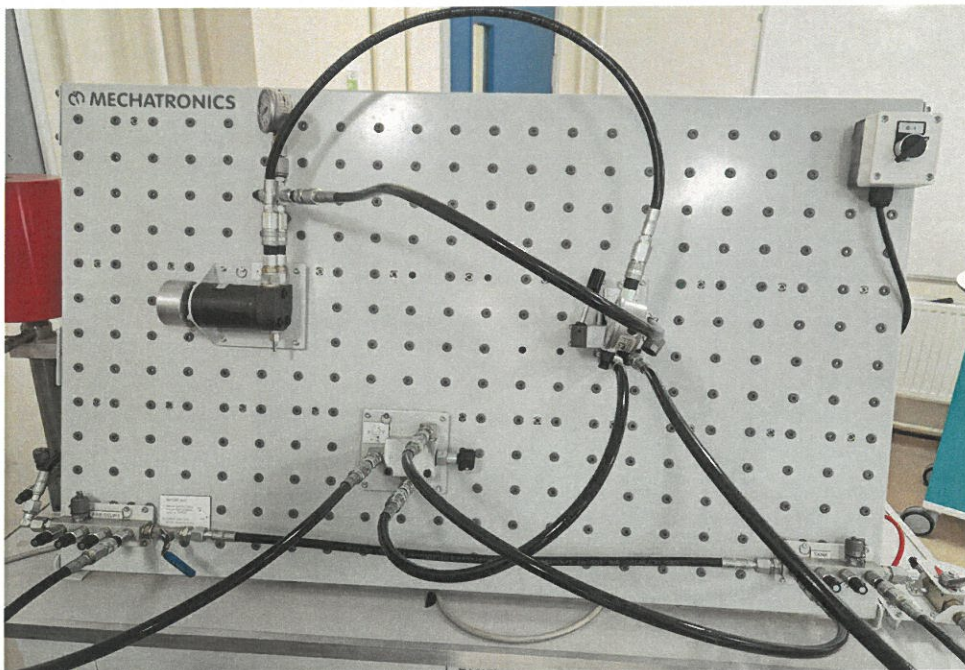


Figure 28, built hydraulic circuit

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Appendix A

Task 2 handwritten calculations.

Task 2 - Actuator calculations

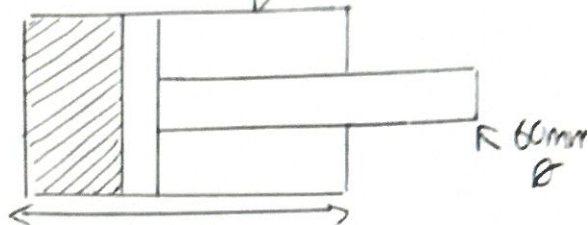
$D = 150 \text{ mm } \varnothing$

- a) System pressure needed.

PI $P = F/A$

$$P = \frac{50 \times 10^3}{\left(\frac{\pi \times 0.150^2}{4}\right)} = 2.829 \times 10^6 \text{ Pa} \quad S = 600 \text{ mm} \quad \rightarrow 50 \text{ kN}$$

Flow rate $Q = 22 \text{ dm}^3/\text{min}$



$P = 2.83 \text{ MPa}$

- b) Force with which it pulls, given the same pressure

$$F = P \times A = 2.83 \times 10^6 \times \left(\frac{\pi \times 0.150^2}{4}\right) - \left(\frac{\pi \times 0.06^2}{4}\right)$$

$$F = 42.01 \times 10^3$$

$F = 42.01 \text{ kN}$

- c) Time taken to extend fully $V = A \times L$

$$\text{Volume} = \frac{\pi \times 0.150^2}{4} \times 0.6 = 10.6 \times 10^{-3}$$

$$\frac{V}{Q} = \frac{10.6}{22} = 0.481 \text{ min} \times 60 = \underline{\underline{28.9 \text{ seconds}}}$$





d) The velocity on the outward stroke

$$C = \frac{S}{t} = \frac{0.6}{28.9} = \underline{\underline{0.021 \text{ m/s}}} \quad \underline{\underline{21 \text{ mm/s}}}$$

e) Time taken to retrace fully

$$V = \pi \times \left(\frac{0.150^2 - 0.06^2}{4} \right) \times 0.6 = 8.906 \times 10^{-3}$$

$$\frac{V}{Q} = \frac{8.906}{22} = 0.405 \times 60 = \underline{\underline{24.29 \text{ seconds}}}$$

f) The velocity on the inward stroke

$$C = \frac{0.6}{24.29} = \underline{\underline{0.025 \text{ m/s}}} \quad \underline{\underline{25 \text{ mm/s}}}$$

g) Power calculation on outward stroke

$$WD = F \times d = 50 \times 0.6 = \underline{\underline{30 \text{ kJ}}}$$

$$\text{Power} = \frac{WD}{\text{time}} = \frac{30 \times 10^3}{28.9} = \underline{\underline{1038 \text{ watts}}}$$

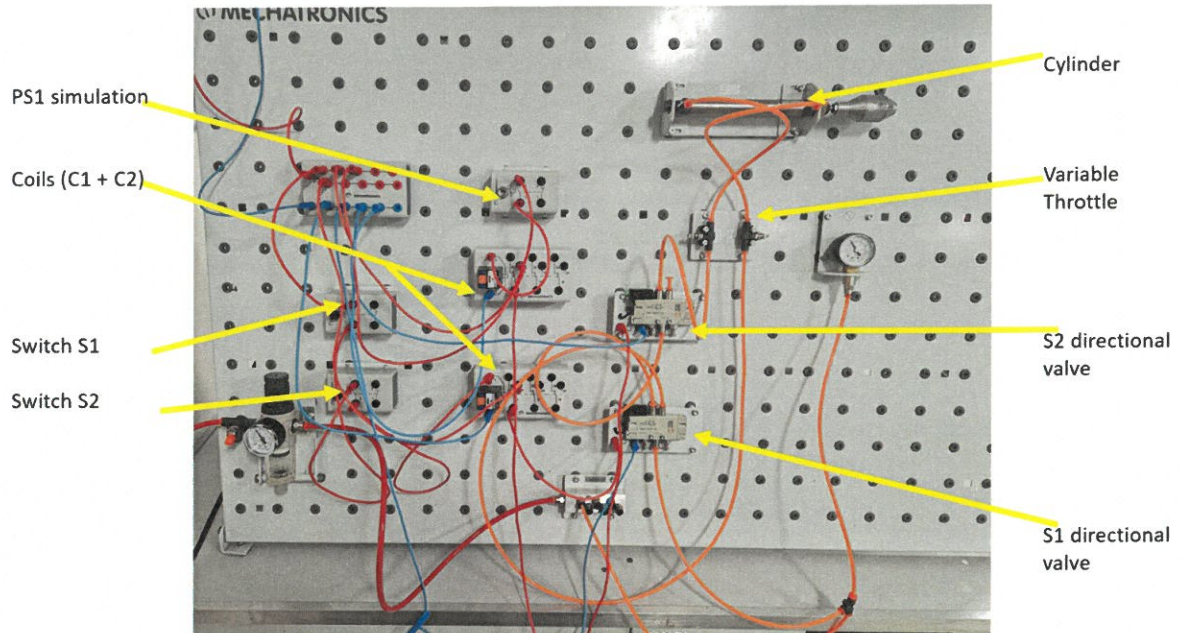


Appendix B

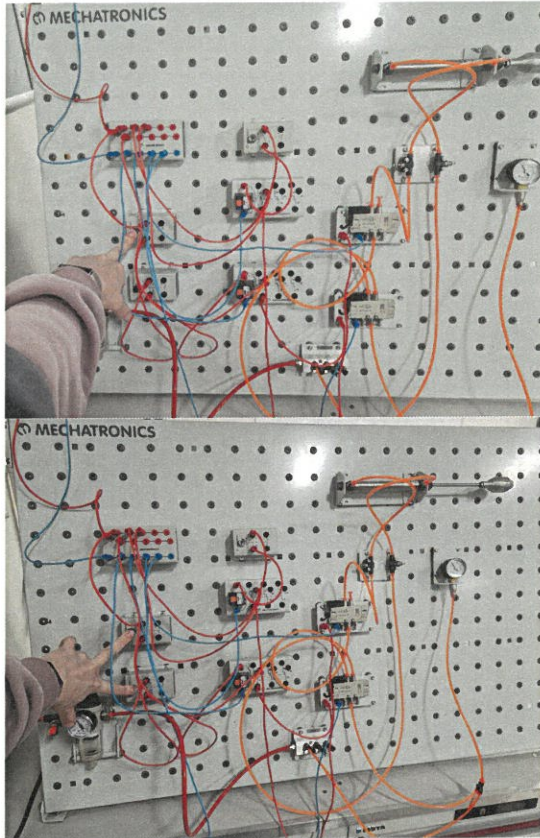
Video link to pneumatic circuit running/ in use for task 3.

[20240502_165756.mp4](#) — Video link works fine.

Circuit photographs for task 3, circuit analysis.

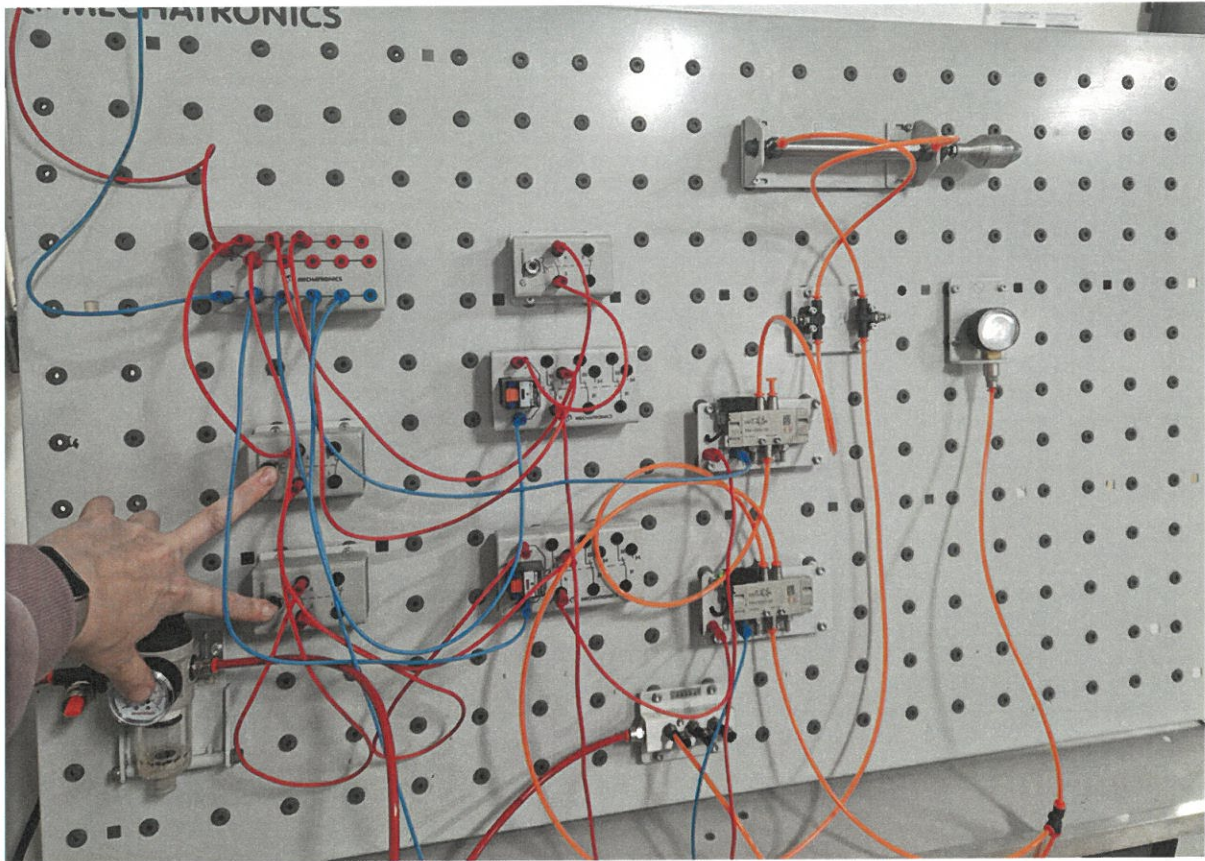


Circuit built in practice; components labelled. Some aspects, such as the pressure switch, had to be simulated using an electrical toggle switch. ✓

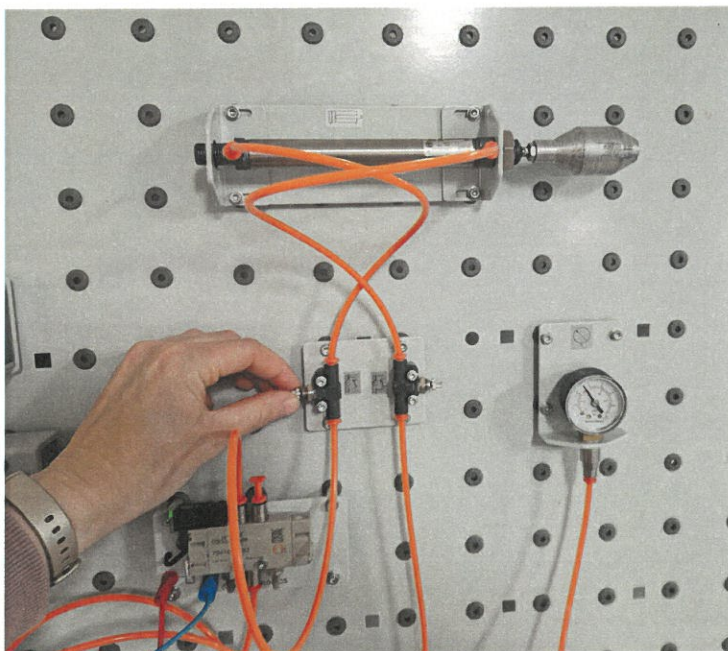


One switch alone will not activate the cylinder, both have to be pressed.





If the pressure switch PS1 senses a low pressure in the system, it will not operate, even when the two switches S1 and S2 are activated. ✓



The speed of the inward and outward stroke of the cylinder was adjustable on the variable throttles. ✓



Appendix C

Video link to pneumatic circuit running/ in use.

[20240411_174801.mp4](#)



Appendix D

Video link to hydraulic circuit running/ in use.

[20240418_163721.mp4](#)





STUDENT FEEDBACK FORM

This section details the *extent* to which the assessment criteria are demonstrated by you, which in turn determines your mark. The marks available for each category of skill are shown. Lecturers will use the space provided to comment on the achievement of the task(s), including those areas in which you have performed well and areas that would benefit from development/improvement.

Generic Assessment Criteria	Marks available	Marks awarded
1. Engagement with Literature Skills	20	
2. Knowledge and Understanding Skills	50	
3. Cognitive and Intellectual Skills	0	
4. Practical Application Skills	20	
5. Transferable Skills for Life and Professional Practice	10	



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Assessment Mark (Assessment marks are subject to ratification at the Exam Board. These comments and marks are to give feedback on module work and are for guidance only until they are confirmed.)	Late Submission Penalties (tick if appropriate)		%
	Up to 1 week late (40% Max)		
	Over 1 week late (0%)		