



The University of Jordan  
School of Engineering  
Mechatronics Engineering Department

Fluid Power Engineering Lab 0908464

09

**The University of Jordan**  
**School of Engineering**  
**Mechatronics Engineering Department**  
**Fluid Power Engineering lab**  
**Modified & Revised By: Eng. Rasha Noufal / 2018**

## EXPERIMENTS

Experiments No.	Experiments Name	Page No.
Experiment No. 1	Introduction to FluidSIM Program	3
Experiment No. 2	Pneumatic Control of a Double-acting Cylinder	15
Experiment No. 3	Electro pneumatics Control Technology	25
Experiment No. 4	Introduction to Hydraulic Trainer	35
Experiment No. 5	Sequential control of a 2 double acting cylinder	51
Experiment No. 6	Electro pneumatics Sequential control of a 2 double acting cylinder	62
Experiment No. 7	Regenerative Circuits	70
Experiment No. 8	Pneumatic sequential control of a 3 double acting cylinder	83
Experiment No. 9	Electro pneumatic sequential control of a 3 double acting cylinder	88
Experiment No. 10	Hydraulic Motor Circuit	96

**The University Of Jordan**  
**School of Engineering**  
**Mechatronics Engineering Department**  
**Fluid Power Engineering Lab**  
**Experiments No.1/ Part One**  
**Introduction to FluidSIM**

**Objective:** Students develop a hydraulic and pneumatic circuit in FluidSIM.  
 The student should be able to build the circuit using FluidSIM and try different loads in order to realize its effect on the system performance.

**Part one - A : Control of a Double Acting Cylinder**

To understand how a double acting cylinder can be controlled using a four-way directional valve.

**1- Flow rate:**

is the volume of fluid passing a point in a given period of time.

Metric units:                      Flow rate  $(l/min) = \frac{\text{Velocity (cm/min)} \times \text{Area (cm}^2\text{)}}{1000}$

English units:                      Flow rate  $(gal(us)/min) = \frac{\text{Velocity (in/min)} \times \text{Area (in}^2\text{)}}{231}$

**2- Velocity:**

is the average speed of a particle of fluid past a given point.

**3- Flow rate and rod speed:**

The speed at which a cylinder rod moves is determined by how fast the pump can fill the volume behind the cylinder piston.

The speed of cylinder rod (V) is calculated by dividing the oil flow rate (Q) by the piston area (A) being acted upon.

$$\text{Rod speed (V)} = \frac{\text{Flow rate (Q)}}{\text{Piston area (A)}}$$

Piston area (A)

**Extension speed**

Metric units:

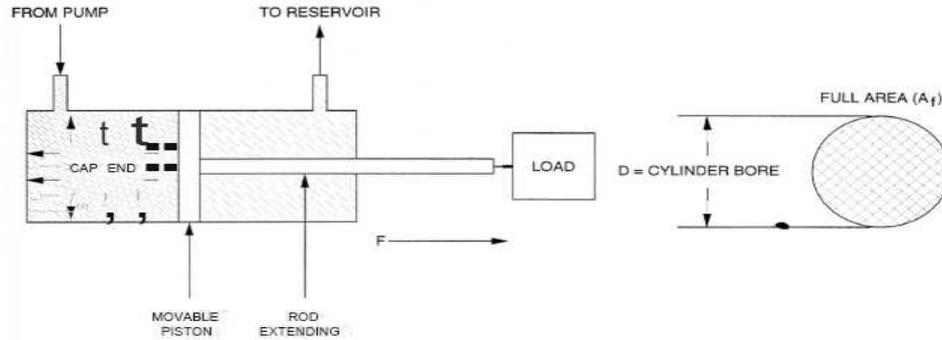
$A_f (cm^2) \times 60$

$$V (cm/s) = \frac{Q (l/min) \times 1000}{A_f}$$

English units:

$A_f (in^2) \times 60$

$$V (in/s) = \frac{Q (gal (US) /min) \times 231}{A_f}$$



$$A_f = \pi \times r^2 = \pi \times D^2/4$$

**Retraction speed**

Metric units:

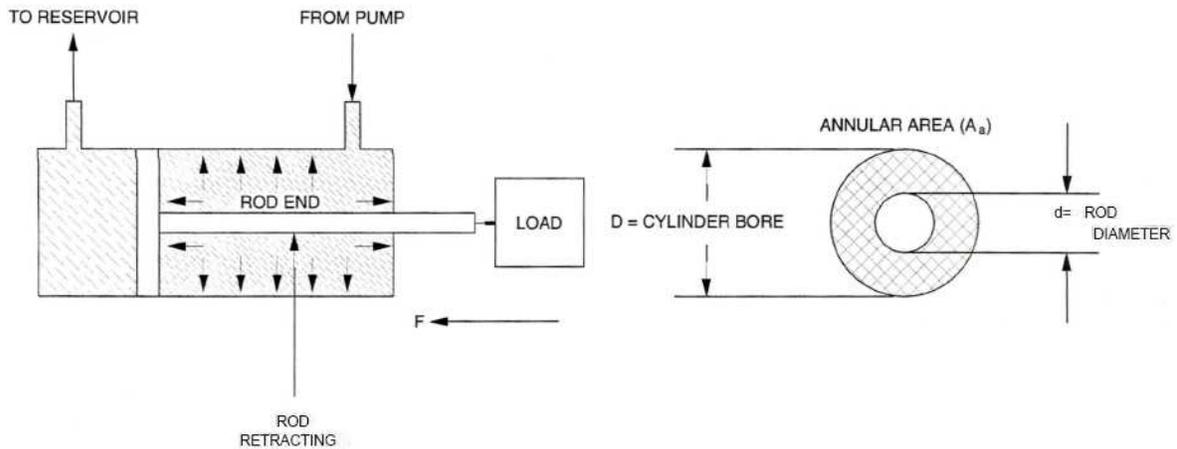
$A_a (cm^2) \times 60$

$$V (cm/s) = \frac{Q (l/min) \times 1000}{A_a}$$

English units:

$A_a (in^2) \times 60$

$$V (in/s) = \frac{Q (gal (US) /min) \times 231}{A_a}$$



$$A_a = (\pi \times D^2/4) - (\pi \times d^2/4)$$

$$= (D^2 - d^2) \times \pi / 4$$

**4- Pascal's Law:**

Pascal's Law states that pressure applied on a confined fluid is transmitted undiminished in all direction, and acts with equal force on equal areas, and at right angles to them.

The generated pressure is equal to the force applied to the top of the stopper divided by the area of the stopper.

Metric units:                      Pressure (kPa) =  $\frac{\text{Force (N)} \times 10}{\text{Area (cm}^2\text{)}}$

English units:                      Pressure (Psi) =  $\frac{\text{Force (lb)}}{\text{Area (in}^2\text{)}}$

### Part one - B: Build the circuit using FluidSIM

After you have been introduced to the variant blocks of the FluidSIM, You are now ready to build Schematic diagram in Fig.

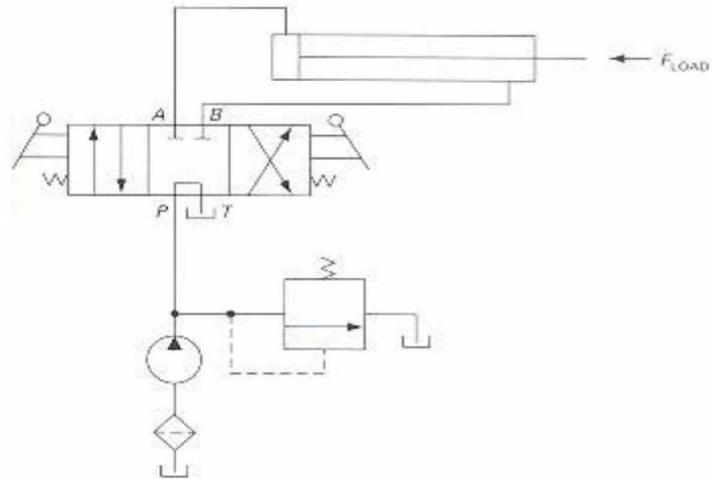


Fig.1 Double Acting Cylinder Control Circuit

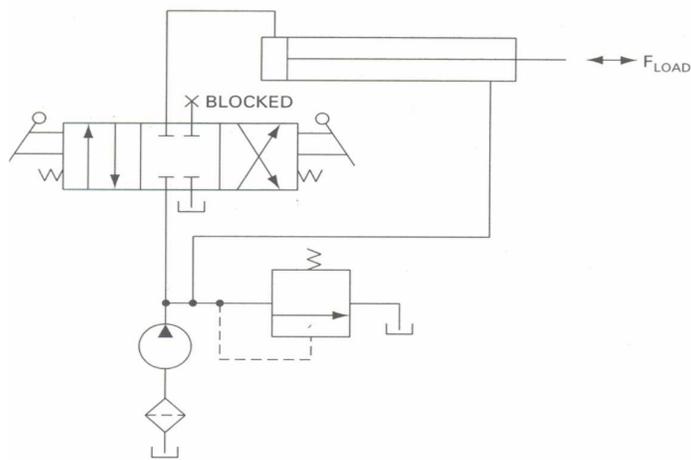


Fig.2 Regenerative Circuit

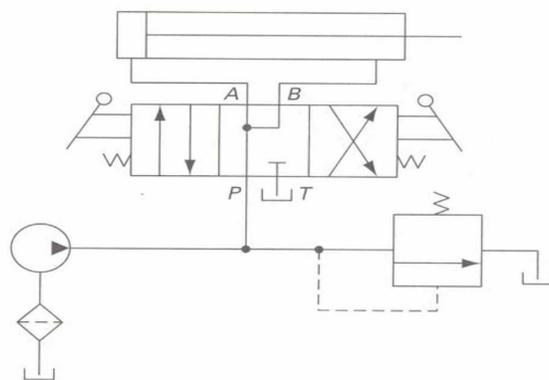


Fig.3 Regenerative Circuit

NOTE: The components settings and dimensions are as following:

Relief valve setting at 1500 psi

piston area = 20 in<sup>2</sup>

rod area = 10 in<sup>2</sup>

stroke length = 50 in

pump flow = 25 gpm

pump speed = 1200 rpm.

**The University Of Jordan  
School of Engineering  
Mechatronics Engineering Department  
Fluid Power Engineering Lab  
Experiments No.1/ Part One  
Introduction to FluidSIM**

**In class Lab Report**

Date: \_\_\_\_\_

Section: \_\_\_\_\_

Group's Names:

1-

2-

3-

4-

**Part three: Procedure**

Q1: Brief description of how the above circuits work.

Q2: Calculate the extracting and retracting cylinder speeds in both cases (normal and regenerative)? Comment on the results.

Q3: Calculate the maximum load that can be attached to the cylinder in both cases? Comment on the results.

Q4: What is the purpose of a regenerative circuit? (Use equations to explain that).

**The University Of Jordan**  
**School of Engineering**  
**Mechatronics Engineering Department**  
**Fluid Power Engineering Lab**  
**Experiments No.1**  
**Introduction to FluidSIM/ Part Two**

**Objective:** Students Develop, connection and operation of simple, practical hydraulic and pneumatic circuit in FluidSIM.  
 The student should be able to describe the operation of a directional control valve.

### Introduction

Hydraulic and pneumatic systems perform a variety of tasks, ranging from very simple to the very complex. Controlling cylinder is one of the most important aspects of hydraulics and pneumatics. For example, two cylinders may be required to operate at the same speed, or a cylinder may need to extend rapidly under no load conditions. FluidSIM is a design, animation and simulation software tool. It was created for the automation industry, specifically to fulfill engineering, training, and testing requirements.

### Part two – A : Hydraulic Cylinder Sequence Circuit

To understand the sequence circuit and to know how build such circuit using FluidSIM.

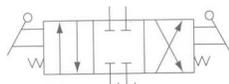
**Operation of a basic hydraulic circuit:**

A hydraulic circuit is a path for Oil to flow through hoses and components.

1- The **reservoir** holds the oil 

2- The **pump** (pushes) the oil, attempting to make it flow through the circuit. 

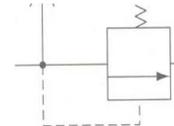
3- The **directional control valve** allows the operator to manually control the oil flow to the cylinder.



4- The **cylinder** converts fluid energy into linear mechanical power.



5- The **relief valve** limits system pressure to a safe level by allowing oil to flow directly from pump back to the reservoir when pressure at the pump output reaches a certain level.



After you

**Build the circuit using FluidSIM:**

have been introduced to the variant components of the hydraulic system, you are now ready to build Schematic diagram in Fig. using FluidSIM.

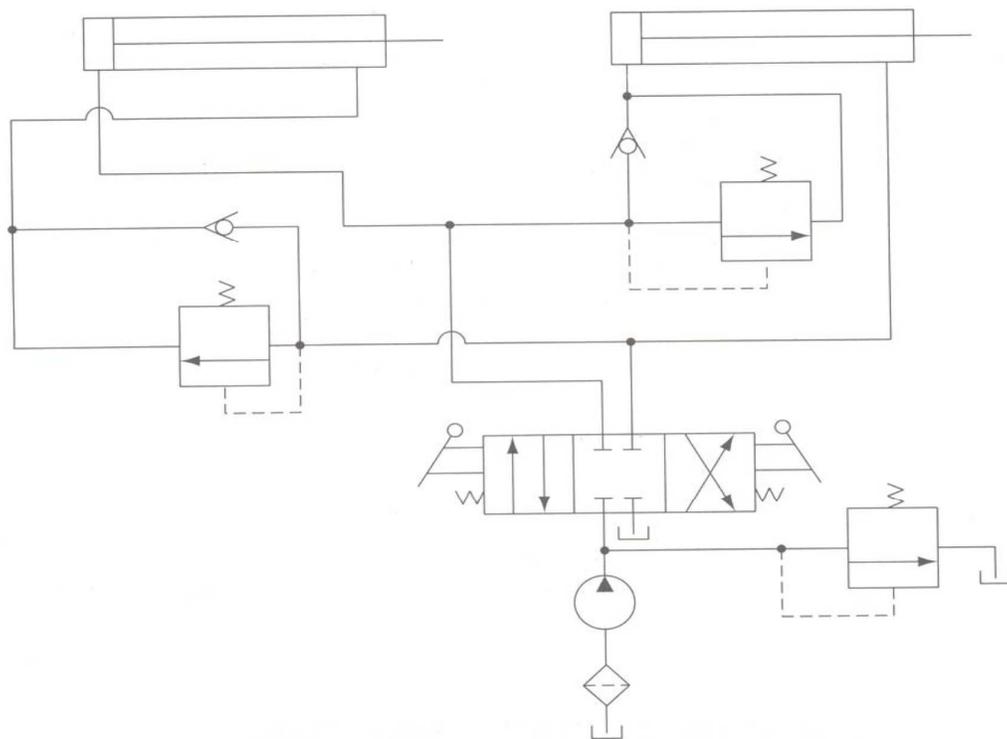


Fig.1 Hydraulic Sequence Circuit

NOTE: The components settings and dimensions are as following:

Relief valve setting at 1500 psi

For both cylinder:

piston area = 20 in<sup>2</sup>

rod area = 10 in<sup>2</sup>

stroke length = 50 in

pump flow = 25 gpm

pump speed = 1200 rpm.

**Part two – B: Parallel and Series cylinder Circuits**

To show how two identical cylinders can be synchronized by piping them in parallel and series. Moreover, this lab is aimed at providing the students with ideas on how to change the cylinders specifications in order to synchronize the motion of two cylinders connected in series.

**Build the circuit using FluidSIM:**

After you have been introduced to the variant components of the hydraulic system, you are now ready to build Schematic diagram in Fig. using FluidSIM.

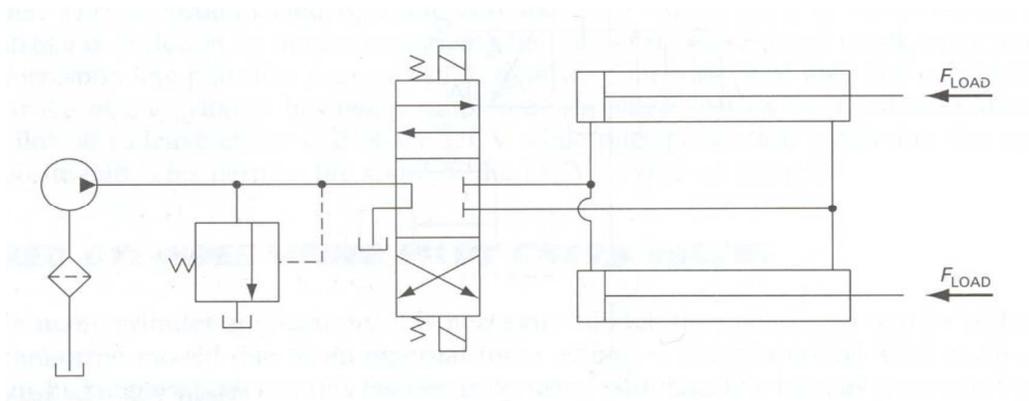


Fig.2 Parallel Cylinder Circuit

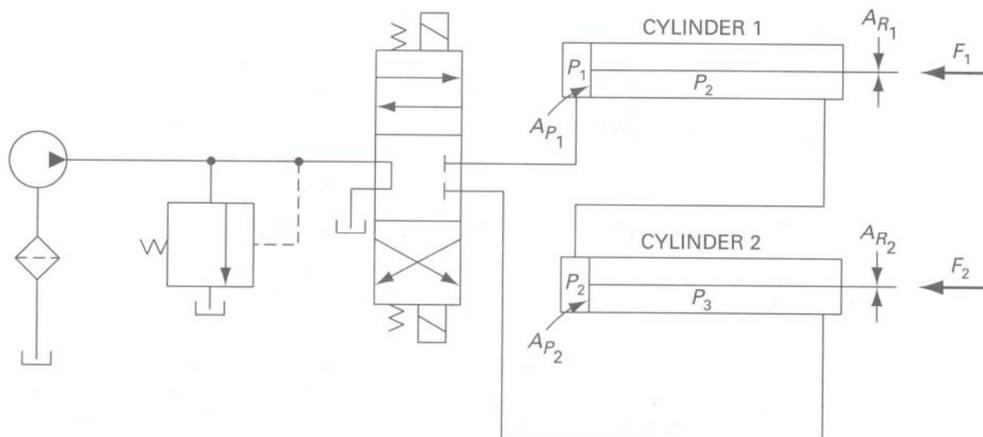


Fig.3 Series Cylinder Circuit

## Part two – C : Meter-in vs. Meter-out Flow Control Valve System

Flow Control Valves (FCVs) are used in industry for cylinder speed control. Therefore, the aim of this experiment is to illustrate the circuit for meter-in and meter-out speed control as well as the difference between them.

A **flow control valve** as an adjustable resistance to flow that operates very much like a faucet. By adjusting the resistance, or opening, of this valve, you can modify the rate of oil flow to a cylinder and, therefore, the speed of its piston rod.

### Flow control circuits:

There are two ways to meter the oil flow in order to control the speed of a cylinder, which are: **meter-in** and **meter-out**.

With the **meter-in** method, the flow control valve is connected in series between the pump and the cylinder, as figure 4 shows. It restricts the working oil flow to the cylinder. The extra flow delivered by the pump is drained back to the reservoir through the relief valve.

With the **meter-out** method, the flow control valve is connected in series between the cylinder and the reservoir, as figure 5 shows. It restricts the flow away from the cylinder. The extra flow delivered by the pump is drained back to the reservoir through the relief valve.

### Build the circuit using FluidSIM:

After you have been introduced to the variant components of the hydraulic system, you are now ready to build Schematic diagram in Fig. using FluidSIM.

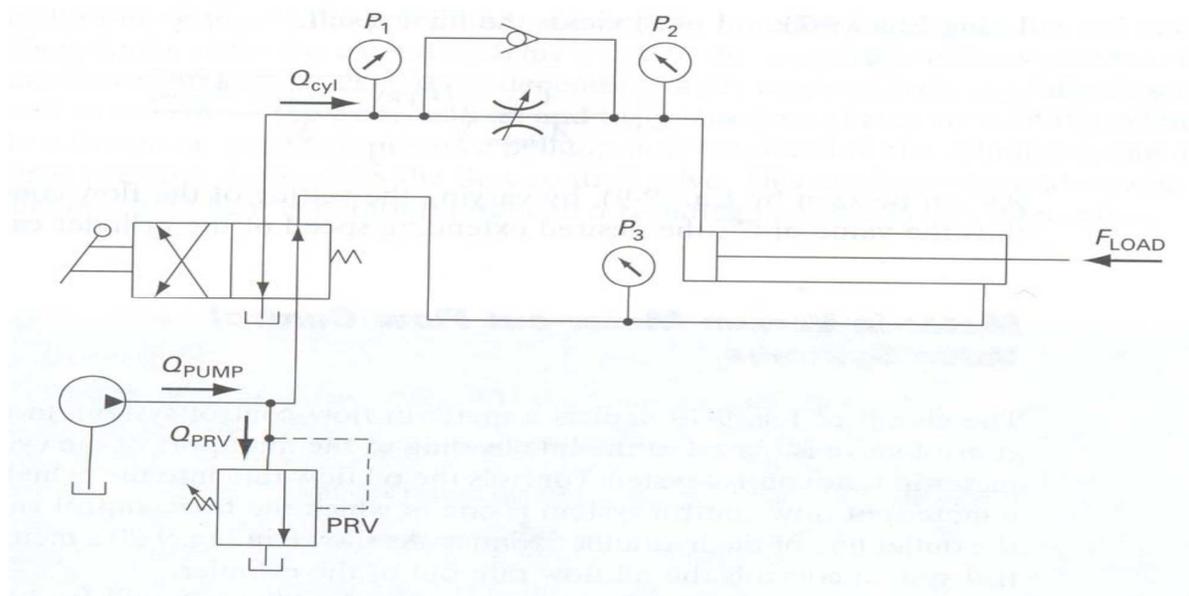


Fig.3 Meter-in speed control of hydraulic cylinder during extending stroke

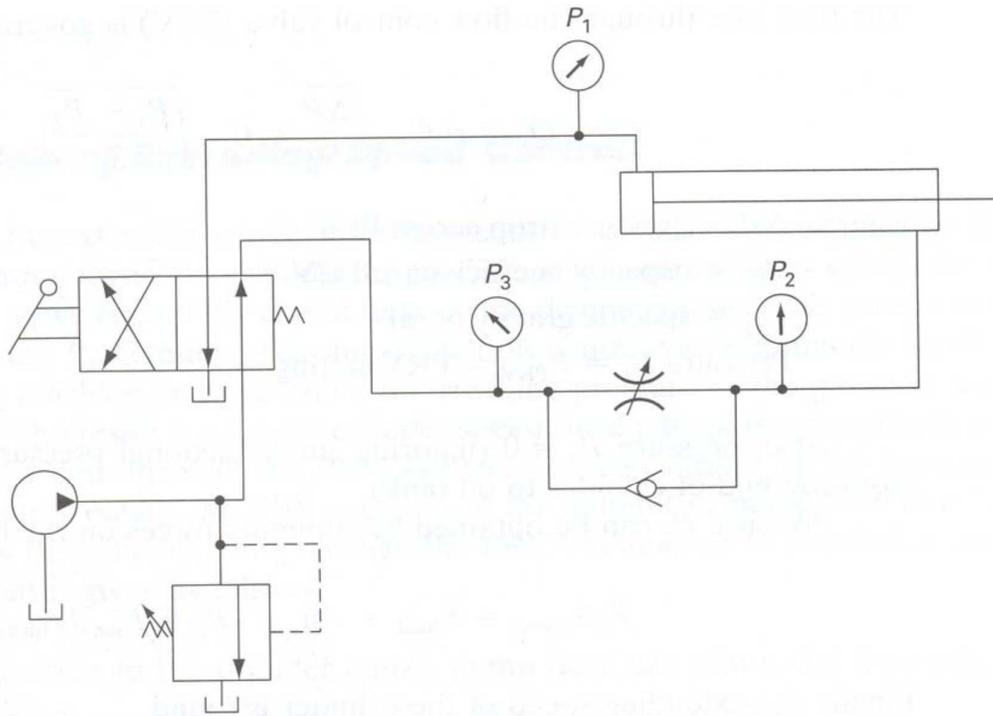


Fig.4 Meter-out speed control of hydraulic cylinder during extending stroke

NOTE: The components settings and dimensions are as following:

Relief valve setting at 2000 psi

piston diameter = 6 in

rode diameter = 2 in

stroke length = 50 in

pump displacement = 0.026 g/rev

pump speed = 1800 rpm

FCV diameter = 0.09 in .

**The University Of Jordan  
School of Engineering  
Mechatronics Engineering Department  
Fluid Power Engineering Lab  
Experiments No.1/ Part Two  
Introduction to FluidSIM**

**In class Lab Report**

Date: \_\_\_\_\_

Section: \_\_\_\_\_

Group's Names:

- 1-
- 2-
- 3-
- 4-
- 5-

**Part one: Hydraulic Cylinder Sequence Circuit**

Q1: Brief description of how the circuits Fig.1 work.

Q2: Calculate the maximum load that can be attached to the cylinder? Comment on the results.

## Part two: Parallel and Series cylinder Circuits

Q1: Brief description of how the above circuits work.

Q2: For the series cylinder circuit, what pump pressure is required if the cylinder loads are 5000 lb each and cylinder 1 has a piston area of 10 in<sup>2</sup>?

## Part three: Meter-in vs. Meter-out Flow Control Valve System

Q1: What are the stroke speeds in both cases at 10%,50%,80% and 100% FCV opening?

Q2: Design a meter-in and meter-out control circuit of hydraulic cylinder during retracting stroke.

The following data are given:

Desired speed = 10 in/s.

Cylinder piston diameter = 2 in.

Cylinder load: 4000 lb.

PRV setting= 1000 psi.

**The University Of Jordan**  
**School of Engineering**  
**Mechatronics Engineering Department**  
**Fluid Power Engineering Lab**  
**Experiments No.2**  
**Pneumatic Control of a Double-acting Cylinder**

**Objective:** Students will be able to control of double-acting cylinder, and knowing various types of speed regulation of the piston rod movement of double-acting cylinder.

### Introduction

Pneumatics system performs a variety of tasks, ranging from the very simple to the very complex. Controlling cylinders is one of the most important aspects of pneumatics. For example, two cylinders may be required to operate at the same speed, or a cylinder may need to extend rapidly under no load conditions.

### Pre-Lab

⇒ **Pre-Lab:** the required pneumatic circuit diagrams using the FluidSIM; show the whole connections and components required for each circuit.

⇒ **In the lab:** Connect the circuits and verify their operation. sure that the pressure is 4 bars and is connected correctly. Double check your connections before switching the compressor on.

### Part one: Control of a double-acting cylinder

#### **Direct control of a double-acting cylinder with push-button.**

**Aim:**

This exercise provides direct control of double-acting cylinders with manually operated 5/2 directional control valves. In addition, the effect of adjustable spring cushioning in double-acting cylinders can be observed.

**Task:**

- The piston rod of a double-working cylinder (Z1) should extend after actuating a button.
- After releasing the button (S1), the piston of the cylinder should retract automatically to its back position.

**List of equipment:**

Description:

- (01) Air service unit (filter with water separator, pressure regulator and pressure gauge) with 3/2 directional control ball valve
- (02) Distributor, 6-fold
- (04) Double-acting cylinder with adjustable spring cushioning
- (08) 5/2 directional control valve with push-button Accessories

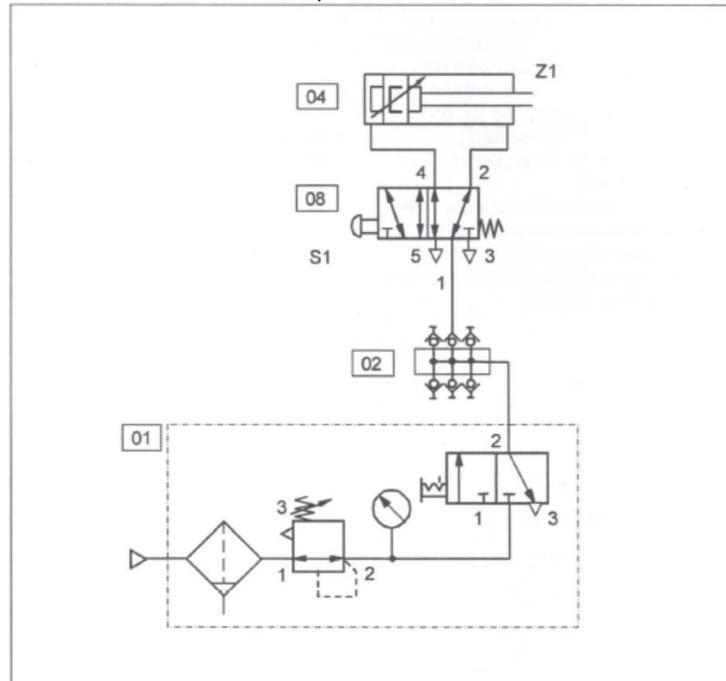


Figure 2.1: Direct control of a double-acting cylinder

**Conclusion:**

- The double-acting cylinder can be directly controlled by a \_\_\_\_\_.
- In the basic setting (spring position) of a directional valve, port 1 supplied with compressed air, port 2 is always \_\_\_\_\_ and port 4 always \_\_\_\_\_.

## Part two: Speed regulation of a double-acting cylinder

### Aim:

In this exercise, the various types of speed regulation (throttling) of the piston rod movements of double-acting cylinders with one-way flow control valves are looked at and the effects are observed.

### Task:

- The cylinder is controlled with a manually operated button (actuator S1). After releasing the button (S1), the piston of the cylinder should retract automatically to its back position.

### List of equipment:

Description:

- **(04)** Double-acting cylinder with adjustable spring cushioning
- **(08)** 5/2 directional control valve with push-button Accessories
- **(15)** Flow control valves with non-return, adjustable

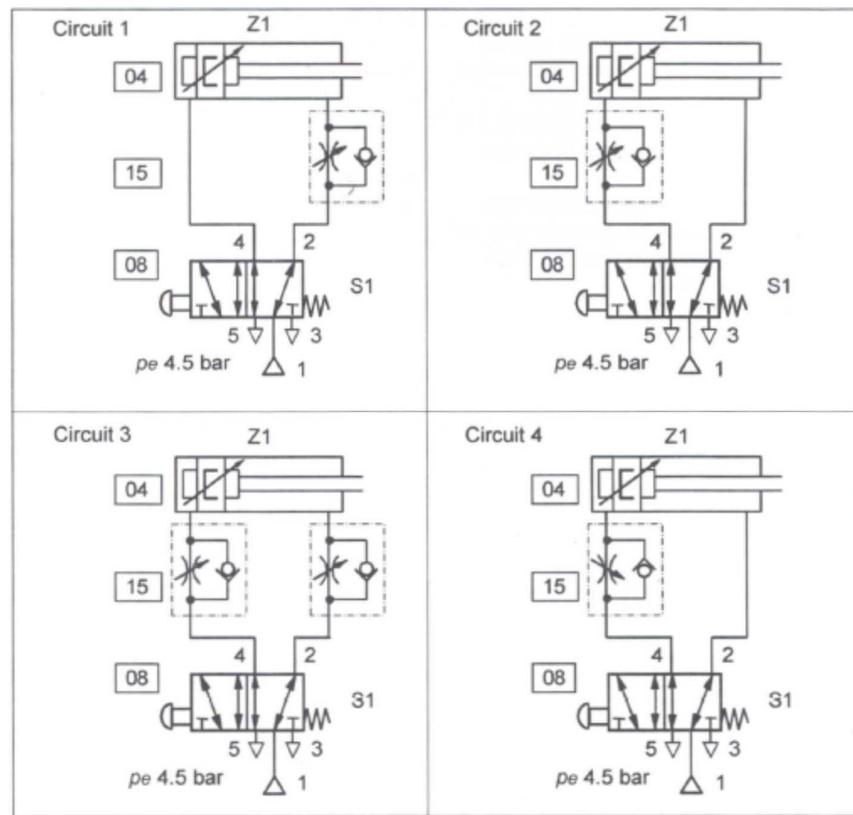


Figure 2.2: Speed regulation of a double-acting cylinder

### Conclusion:

Referring to figure 2, which circuit demonstrates the following?

- a. In Circuit ( ): The speed of the cylinder piston is restricted when extending.
- b. In Circuit ( ): The speed of the cylinder piston is restricted when retracting.
- c. In Circuit ( ): Both speed of the cylinder piston are restricted.

## Part three: Controlling a double-acting cylinder with impulse valve

### Aim:

In this exercise we examine how a pneumatically operated impulse valve functions when controlling a double acting cylinder.

Upon the completion of this task, the student will be

- Familiar with indirect actuation of a double acting cylinder by using a double pilot valve.
- Using the 3/2 way roller valve for automatic return of the cylinder.

### Task description:

Wooden planks are to be pushed along from a gravity feed magazine to a clamping device as shown in Fig.3 By pressing a pushbutton valve one plank is pushed by the slide out of the gravity feed magazine. After the slide has reached the forward end position it returns to its start position.

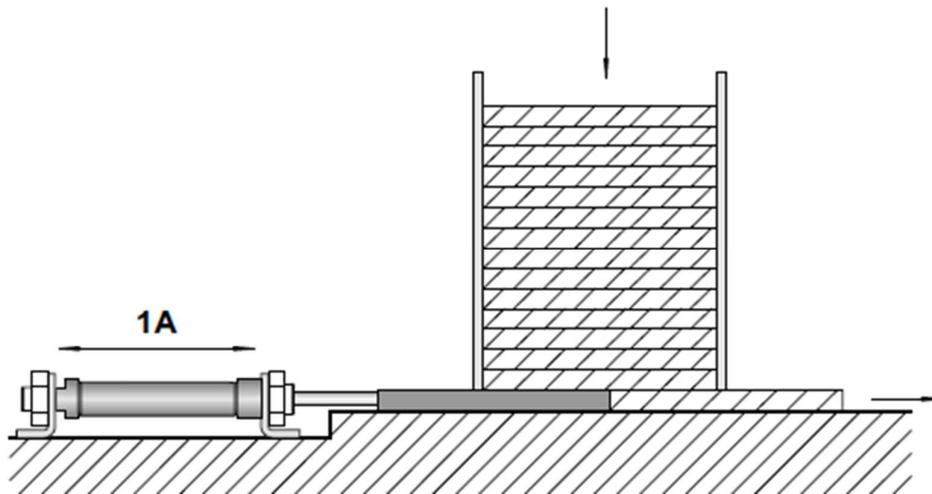


Fig. 2.3: Positional sketch

### List of equipment:

Description:

- **(04)** Double-acting cylinder with adjustable spring cushioning
- **(11)** 5/2 directional control valve, impulse valve
- **(15)** Flow control valves with non-return, adjustable
- **(06)** 3/2 directional control valve, with manually operated push-button
- **(07)** 3/2 way roller valve for automatic return of the cylinder.

### Task requirements:

1. Draw pneumatic circuit diagram to control the movement of the slide.
2. Simulate the circuit using Fluid SIM software.
3. Assemble the circuit practically and check its operation.



## Part Four: Displacement dependent control of a double-acting cylinder

### Aim:

The displacement-dependent control of a double-acting cylinder by using limit switches in demonstrated in this exercise.

Upon the completion of this task, the student will be

- Familiar with indirect actuation of a double acting cylinder by using a double pilot valve.
- Familiar with using different types of directional control valves

### Task description:

Using a diverting device, parts are to be moved from one conveyor track onto the other in a linear sequence as illustrated in Fig. 2.5. By operating a selector valve the oscillating piston rod of a cylinder pushes the turntable via a pawl in stepped sequence. The parts are diverted and transported onwards in the opposite direction. By returning the selector valve back to the normal position the drive unit is switched off.

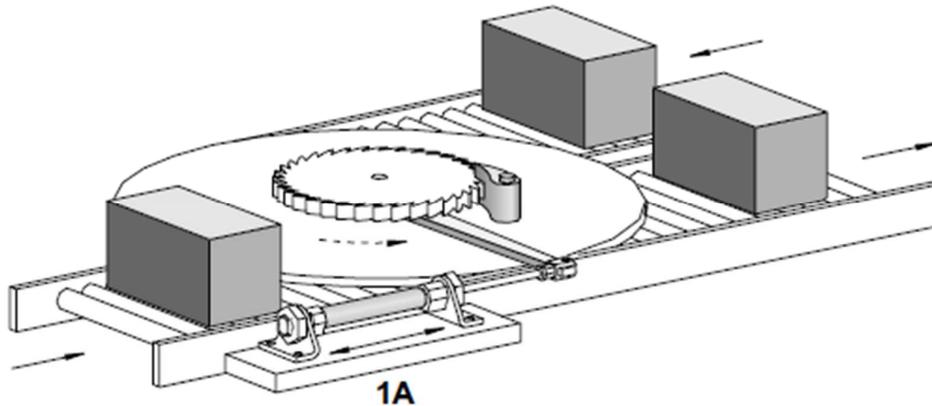


Fig. 2.5: Positional sketch

### Task requirements:

1. Draw a pneumatic circuit diagram to control the operation of the piston.
2. Simulate the circuit using FluidSIM software.
3. Assemble the circuit practically and check its operation.

### List of equipment:

Description:

- (13) 3/2 directional control valves, with roller
- (04) Double-acting cylinder with adjustable spring cushioning
- (11) 5/2 directional control valve, impulse valve
- (15) Flow control valves with non-return, adjustable
- (06) 3/2 directional control valve, with manually operated push-button
- (13) 3/2 way roller valve for automatic return of the cylinder.

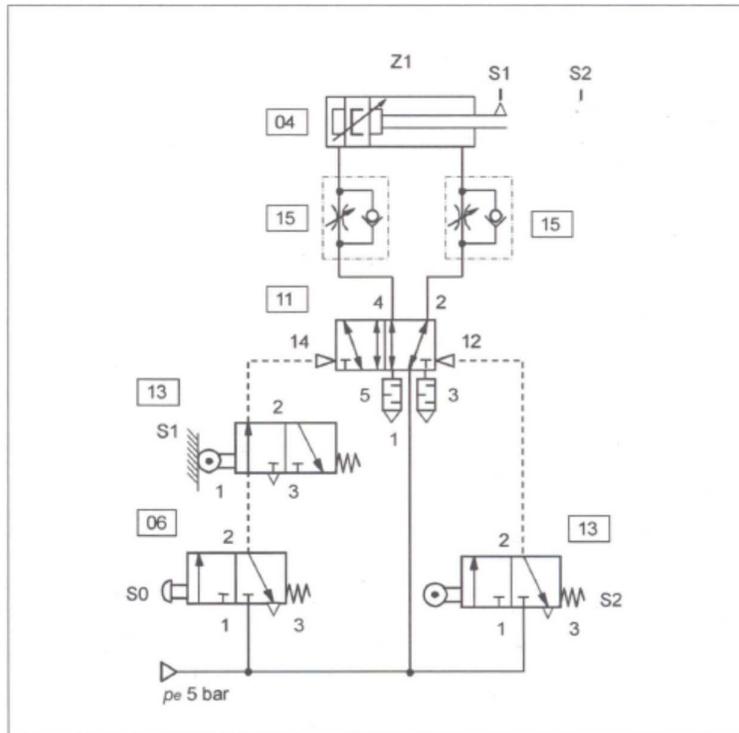
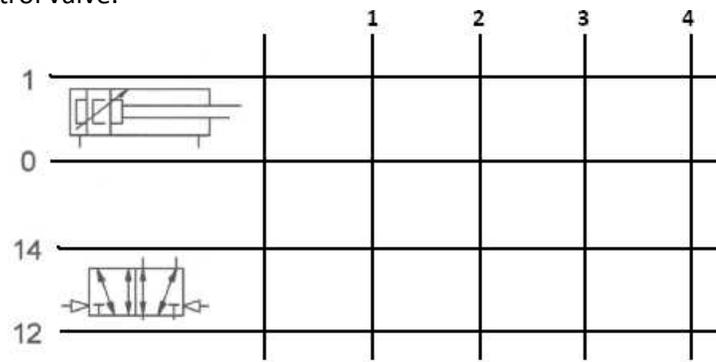


Figure 2.4 : Displacement dependent control of a double-acting cylinder

**Conclusion:**

- Design the functional diagram (stroke-time diagram) for the cylinder and the 5/2 directional control valve.



- What are used for a displacement dependent control of a double-acting cylinder?

## Part Five: Pressure-dependent control of a double acting cylinder

### Aim:

By using a 3/2 directional control valve with adjustable minimum pressure of response, a pressure dependent control (and in addition displacement dependent) control of a double acting cylinder is put into effect.

Upon the completion of this task, the student will be

- Familiar with indirect actuation of a double acting cylinder with a double pilot valve.
- Able to use and adjust the pressure sequence valve.

### Task description:

A plastic component is embossed using a die driven by a double-acting cylinder. The die is to advance and emboss the plastic when a push button is operated. The return of the die is to be effected when a preset pressure is reached. The embossing pressure is to be adjustable.

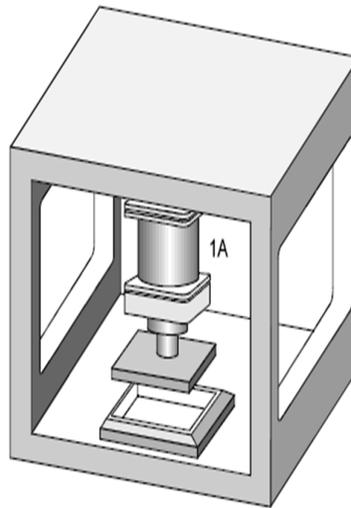


Fig. 2.5 Positional sketch

### Task requirements:

1. Draw pneumatic circuit diagram
2. Simulate the circuit using Fluid SIM software.
3. Assemble the circuit practically and check its operation

### List of equipment:

Description:

- (21) Pressure gauge
- (22) 3/2 directional control valve, with adjustable operating pressure
- (13) 3/2 directional control valves, with roller
- (04) Double-acting cylinder with adjustable spring cushioning
- (11) 5/2 directional control valve, impulse valve
- (15) Flow control valves with non-return, adjustable
- (06) 3/2 directional control valve, with manually operated push-button
- (13) 3/2 way roller valve for automatic return of the cylinder.
-

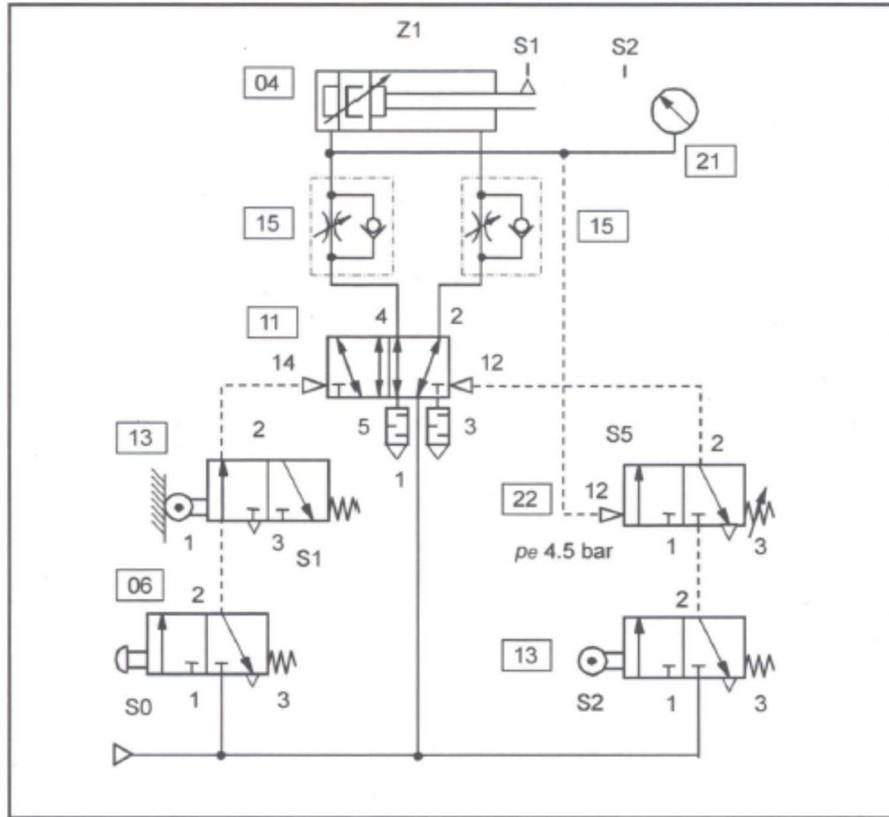


Figure 2.6 : Pressure dependent control of a double-acting cylinder

**Conclusion:**

- Mention the conditions to extend the piston of the cylinder.

---

- Mention the conditions to retract the piston of the cylinder.

---

- Design the functional diagram (stroke-time diagram) for the cylinder and the 5/2 directional control valve.

	1	2	3	4
1 				
0				
14 				
12				



**The University Of Jordan**  
**School of Engineering**  
**Mechatronics Engineering Department**  
**Fluid Power Engineering Lab**  
**Experiments No.3**  
**Electro pneumatics Control Technology**

**Objective:** This exercises conveys basic knowledge and skills on setting up and commissioning an electro pneumatic control using the example of a direct electric activation of a single acting cylinder.

**Pre-Lab**

- ⇒ **Pre-Lab:** the required pneumatic circuit diagrams using the FluidSIM SW; show the whole connections and components required for each circuit.
- ⇒ **In the lab:** Build your designs and verify their operation. sure that the pressure is 4 bars and is connected correctly. Double check your connections before switching the compressor on.

**Part I: Command-variable control of a double acting cylinder**

**Aim:**

This exercise demonstrates the control of a double-acting cylinder with an electrically controlled, spring return 5/2 directional control valve without the use of a relay.

**Title: Diverting machine**

**Problem description:**

The parts used in the diverting machine are to be moved from one conveyor track to another conveyor track. By pressing a pushbutton switch the frame of the diverting machine is pushed forward. The part is moved over and transported onwards in the opposite direction. By pressing another pushbutton switch the frame is returned to its start position as shown below in Fig 3.1

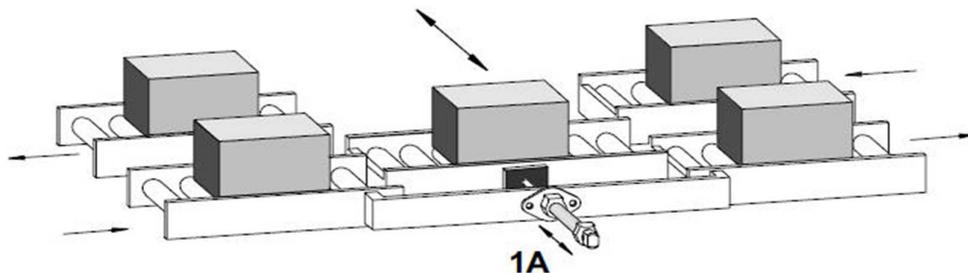


Fig 3.1 Positional sketch of the diverting machine

**List of equipment:**

Description:

- (04) Double-acting cylinder, with annular solenoid
- (32) 5/2 directional control impulse valve, electrically controlled
- (37) Unit, 1 control switch, 2 push buttons
- (50) Power supply unit
- (42) Unit, electric manifold
- (01) Pneumatic air service unit
- (02) Compressed air distributor

**Procedures:**

1. Draw the elector-pneumatic circuit using the FluidSim software
2. Test the circuit functions against any errors or mistakes.
3. Construct the circuit on the workstation
4. Write down your notes and observations.

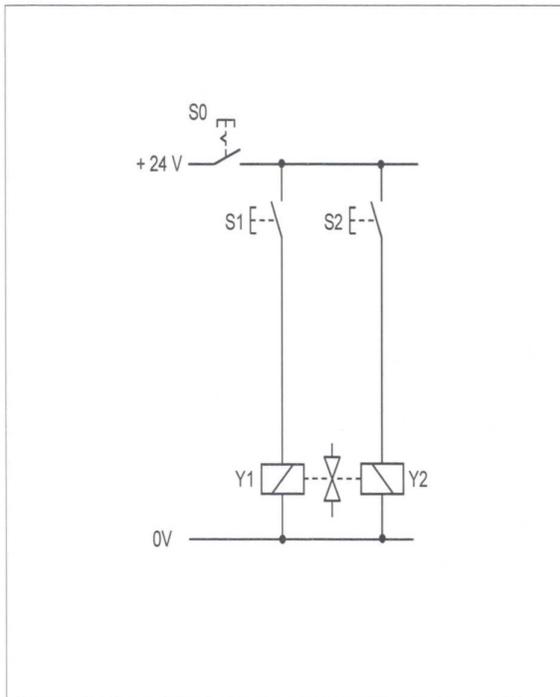


Figure 3.2: Electric circuit diagram

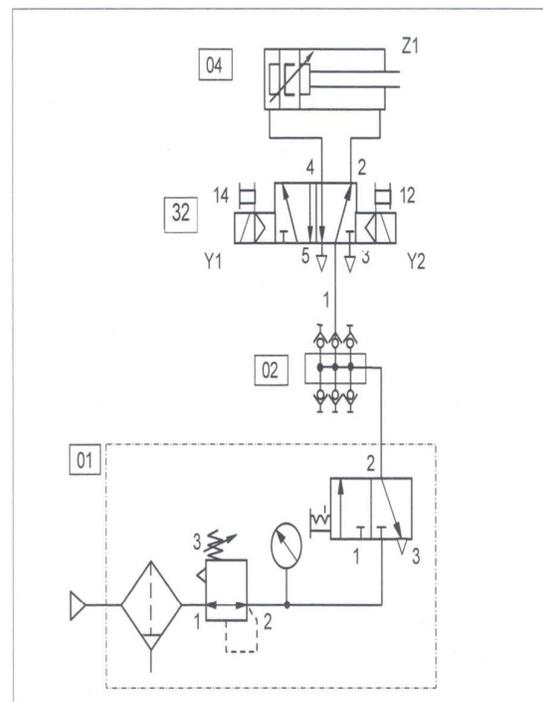


Figure 3.3: Pneumatic circuit diagram

**Conclusion:**

- The double-acting cylinder can be directly controlled by a \_\_\_\_\_.
- In the basic setting (spring position) of a directional valve, port 1 supplied with \_\_\_\_\_, port 2 is always \_\_\_\_\_, port 4 always \_\_\_\_\_ and port 5 and 3 are always \_\_\_\_\_.

- Start the system by pressing S1 momentarily assuming that the switch S0 is on , step what the system do:

---

---

---

- What the initial or center position for (3/2) 5/2 directional control impulse valve, electrically controlled

---

---

## Part II: Holding element control of a double acting cylinder

### Aim:

This exercise conveys knowledge on the application of relays in electro pneumatic controls. The valve solenoids are controlled through relay contacts and not directly through the signaling elements.

### Title: Bulk material

### Problem description:

Bulk material is to be emptied from a hopper as shown below in Fig.3.4. By pressing a pushbutton switch, the hopper is opened and the bulk material is emptied out. By pressing another pushbutton switch the hopper is closed again.

Hint: The controlling circuit should contain relays for the indirect control

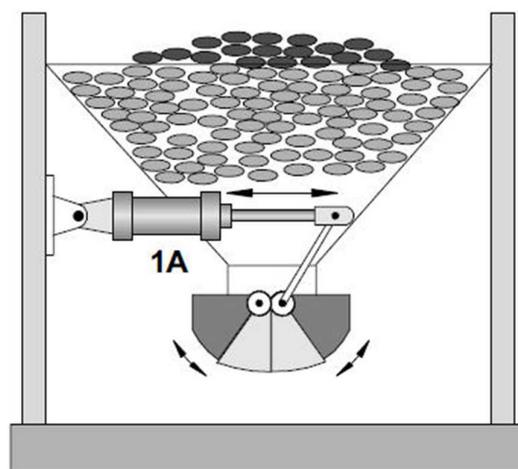


Fig. 3.4 Positional sketch of the hopper machine

**List of equipment:**

Description:

- (04) Double-acting cylinder, with annular solenoid
- (32) 5/2 directional control impulse valve, electrically controlled
- (37) Unit, 1 control switch, 2 push buttons
- (34) Relay unit 4 changeover contacts
- (50) Power supply unit
- (42) Unit, electric manifold
- (01) Pneumatic air service unit
- (02) Compressed air distributor

**Procedures:**

1. Draw the elector-pneumatic circuit using the FluidSim software
2. Test the circuit functions against any errors or mistakes.
3. Construct the circuit on the workstation
4. Write down your notes and observations.

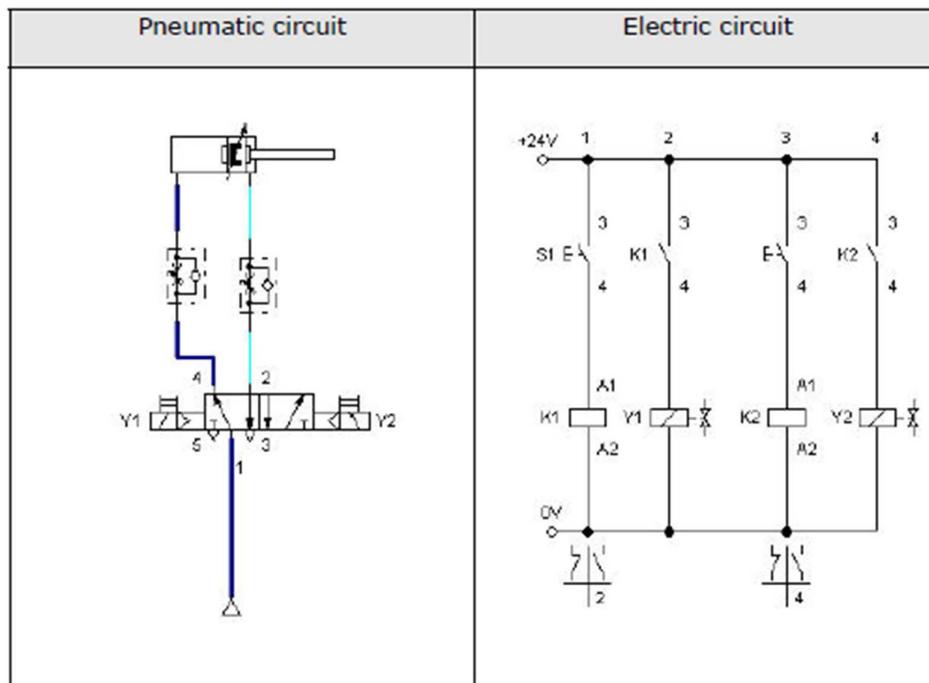


Figure 3.5: Pneumatic circuit diagram

**Conclusion:**

- Start the system by pressing S1 momentarily, step what the system do:

---



---

- pressing S2 momentarily, step what the system do:

---



---

- what the different between part one and two

---



---

### Part III: Basic Circuit with electric latching circuit

#### Aim:

This exercise the various possible circuits with latching (storage circuits) in relay technology are demonstrated.

#### Title: Opening/closing the flow in a pipeline

The double acting cylinder (1A) in Fig. 3.6 is used to open and close the main valve in a pipeline. Draw an electro-pneumatic circuit to control the movement of cylinder (1A).

Hint: The valve is opened by pressing the pushbutton switch. When the pushbutton is released the valve is closed.

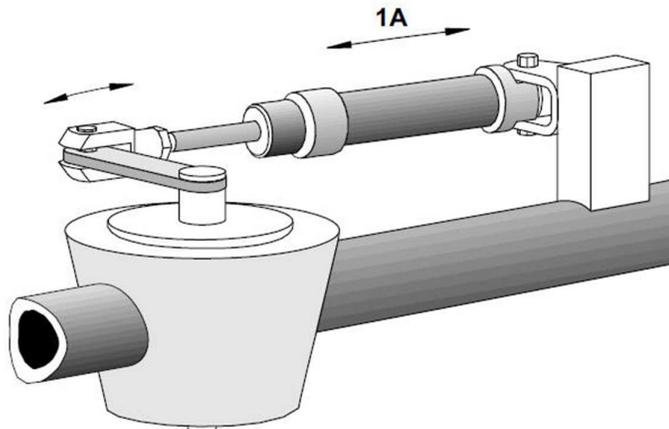


Fig. 3.6 Positional sketch machine

#### List of equipment:

Description:

- (04) Double-acting cylinder, with annular solenoid
- (31) 5/2 directional control impulse valve, electrically controlled, spring return
- (37) Unit, 1 control switch, 2 push buttons
- (34) Relay unit 4 changeover contacts
- (50) Power supply unit
- (42) Unit, electric manifold
- (01) Pneumatic air service unit
- (02) Compressed air distributor

**Procedures A:**

1. Draw the elector-pneumatic circuit using the FluidSim software
2. Test the circuit functions against any errors or mistakes.
3. Construct the circuit on the workstation
4. Write down your notes and observations.

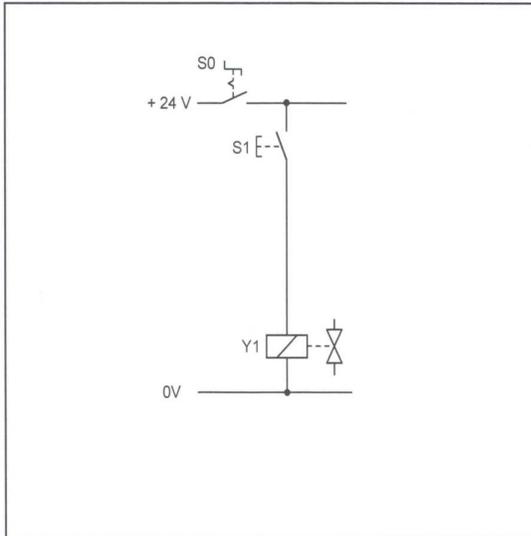


Figure 3.8: Electric circuit diagram

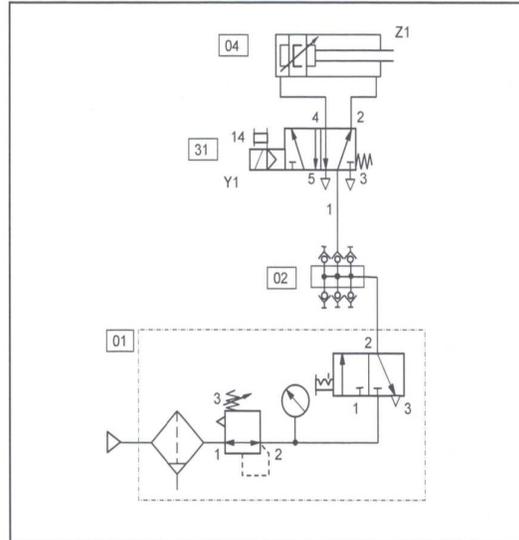


Figure 3.7: Pneumatic circuit diagram

**Conclusion:**

- Start the system by pressing S1 momentarily assuming that the switch S0 is on , step what the system do:

---



---



---



---

- what the different between part two and three

---



---

**Procedures B:**

1. Connect the circuit shown in Figures 3.8.

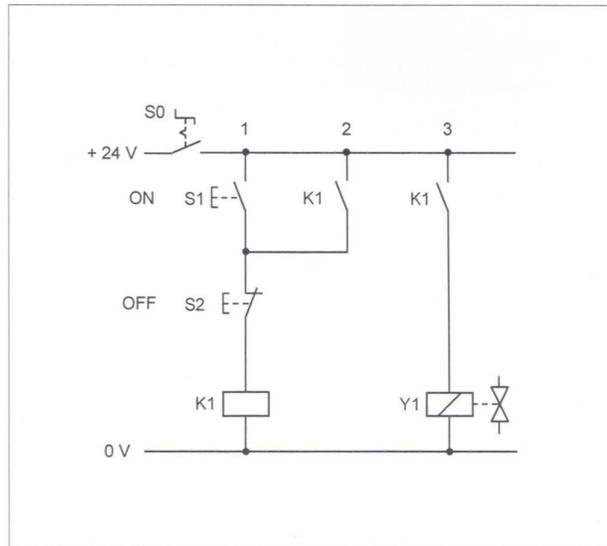


Figure 3.8: Electric circuit diagram (dominant "off")

**Conclusion:**

- Start the system by pressing S1 momentarily assuming that the switch S0 is on , step what the system do:

---



---



---



---

## Part IV: Displacement dependent control of a double acting cylinder

### Aim:

Cylinder switches and an electrically controlled 5/2 directional control impulse valve are used in this displacement- dependent control of a double-acting cylinder.

### Problem description:

The double acting cylinder shown in Fig.3.9 below is used to generate an oscillating movement in order to provide a belt timely movement. When the detent switch is turned on, the piston rod starts oscillating. Two limit switches should be used to control the length of the forward and backward strokes.

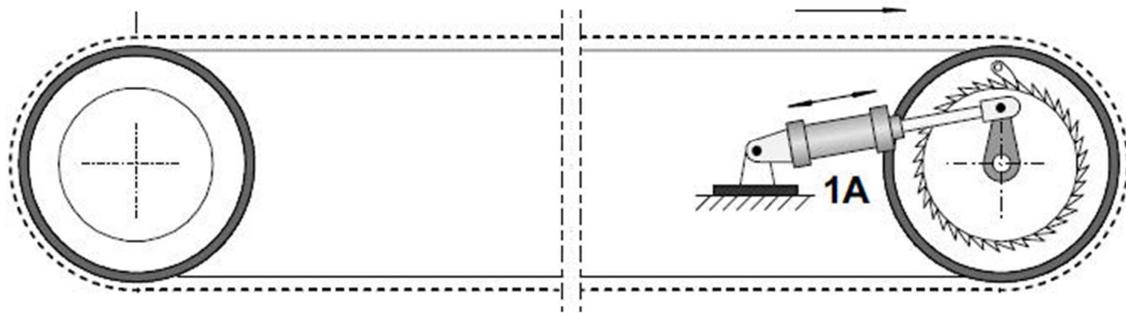


Fig.3.9

### List of equipment:

Description:

- (04) Double-acting cylinder, with annular solenoid
- (32) 5/2 directional control impulse valve, electrically controlled
- (15) one way flow control valve
- (37) Unit, 1 control switch, 2 push buttons
- (34) Relay unit 4 changeover contacts
- (38) Cylinder switches
- (50) Power supply unit
- (42) Unit, electric manifold
- (01) Pneumatic air service unit
- (02) Compressed air distributor

### Required procedures

1. Draw the electro-pneumatic circuit (indirect control) using the FluidSim software
2. The speed of the forward and backward stroke of the cylinder rod is adjustable
3. Test the circuit functions against any errors or mistakes.
4. Construct the circuit on the workstation
5. Write down your notes and observations.

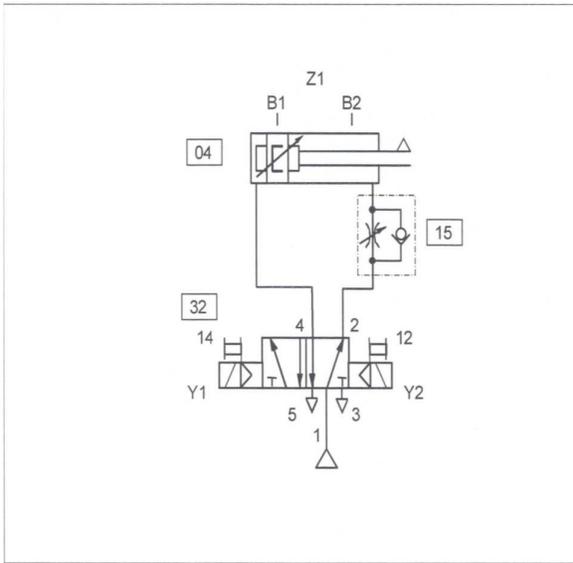


Fig. 3.10: Pneumatic circuit diagram

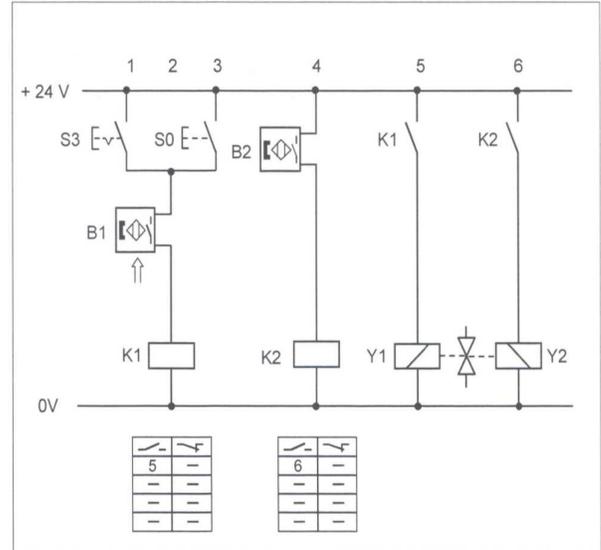


Fig. 3.11: Electric circuit diagram

**Conclusion:**

- Start the system by pressing S0 momentarily , step what the system do:

---



---

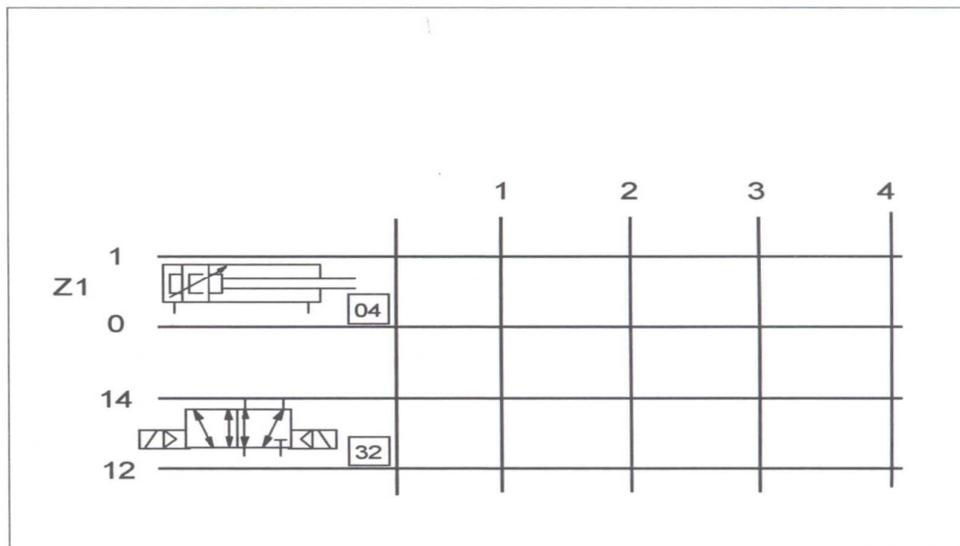


---



---

- Design the functional diagram (stroke-time diagram) for the cylinder and the 5/2 directional control valve.





**University Of Jordan**  
**School of Engineering**  
**Mechatronics Engineering Department**  
**Fluid Power Engineering Lab**  
**Experiments No.4**  
**Introduction to Hydraulic Trainer**

**Objective:**

Students will be able to identify the hydraulics Trainer components and to safely operate the trainer.

The student should be able to state the laws governing hydraulic, and perform simple calculation involving force, pressure, area, velocity, and flow rate.

**Introduction**

Pressure is the amount of force exerted against a given surface. Flow is the movement of fluid caused by a difference in pressure between two points.

Fluid always flows from a higher pressure point to a lower pressure point.

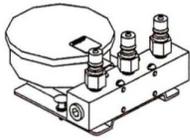
When two parallel paths of flow are available, fluid will always take the path of least resistance.

In a hydraulic circuit, flow is produced by the action of a pump, which continuously discharges the oil at a certain flow rate. Pressure is not created by the pump itself but by resistance to the oil flow. When the oil is allowed to flow with no resistance through a hydraulic circuit, the pressure in that circuit is theoretical zero.

**Part one: Identify the Hydraulic Trainer Components**

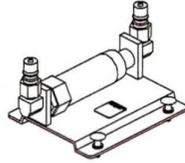
**In the first part, you will identify the various components of your Hydraulics Trainer.**

The components illustrated in Figure 1 are supplied with your Hydraulics Trainer. Draw the symbol of each component:



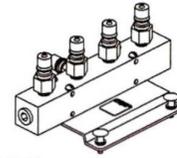
P/N:6350  
PRESSURE GAUGE (2)

SYMBOL: \_\_\_\_\_



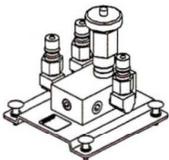
P/N:6351  
FLOWMETER

SYMBOL: \_\_\_\_\_



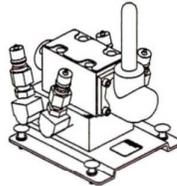
P/N:6390  
MANIFOLD, 5 PORTS, FIXED (2)

SYMBOL: \_\_\_\_\_



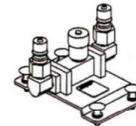
P/N:6322  
RELIEF VALVE

SYMBOL: \_\_\_\_\_



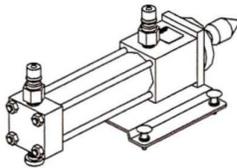
P/N:6320  
DIRECTIONAL VALVE,  
LEVER OPERATED

SYMBOL: \_\_\_\_\_



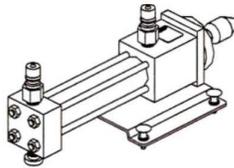
P/N:6321  
FLOW CONTROL VALVE,  
NON COMPENSATED

SYMBOL: \_\_\_\_\_



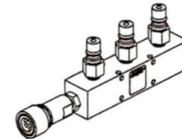
P/N:6341  
DOUBLE-ACTING CYLINDER,  
3.8-cm BORE

SYMBOL: \_\_\_\_\_



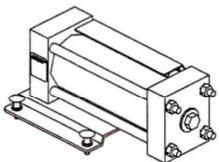
P/N:6340  
DOUBLE-ACTING CYLINDER,  
2.5-cm BORE

SYMBOL: \_\_\_\_\_



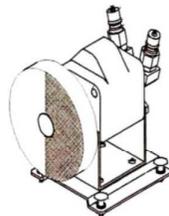
P/N:6391  
MANIFOLD, 4 PORTS, MOBILE (2)

SYMBOL: \_\_\_\_\_



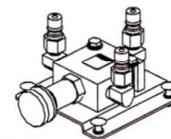
P/N:6380  
LOADING DEVICE, SPRING TYPE

SYMBOL: \_\_\_\_\_



P/N:6342  
BIDIRECTIONAL MOTOR  
AND FLYWHEEL

SYMBOL: \_\_\_\_\_



P/N:6323  
PRESSURE REDUCING VALVE

SYMBOL: \_\_\_\_\_

Fig.1 Identify the Hydraulics Trainers components

## Part two: Limiting System Pressure

The relief valve supplied with your kit of hydraulic components is called a pilot-operated type. The valve body has three parts: a pressure (**P**) port, which is to be connected to the pump pressure line, a tank (**T**) port, which is to be connected to the reservoir, and vent (**V**), which is to be used for control of the valve from a remote point by external valve. The pressure at which the relief valve begins to open is called cracking pressure.

In the part of the exercise, you measured the minimum pressure setting by a relief valve which is connected between the pump pressure line and reservoir and by opening the valve completely.

You then tested the effect of pressure limitation on a basic hydraulic circuit.

### PROCEDURE

Connect the circuit shown in Figures 2 and 3. Make sure to mount the 3.81-cm (1.5-in) bore cylinder in a position where its rod can extend freely.

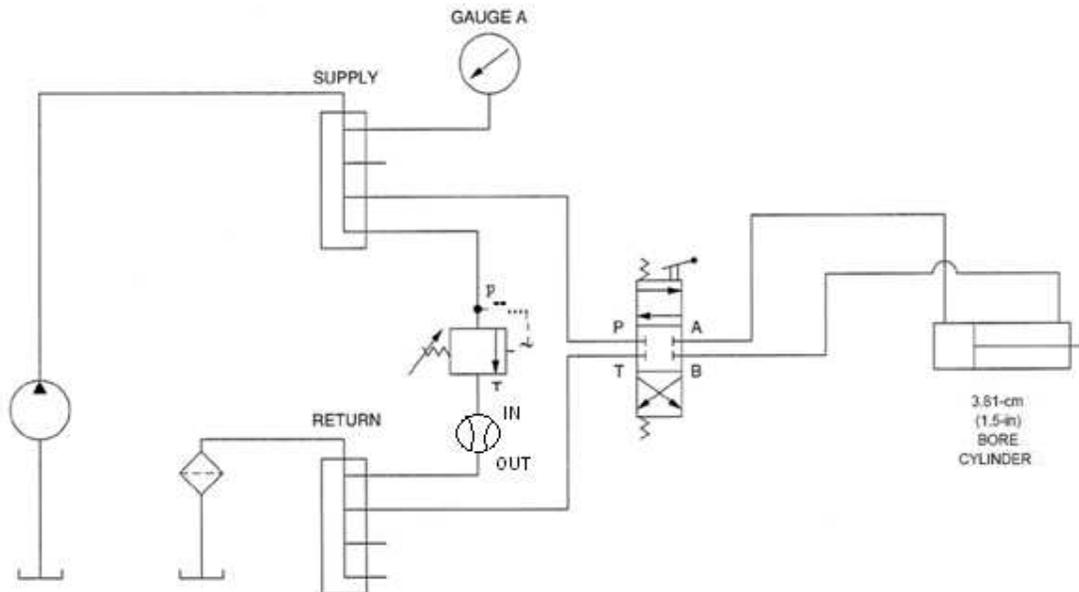


Fig.2 Schematic diagram of the cylinder actuation circuit

- Make sure the hoses are firmly connected. Open the Relief Valve completely by turning its adjustment knob fully counterclockwise.
- Turn on the power Unit.
- Turn the Relief Valve adjustment knob clockwise until gauge A reads 1400 kPa (200 psi).
- Stay clear of the cylinder rod. Move the lever of the Directional Control Valve toward the valve body, which should extend the cylinder rod. Then, move the lever outward from the valve body, which should retract the rod.

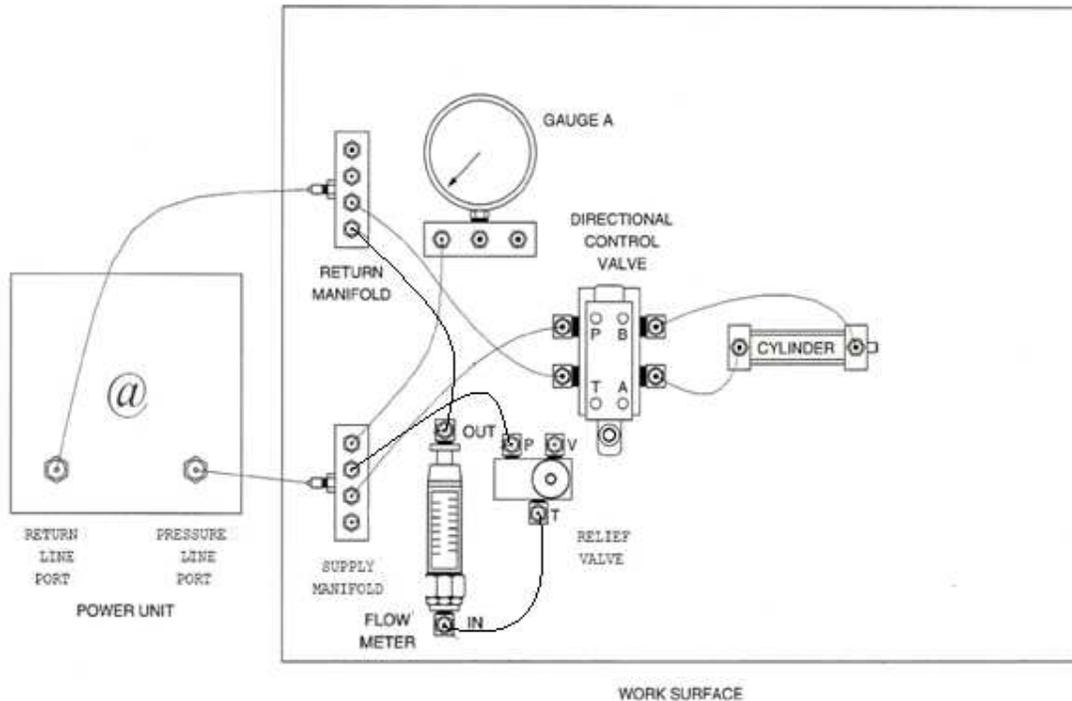


Fig.3 Connection diagram of the cylinder actuation circuit

- While watching the reading of gauge A, move the lever of the directional Valve toward the Valve body to extend the cylinder rod. What is the pressure at gauge A during the extension stroke of the rod?

Pressure = ----- KPa or ----- Psi

- What is the pressure at gauge A when the cylinder is fully extended?

Pressure = ----- KPa or ----- Psi

- Move the lever of the directional valve outward from the valve body to retract the cylinder rod.
- Turn relief Valve adjustment knob clockwise until gauge A reads 2100 kPa (300 psi).
- While watching the reading of gauge A, move the lever of the directional valve toward the valve body to extend the cylinder rod. What is the pressure at gauge A during the extension stroke of the cylinder rod?

Pressure = ----- KPa or ----- Psi

- What is the pressure at gauge A when the cylinder rod is fully extended?

Pressure = ----- KPa or ----- Psi

- Move the lever of the directional valve outward from the valve body to retract the cylinder rod.
- Turn off the Power Unit. Open the Relief Valve completely by turning its adjustment knob fully counter clockwise.

Q. Explain the reason for the nearly identical pressures registered during cylinder extension at the two relief valve pressure settings.

---

---

---

Q. Why does the circuit pressure increase when the cylinder rod is fully extended?

---

---

---

- Disconnect all hoses. It may be necessary to move the directional valve lever back and forth to relieve static pressure; the quick connects can then be removed. Wipe off any hydraulic oil residue.
- Remove all components from the work surface and wipe off any hydraulic oil residue. Return all components to their storage location.

### Part three: Flow rate and Velocity

The student should be describe the operation of a flow control valve, establish the relationship between flow rate and velocity and operate meter-in and meter-out flow control circuits.

#### Flow control circuits

There are three ways to meter the oil flow in order to control the speed of a cylinder, which are: meter-in, meter-out, and bypass.

With the **meter-in method**, the flow control valve is connected in series between the pump and the cylinder, as Figure 4(a) shows. It restricts the working oil flow to the cylinder. The extra flow delivered by the pump is drained back to the reservoir through the relief valve. This method is useful to control cylinders having a load that resists to the pump delivery, as cylinders raising a load.

With the **meter-out method**, the flow control valve is connected in series between the cylinder and the reservoir, as Figure 4(b) shows. It restricts the flow away from the cylinder. The extra flow delivered by the pump is drained back to the reservoir through the relief valve. This method is useful to slow down cylinders having a load that tends to run away, as cylinders lowering a load.

With the **bypass method**, the flow control valve is connected between the pump and the reservoir, as Figure 4 (c) shows. The extra flow is diverted directly to the reservoir through the flow control valve. This method is more energy efficient than the meter-in and meter-out methods because the extra flow returns to the reservoir at the load pressures' rather than at the

relief valve pressure. However, this method is less accurate because it does not provide direct control of the working flow to the cylinder.

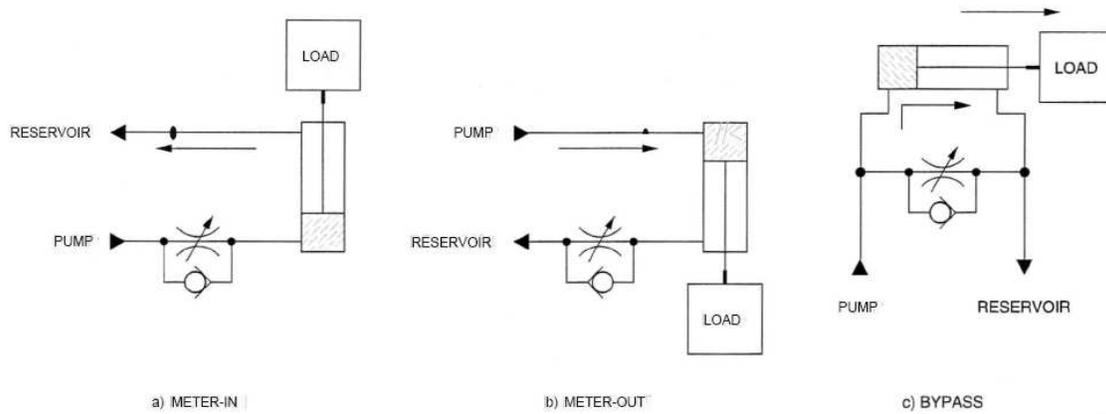


Fig.4 Basic flow control circuits

In this exercise, you will test the operation of meter-in and meter-out flow control circuits while noting the actuation times and pressure drops across the trainer Flow Control Valve.

Flow Control Valves (FCVs) are used in industry for cylinder speed control. Therefore, the aim of this experiment is to illustrate the circuit for meter-in and meter-out speed control as well as the difference between them.

A **flow control valve** as an adjustable resistance to flow that operates very much like a faucet. By adjusting the resistance, or opening, of this valve, you can modify the rate of oil flow to a cylinder and, therefore, the speed of its piston rod.

**Meter-in flow control circuit:**

Connect the circuit shown in Figures 5 and 6. This circuit meters the oil flow going to the cylinder.

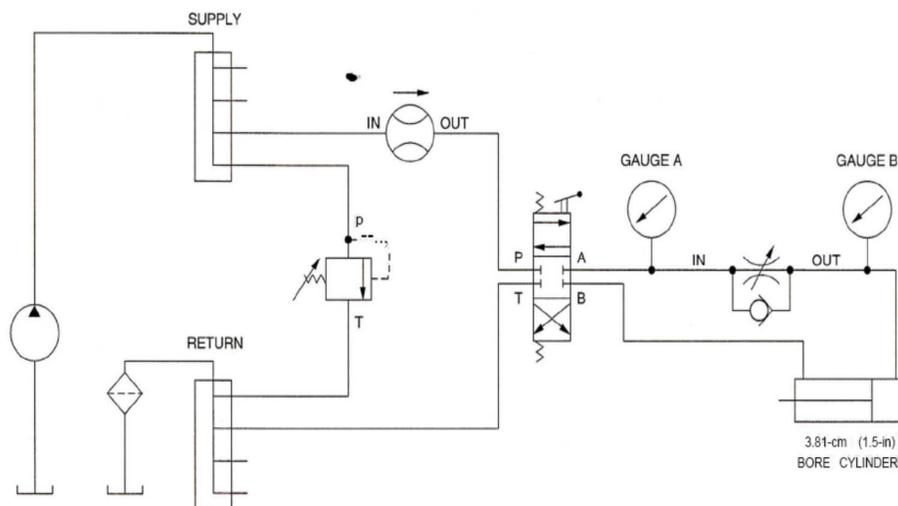


Fig.5 Schematic diagram of a meter-in flow control circuit.

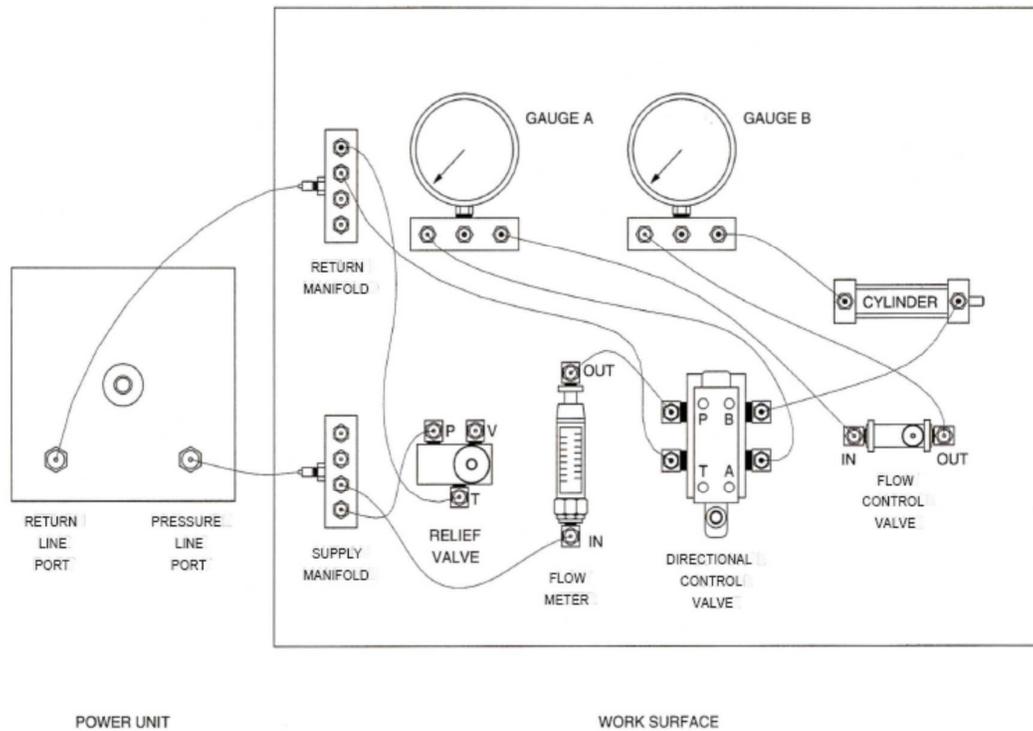


Fig.6 Connection diagram of a meter-in flow control circuit.

**Notice** that the Flow Control Valve must be connected so that the arrow points away from the pump.

- Before starting the power unit, perform the following start-up procedure:
  - a) Make sure the hoses are firmly connected.
  - b) Check the level of the oil in the reservoir. Add oil if required.
  - c) Put on safety glasses.
  - d) Make sure the power switch on the Power Unit is set to the OFF position.
  - e) Plug the Power Unit line cord into an ac outlet.
  - f) Open the Relief Valve completely (turn knob fully counterclockwise).
- Close the Flow Control Valve completely by turning its adjustment knob fully clockwise.
- Turn on the power Unit.
- Move the lever of the directional valve toward the valve body and observe the pressure reading at gauge A. Since the Flow Control Valve is fully closed, the pumped oil is blocked at the Flow Control Valve and is now being forced through the relief valve, so gauge A indicates the minimum pressure setting of the relief valve. While keeping the directional valve lever shifted, turn the relief valve adjustment knob clockwise until gauge A reads 2100 kPa (300 psi).
- With the lever of the directional valve still shifted toward the valve body, open the Flow Control Valve, 1 turn counterclockwise, to extend the rod. You should observe that the extension speed increases as you increase the opening of the Flow Control Valve.
- Move the lever of the directional valve outward from the valve body to retract the rod. Did the rod retract faster than it extended?

Yes       No

- Move the lever of the directional valve toward the valve body to extend the cylinder rod. As the rod extends, close the Flow Control Valve completely by turning its adjustment knob fully clockwise. Does the Flow Control Valve provide direct control of the rod speed?  
 Yes       No
- Retract the rod by moving the lever of the directional valve outward from the valve body. Observe that the rod still retracts at full speed even though the Flow control Valve is completely closed. Explain why.

---



---



---



---

- Open the flow control valve 1 turn counter clockwise.
- Now adjust the Flow Control Valve to 1.5 l/min. To do so, move the lever of the directional valve toward the valve body to extend the cylinder rod. As the cylinder extends, observe the Flow meter reading. Adjust the Flow Control Valve so that the Flow meter reads 1.5 l/min, then retract the rod. Accurate adjustment may require that the cylinder be extended and retracted several times.

Note: The trainer Flow meter provides a "lpm" reading. Lpm means l/min, that is, "liters per minute".

- Measure the time required for the rod to extend fully using a stopwatch. Record this value in Table 1 under "ACTUAL". Also record the readings of gauges A and B while the rod is extending. When you have finished, retract the rod.

Flow rate to cylinder	Actual extension time	Gauge A	Gauge B	$\Delta P$ (Gauge A – Gauge B)
1.5 l/min				
2.0 l/min				
2.5 l/min				

Table 1 Meter-in flow control circuit data

- Repeat last two steps for other flow rate in Table 1.
- Turn off the Power Unit. Open the Relief Valve completely by turning its .adjustment knob fully counter clockwise.
- Does the rod speed increase or decrease as the flow rate decrease?

---



---

- According to Table 1, does the pressure drop across the valve increase or decrease as the opening of the valve is increased? Why?

---



---



---

**Meter-out flow control circuit:**

In the second part of the exercise, you used meter-out control to change the cylinder extension speed.

Connect the circuit shown in Figures 7 and 8. This circuit meters the oil flow going out of the pump.

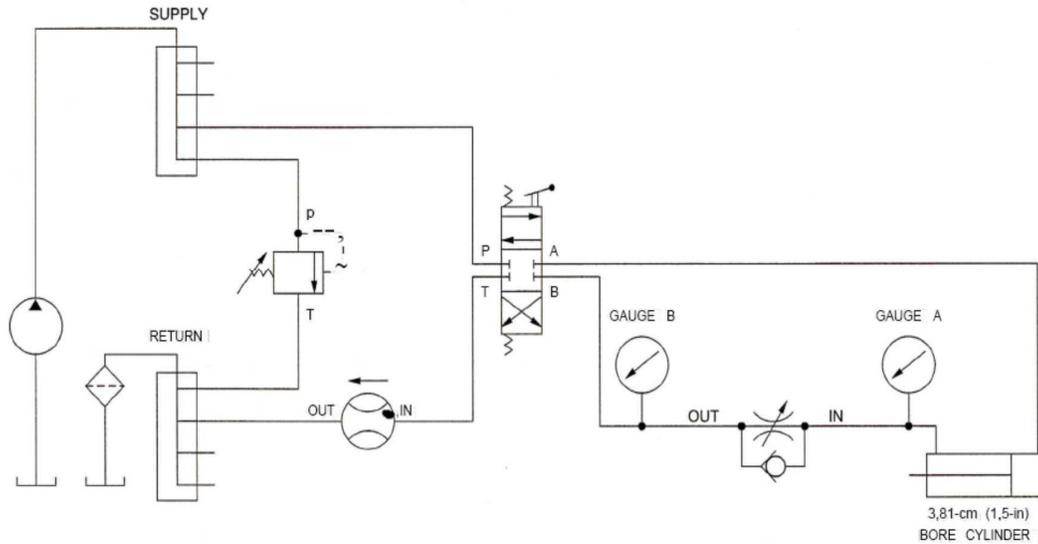


Fig.7 Schematic diagram of a meter-out flow control circuit.

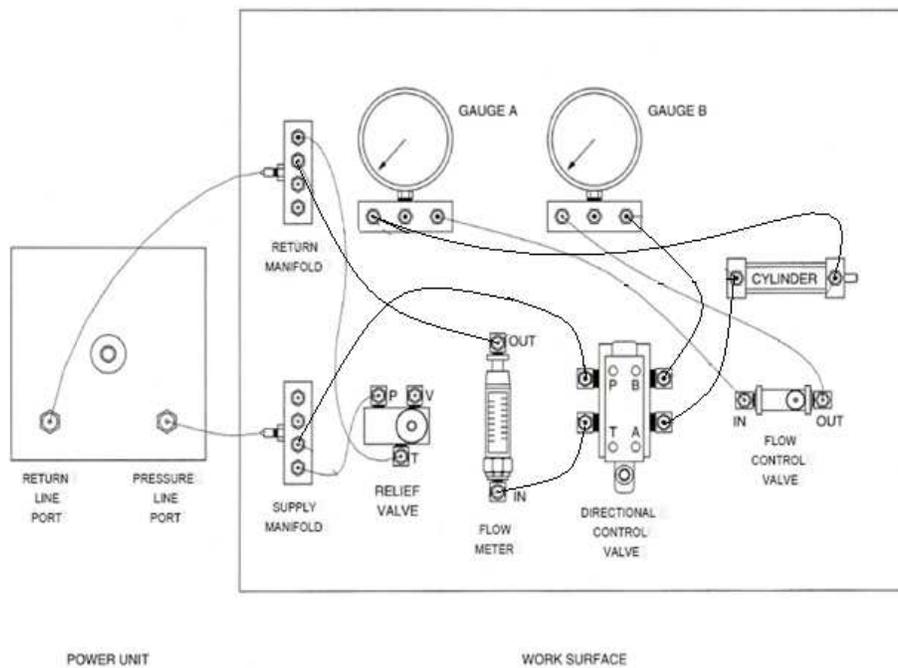


Fig.8 Connection diagram of a meter-out flow control circuit.

Notice that the Flow Control Valve must be connected so that the arrow points away from the pump.

- Close the Flow Control Valve completely by turning its adjustment knob fully clockwise.
- Turn on the power unit.
- Move the lever of the directional valve outward from the valve body to retract the cylinder rod completely. With the cylinder rod fully retracted, all the oil from the pump now flows through the Relief Valve and gauge B indicates the minimum pressure setting of the Relief Valve. While keeping the directional valve lever shifted, turn the Relief Valve adjustment knob clockwise until gauge B reads 2100 kPa (300 psi).
- Move the lever of the directional valve toward the valve body to extend the cylinder rod. As the rod extends, open the Flow Control Valve 1 turn counterclockwise. You should observe that the extension speed of the rod increases as you increase the Flow Control Valve opening. Retract the rod.
- Move the lever of the directional valve toward the valve body to extend the cylinder rod. As the rod extends, close the Flow Control Valve completely by turning its adjustment knob fully clockwise. Does the Flow Control Valve provide direct control of the rod speed?  
 Yes       No
- Retract the rod. Does the setting of the Flow Control Valve have an effect on the retraction speed?  
 Yes       No
- Adjust the Flow Control Valve so that the Flow meter reads 1.5 l/min as the rod extends, then retract the rod.
- Measure the extension time of the cylinder rod. Record this value in Table 2 under "Extension". Also record the readings of gauges A and B while the rod is extending.

Flow rate to cylinder	Actual extension time	Gauge A	Gauge B	$\Delta P$ (Gauge A – Gauge B)
1.5 l/min				
2.0 l/min				
2.5 l/min				

Table 2 Meter-out flow control circuit data

- Repeat last two steps for other flow rate in Table 2.
- Turn off the Power Unit. Open the Relief Valve completely by turning its adjustment knob fully counterclockwise.
- According to Table 2, does the pressure drop across the valve increase or decrease as the opening of the valve is increased? Why?

---



---

- Are the pressure drops in Table 2 for a meter-out circuit similar to the pressure drops in Table 1 for a meter-in circuit? Why?

---



---



---

**Part four: Pressure and Force**

In this experiment, you will verify the formula  $F=PX A$  by measuring the compression force of cylinder, then you will demonstrate what happens when equal pressure is applied to both sides of a piston.

**PROCEDURE**

Connect the circuit shown in Figure 9, 10. Use the 2.54-cm (1-in) bore cylinder.

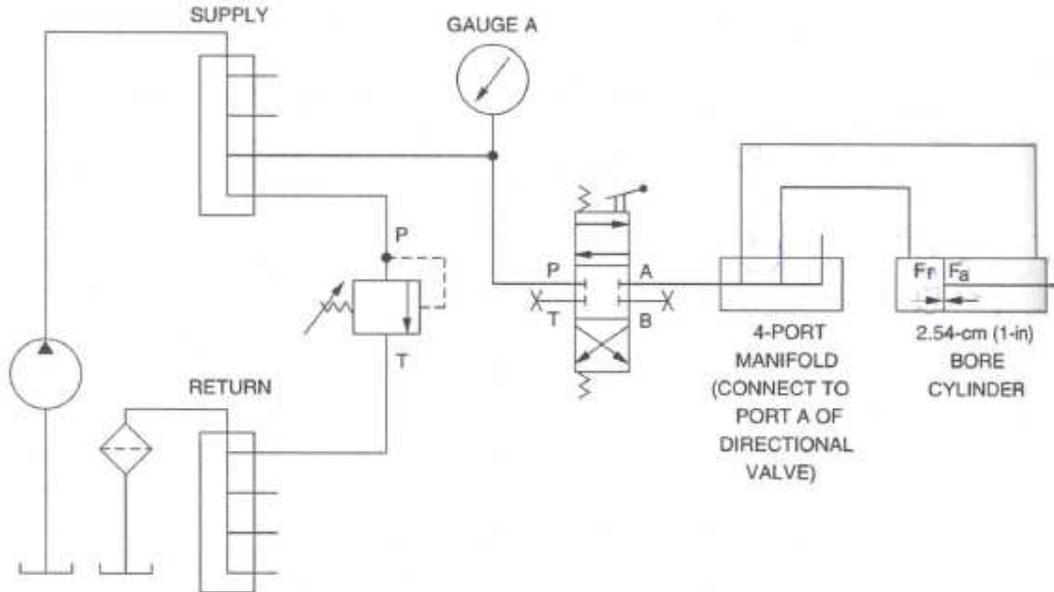


Fig. 9 Schematic diagram of Applying equal pressure on both sides of a piston.

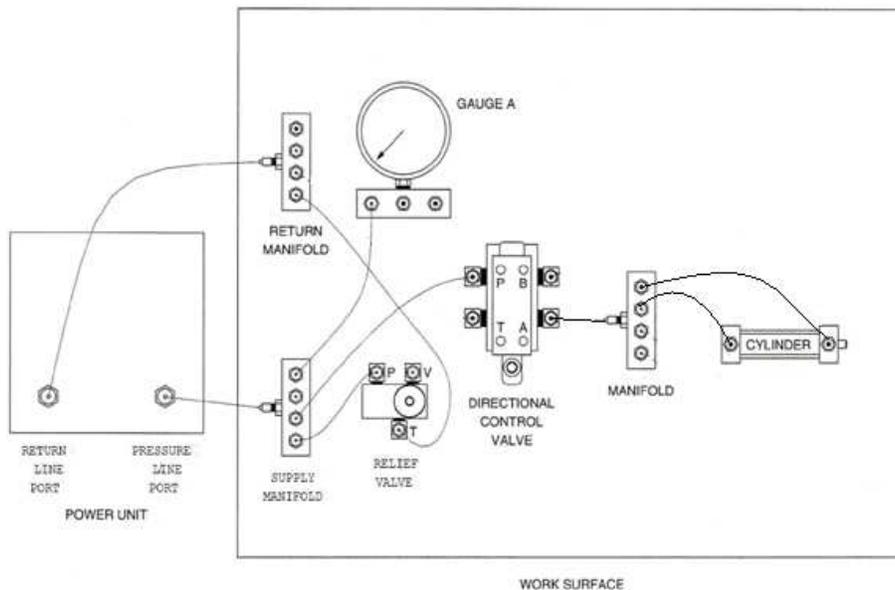


Fig.10 Connection diagram of Applying equal pressure on both sides of a piston.

- Examine the circuit of Figure 9. Predict which side of the piston will develop the most force.
- 

- What do you think will happen to the cylinder rod?
- 

- - Turn on the power unit.
  - Turn the Relief Valve adjustment knob clockwise until the circuit pressure at gauge A equals 2100 kPa (300 psi).
  - While observing the cylinder rod, move the lever of the directional valve toward the valve body so that the pumped oil is directed toward both sides of the cylinder piston. In which direction does the rod move? Why?
- 
- 
- 

- Turn off the Power Unit. Open the relief valve completely (turn knob fully counterclockwise) .

**The University Of Jordan**  
**School of Engineering**  
**Mechanical Engineering Department**  
**Fluid Power Engineering Lab**  
**Experiments No.4**  
**Introduction to Hydraulic Trainer**

**In class Lab Report**

Date: \_\_\_\_\_

Section: \_\_\_\_\_

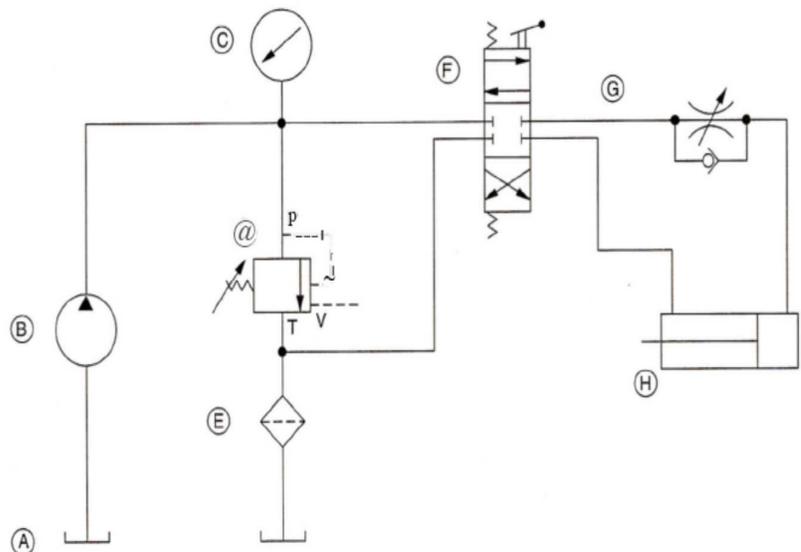
Group's Names:

- 1-
- 2-
- 3-
- 4-
- 5-

**Part one: Identify the Hydraulic Trainer Components**

Q1: Study the graphic diagram shown below and identify each of the lettered symbols.

- A. -----
- B. -----
- C. -----
- D. -----
- E. -----
- F. -----
- G. -----
- H. -----



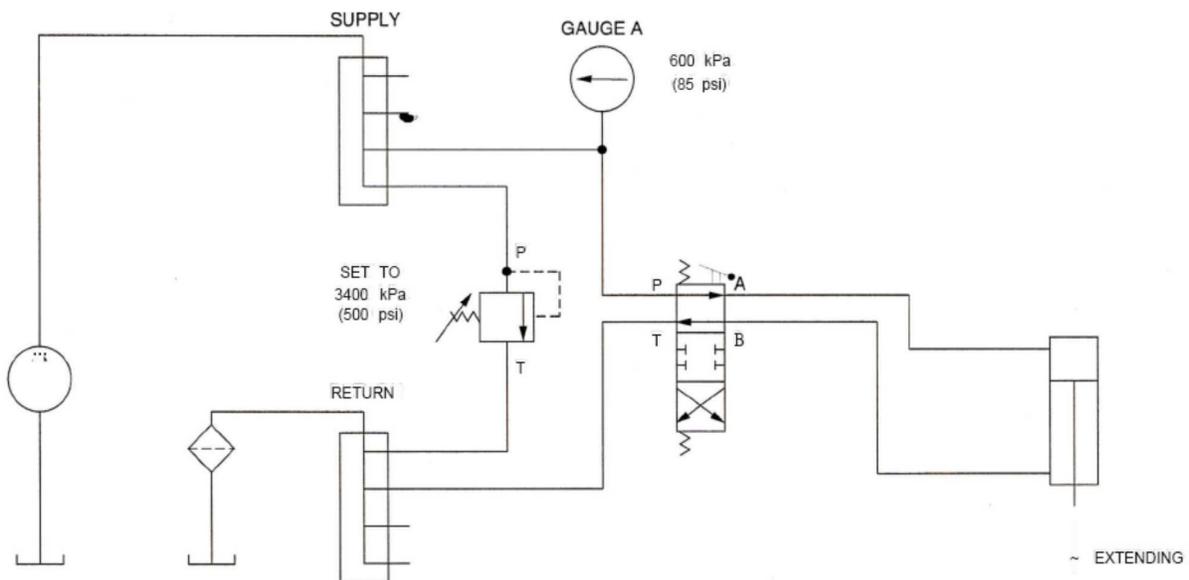
## Part two: Limiting System Pressure

Q1: What is the purpose of a relief valve?

Q2: What might happen to a hydraulic system if the tank port of the relief valve is not connected to the power unit return line port?

Q3: In the circuit of Figure below, what will be the pressure reading of gauge A during cylinder extension and when the cylinder is fully extended if the relief valve pressure setting is changed from 3400 kPa (500 psi) to 6900 kPa (1000 psi)?

**Note:** The pressure required to extend the cylinder rod is 600 kPa (85 psi).



### Part three: Flow rate

Q1: Find two ways to decrease the speed at which a cylinder rod extends or retracts.

Q2: What flow rate is required to make a 10.16 cm bore X 3.81 cm rod X 30.48 cm stroke cylinder extend in 6 second?

Q3: What type of metering circuit is used to control cylinders having a load that resists to the pump delivery, as cylinders raising a load?

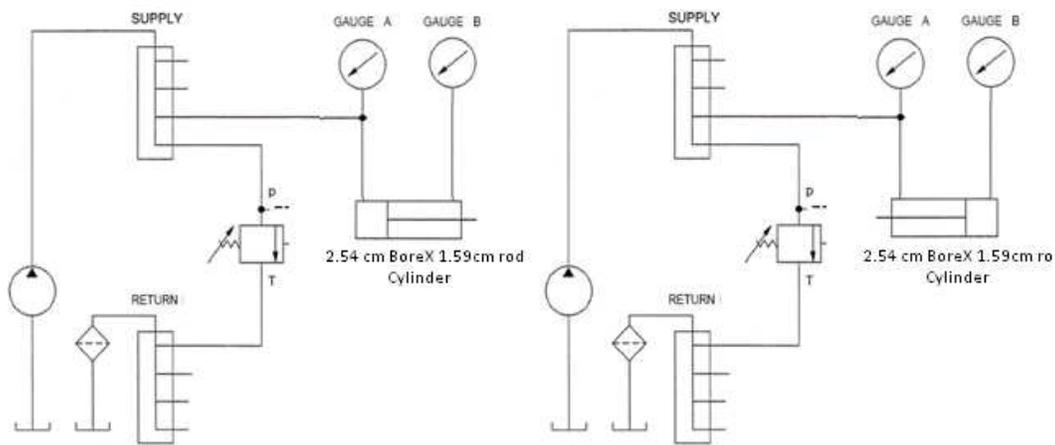
Q4. What type of metering circuit is used to slow down cylinders having a load that tends to run away, as cylinders lowering a load?

### Part four: Pressure and Force

Q1. How much pressure must be applied to the cap end of a 2.54-cm (1-in) bore cylinder in order to compress a spring 5.08 cm (2 in), if the spring rate is 728 N/cm (416 lb/in)?

Q2. In the circuit of Fig. 11(a), what will be the pressure at gauge B if the pressure at gauge A pressure is raised to 3500 kPa (500 psi)?

Q3. In the circuit of Fig.11 (b), what will be the pressure at gauge B if the pressure at gauge A pressure is raised to 3500 kPa (500 psi)?



(a) Pressure applied on full piston area.

(b) Pressure applied on annular piston area.

Figure 11 Determining pressure distributions in a cylinder

**The University Of Jordan**  
**School of Engineering**  
**Mechatronics Engineering Department**  
**Fluid Power Engineering Lab**  
**Experiments No.5**  
**Sequential control of a 2 double acting cylinder**

**Objective:** This exercises helps to understand sequential controls and provides practical knowledge of setting up and commissioning a control system with two pneumatic drives.

**Pre-Lab**

⇒ **Pre-Lab:** the required pneumatic circuit diagrams using the FlwidSIM; show the whole connections and components required for each circuit.

⇒ **In the lab:** Build your designs and verify their operation. sure that the pressure is 4 bars and is connected correctly. Double check your connections before switching the compressor on.

**Part I: Time delay valve and sequence control systems**

**Task 1: Pressing device with time control**

**Learning objectives:**

Upon the completion of this task, the student will be

- Familiar with the set-up and mode of operation of a time delay valve normally closed.
- Able to recognize and sketch the time delay valve.
- Able to choose different pneumatic components according to the given conditions.

**Problem Description:**

A double acting cylinder is used to press glued components together. Upon operation of a push button, the clamping cylinder extends as shown in Fig. 5.1 below. Once the fully advanced position is reached, the cylinder is to remain for a time of  $T = 6$  seconds and then retract to the initial position automatically. The cylinder retraction is to be adjustable. A new start cycle is only possible after the cylinder has fully retracted.

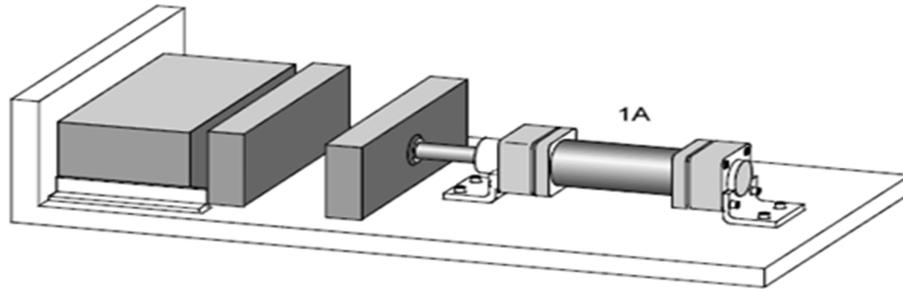
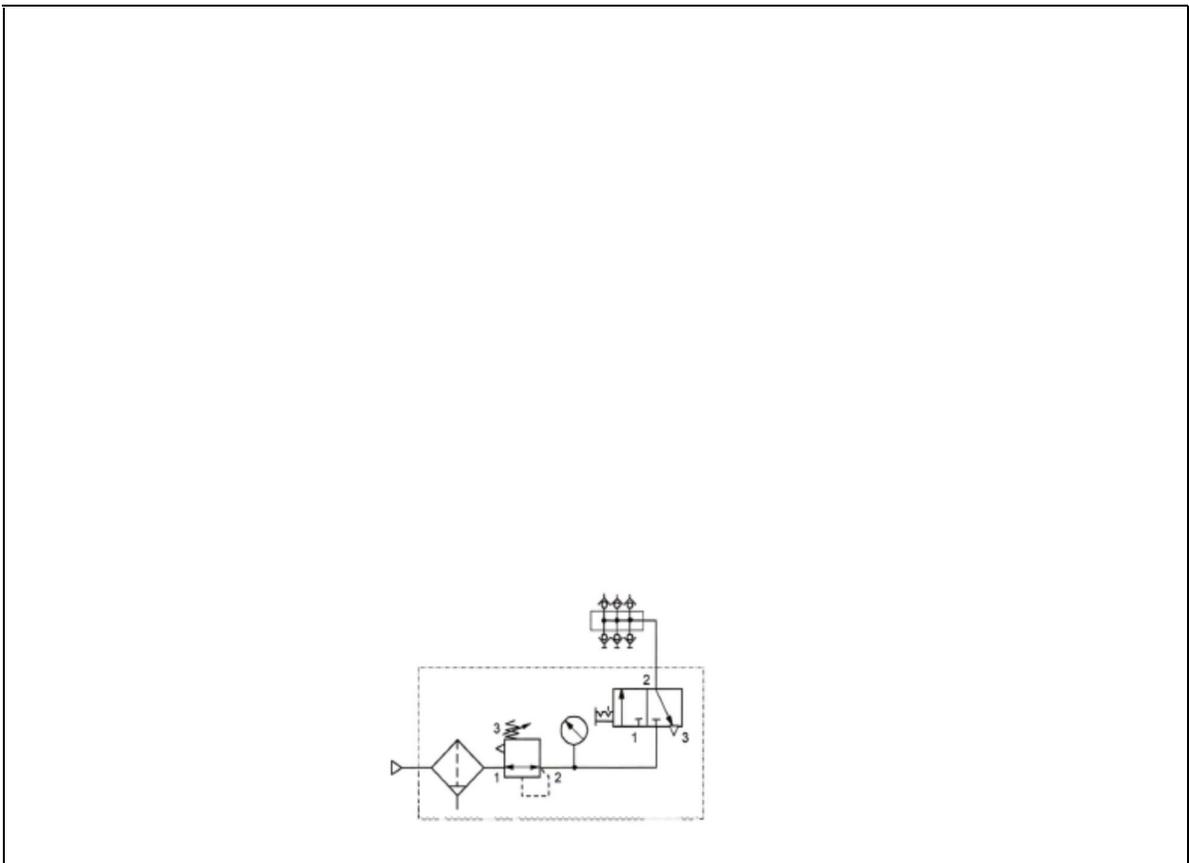


Fig. 5.1 Positional sketch

**Requirements:**

1. Draw pneumatic circuit diagram using the space provided below.
2. Simulate the circuit using FluidSIM software.
3. Assemble the circuit practically and check its operation.

**Pneumatic circuit diagram**

## Part II: Quick Exhaust valve

### Introduction to Quick Exhaust valve:

In many applications especially with single acting cylinders, it is a common practice to increase the piston speed during retraction of the cylinder to save the cycle time.

This is carried out by incorporating a quick exhaust valve. The quick exhaust valve has essentially three ports: supply port 1, is connected to the output of the final control element (directional control valve). The output port 2 of this valve is directly fitted on to the working port of cylinder. The exhaust port 3 is left open to the atmosphere. The I.S.O. symbol for quick exhaust valve is shown in the Fig. (5.2).

### 3.2 Way of operation

Compressed air flows from the directional control valve to the cylinder via the quick exhaust valve from port (1) to port (2). Exhaust port 3 is closed at this time.

When pressure at port 1 drops, exhaust flow occurs from port (2) to port (3) as illustrated in Fig. (5.3.c). In order to implement optimized quick exhaust, the valve must be connected directly to the cylinder's supply port.

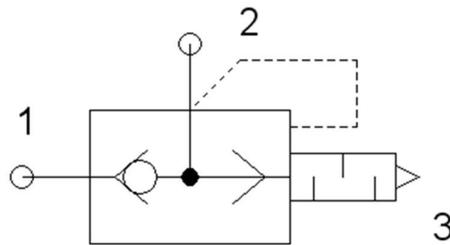


Fig. 5.2. ISO symbol of quick exhaust valve

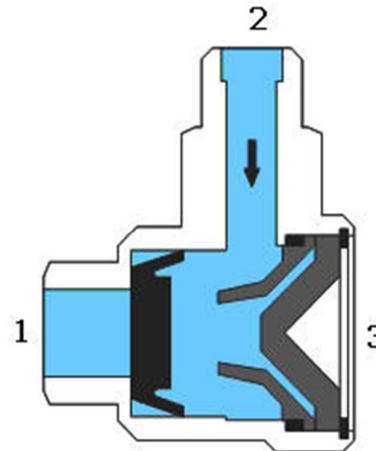


Fig.5.3. Schematic diagram of the quick exhaust valve

### Task 2: Edge folding device

#### Learning objectives:

Upon the completion of this task, the students will be

- Familiar with the set-up and mode of operation of a normally closed 3/2- way valve and 5/2 way valve.
- Able to recognize and sketch the Two Pressure Valve.
- Able to construct a complete circuit with different conditions.

#### problems Description:

In order to maintain a safe operating environment for the forming machine operator, the forming machine that is shown in Fig. (5.4) has to be operated by two push button valves at the same time. Operation of the two push button valves causes the forming tool of an edge-folding device to fall down rapidly (forward stroke of the double acting cylinder). If both or even just one push button is released, the double acting cylinder (1A) slowly should slowly return to the initial position (the backward stroke of the double acting cylinder should be slow).

**Requirements:**

1. Draw pneumatic circuit diagram using the space provided below.
2. Simulate the circuit using FluidSIM software.
3. Assemble the circuit practically and check its operation.

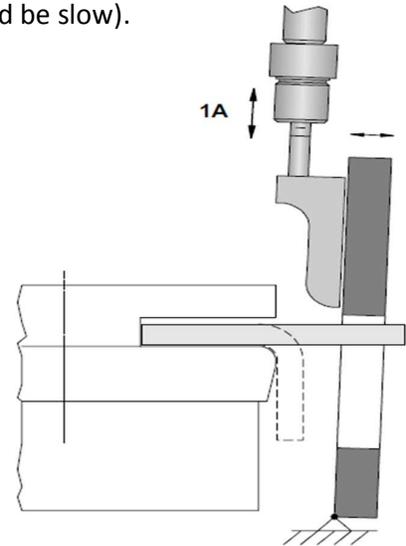
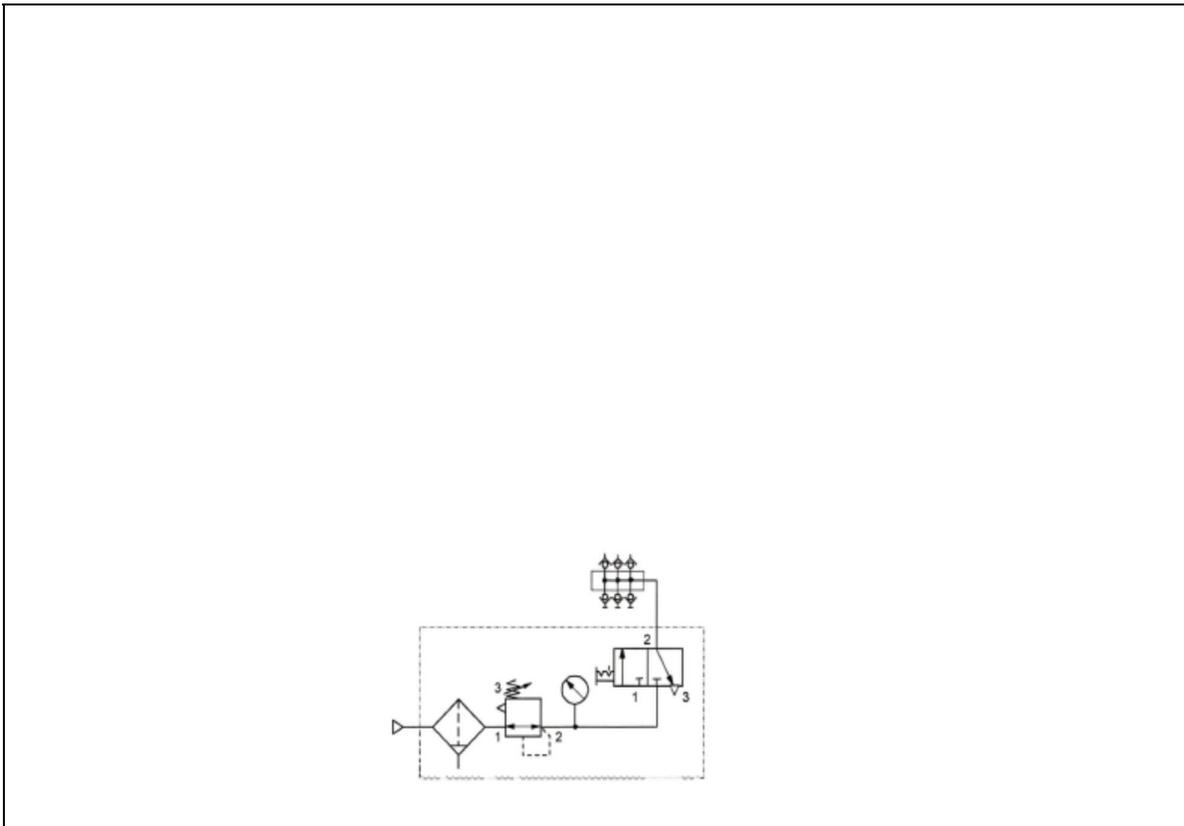


Fig. 5.4 Positional sketch



**Part III: Logic functions**

**Task 3: Pneumatics OR circuit**

**Problem Description:**

A flap control is used to empty granular material from a container. The machine should be operated from two different locations using two push button valves. By pressing any one of two pushbutton valves the flap is opened and the granular material is emptied from its container. After releasing the pushbutton valve the flap control is closed again as shown in the Fig. 5.5 below.

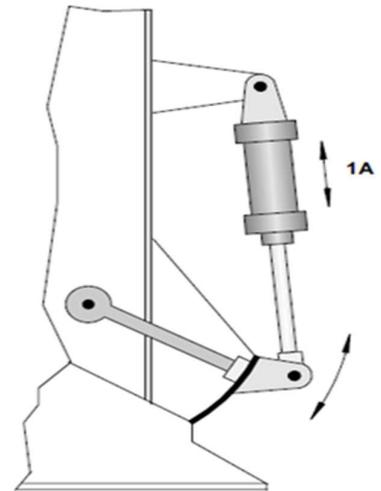
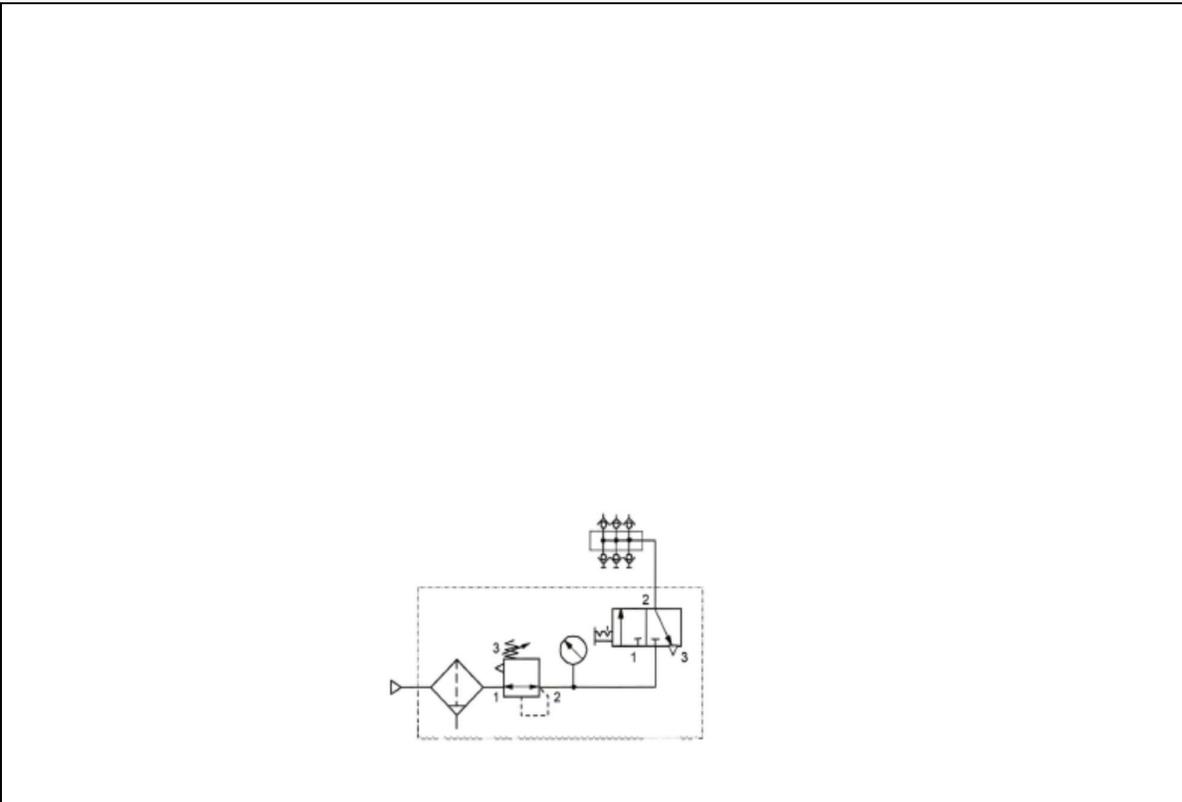


Fig. 5.5 Positional sketch

**Requirements:**

1. Draw pneumatic circuit diagram using the space provided below.
2. Simulate the circuit using FluidSIM software.
3. Assemble the circuit practically and check its operation.



## Part IV: Basic Circuit with Pneumatic latching circuit

### Task 4: Pneumatics latching circuit

#### Objectives:

Upon the completion of this task, the student should be able to control a pneumatic system by using a pneumatic latching circuit.

#### Problem description:

Parts are to be pushed away from a multi-track gravity feed magazine into a clamping device as shown below in Fig.5.6. By pressing a pushbutton switch the parts are pushed out of the multi-track gravity feed magazine by a slide. After the slide has reached the forward end position it has to return to its start position.

Hint: A impulse 5/2 DCV spring return is to be used for flow control.

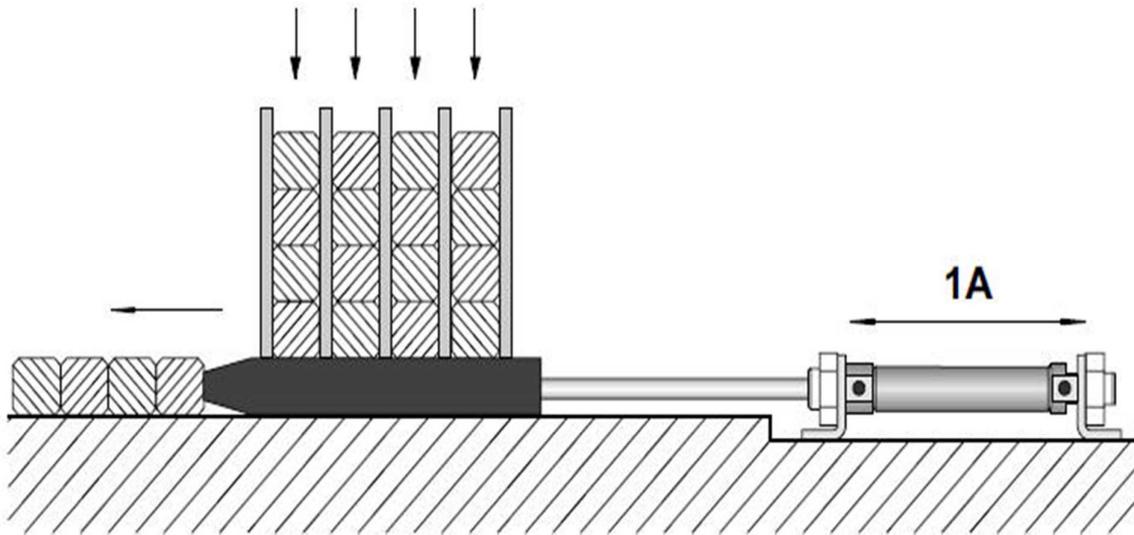
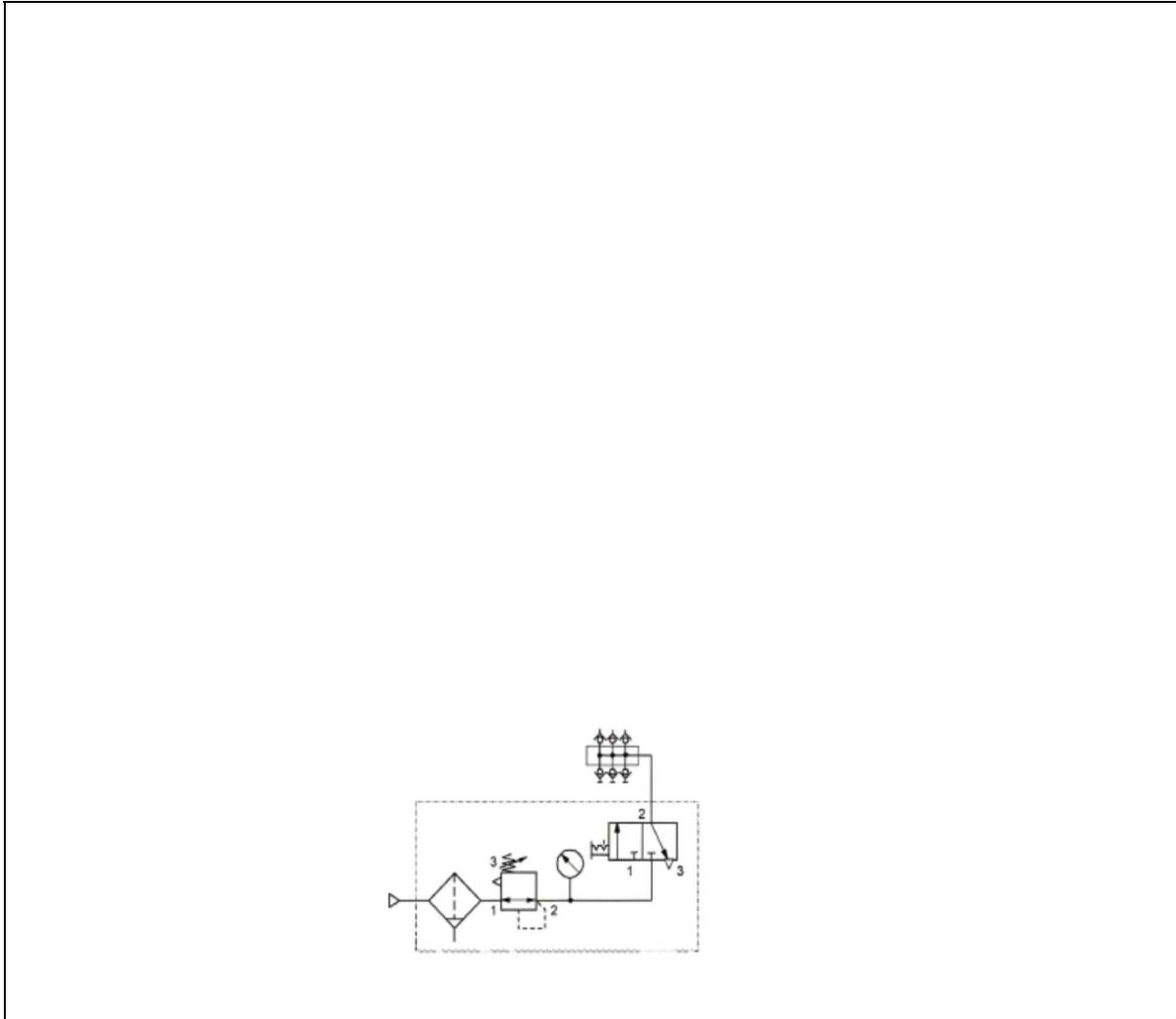


Fig. 5.6

#### Required procedures:

- 1- Draw the pneumatic circuit using the FluidSim software
- 2- Test the circuit functions against any errors or mistakes.
- 3- Construct the circuit on the workstation



### Part V: Sequential control of a double cylinder A

- Build your design ( Pneumatic circuit diagram ) to complete the task description in function diagram in Fig.5.7
- Note  
  
S1 and S2: 3/2 directional control valve , with roller , to induction of position for cylinder one .  
S3 and S4 : 3/2 directional control valve , with roller , to induction of position for cylinder two .
- Drawing the circuit diagram with symbols and port symbols.  
  
Note : Suppose initial position for two cylinder in retract position.

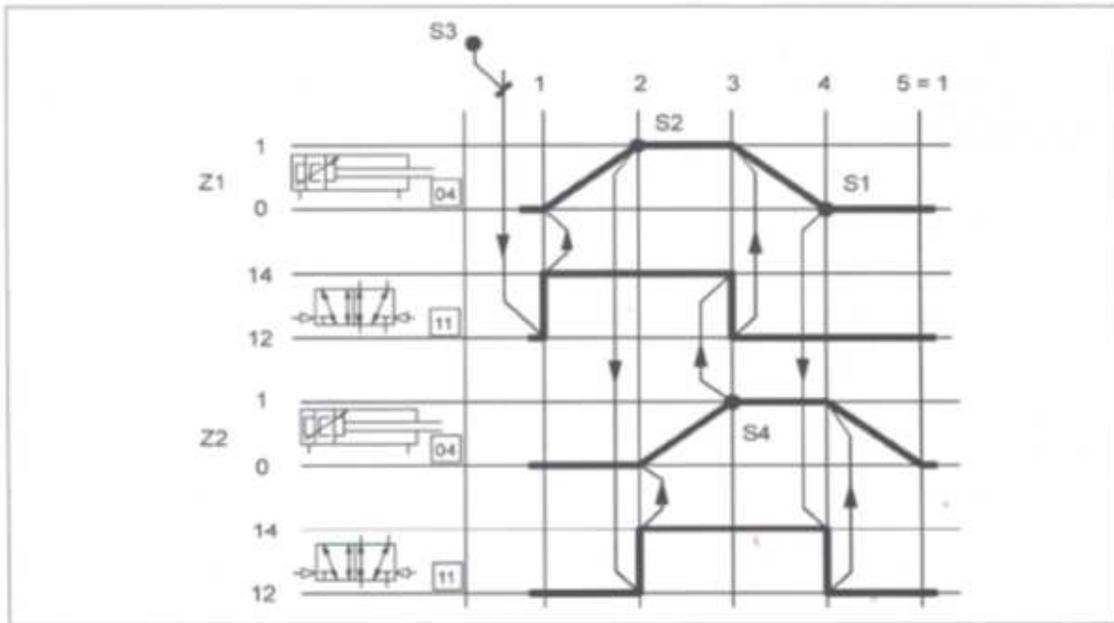
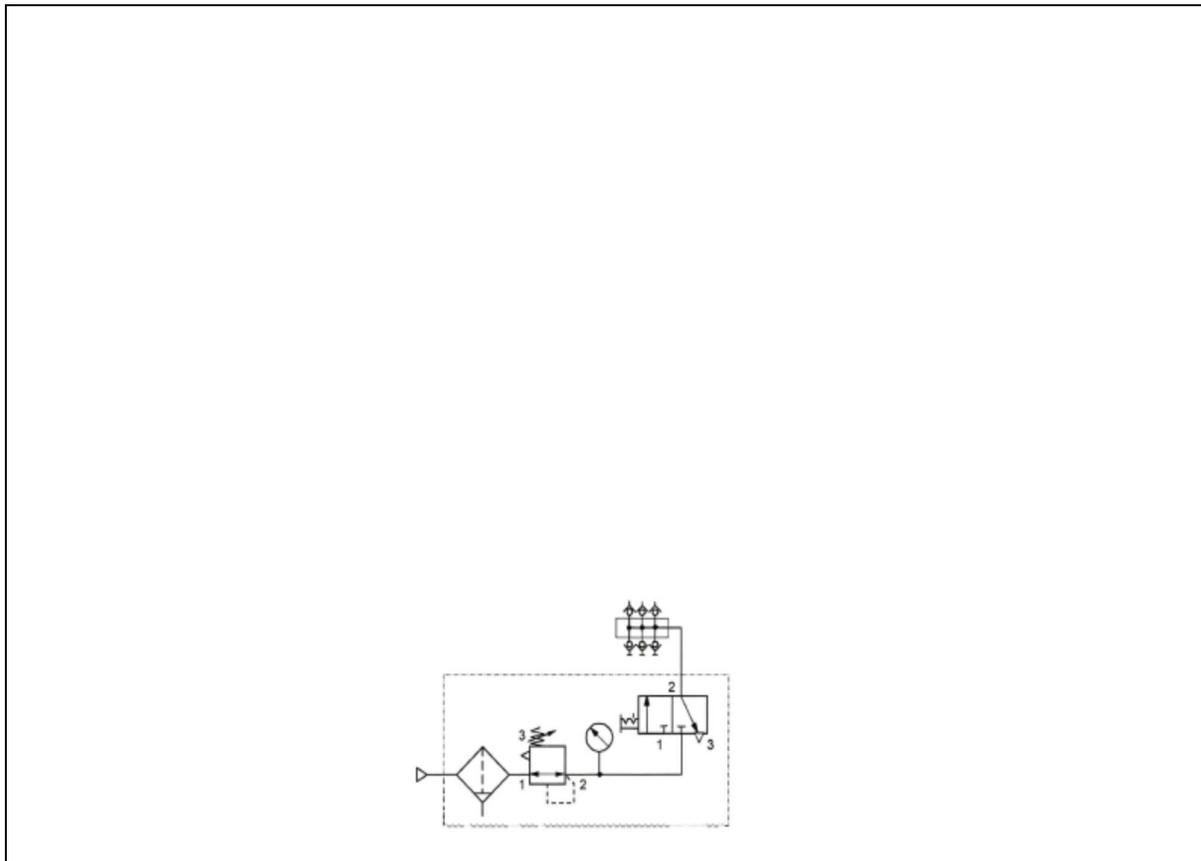


Fig.5.7 Function diagram (stroke-time diagram)

**Pneumatic circuit diagram**



## Part VI: Sequential control of a double cylinder B

### Aim:

This exercise helps to understand sequential controls and provides practical knowledge of setting up a control system with two pneumatic drives.

Upon the completion of this task, the student should be able to

- Explain the displacement step diagrams

### Problem description:

In the transfer station shown below in Fig. 5.8, the blocks are to be transferred from a magazine to a processing station. The blocks are pushed out of the magazine by cylinder 1A and transferred to the processing station by cylinder 2A. The piston rod of cylinder 1A may only return when the piston rod of cylinder 2A has reached the retracted end position.

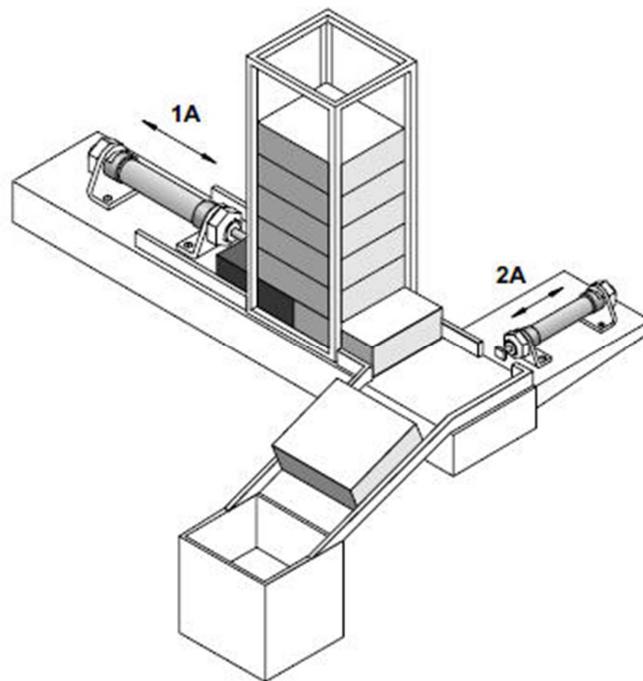
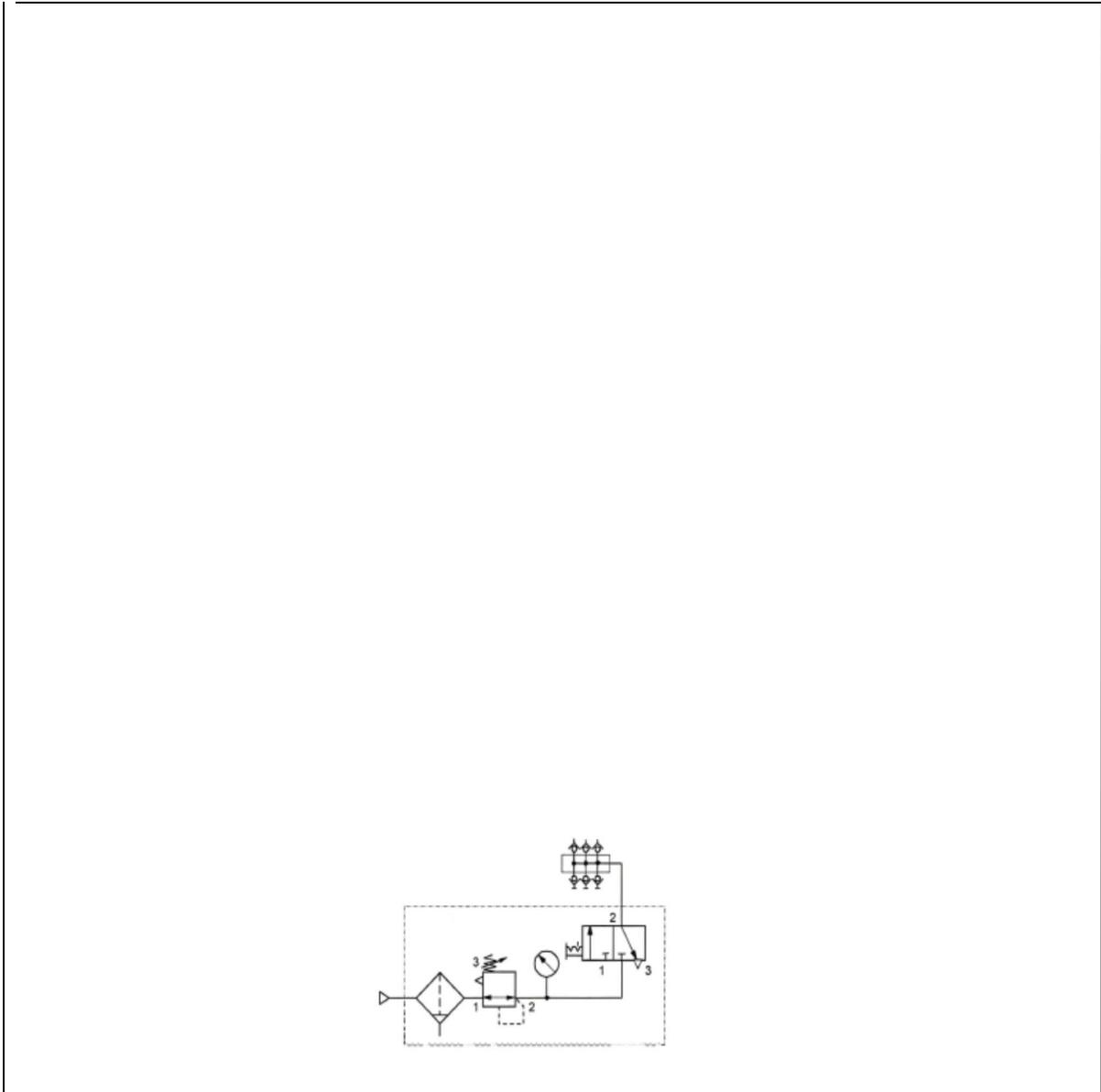
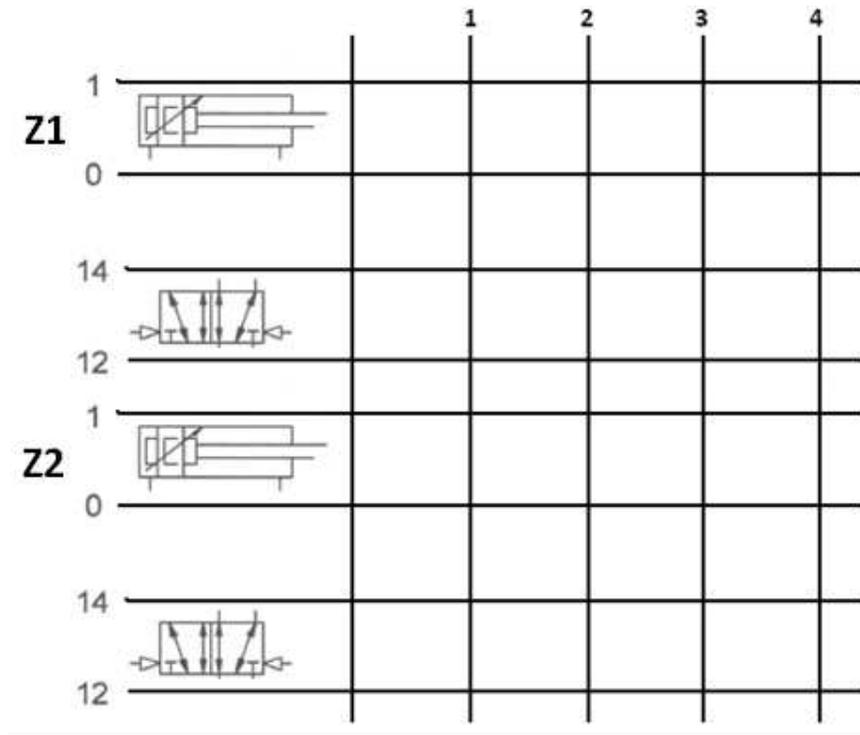


Fig.5.8



- Design the functional diagram (stroke-time diagram) for the cylinder and the 5/2 directional control valve.



**The University Of Jordan**  
**School of Engineering**  
**Mechatronics Engineering Department**  
**Fluid Power Engineering Lab**  
**Experiments No.6**  
**Electro pneumatics Sequential control of a 2 double acting cylinder**

**Objective:** This exercises helps to understand sequential controls and provides practical knowledge of setting up and commissioning a control system with two pneumatic drives.

**Pre-Lab**

⇒ **Pre-Lab:** the required pneumatic circuit diagrams using the FluidSIM; show the whole connections and components required for each circuit.

⇒ **In the lab:** Build your designs and verify their operation. sure that the pressure is 4 bars and is connected correctly. Double check your connections before switching the compressor on.

**Part I: Electro pneumatics Sequential control of 2 double acting cylinders A**

**Task:**

- Build your design ( Pneumatic circuit diagram and Electric circuit diagram ) to complete the task description in function diagram in Figure 6.1
- Note  
B1 and B2 : Electric limit switch with roller lever , to induction of position for cylinder one .  
B3 and B4 : Electric limit switch with roller lever, to induction of position for cylinder two .
- Drawing the circuit diagram with symbols and port symbols.

Note : Suppose initial position for two cylinder in retract position.

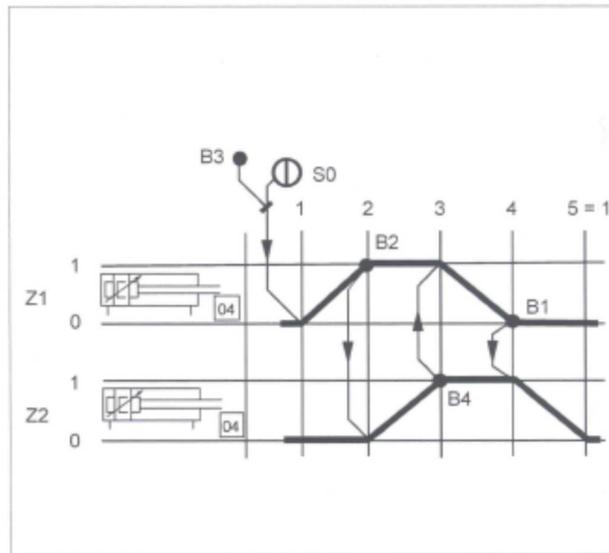
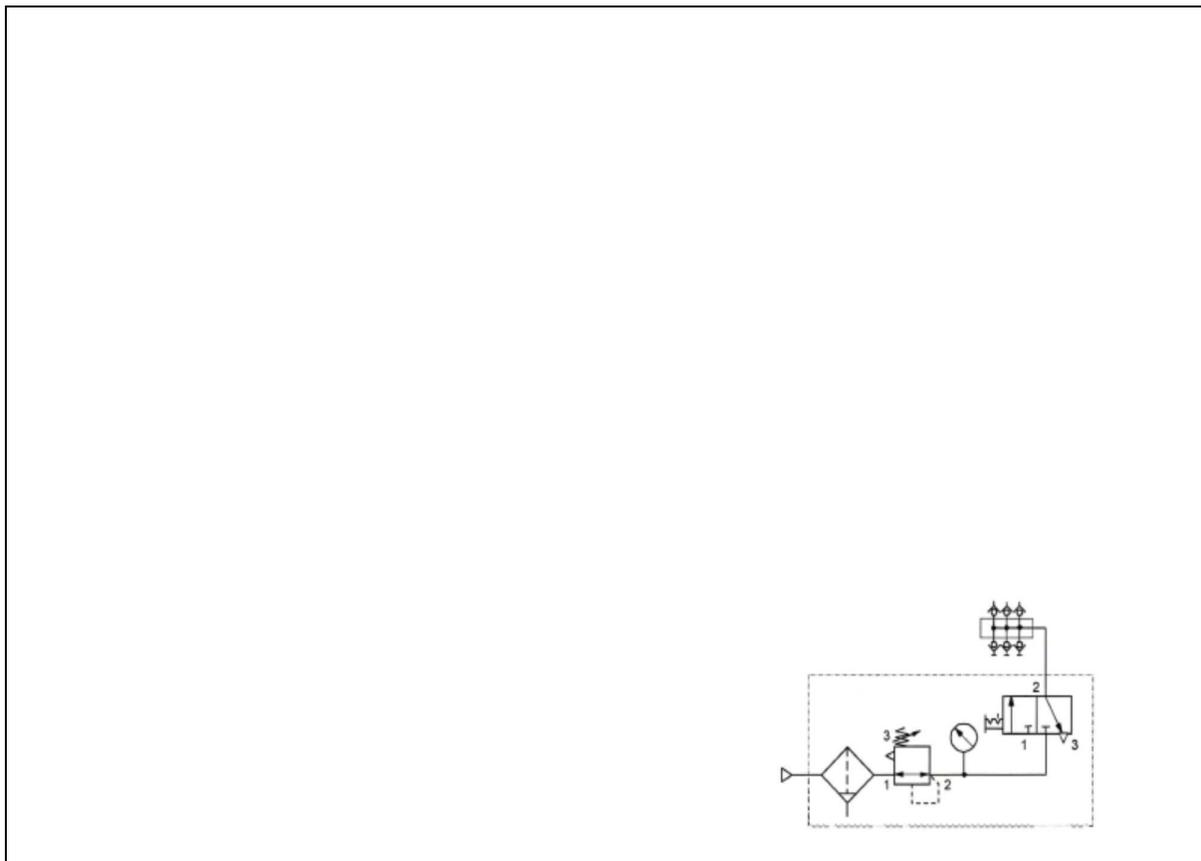


Figure 6.1: Function diagram (stroke-time diagram)

**Pneumatic circuit diagram**

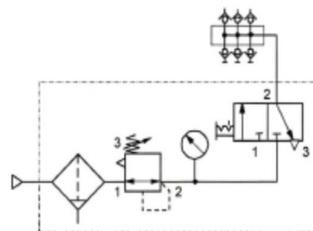




**Part III: Sequential control of 2 double acting cylinders with two spring return****Task:**

- Build your design ( Pneumatic circuit diagram and Electric circuit diagram ) to complete the task description in function diagram in Figure 6.1, **Using two 5/2 directional control electrically controlled with spring return** .
- Note  
B1 and B2 : Electric limit switch with roller lever , to induction of position for cylinder one .  
B3 and B4 : Electric limit switch with roller lever, to induction of position for cylinder two .
- Drawing the circuit diagram with symbols and port symbols.

Note : Suppose initial position for two cylinder in retract position.

**Pneumatic circuit diagram**

## Part IV: Electro pneumatics Sequential control of a double cylinder B

### Task:

- Build your design ( Pneumatic circuit diagram and Electric circuit diagram ) to complete the task description in function diagram in Figure 6.2 , **Using 5/2 directional control electrically controlled .**

- Note

B1 and B2 : Electric limit switch with roller lever, to induction of position for cylinder one .

B3 and B4 : Electric limit switch with roller lever, to induction of position for cylinder two .

- Drawing the circuit diagram with symbols and port symbols.

Note : - Suppose initial position for two cylinder in retract position.

- The working speed of both cylinders should be infinitely adjustable in both directions.

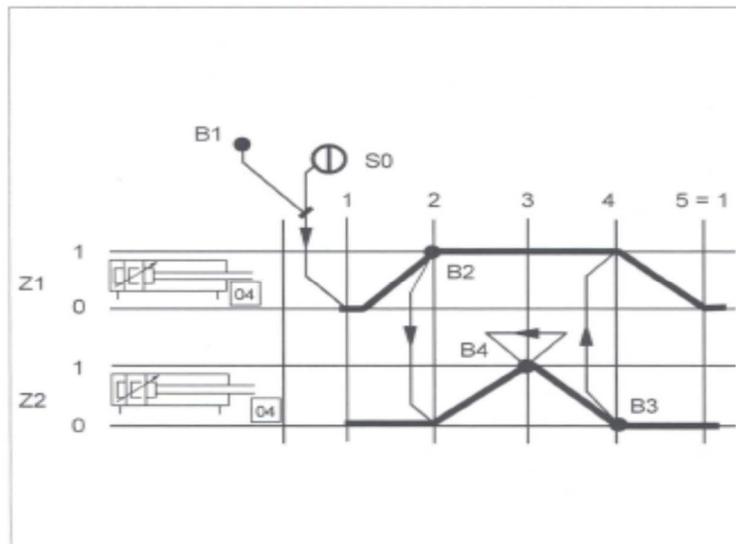
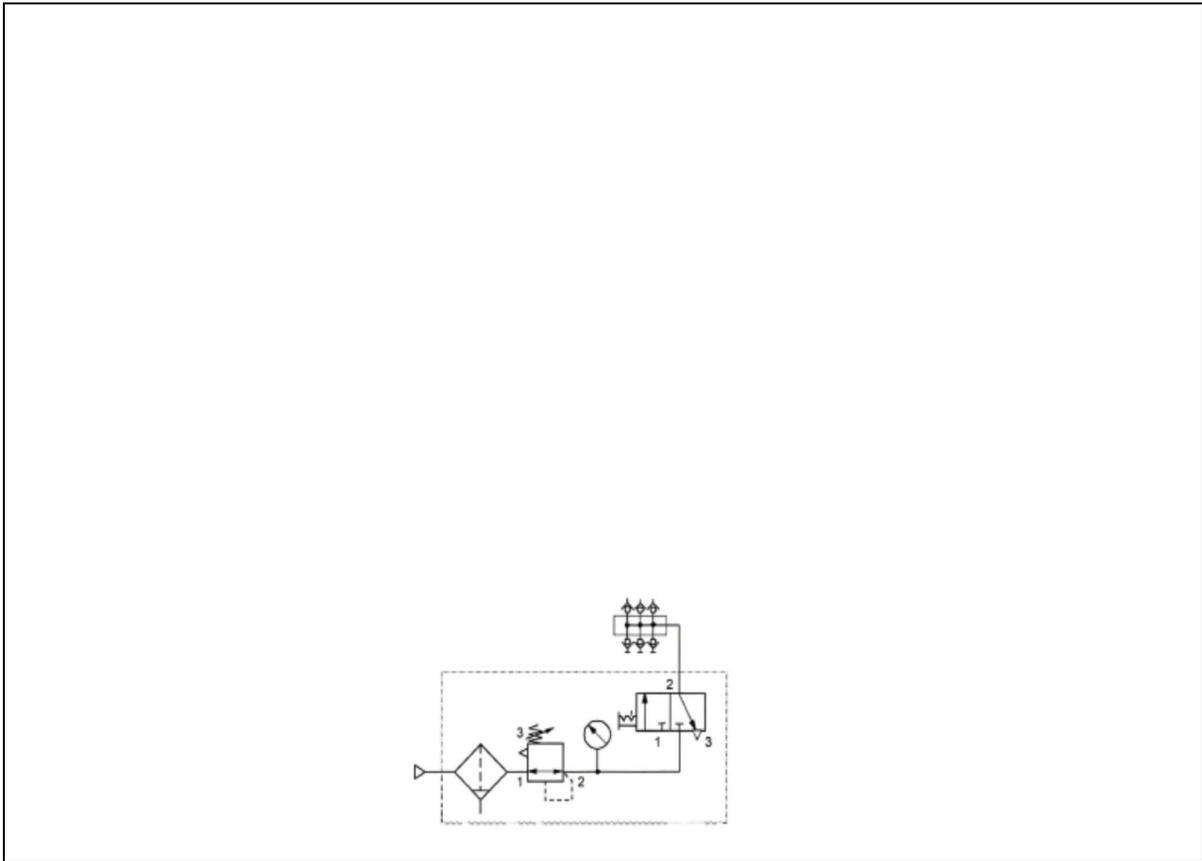


Figure 6.2: Function diagram (stroke-time diagram)

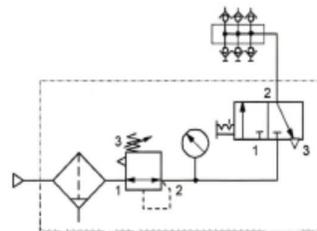
**Pneumatic circuit diagram**



**Part V: Electropneumatics Sequential control of 2 double acting cylinders with spring return valves****Task:**

- Build your design ( Pneumatic circuit diagram and Electric circuit diagram ) to complete the task description in function diagram in Figure 6.2 , **Using one 5/2 directional control electrically controlled with spring return and one double 5/2 directional control electrically controlled.**
- Note  
B1 and B2 : Electric limit switch with roller lever, to induction of position for cylinder one .  
B3 and B4 : Electric limit switch with roller lever, to induction of position for cylinder two .
- Drawing the circuit diagram with symbols and port symbols.

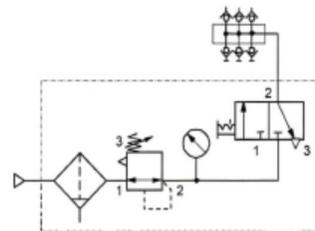
Note : - Suppose initial position for two cylinder in retract position.  
- The working speed of both cylinders should be infinitely adjustable in both directions

**Pneumatic circuit diagram**

**Part VI: Electro pneumatics Sequential control of 2 double acting cylinders with two spring return****Task:**

- Build your design ( Pneumatic circuit diagram and Electric circuit diagram ) to complete the task description in function diagram in Figure 6.2 , **Using two 5/2 directional control electrically controlled with spring .**
- Note  
B1 and B2 : Electric limit switch with roller lever, to induction of position for cylinder one .  
B3 and B4 : Electric limit switch with roller lever, to induction of position for cylinder two .
- Drawing the circuit diagram with symbols and port symbols.

Note : - Suppose initial position for two cylinder in retract position.  
- The working speed of both cylinders should be infinitely adjustable in both directions

**Pneumatic circuit diagram**

**The University Of Jordan**  
**School of Engineering & Technology**  
**Mechatronics Engineering Department**  
**Fluid Power Engineering Lab**  
**Experiments No.7**  
**Regenerative and Parallel Circuits**

**Objective:** Students will be able to describe the operation of a regenerative circuit, describe the effect of regeneration on cylinder speed and describe the effect of regeneration on cylinder force.

### Introduction

The primary purpose of regenerative circuits is to provide rapid extension speeds with a minimum pump output flow. Regeneration is accomplished by sending the oil which flows out of the rod end of a cylinder back into the cap end of this cylinder.

### Part I: Effect of regeneration on cylinder extension time

In this part of the exercise, you will determine the effect of regeneration on the extension time of a cylinder. To do so, you will measure the time required for a cylinder to extend in both regenerative and normal modes of operation. You will then compare the results obtained in each mode.

In this exercise, you learned that a regenerative circuit increases the extension speed of a cylinder. You caused a cylinder to extend more rapidly by applying equal pressures to both sides of the piston. The extension time was reduced by a factor equal to the ratio of the full piston area to the rod area,  $A_f / A_{rod}$ .

**Cylinder speed during regeneration:**

S.I Units:

$$\text{Extension speed (cm/s)} = \frac{\text{Flow rate (l/min)} \times 1000}{\text{Rod area (cm}^2\text{)} \times 60}$$

English Units:

$$\text{Extension speed (in/s)} = \frac{\text{Flow rate (gal/min)} \times 231}{\text{Rod area (in}^2\text{)} \times 60}$$

The formula for calculating the amount of time required for a cylinder in regeneration to complete its stroke is the formula for extension speed divided into the stroke length.  
The formula is as follows:

S.I Units:

$$\text{Extension time (s)} = \frac{\text{Rod area (cm}^2) \times 60 \times \text{Stroke length (cm)}}{\text{Flow rate(l/min)} \times 1000}$$

English Units:

$$\text{Extension time (s)} = \frac{\text{Rod area (in}^2) \times 60 \times \text{Stroke length (in)}}{\text{Flow rate(gal/min)} \times 231}$$

- Connect the circuit shown in Figure 1. In this circuit, the Flow Control Valve will be used to reduce the flow into the circuit so the cylinder speed is easier to time.

Note: Do not connect the Loading Device to the cylinder yet. The Loading Device will be used later in the exercise.

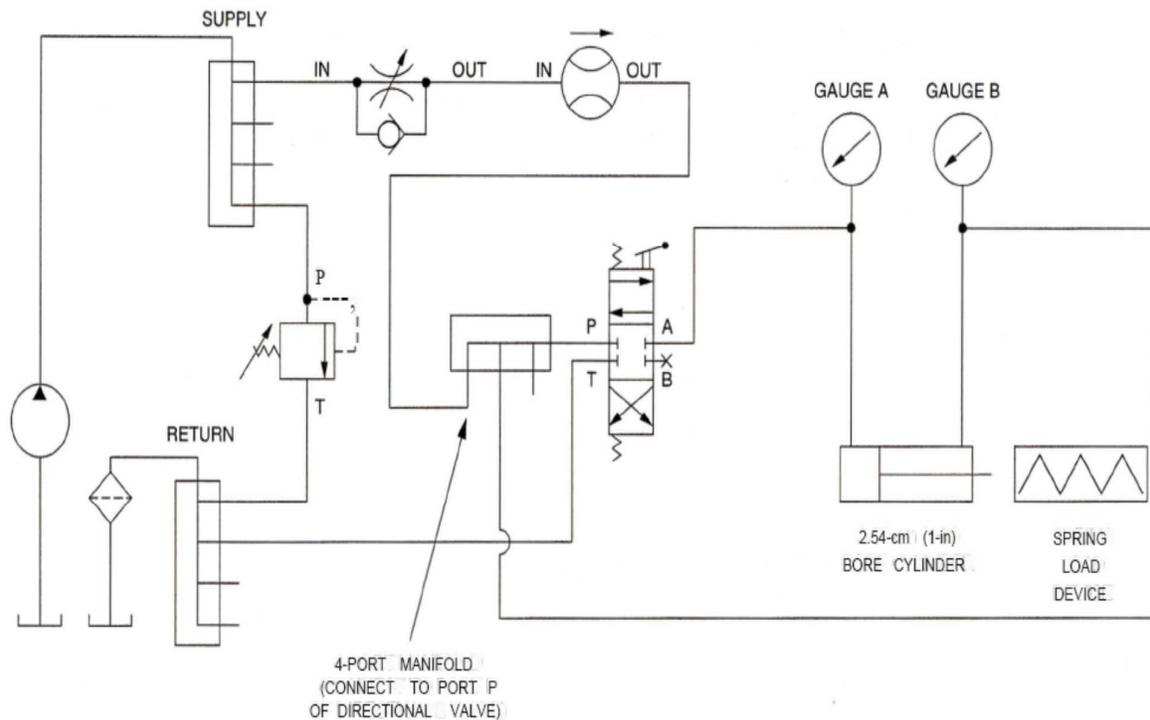


Fig.1 Cylinder in a regenerative circuit.

- Before starting the power unit, perform the following start-up procedure.
  - a. Make sure the hoses are firmly connected.
  - b. Check the level of the oil in the reservoir. Add oil if required.
  - c. Put on safety glasses.
  - d. Make sure the power switch on the Power Unit is set to the OFF position.
  - e. Plug the Power Unit line cord into an ac outlet.
  - f. Open the Relief Valve completely (turn knob fully counterclockwise).
- Open the flow control valve completely (turn knob fully counterclockwise ).
- Turn on the power Unit.
- With the directional valve lever in the center position, the pump flow is blocked at the rod end of the cylinder, and gauge B indicates the Relief Valve pressure setting. Turn the Relief Valve adjustment knob clockwise until the circuit pressure at gauge B is 2100 kPa (300 psi).
- Move the lever of the directional valve toward the valve body to extend the cylinder and adjust the Flow Control Valve so that the Flowmeter reads 1.5 l/min [0.4 gal(US)/min] during cylinder extension, then retract the cylinder. Accurate adjustment may require that the cylinder be extended and retracted several times.
- Extend the cylinder and note the extension time and the pressure readings at gauges A and B as the cylinder extends. Record these in the "Regenerative" row of Table 1.

Circuit Condition	Extension Time	Extension Pressures	
		Gauge A	Gauge B
Regenerative			
Normal			

Table 1. Cylinder data in regenerative and normal modes

- Retract the cylinder.
- Turn on the power unit. Open The relief valve completely (turn knob fully counterclockwise).
- Change your regenerative circuit into a normal (non-regenerative) circuit. To do so, disconnect the rod end of the cylinder from the 4-port manifold installed on port P of the directional valve, then connect the rod end to port B of the directional valve, as Figure 2 shows.

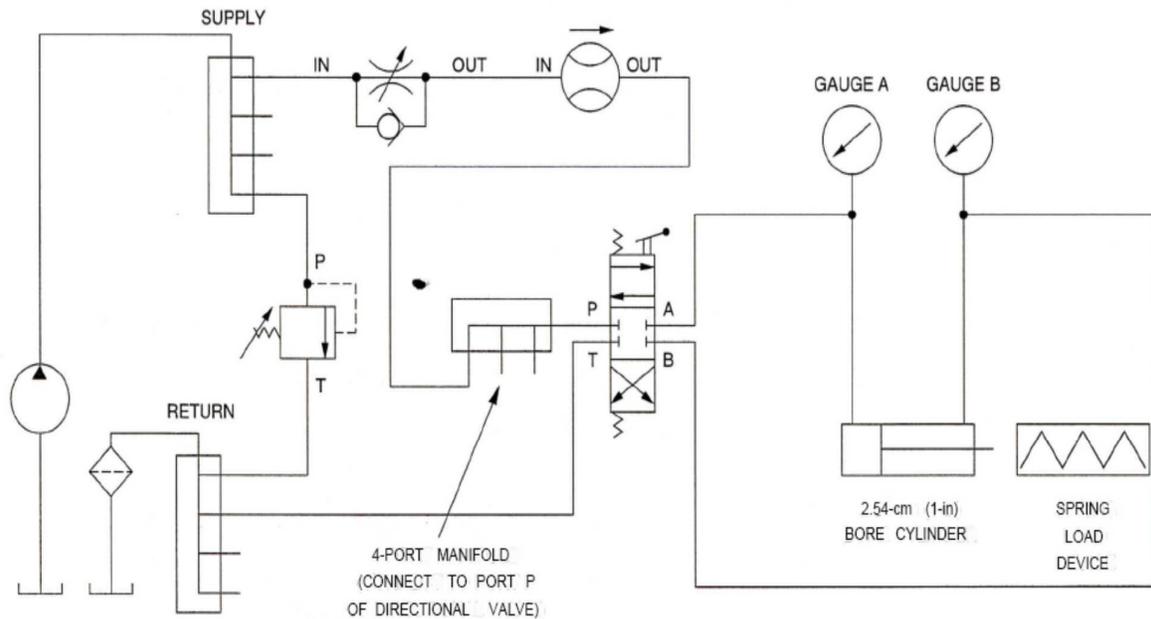


Fig.2 Cylinder in a normal (non regenerative circuit).

Note: Do not connect the Loading Device to the cylinder yet. The Loading Device will be used later in the exercise.

- Turn on the Power Unit.
- Move the lever of the directional valve toward the valve body to extend the cylinder fully. While keeping the valve lever shifted, turn the Relief Valve adjustment knob clockwise until the circuit pressure at gauge A is 21 00 kPa (300 psi). Retract the cylinder by moving the lever of the directional valve outward from the valve body.
- Turn Move the lever of the directional valve toward the valve body to extend the cylinder and adjust the Flow Control Valve so that the Flowmeter reads 1.5 l/min [0.4 gal(US)/min] during cylinder extension, then retract the cylinder. Accurate adjustment may require that the cylinder be extended and retracted several times.
- Extend the cylinder and note the extension time and the pressure readings at gauges A and B as the cylinder extends. Record these in the "Normal" row of Table 1.
- Retract the cylinder.
- Turn off the power unit. Open The relief valve completely (turn knob fully counterclockwise).

- According to Table 3-8, is the extension time observed in regenerative mode shorter than that observed in normal mode? Why?

---

---

---

- Calculate the theoretical extension time of the 2.54-cm (1-in) bore x 1.59-cm (0.625-in) rod x 10.16-cm (4-in) stroke cylinder in regeneration when the flow rate is 1.51/min [0.4 gal(US)/min]. Then, compare your result with the actual extension time recorded in Table 1. Are these values approximately equal?

---

---

---

## Part II: Effect of regeneration on cylinder force output

In the second part of the exercise, you will determine the effect of regeneration on the force output of a cylinder. To do so, you will measure the force output of a cylinder in both regenerative and normal modes of operation. You will then compare the results obtained in each mode.

### **Cylinder force during regeneration:**

the force generated by the cylinder during extension is equal to the circuit pressure multiplied by the rod area.

In equation form:

S.I Units:

$$\text{Force (N)} = \text{Pressure (kPa)} \times \text{Rod area (cm}^2\text{)}$$

English Units:

$$\text{Force (lb)} = \text{Pressure (psi)} \times \text{Rod area (in}^2\text{)}$$

- Change your circuit into a regenerative circuit. To do so, disconnect the rod end of the cylinder from port B of the directional valve, then connect the rod end to the 4-port manifold installed on port P of the directional valve, as shown in Figure 1.
- Disconnect the 2.54-cm (1-in) bore cylinder from the circuit. Remove the cylinder from its adapter by unscrewing its retaining ring. Make sure the cylinder tip (bullet) is removed from the cylinder rod end. Screw the cylinder into the Loading Device. Then, reconnect the cylinder into the circuit as shown in-Figure 1.
- Clip the NEWTON/LBF-graduated ruler to the Loading Device, and align the "0" mark with the colored line on the load piston.
- Open the flow control valve completely (turn knob fully counterclockwise).
- Turn on the power unit.
- Move the lever of the directional valve toward the valve body and turn the Relief Valve adjustment knob clockwise until the circuit pressure at gauge A is 4200 kPa (600 psi), then turn the knob counterclockwise to decrease the circuit pressure until gauge A reads 3500 kPa (500 psi). Release the valve lever.
- Note and record the force reading on the Loading Device in the "Regenerative" row of Table 2.

Circuit Condition	Cylinder force output
Regenerative	
Normal	

Table 2. Effect of regeneration on cylinder force.

- Retract the cylinder, then turn off the Power Unit. Open the Relief Valve completely (turn knob fully counterclockwise).
- Change your regenerative circuit into a normal circuit. To do so, disconnect the rod end of the cylinder from the 4-port manifold installed on port P of the directional valve, then connect the rod end to port B of the directional valve, as shown in Figure 2.
- Turn on the power unit.
- Move the lever of the directional valve toward the valve body and turn the Relief Valve adjustment knob clockwise until the circuit pressure at gauge A is 4200 kPa (600 psi), then turn the knob counterclockwise to decrease the circuit pressure until gauge A reads 3500 kPa (500 psi). Release the valve lever .
- Note and record the force reading on the Loading Device in the "Normal" row of Table 2.
- Retract the cylinder, then turn off the Power Unit. Open the Relief Valve completely (turn knob fully counterclockwise).
- According to Table 2, is the force observed in regeneration mode reduced from that observed in normal mode? Explain why.

---

---

---

---

- Calculate the theoretical force output of the 2.54-cm (1-in) bore x 1.59-cm (0.625-in) rod x 10.16-cm (4-in) stroke cylinder in regeneration. Then, compare your result with the actual force output recorded in Table 2. Are these values approximately equal?

---

---

---

---

- Disconnect the Power Unit line cord from the wall outlet, then disconnect all hoses. Wipe off any hydraulic oil residue.
- Remove all components from the work surface and wipe off any hydraulic oil residue. Return all components to their storage location.
- Clean up any hydraulic oil from the floor and from the trainer. Properly dispose of any paper towels and rags used to clean up oil.

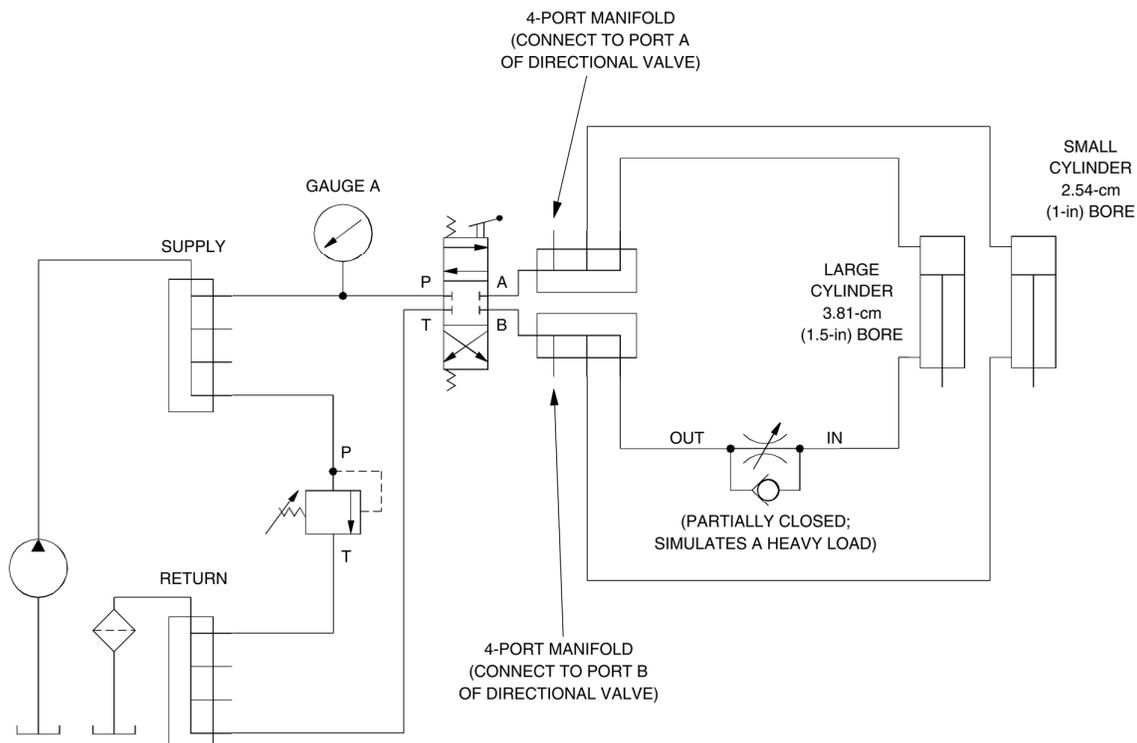
## Part III: Cylinders in Parallel

### EXERCISE OBJECTIVE

- To describe the operation of a parallel circuit;
- To describe the extension sequence of parallel cylinders having differing bore sizes;
- To synchronize the extension of parallel cylinders using a flow control valve.

### PROCEDURE

- Connect the circuit shown in Fig. 3.



**Fig.3. Cylinders in parallel with a heavy load on the large cylinder**

- Examine the circuit in Fig.3. The cylinders are in parallel with each other. The Flow Control Valve acts as a loading device on the large cylinder [3.81-cm (1.5-in) bore] only, so the cylinders are unevenly loaded. The Flow Control Valve is partially closed to simulate a heavy load on the large cylinder.

When the directional valve is shifted to extend the cylinders, the oil from the pump is directed to the cap side of both cylinders at the same time. The large cylinder must counteract the high resistance offered by the Flow Control Valve before it can extend. The small cylinder [2.54-cm (1-in) bore] must counteract the resistance of the oil flowing back to the reservoir before it can extend. The cylinder requiring the lowest pressure to move will extend first.

Predict which cylinder will extend first when the Flow Control Valve is partially closed to simulate a heavy load on the large cylinder, and explain why.

- 
- 
- 
- Before starting the Power Unit, perform the following start-up procedure:
    - a. Make sure the hoses are firmly connected.
    - b. Check the level of the oil in the reservoir. Add oil if required.
    - c. Put on safety glasses.
    - d. Make sure the power switch on the Power Unit is set to the OFF
    - e. position.
    - f. Plug the Power Unit line cord into an ac outlet.
    - g. Open the Relief Valve completely (turn knob fully counterclockwise).
  
  - Close the Flow Control Valve completely (turn knob fully clockwise), then open it ½ turn.
  
  - Turn on the Power Unit.
  
  - Turn the relief valve adjustment knob clockwise until the circuit pressure at gauge A is 2100 kPa (300 psi).
  
  - Move the lever of the directional valve toward the valve body to extend the two cylinders and observe them as they extend. Which cylinder extended first? Why?  

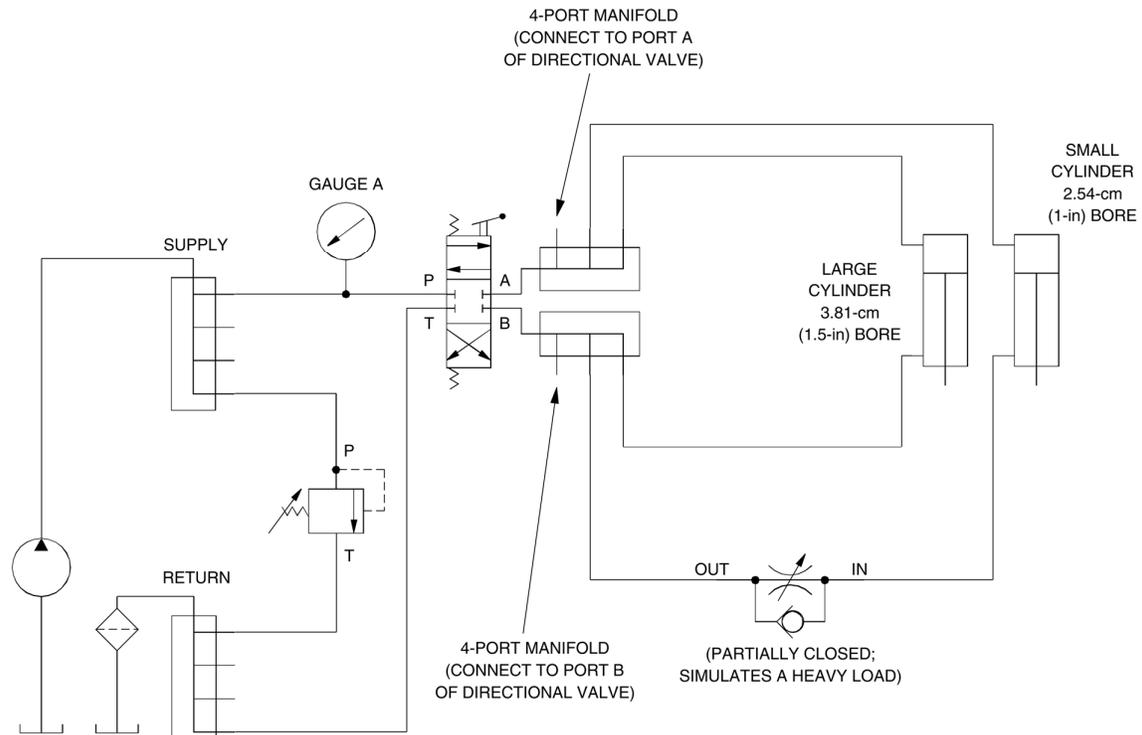
---

---

---
  
  - Retract the cylinders.
  
  - Turn off the Power Unit. Open the Relief Valve completely (turn knob fully counterclockwise).

**Part IV: Cylinder synchronization using a Flow Control Valve**

- Modify your circuit connections in order to place the loading device (Flow Control Valve) on the small cylinder [2.54-cm (1-in) bore], as Fig.4. shows.



**Fig.4. Cylinders in parallel with a heavy load on the small cylinder.**

- Predict which cylinder will extend first when the Flow Control Valve is partially closed to simulate a heavy load on the small cylinder.
- Close the Flow Control Valve completely (turn knob fully clockwise), then open it ¼ turn.
- Turn on the Power Unit.
- Turn the Relief Valve adjustment knob clockwise until the circuit pressure at gauge A is 2100 kPa (300 psi).
- Move the lever of the directional valve toward the valve body to extend the two cylinders and observe them as they extend. Which cylinder extended first? Why?

---



---



---

- Retract the cylinders.
- Adjust the setting of the Flow Control Valve so that both cylinders complete their full stroke at the same time during extension. Accurate adjustment may require that the cylinders be extended and retracted several times.
- Extend and retract the cylinders several times with the new Flow Control Valve setting. Do the cylinders remain synchronized?

Yes       No

- Let the system run for about 15 minutes. Do not modify the Flow Control Valve setting.
- Extend and retract the cylinders several times. Did the cylinders stay in synchronization?

Yes       No

- Does the Flow Control Valve have to be readjusted when the cylinders are operated over an extended period of time? Explain why

---

---

---

- Try to adjust the Flow Control Valve so that the small cylinder completes its extension approximately 2 seconds after the large cylinder completes its extension. Can the extension sequence of the cylinders be controlled in a parallel circuit? Explain.

---

---

---

- Make sure the cylinders are fully retracted, then turn off the Power Unit. Open the Relief Valve completely (turn knob fully counterclockwise).

- Disconnect the Power Unit line cord from the wall outlet, then disconnect all hoses. Wipe off any hydraulic oil residue.

- Remove all components from the work surface and wipe off any hydraulic oil residue. Return all components to their storage location.

- Clean up any hydraulic oil from the floor and from the trainer. Properly dispose of any paper towels and rags used to clean up oil.

**The University Of Jordan  
School of Engineering  
Mechatronics Engineering Department  
Fluid Power Engineering Lab  
Experiments No.7  
Regenerative Circuits**

**In class Lab Report**

Date: \_\_\_\_\_

Section: \_\_\_\_\_

Group's Names:

- 1-
- 2-
- 3-
- 4-
- 5-

**Part one: Effect of regeneration on cylinder extension time**

Q1: What is the regenerative circuit?

Q2: Would a cylinder extend more rapidly in a normal circuit or a regenerative circuit?

---

**Part two: Effect of regeneration on cylinder force output**

Q1: Would a cylinder generate more force in a normal circuit or in a regenerative circuit?

Q2: What happens to the extension speed and force generated in a regenerative circuit when the piston rod diameter is decreased?

Q3: By which amount is the cylinder force output reduced in a regenerative circuit giving double the normal extension speed?

**The University Of Jordan**  
**School of Engineering**  
**Mechatronics Engineering Department**  
**Fluid Power Engineering Lab**  
**Experiments No.8**  
**Pneumatic sequential control of a 3 double acting cylinder**

**Objective:** This exercises helps to understand sequential controls and provides Practical knowledge of setting up and commissioning a control system with two pneumatic drives.

**Pre-Lab**

⇒ **Pre-Lab:** the required pneumatic circuit diagrams using the FlwidSIM; show the whole connections and components required for each circuit.

⇒ **In the lab:** Build your designs and verify their operation. sure that the pressure is 4 Bars and is connected correctly. Double check your connections before Switching the compressor on.

**Part I: Sequential control of a two double cylinders**

Build your design Pneumatic circuit diagram to complete the task description in function diagram in Figure 8.1 ( A and B are double acting cylinders )

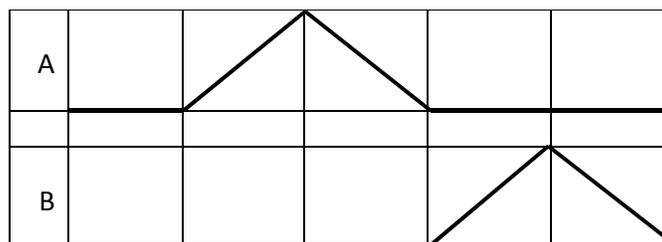
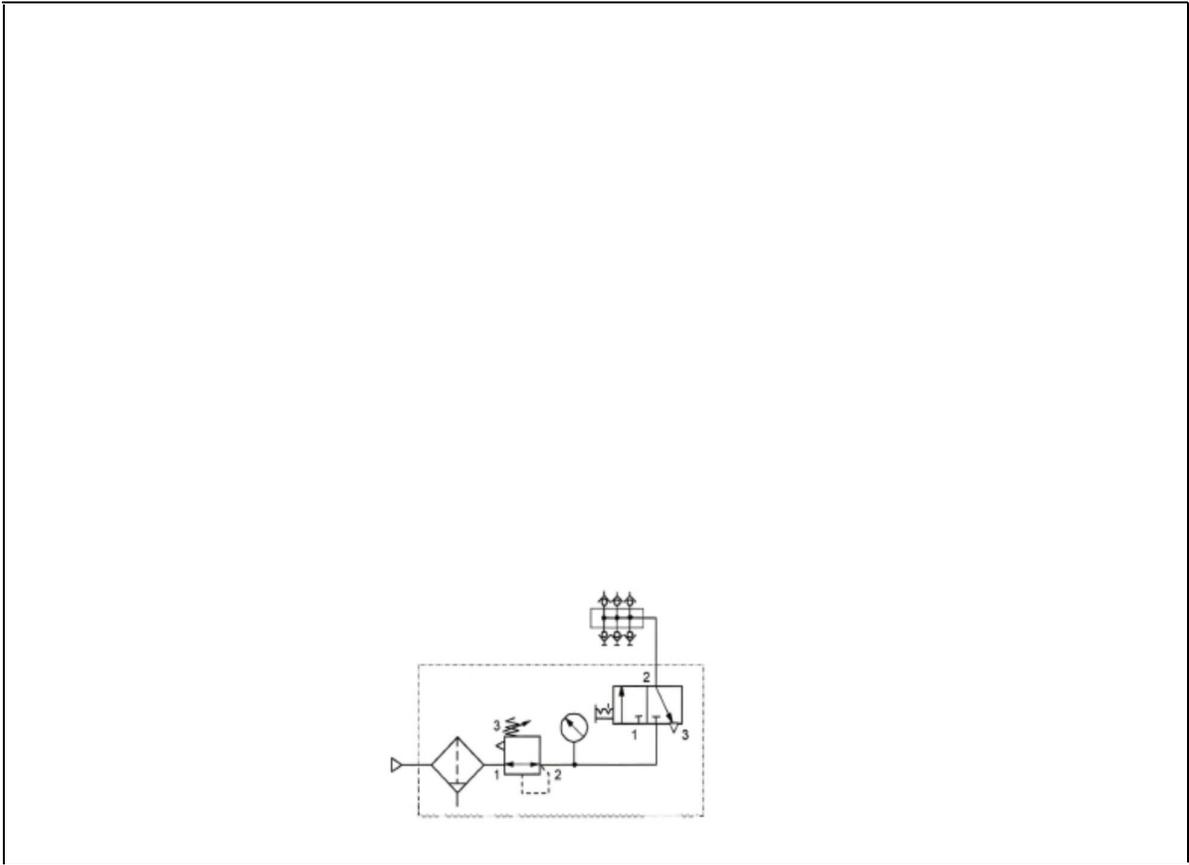


Fig. 8.1 Positional sketch

**Requirements:**

1. Draw pneumatic circuit diagram using the space provided below.
2. Simulate the circuit using FluidSIM software.
3. Assemble the circuit practically and check its operation.

**Pneumatic circuit diagram****Part II: Sequential control of a three double acting cylinder 1**

Build your design Pneumatic circuit diagram to complete the task description in function diagram in Figure 8.2 ( A , B and C are double acting cylinders )

**Requirements:**

4. Draw pneumatic circuit diagram using the space provided below.
5. Simulate the circuit using FluidSIM software.
6. Assemble the circuit practically and check its operation.

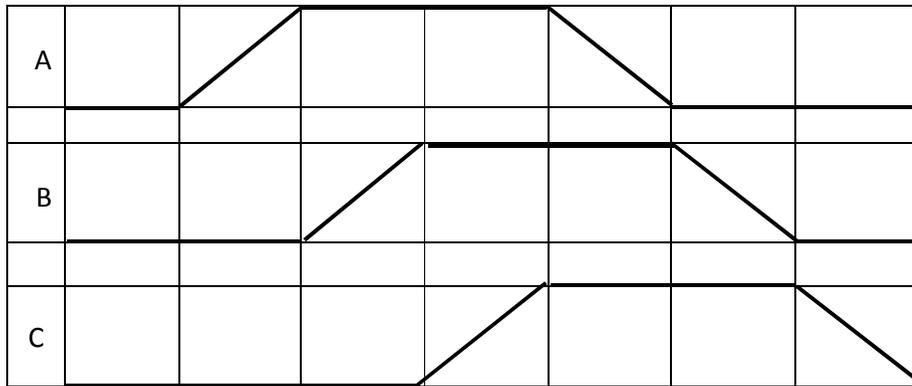
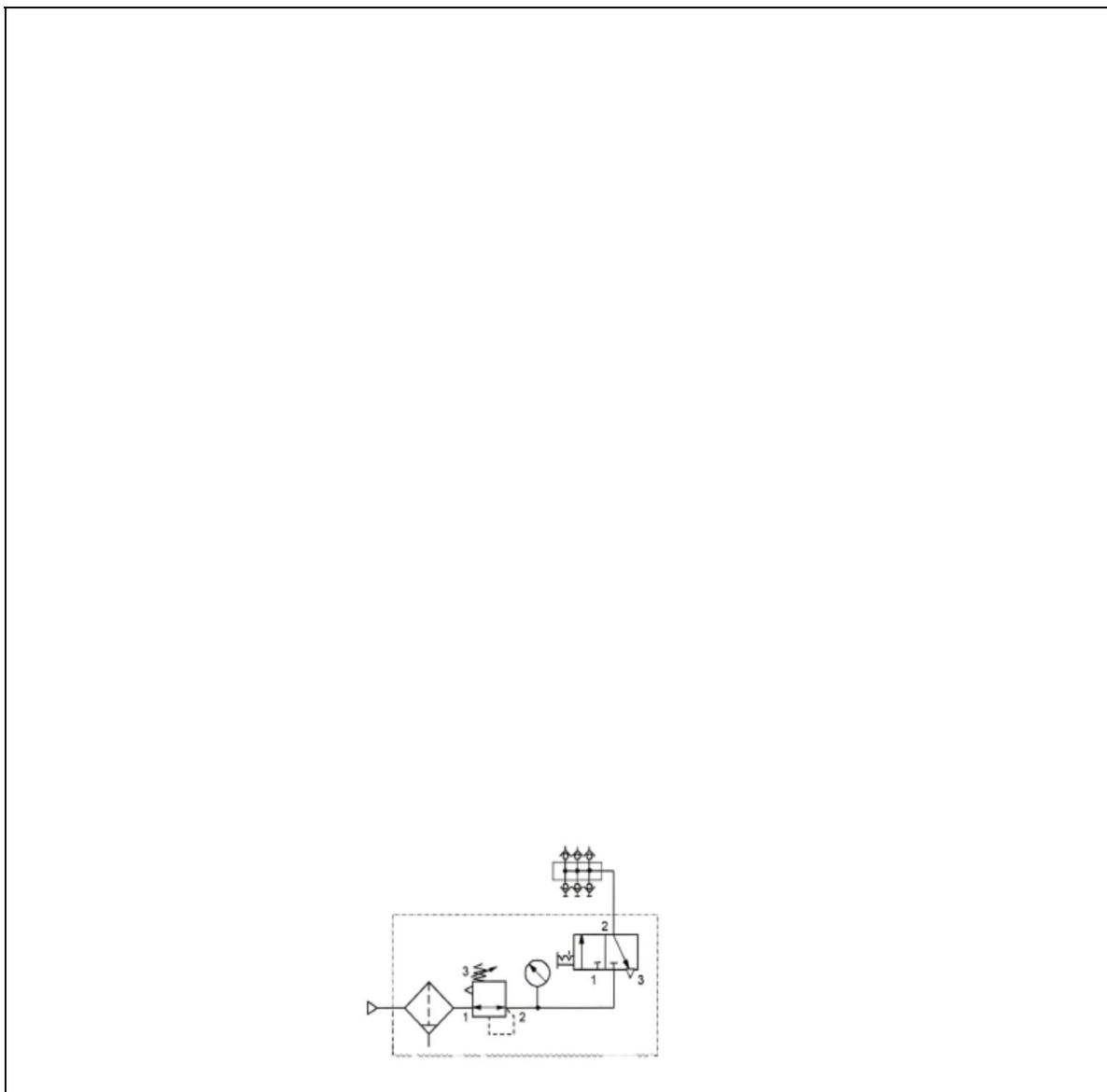


Fig. 8.2

Positional sketch



**Part III: Sequential control of a three double acting cylinder 2**

Build your design Pneumatic circuit diagram to complete the task description in function diagram in Figure 8.2 ( A , B and C are double acting cylinders )

**Requirements:**

1. Draw pneumatic circuit diagram using the space provided below.
2. Simulate the circuit using FluidSIM software.
3. Assemble the circuit practically and check its operation.

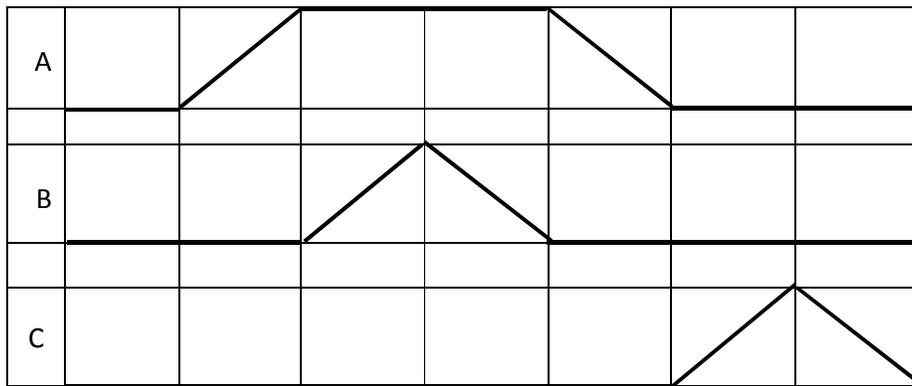
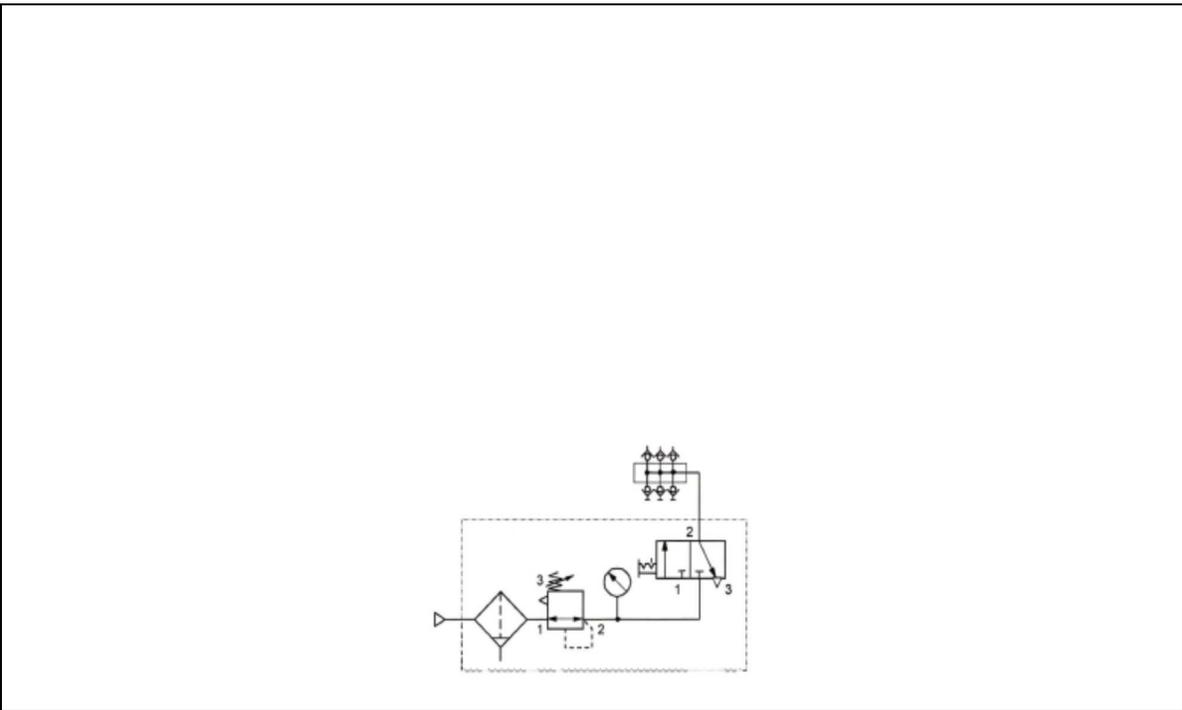


Fig. 8.3 Positional sketch



**Part IV: Sequential control of a three double acting cylinder 3**

Build your design Pneumatic circuit diagram to complete the task description in function diagram in Figure 8.2 ( A , B and C are double acting cylinders )

**Requirements:**

1. Draw pneumatic circuit diagram using the space provided below.
2. Simulate the circuit using FluidSIM software.
3. Assemble the circuit practically and check its operation.

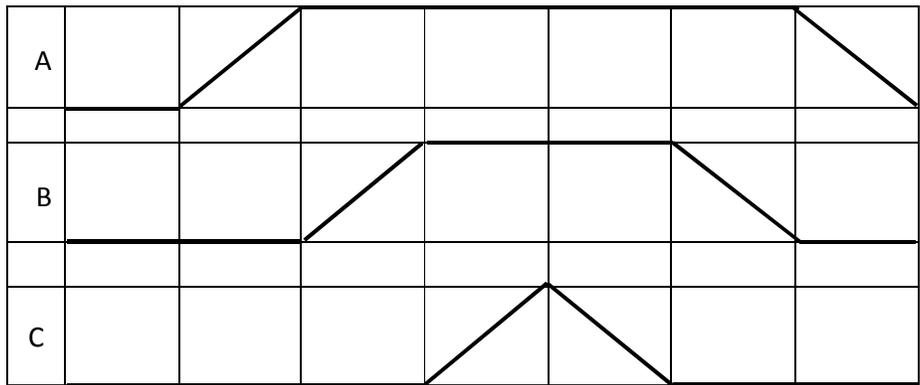
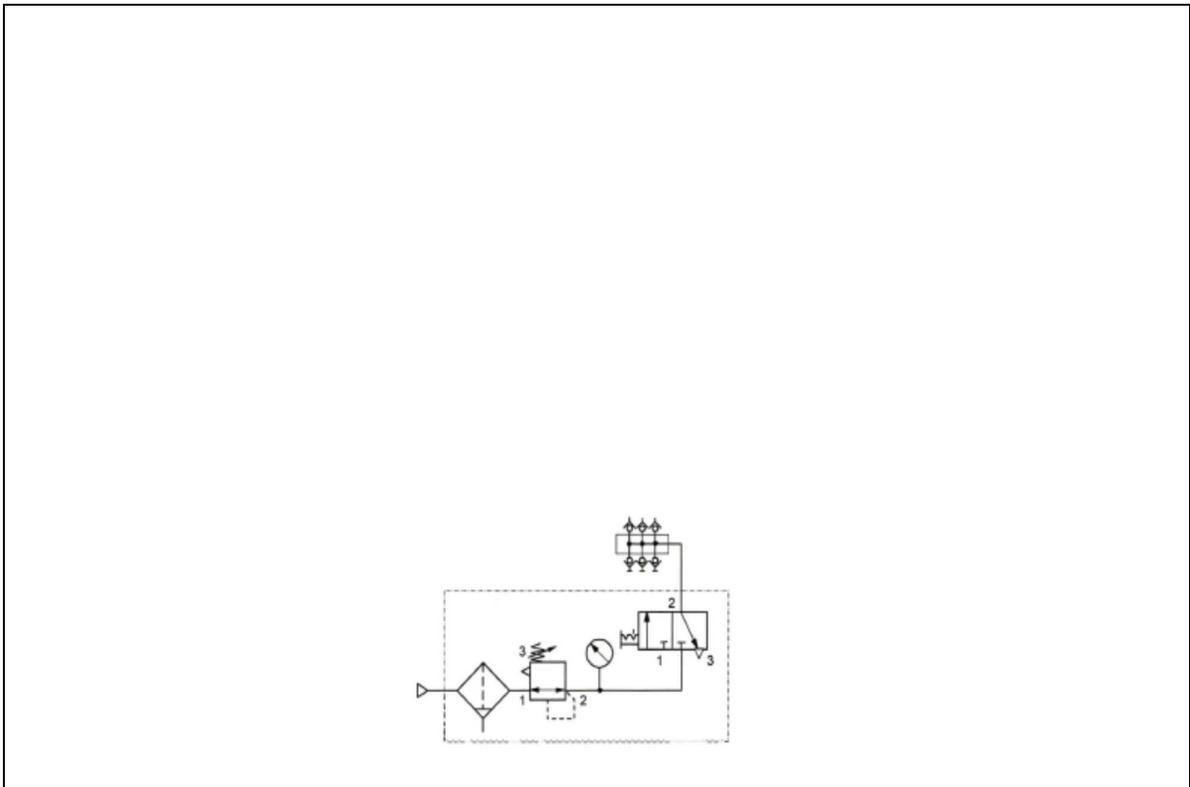


Fig. 8.4 Positional sketch



**The University Of Jordan**  
**School of Engineering**  
**Mechatronics Engineering Department**  
**Fluid Power Engineering Lab**  
**Experiments No.9**  
**Electro pneumatic sequential control of a 3 double acting cylinder**

**Objective:** This exercises helps to understand sequential controls and provides Practical knowledge of setting up and commissioning a control system with two pneumatic drives.

**Pre-Lab**

- ⇒ **Pre-Lab:** the required pneumatic circuit diagrams using the FlwidSIM; show the whole connections and components required for each circuit.
- ⇒ **In the lab:** Build your designs and verify their operation. sure that the pressure is 4 Bars and is connected correctly. Double check your connections before Switching the compressor on.

**Part I: Sequential control of a two double cylinders**

- Build your design Electro Pneumatic circuit diagram to complete the task description in function diagram in Figure 9.1, Using two double 5/2 directional control electrically controlled, ( A and B are double acting cylinders )

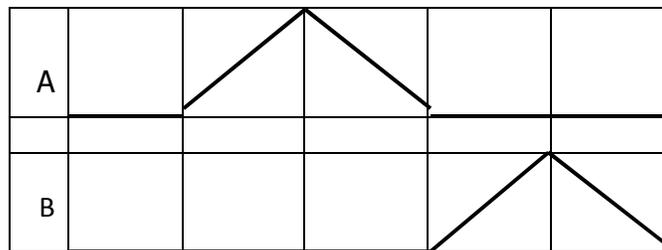


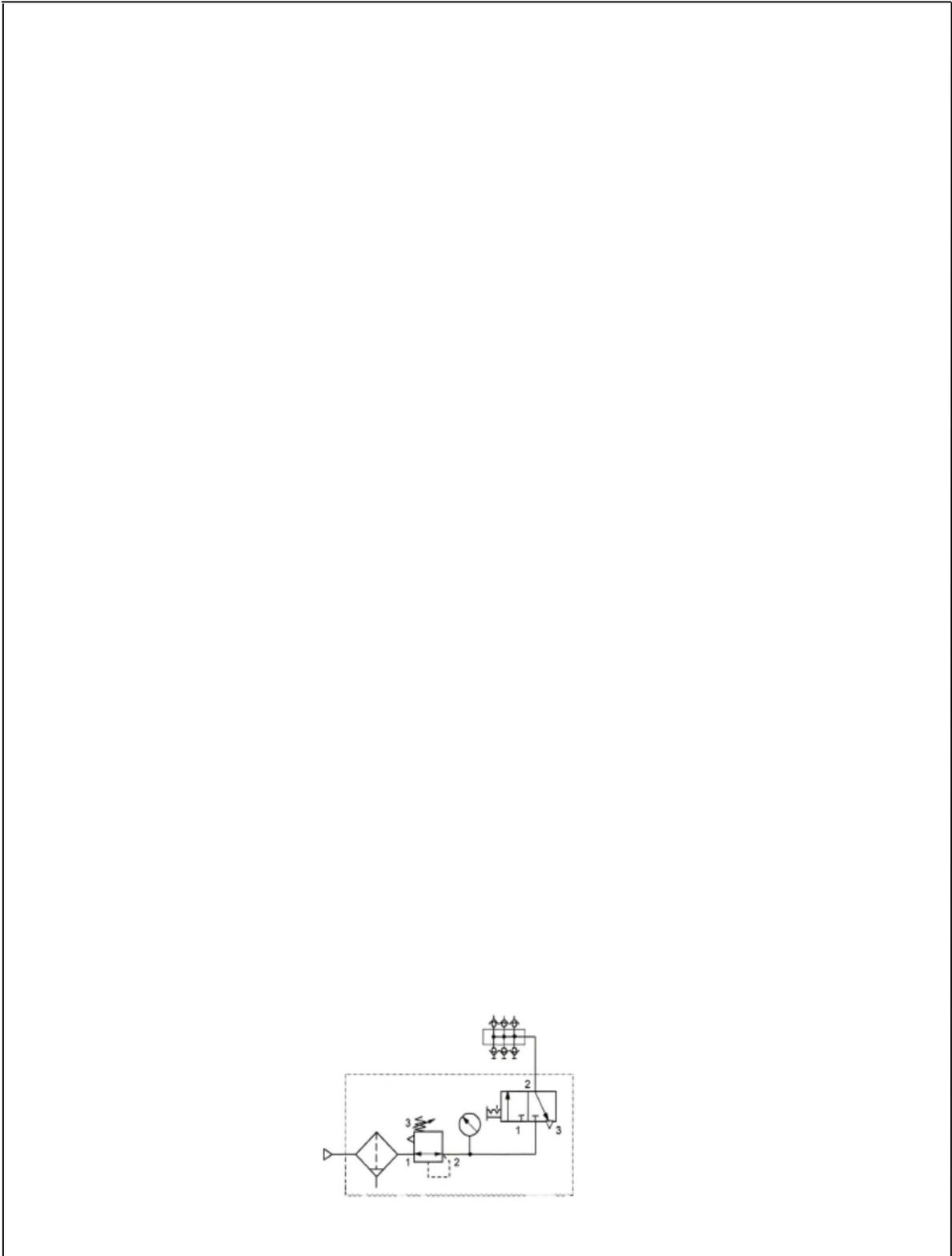
Fig. 9.1 Positional sketch

**Note : allow to use maximum two relays.**

**Requirements:**

4. Draw Electro pneumatic circuit diagram using the space provided below.
5. Simulate the circuit using FluidSIM software.
6. Assemble the circuit practically and check its operation.

**Electro Pneumatic circuit diagram**



**Part II: Sequential control of a three double acting cylinder 1**

Build your design Electro Pneumatic circuit diagram to complete the task description in function diagram in Figure 9.2 ( A , B and C are double acting cylinders )

**Note : not allow to use any relays.**

**Requirements:**

7. Draw Electro pneumatic circuit diagram using the space provided below.
8. Simulate the circuit using FluidSIM software.
9. Assemble the circuit practically and check its operation.

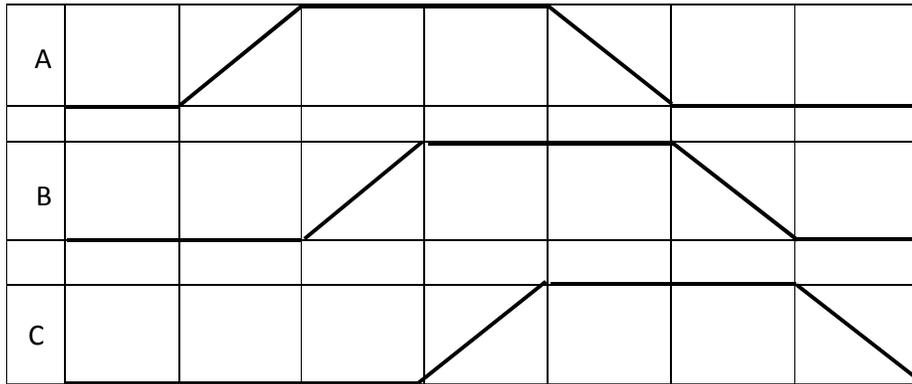
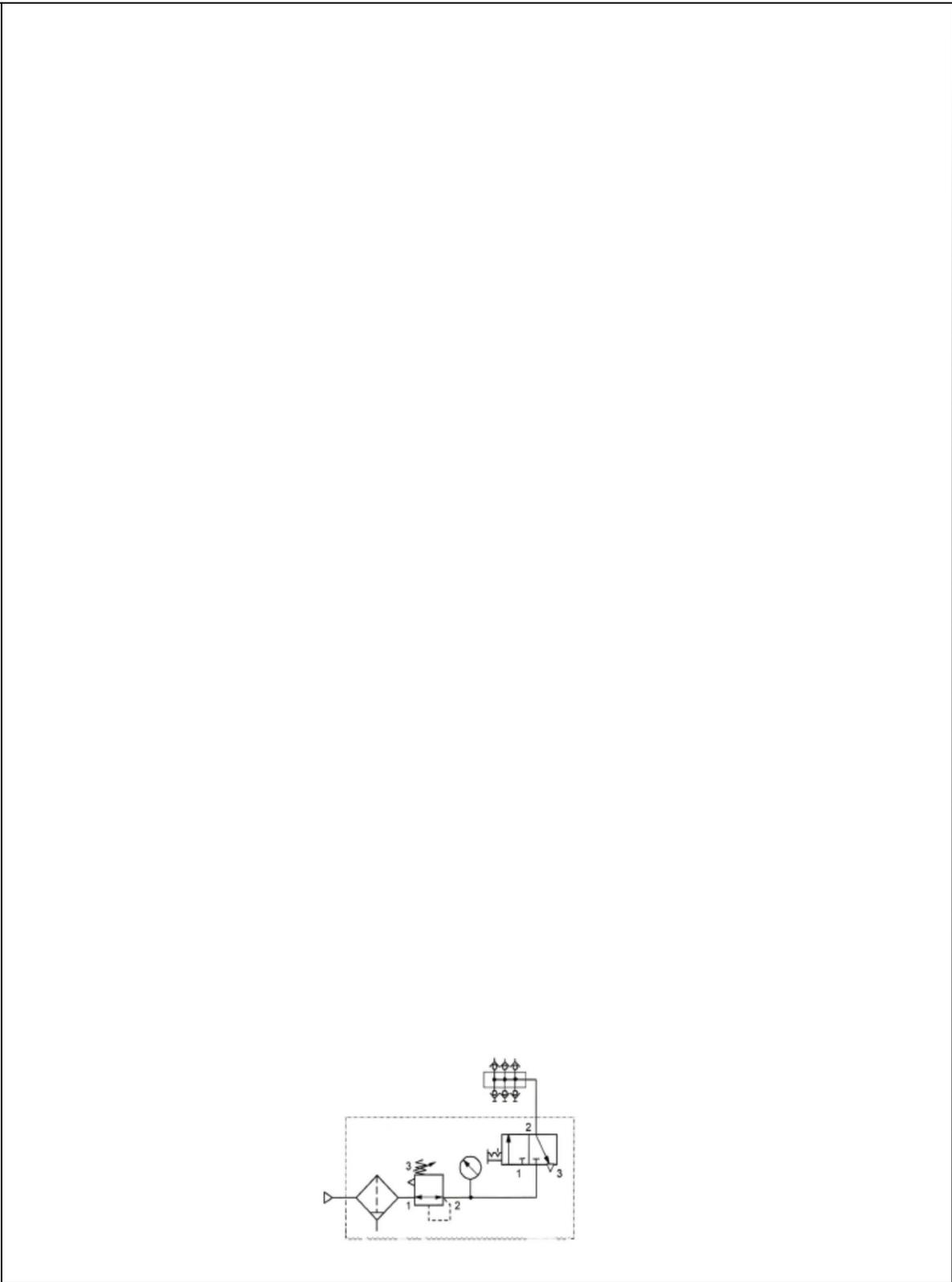


Fig. 9.2 Positional sketch

**Electro Pneumatic circuit diagram**



**Part III: Sequential control of a three double acting cylinder 2**

Build your design Electro Pneumatic circuit diagram to complete the task description in function diagram in Figure 9.3 ( A , B and C are double acting cylinders )

**Note : allow to use three relays maximum.**

**Requirements:**

4. Draw Electro pneumatic circuit diagram using the space provided below.
5. Simulate the circuit using FluidSIM software.
6. Assemble the circuit practically and check its operation.

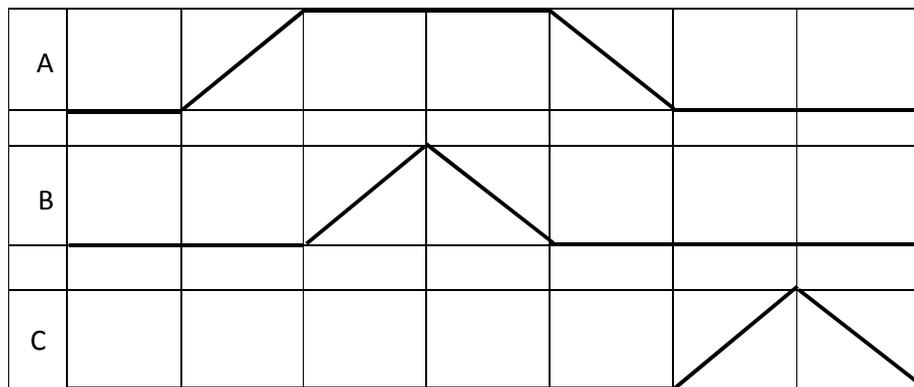
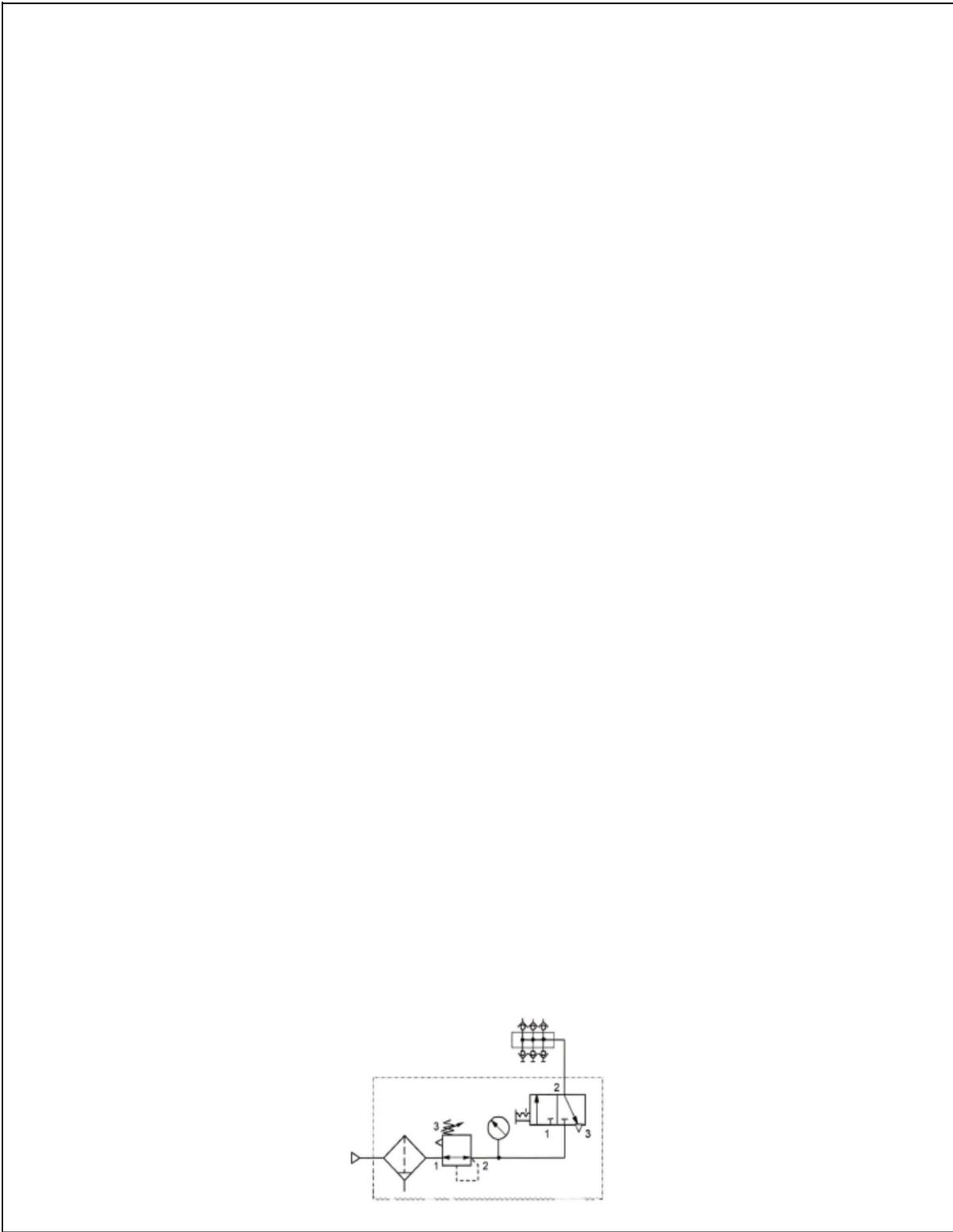


Fig. 9.3 Positional sketch

**Electro Pneumatic circuit diagram**



### Part IV: Sequential control of a three double acting cylinder 3

Build your design Electro Pneumatic circuit diagram to complete the task description in function diagram in Figure 9.4 ( A , B and C are double acting cylinders )

**Note : you allow to use two relays maximum.**

#### **Requirements:**

4. Draw Electro pneumatic circuit diagram using the space provided below.
5. Simulate the circuit using FluidSIM software.
6. Assemble the circuit practically and check its operation.

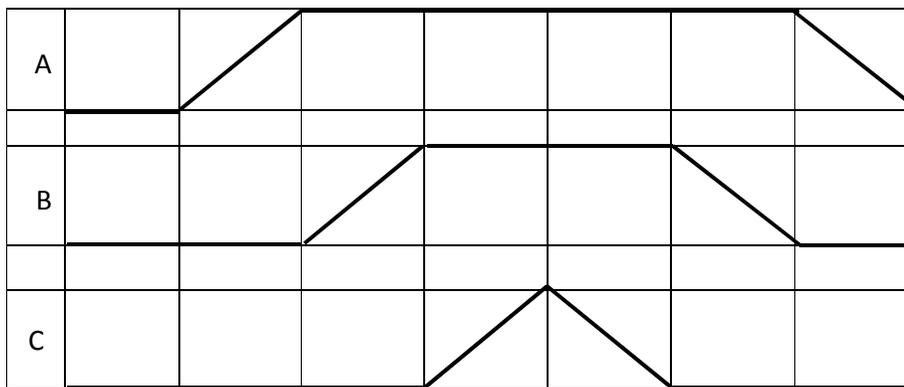
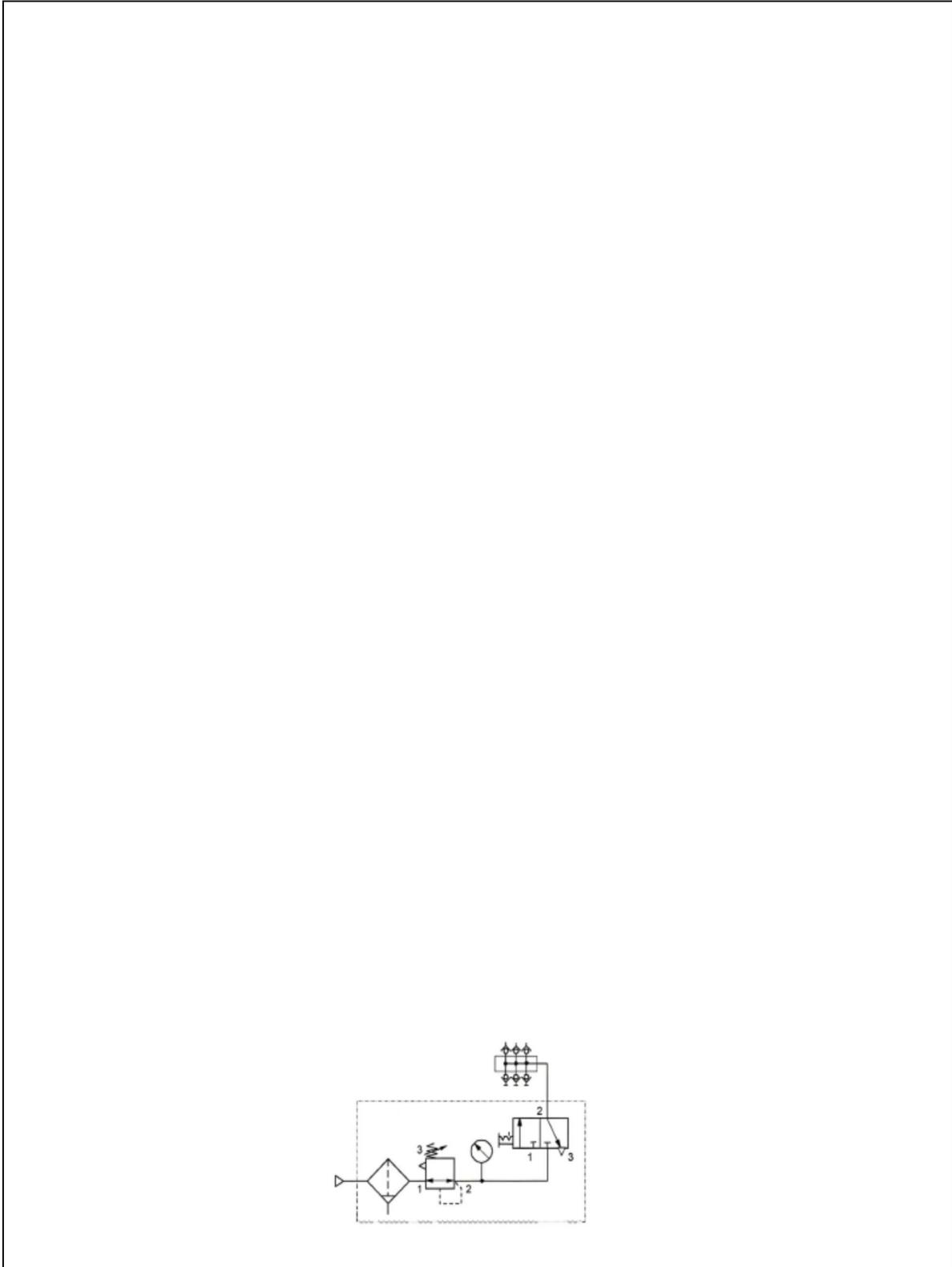


Fig. 9.4 Positional sketch

**Electro Pneumatic circuit diagram**



**The University Of Jordan**  
**School of Engineering**  
**Mechatronics Engineering Department**  
**Fluid Power Engineering Lab**  
**Experiments No.10**  
**Hydraulic Motor Circuit**

**Objective:**

Students will be able to

- 1- Describe the design and operation of a hydraulic motor, calculate the speed of a hydraulic motor, and determine the effect a change in flow rate or pressure has on motor operation.
- 2- To operate a hydraulic motor at constant speed under varying system pressures using a pressure-compensated flow control valve.
- 3- how brake a hydraulic motor gradually and smoothly using a sequence valve.

**Introduction**

Hydraulic motors convert hydraulic energy into mechanical rotary energy. This energy is used to turn a resisting object by means of a shaft. Hydraulic motors have several advantages over electric motors. They can be uni- or bi-directional. They are instantly reversible and they can absorb severe shock loading without damage to the motor. They are smaller than electric motors and respond faster. Hydraulic motors can be overloaded and stalled without damage because excess pressure is diverted over the relief valve.

**Motor speed and volumetric efficiency:**

The speed at which a hydraulic motor turns is determined by how fast it is filled with oil. This speed, then, is directly proportional to the oil flow rate through the motor, and inversely proportional to the motor displacement. The formula for calculating the theoretical speed of a motor is:

S.I Units:

$$\text{Speed}_{(r/min)} = \frac{\text{Flow rate}_{(l/min)} \times 1000}{\text{Displacement}_{(cm^3/r)}}$$

English Units:

$$\text{Speed}_{(r/min)} = \frac{\text{Flow rate}_{(gal(USA)/min)} \times 231}{\text{Displacement}_{(in^3/r)}}$$

### Pressure-compensated flow control valve

Figure 3 shows the pressure-compensated flow control valve supplied with your Hydraulics Trainer, along with its symbol. This valve consists of a needle valve, a compensator spool acting on a bias spring, and a bypass check valve. The needle valve is an adjustable orifice restricting the oil flow from the inlet to the outlet ports.

The compensating spool senses the rate of flow across the needle valve and compresses the spring more or less, as needed, to keep a constant pressure differential and, therefore, a constant flow rate across the needle valve. The check valve allows the oil to flow freely from the outlet to the inlet ports, however it keeps the oil from flowing in the other direction.

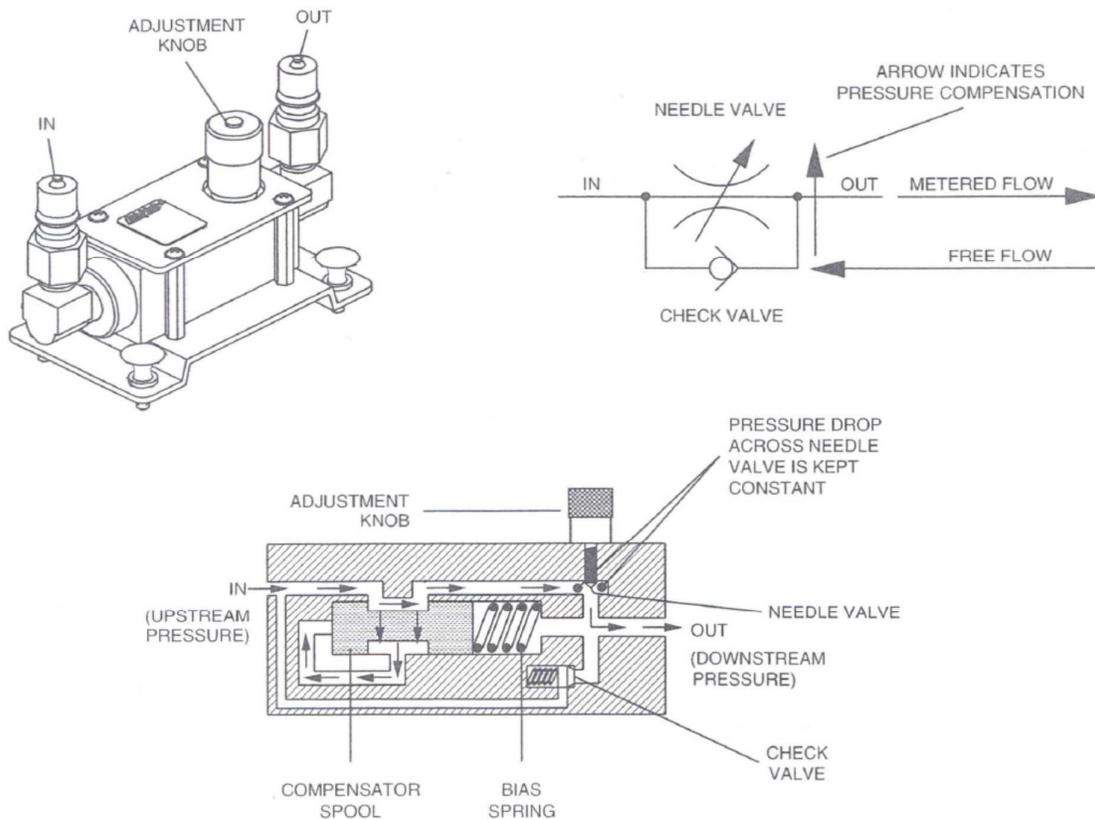


Figure 1, Pressure compensated flow control valve

### Procedure Summary

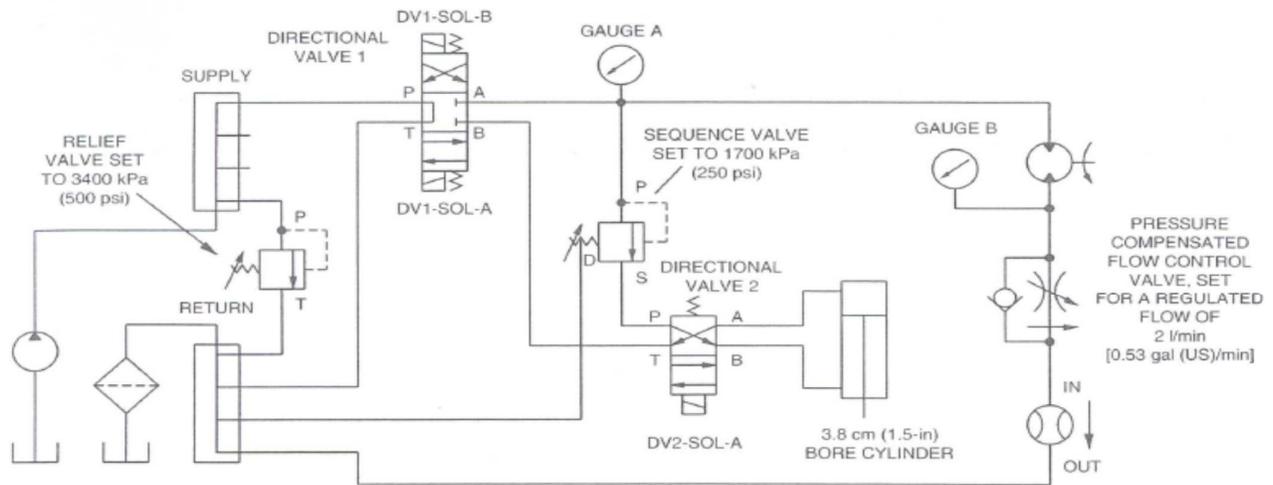
In this part, you will connect and test a hydraulic system that uses a pressure-compensated flow control valve to

- 1- Determine the effect a change in flow rate has on the speed of a hydraulic motor. To do so, you will calculate the speed of the motor at several different flow rates, using theoretical equations.
- 2- Maintain a constant motor speed when the system pressure varies.

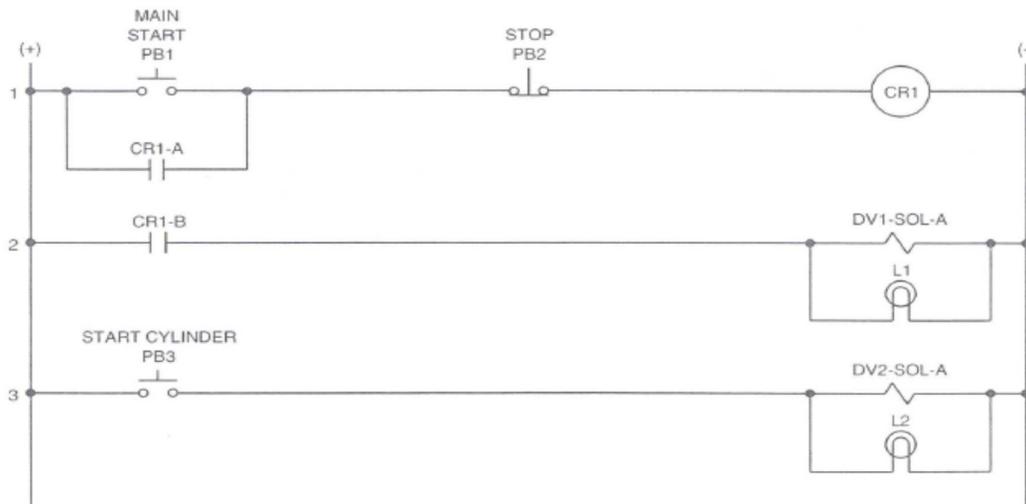
## Part I: Speed Regulation of Hydraulic Motors

### PROCEDURE

- Connect the system shown in Figure 2.
- Close the Sequence Valve completely. First loosen the locking nut on the valve adjustment screw by turning this nut fully counterclockwise. Then, turn the valve adjustment knob fully clockwise.
- Close the Pressure-Compensated Flow Control Valve completely. To do so, turn the valve adjustment knob fully clockwise.



a) Hydraulic section



b) Electrical section

Figure 2, Hydraulic motor operated at constant speed

- Before starting the power unit, perform the following start-up procedure.
  - a. Make sure the hoses are firmly connected.
  - b. Check the level of the oil in the reservoir. Add oil if required.
  - c. Put on safety glasses.
  - d. Make sure the power switch on the Power Unit is set to the OFF position.
  - e. Open the Relief Valve completely (turn knob fully counterclockwise).
- Turn on the Power Unit. Then, turn on the 24 V DC Power Supply.
- Press the MAIN START pushbutton, PB1, to energize solenoid A of Directional Valve 1 and shift this valve to the straight-arrows condition. Since the Sequence Valve and the Flow Control Valve are closed, all the pumped oil is now being forced through the Relief Valve. Turn the adjustment knob of the Relief Valve clockwise until the system pressure at Pressure Gauge A is 3400 kPa (500 psi).
- Set the operating pressure of the Sequence Valve to 1700 kPa (250 psi). To do so, perform the following steps:
  - Turn off the Power Unit.
  - Disconnect the hose coming from port S of the Sequence Valve at port P of Directional Valve 2, then connect it to the return manifold.
  - Turn on the Power Unit.
  - Decrease the operating pressure of the Sequence Valve (Turn knob counterclockwise) until Pressure Gauge A reads 1700 kPa (250 psi).
  - Turn off the Power Unit.
  - Disconnect the hose coming from port S of the Sequence Valve at the return line manifold, then connect it to port P of Directional Valve 2.
  - Turn on the Power Unit.
- Turn the Pressure-Compensated Flow Control Valve adjustment knob counterclockwise to make the motor rotate. Adjust this valve until 2 l/min [0.53 gal(US)/min] is indicated by the Flowmeter.
- Record the pressure level upstream of the Pressure-Compensated Flow Control Valve ( Pressure Gauge B) in the "RETRACTED" row of Table 1.

Cylinder Condition	Flow meter Reading	Gauge B Pressure
RETRACTED	2 l/min [0.53 gal(US)/min]	
EXTENDING		

Table 1, Circuit data with the pressure compensated Flow Control Valve.

- Now press and hold the START CYLINDER pushbutton, PB3, which will cause the cylinder to extend and the pressure to drop upstream of the Pressure-Compensated Flow Control Valve ( Pressure Gauge B). While the cylinder is extending, observe the Flowmeter reading. A change in flow rate is a sign that the motor speed is changing. Does the motor speed change as the cylinder is extending?
-

- Release pushbutton PB3 to retract the cylinder if you have not already done this.
- Again press PB3 to extend the cylinder. While the cylinder is extending, measure the Flowmeter reading and the reading of Pressure Gauge B. Record these in the "EXTENDING" row of Table 1.
- According to Table 1-2, is the flow rate affected across the Pressure- Compensated Flow Control Valve when the pressure upstream of this valve (Pressure Gauge B) decreases? Explain why.

---



---

- Turn off the Power Unit. Disconnect the Pressure-Compensated Flow Control Valve from the circuit and connect the Non-Compensated Flow Control Valve in its place.
- Close the Non-Compensated Flow Control Valve completely (turn knob fully clockwise). Turn on the Power Unit.
- Turn the Non-Compensated Flow Control Valve adjustment knob counterclockwise to make the motor rotate. Adjust this valve until 2 l/min [0.53 gal(US)/min] is indicated by the Flowmeter.
- Record the pressure level upstream of the Non-Compensated Flow Control Valve (Pressure Gauge B) in the "RETRACTED" row of Table 2.

Cylinder Condition	Flow meter Reading	Gauge B Pressure
RETRACTED	2 l/min [0.53 gal(US)/min]	
EXTENDING		

Table 2, Circuit data with the Non-compensated Flow Control Valve.

- Now press and hold the START CYLINDER pushbutton, PB3, which will cause the cylinder to extend and the pressure to drop upstream of the Non-Compensated Flow Control Valve (Pressure Gauge B). While the cylinder is extending, observe the Flowmeter reading. Does the motor speed change as the cylinder is extending?

---

- Release pushbutton PB3 to retract the cylinder. Again press PB3 to extend the cylinder. While the cylinder is extending, measure the Flowmeter reading and the reading of Pressure Gauge B. Record these in the "EXTENDING" row of Table 4.
- According to Table 4, is the flow rate affected across the Non-Compensated Flow Control Valve when the pressure upstream of this valve (Pressure Gauge B) decreases? Why?

---



---

- Turn off the Power Unit. Open the Relief Valve completely by turning its adjustment knob fully counterclockwise. Turn off the 24-V DC Power Supply.

**Part II: Braking of a Hydraulic Motor**

**Procedure Summary**

In this part, you will connect and test a hydraulic system that uses a sequence valve to gradually stop a hydraulic motor.

**PROCEDURE**

- Connect the system shown in Figure 3.

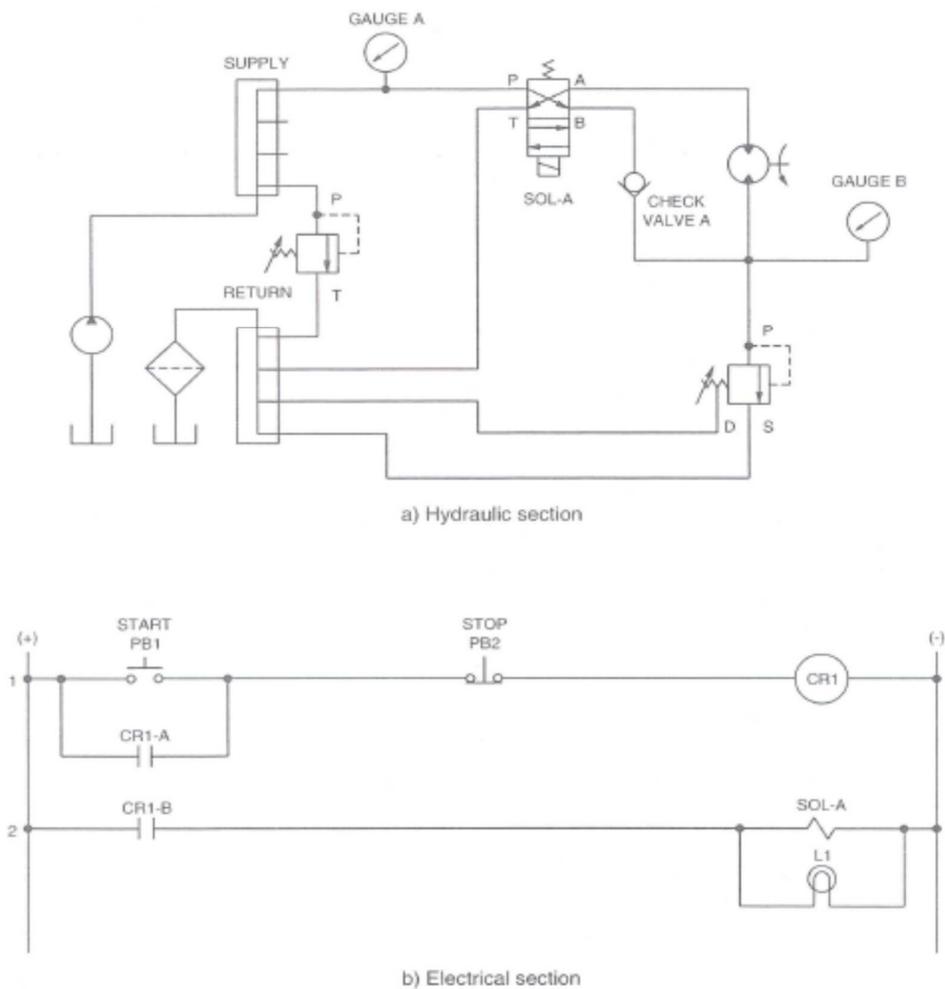


Figure 3. Braking of a Hydraulic motor by means of a sequence valve

- Install the heavyweight flywheel onto the shaft of the motor. To do this, perform the following steps:
  - Slip the flywheel onto the motor shaft, taking care to align the set screw in the flywheel hub with the notch in the motor shaft.
  - Fully tighten the set screw, using the Allen key supplied with your hydraulic motor.
  - Check that the set screw is completely screwed into its hole. The head of the set screw should be flush with the flywheel hub. If not, this is likely because the flywheel is not secured properly. In that case, loosen the set screw and realign the flywheel properly. Retighten the set screw and again check that the set screw is completely screwed into its hole.
- Close the Sequence Valve completely. First loosen the locking nut on the valve adjustment screw by turning this nut fully counterclockwise. Then, turn the valve adjustment knob fully clockwise.
- Turn on the Power Unit. Then, turn on the 24 V DC Power Supply.
- With the Directional Valve in the normal, crossed-arrows condition, the pumped oil is blocked at the Check Valve and Pressure Gauge A indicates the current pressure setting of the Relief Valve. Turn the adjustment knob of the Relief Valve clockwise until the system pressure at Pressure Gauge A is 2100 kPa (300 psi).
- Press the START pushbutton, PB1, to energize solenoid A and start the motor. After the motor has reached full speed, press the STOP pushbutton, PB2, and observe the pressure spike at Pressure Gauge B when the motor stops. Record the magnitude of this spike in the "MAXIMUM" row of Table 3.
- 

SEQUENCE VALVE PRESSURE SETTING	PRESSURE SPIKE AT GAUGE B	BRAKE TIME
MAXIMUM (VALVE CLOSED)		
1400 kPa (200 psi)		
900 kPa (130 psi)		
0 kPa (0 psi)		

Table 3. Pressure spike and brake time versus the pressure setting of the sequence valve.

- Press the START pushbutton to start the motor. After the motor has reached full speed, press the STOP pushbutton and measure the time required for the motor to stop, using a stopwatch. Record this brake time in the "MAXIMUM" row of Table 5.

**Note:** After the STOP pushbutton is pressed, the motor will come to a stop and then start to rotate in the opposite direction for a brief period due to oil leakage through the motor. Stop your stopwatch just before the motor starts to rotate in the opposite direction.

- Adjust the operating pressure of the Sequence Valve to 1400 kPa (200 psi). To do so, perform the following steps:
  - Turn off the Power Unit. Remove the hose connecting the Check Valve to port B of the Directional Valve. This will block the motor return line so the oil discharging from the motor outlet will be forced to flow through the Sequence Valve at whatever pressure this valve is set for. Turn on the Power Unit.
  - Press the START pushbutton. Decrease the operating pressure (turn knob counterclockwise) of the Sequence Valve until the motor begins to rotate. The operating pressure of the Sequence Valve is now slightly lower than the 2100-kPa (300-psi) pressure setting of the Relief Valve, as indicated by Pressure Gauge B. Further decrease the operating pressure of the Sequence Valve until Pressure Gauge B indicates 1400 kPa (200 psi). Press the STOP pushbutton.
  - Turn off the Power Unit. Reconnect the Check Valve to port B of the Directional Valve. Turn on the Power Unit.
- Press the START pushbutton, PB1, to energize solenoid A and start the motor. After the motor has reached full speed, press the STOP pushbutton, PB2, and observe the pressure spike at Pressure Gauge B when the motor stops. recording the requested information in the "1400 kPa (200 psi)" row of Table 5.
- Press the START pushbutton to start the motor. After the motor has reached full speed, press the STOP pushbutton and measure the time required for the motor to stop, using a stopwatch. Record this brake time in the "1400 kPa (200 psi)" row of Table 5.

**Note:** After the STOP pushbutton is pressed, the motor will come to a stop and then start to rotate in the opposite direction for a brief period due to oil leakage through the motor. Stop your stopwatch just before the motor starts to rotate in the opposite direction.
- Set the operating pressure of the Sequence Valve to the lowest possible level (900 kPa/130 psi approximately) by turning its knob fully counterclockwise.
- Repeat last two steps, recording the requested information in the "900 kPa (130 psi)" row of Table 5.
- Now bypass the Sequence Valve completely. To do so, turn off the Power Unit. Disconnect the end of the hose connected to port P of the Sequence Valve and connect it directly to the return manifold. Turn on the Power Unit.
- Repeat last two steps, recording the requested information in the "0 kPa (0 psi)" row of Table 5.

- Turn off the Power Unit. Open the Relief Valve completely by turning its adjustment knob fully counterclockwise. Turn off the 24-V DC Power Supply.
- According to Table 5, how does decreasing the pressure setting of the Sequence Valve affect the magnitude of the pressure spike? Why?

---

---

---

- How does decreasing the pressure setting of the Sequence Valve affect the time required to stop the motor? Why?

---

---

---

**The University Of Jordan  
School of Engineering  
Mechatronics Engineering Department  
Control of Hydraulic & Pneumatic System Lab  
Experiments No.10  
Hydraulic Motor Circuit**

**In class Lab Report**

Date: \_\_\_\_\_

Section: \_\_\_\_\_

Group's Names:

- 1-
- 2-
- 3-
- 4-
- 5-

**Part I: Speed Regulation of Hydraulic Motors**

Q1: What is the primary difference between a pressure-compensated flow control valve and a non-compensated flow control valve?

Q2: What is the function of the pressure-compensated flow control valve in the system shown in Figure 2 ?

**Part II: Braking of a Hydraulic Motor**

Q1: What is the function of the sequence valve in the motor braking system of Figure 3?

Q2: Explain the operation of the sequence valve in the motor braking system of Figure 3?

Q3: In a motor braking system, why is it important to allow the oil to flow directly from the reservoir into the rotating motor when the motor is braking?