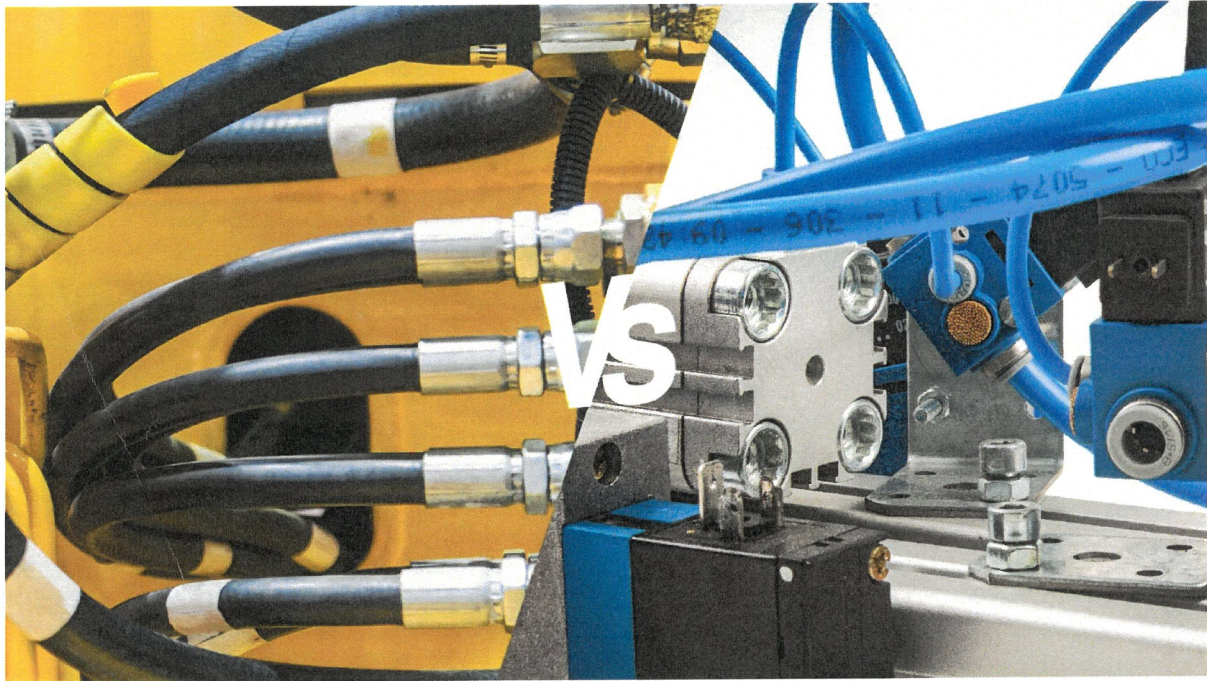


Marked 15/02/24
JM.

Programme title would
be useful - HNC
Instrumentation
Engineering.

Pneumatics and Hydraulics



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Module: Pneumatics and Hydraulics

Assignment: Pneumatics & Hydraulics Devices and
Calculations

Contents

Pneumatics and Hydraulics Front Cover.....	1
List of Figures	3
List of Equations	4
Introduction	5
Task 1 - Prime Movers and Conditioning	6
Task 2 – Calculations.....	18
References	24

→ you could include your sub-headings
in the ToC - (add as a 'level 2' heading)
e.g. 2.1 compressors

List of Figures

Figure 1. Force transmitted through a fluid.	6
Figure 2. Multiplication of forces in fluid power systems.	7
Figure 3. Gangway Solutions who supplied Dragon LNG it's Gangway.....	9
Figure 4. Double acting cylinder	9
Figure 5. Scotch Yoke Spring Return Actuator	10
Figure 6. Oil-Free Rotary Screw Compression area	12
Figure 7. Internal Gear Pump Flow	14
Figure 8. Double Acting Piston Pump Internal Diagram.....	15
Figure 9. Spring Loaded PRV Design	17



List of Equations

Equation 1 - General Gas Equation	19
Equation 2 - Pascal's Law.....	22
Equation 3 - Area of a Circle	22
Equation 4 - Newton's Second Law	23

✓
*Good effort to include
equation list.*

Introduction

This assignment introduces the main components of pneumatic and hydraulic systems and their comparisons. It will cover areas such as power sources, pressure regulation, pressure drops, forces, and gas laws in pneumatics and hydraulics. These laws and understanding will be clarified through calculations and research. ✓

Task 1 - Prime Movers and Conditioning

Introduction to Fluid Power Systems:

Fluid power is the term used when talking about pneumatic and hydraulic power systems. These systems operate by utilising the generation of effective power, control and transmission of fluids. The fluid power when the fluid is a liquid is named hydraulics. The fluid power when the fluid is a gas is known as pneumatics (Sathyabama University, 2020). Both systems are used to provide force and motion to mechanisms. This force can be in the form of pushing, pulling, rotating, regulating or driving. They are employed due their high power to weight ratio, versatility and ease of control.

Fluid power systems effectiveness can be highlighted through Pascal's law. The law is as follows "Pressure applied to a confined fluid is transmitted undiminished in all directions throughout the fluid and acts perpendicular to the surface in contact with the fluid," (Mobley, 2001).

* Full stop after reference to show it forms part of the sentence.

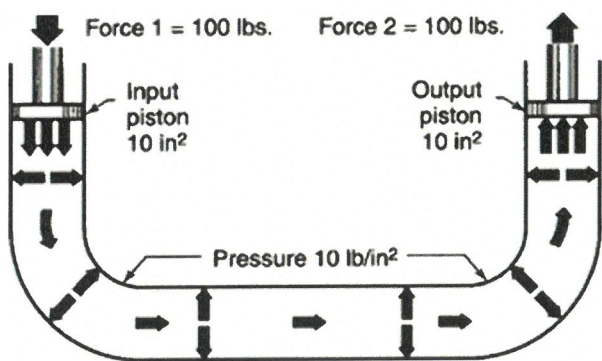


Figure 1. Force transmitted through a fluid. (reference?)

However, this law can be amplified through multiplication and variation of forces as linear and rotary forces can be multiplied by a kilogram to several hundred to this is one the reasons why fluid power systems are utilised in today's process systems.

* Page number should be here.

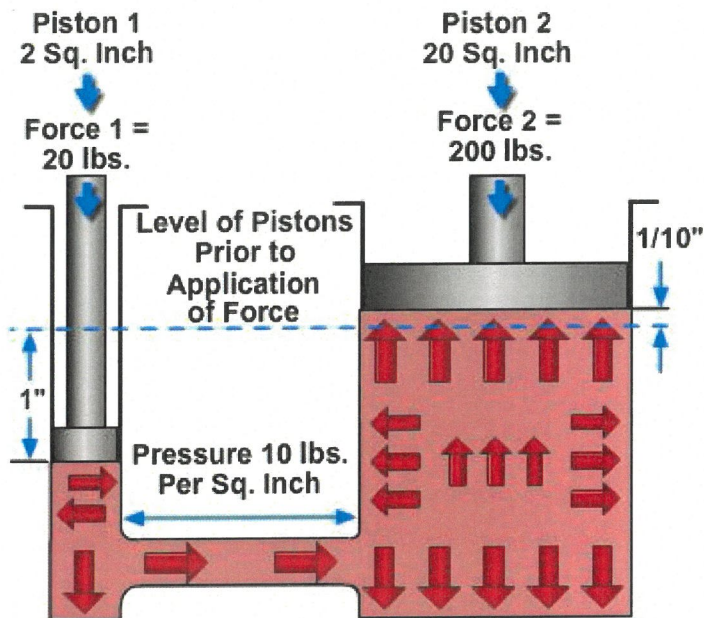


Figure 2. Multiplication of forces in fluid power systems.

(ref?)

Similarities in Hydraulic and Pneumatic Systems:

Both systems function on Pascal's law which is how the systems apply pressure to fluids and use the power generated to operate actuators. Due to force being applied through the fluid, a remote location can be used to store the power sources relative to where the work is carried out by the actuators. ✓

The system components that are used in Pneumatic and Hydraulic systems are very similar in their equipment line up. A compressor will be used in a Pneumatic system and a pump is used in a Hydraulic system to generate a fluid flow. Valves are then used to control the direction and flow of the fluid. Finally, actuators such as hydraulic rams, or instrument air operated valves convert this fluid power into mechanical power to output the action needed on the process plant. ✓

Maintenance on these systems have many overlaps due to fluid power dynamics crossing over regardless of whether the fluid is a liquid or a gas. Sealing of the vessels, hose connections and hose condition is vital to maintain the function of the system. ✓

↳ Are there varying issues with regards to these functions?

Both pneumatic and hydraulics are governed by the health and safety executive.

Many laws are an umbrella for fluid power systems. For example, Health and Safety

at work act 1974, Provision and Use of work equipment regulations (PUWER) 1998, Pressure systems safety regulations (PSSR) 2000 etc.

*How does this legislation impact fluid power systems?
- Discussed later.*

Differences in Hydraulics and Pneumatic power systems:

Firstly, the medium used in the systems are different. In a hydraulic system liquid is used to generate power whereas gas is used in a pneumatic system. Liquid is incompressible and results in the system being more efficient in the power generation as no energy is lost to compression (Hanna, 2021). This means hydraulics can generate much higher levels of pressure. Industrial systems using hydraulic systems usually operate through various pressure ranges in hydraulics. The standard for maximum working pressure of hydraulics is 10,000 PSI (Hi-Force, 2016). The medium used in Pneumatic (Gas) usually air has a much lower mass density than liquid and is easily compressed. This leads to a lot less generation of power by the pneumatic system as energy is lost through the compression of the gas. The general operating range of pneumatic systems is 80 PSI to 145 PSI (Fluidsys, 2022).

The expected accuracy and repeatability of the fluid power system also is affected by the medium being used. Due to air's compressibility, it can introduce less predictable movement making it more difficult to achieve precise control like hydraulic systems. The incompressibility of liquids leads to a more precise output and a steadiness of force as the pressure is constant and doesn't vary (Henneberry, 2020).

The exert of pressure on an actuator is much quicker in pneumatic systems due to compressed air having a high flow rate due to a low mass density making it easier for the air to flow through the pipework which allows a quick release of power. This may be crucial in some systems where valves and cylinders can change position rapidly to respond to process situations. Liquid has a higher mass density, and this affects the flow rate through the pipework resulting in a longer time to achieve the desired pressure in the system to operate the actuator (King, 2020).

Industrial Sector Applications of Pneumatics and Hydraulics:



Figure 3. Gangway Solutions who supplied Dragon LNG it's Gangway. ✓

The gangway pictured above is like the one used at Dragon LNG. The gangway utilises hydraulics to operate as needed. Many different functions can be used to achieve the desired position of the gangway when connecting the jetty to the ship. The system operates using an internal gear pump with a fixed displacement and an oil reservoir to pressurise the chosen rams to achieve the position needed. The hydraulics power functions such as slew right and left, extend or retract, or elevate or lower the gangway. ✓

DOUBLE ACTING CYLINDER

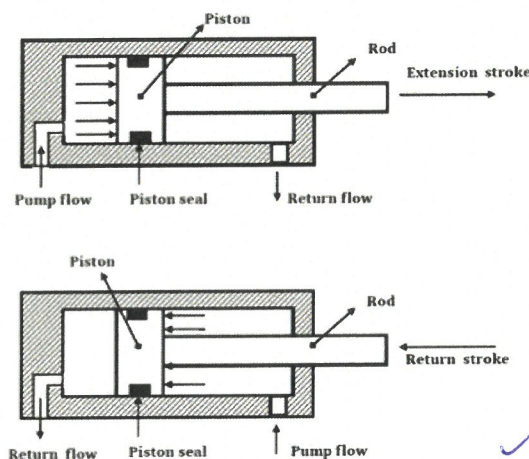


Figure 4. Double acting cylinder ✓

The process behind the operation of the gangway is double acting cylinders. The pressurised oil enters one side of the cylinder this will depend on the lever energised, the pressurised oil will then drive the piston and the ram will extend or retract depending on the operation. The term fixed displacement is related to the fixed amount of flow per revolutions of the gears causing a linear increase in the flow if the revolutions are increased. This is beneficial as it results in a smooth output due to continuous meshing of the gears. This smooth operation is needed when landing a gangway on a ship. ✓

Two very good workplace applications of pneumatics and hydraulics.

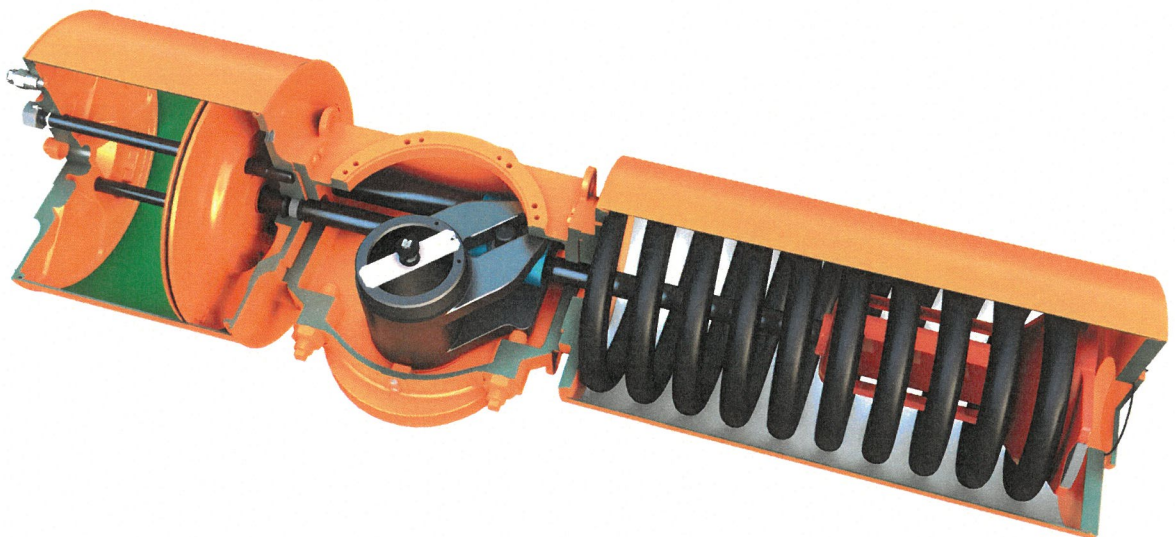


Figure 5. Scotch Yoke Spring Return Actuator

The actuator displayed is used at Dragon LNG for the emergency shutdown valves. Depending on the position of the failsafe will determine the position of the valve if the pneumatic system fails to protect the plant. The left-hand side of actuator is where the pneumatic air is connected to the actuator. It works by the pneumatic air pressure force overcoming the spring force and driving the valve into its position. ✓ The air flow is controlled by the distributed control system by a panel operator. The panel operator will open and close the valve as needed. If the panel operator wants to change the position of the valve the air vents to atmosphere and the spring drives the valve into its desired position. ✓ If the valve is in a failure open position the air pressure will drop in the chamber and the force of the spring will drive the valve

open. If the valve is in a fail closed position the same will occur however the spring will drive the valve closed.

Health, safety and environmental factors associated with fluid power systems:

The use of fluid power systems comes with health and safety factors which can be expected due to the amount of pressure and force the systems can generate. It is essential to manage these factors so operators can ensure safety to themselves and others working on or near the systems. The regulations and standards that cover fluid power systems is the Pressure System Safety Regulations 2000 (PSSR) and ISO 4413:2010 (Hydraulic Fluid Power). The purpose of these legislations is to "prevent serious injury from the hazard of stored energy as a result of the failure of a pressure system or one of its component parts. (HSE, n.d.)" *use current year for live information.*

The pressure in these systems can cause equipment to fail under high pressures.

This can lead to hose ruptures and fittings failing resulting in high pressure releases.

The release of high-pressure oils can cause injection into the skin (Pirtek, 2022). *resulting in what?*

The medium used in hydraulic systems is often oils, leaks in the system can result in spills. The oils are a potential fire risk and a slipping hazard. Spill kits are often placed adjacent to oil systems to deal with the event correctly.

Pneumatic systems can generate high level of noise which can be above the safe amount of decibels when working. Silencers can be used, and hearing equipment should be supplied by the employer if the noise cannot be controlled.

Oils are a contaminant it is important that they are disposed of correctly to avoid harming the environment. Designated oil wastes are required on sites to ensure the removal process is correct.

Good awareness of H&S factors.

1.)

Air Compressor:

To supply air compression to a pneumatic process in a temperature-controlled room, the correct type of air compressor needs to be selected. From researching company sources, the best fit for the purpose of maintaining clean air and temperature control would be the Oil-free Rotary Screw compressor ✓ ZR by Atlas ← reference? Copco. This compressor is designed to have a low lifecycle cost while maintaining and delivering the highest quality air for industry standards. The compressor is used in food, pharmaceutical, automotive, medical, chemical and process industries. ✓

This compressor uses a female and male rotary screws that when rotated air get pulled into the path of the screw design and gets compressed as the volume decreases as the air is forced through the screws. ✓ An external gear is used to synchronize the position of the counter-rotating screw elements, this gear effectively stops the two rotors from physically touching each other resulting in no friction, so oil is not needed for lubrication. Oil free compressors have a 0 class regarding the ISO 8573-1 standard, due to their being no oil present in the compression phase of the cycle which contaminates the air quality. (JHForster, 2021). ✓

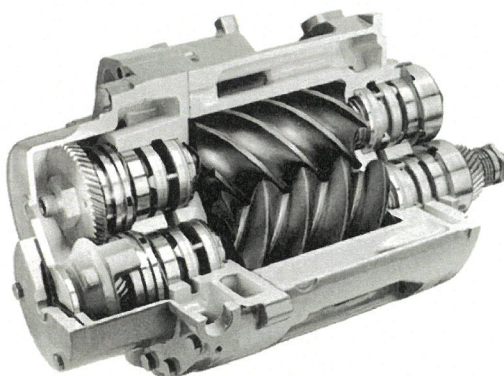


Figure 6. Oil-Free Rotary Screw Compression area

The package of the air compression unit is an all-in-one solution. The dryer ✓ package which can be altered to control the dew point of the air is also fitted into

the unit. The unit also features a variable speed drive to minimise the energy costs.

The ZR type is water cooled. This compressor can be fitted with an energy recovery unit to help achieve the low carbon economic goals of today. Up to 94% of the compressors electrical energy is converted into compression heat. Without the recovery unit this heat would be lost to the atmosphere. The recovery unit could be used to in conjunction with the temperature controller in the room to maintain the temperatures (Atlas Copco, 2023).

Oil free screw compressors are reliable and efficient, the absence of oil in the compression phase reduces the amount of man hours needed to maintain the equipment, which is beneficial in a clean room environment. ✓

Air conditioning appropriate for the clean room:

To maintain the air quality and temperature an air conditioning unit will need to be used. A Heating, Ventilation and Air Conditioning (HVAC) unit would be needed to maintain the air quality of the clean room. These air conditioning units can increase the air supply, altering airflow patterns, high efficiency filters to remove particulates and room pressurisation. The increased air supply results in more air changes per hour with air filtered through High-Efficiency Particulate (HEPA) air filters (Cleanroom Architecture System, 2021) ✓

2.)

Internal Gear Pump:

Internal gear pumps are a simple design with limited moving parts, they are versatile and can pump liquids within a large viscosity range. The operating temperature of the pumps can reach 400 degrees C. The internal gear pump pumps a fixed volume of liquid between meshing gears to discharge a constant pulse free flow. The flow rate of the liquid is proportional to the revolutions of the gears (Michael Smith Engineers, 2014). ✓

The liquid enters the suction side of the gear pump between the rotor and the idler. ✓

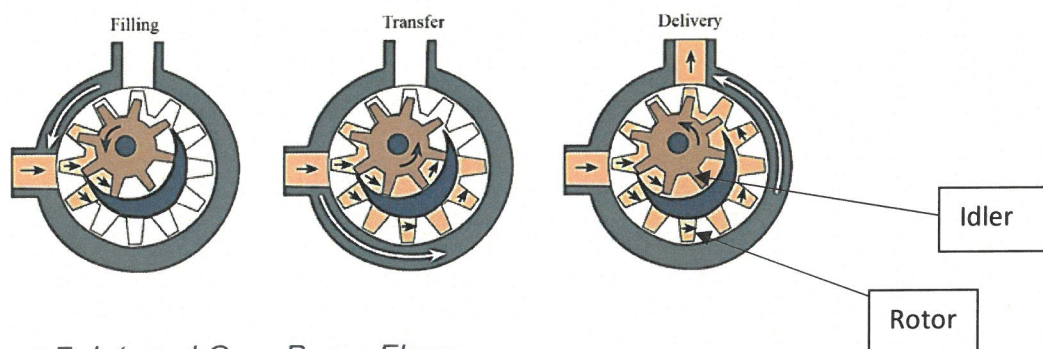


Figure 7. Internal Gear Pump Flow

Liquid travels through the pump through the gear within gear principle. The crescent shaped part acts as a seal between the outer gear and the internal gear and the suction side and discharge side. The pump is now flooded with the liquid, prior to exiting the discharge line the two gears mesh together reducing the volume increasing the pressure and forcing the liquid out of the discharge line (Michael Smith Engineers, 2014). The internal gear is connected to the driving shaft resulting in the internal gear being the driving force of the pump. The external gear is the driven gear. ✓

Susceptible to premature wear.

Piston Pump:

Piston pumps is a type of is a reciprocating pump. They are used in applications with a lower flow rate and a moderate pressure of up to 2000 PSI. The sealing packing on the pump is attached to the piston and moves with the piston as can be seen on figure 8.

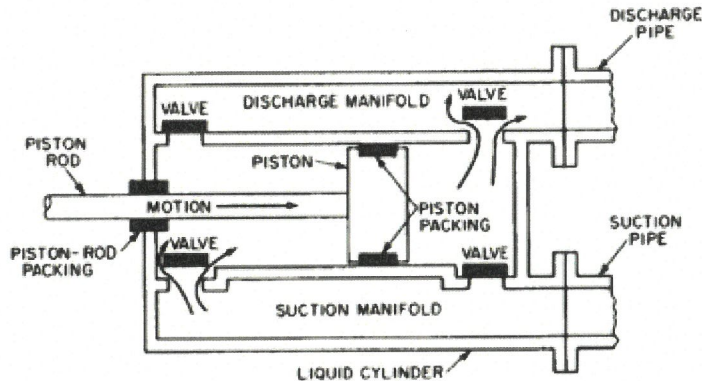


Figure 8. Double Acting Piston Pump Internal Diagram

The operating principle of a piston pump is that a solid will displace a volume of liquid equal to its own volume. Figure 8. Illustrates the operation of a piston pump, when the piston rod drives down or right on the diagram the volume is reduced and the pressure increases forcing the discharge valve open. While on the left-hand chamber the piston's driving motion is causing a vacuum effect pulling liquid into through the suction valve. The piston will then retract causing the same outcome but through different flow paths.

which pump has the best efficiency? are they comparable?

3.)

Various equipment is used to control pressure within a pneumatic and hydraulic system. It is important to maintain the pressure within the operating parameters of the system to ensure safety, prolong the life of the system and to keep the fluid in the pipework. The choice of equipment will depend on the systems operational requirements.

Pressure regulator or Pressure Reducing Valve:

A pressure regulator or pressure reducing valve are mechanical devices which automatically performs pressure control to prevent the pressure in the system from exceeding the operating parameters and to reduce the pressure to achieve optimal conditions for downstream equipment. They reduce a high often variable upstream pressure to a lower outlet pressure despite varying flow demand. These regulators or reducing valves can be automated so that the flow rate can be adjusted through the valve by a control system, or they can be mechanically set into a pressure control range (Emerson, 2023). ✓ *Diagram?*

Pressure Relief Valve:

A pressure relief valve is a safety valve that is designed to protect against the system from over pressurising the system out of it's safe working parameters. When an over pressure event occurs the pressure relief valve directs the high-pressure fluid to a low-pressure system to reduce the pressure in the upstream system. As the pressure relief valve is a safety valve the valve must be capable of operating if the power source fails, hence why pressure relief valves are often mechanical and use the high pressure to function. The most common type of pressure relief valve is a spring-loaded design, the valve works by when the system pressure reaches and surpasses the spring pressure, the spring compresses and opens a relief path for the fluid to a lower pressure system such as tank in a hydraulic system or to atmosphere generally if a pneumatic system (Crosby Valve Inc., 1997). ✓

*Both upstream and downstream
pressure control methods discussed.*

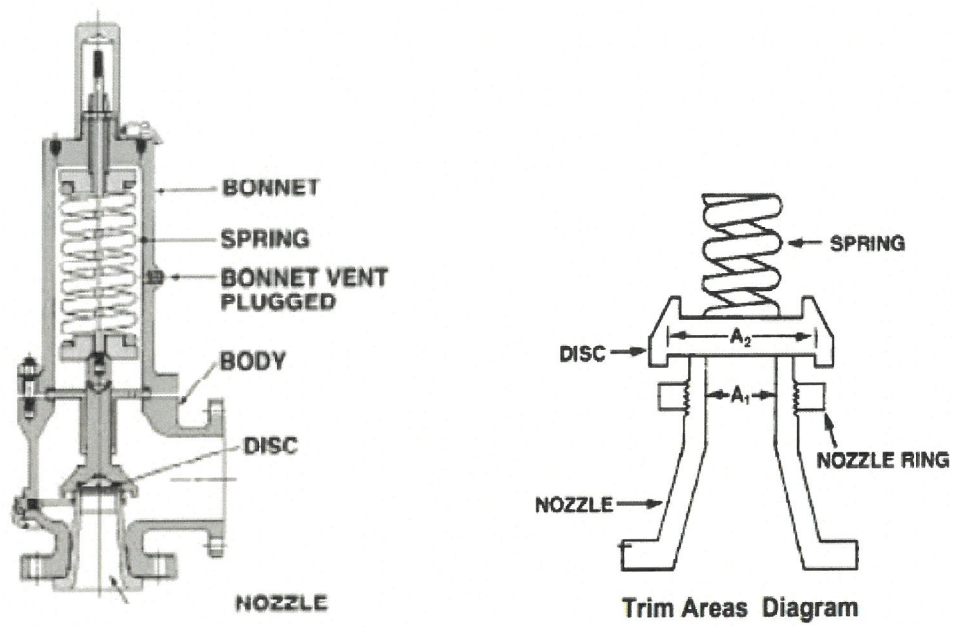


Figure 9. Spring Loaded PRV Design



Task 2 – Calculations

Apply fluid power knowledge and relevant formulas to solve the following series of tasks that encompass the various stages which influence system pressure before reaching an actuator.

2.1 Compressor

A two-stage compressor is drawing in 25 cubic metres per minute of free air at N.T.P condition.

Determine the output flow rate based on the following instrumented values.

	Instrumented Values	
	Stage 1	Stage 2
Temperature	w	y
Pressure (Absolute)	x	z

Student	w	x	y	z
JC	40°C	510kPa	72°C	900kPa
KC	42°C	525kPa	70°C	850kPa
SD	45°C	540kPa	75°C	800kPa
JH	48°C	500kPa	68°C	1MPa
PP	39°C	555kPa	76°C	800kPa
HR	43°C	535kPa	72°C	950kPa

	Instrumented Values	
	Stage 1	Stage 2
Temperature	39°C	76°C
Pressure (Absolute)	555kPa	800kPa

N.T.P = 20°C, 101.325kPa

$$V1 = 25 \text{ m}^3 \quad V2 = 4.86 \text{ m}^3 \quad V3 = 3.77 \text{ m}^3$$

$$P1 = 101.325 \text{ kPa} \quad P2 = 555 \text{ kPa} \quad P3 = 800 \text{ kPa}$$

$$T1 = 20^\circ\text{C} \quad T2 = 39^\circ\text{C} \quad T3 = 76^\circ\text{C}$$

$$T1 = 273 + 20 \text{ K} \quad T2 = 273 + 39 \text{ K} \quad T3 = 273 + 76 \text{ K}$$

$$\frac{(P1 \times V1)}{T1} = \frac{P2 \times V2}{T2}$$

Equation 1 - General Gas Equation

$$V2 = \frac{P1 \times T2 \times V1}{P2 \times T1}$$

$$V2 = \frac{101.325 \times 312 \times 25}{555 \times 293}$$

$$V2 = 4.86 \text{ m}^3/\text{min} \quad \checkmark$$

$$V3 = \frac{P2 \times T3 \times V2}{P3 \times T2}$$

$$V3 = \frac{555 \times 349 \times 4.86}{800 \times 312}$$

$$V3 = 3.77 \text{ m}^3/\text{min} \quad \checkmark$$

Clear method.

2.2 Pipe Losses

A 20mm diameter flexible air hose is connected to the air receiver outlet, the hose is 62 metres in length.

Determine the available pressure at the end of the pipe by taking the pressure losses at steady flow into account, the flow rate is restricted to 20 cubic decimetres per second.

Also calculate the pneumatic force of the air at the end of the pipe.

Refer to Figure 1 – Pressure Nomogram.

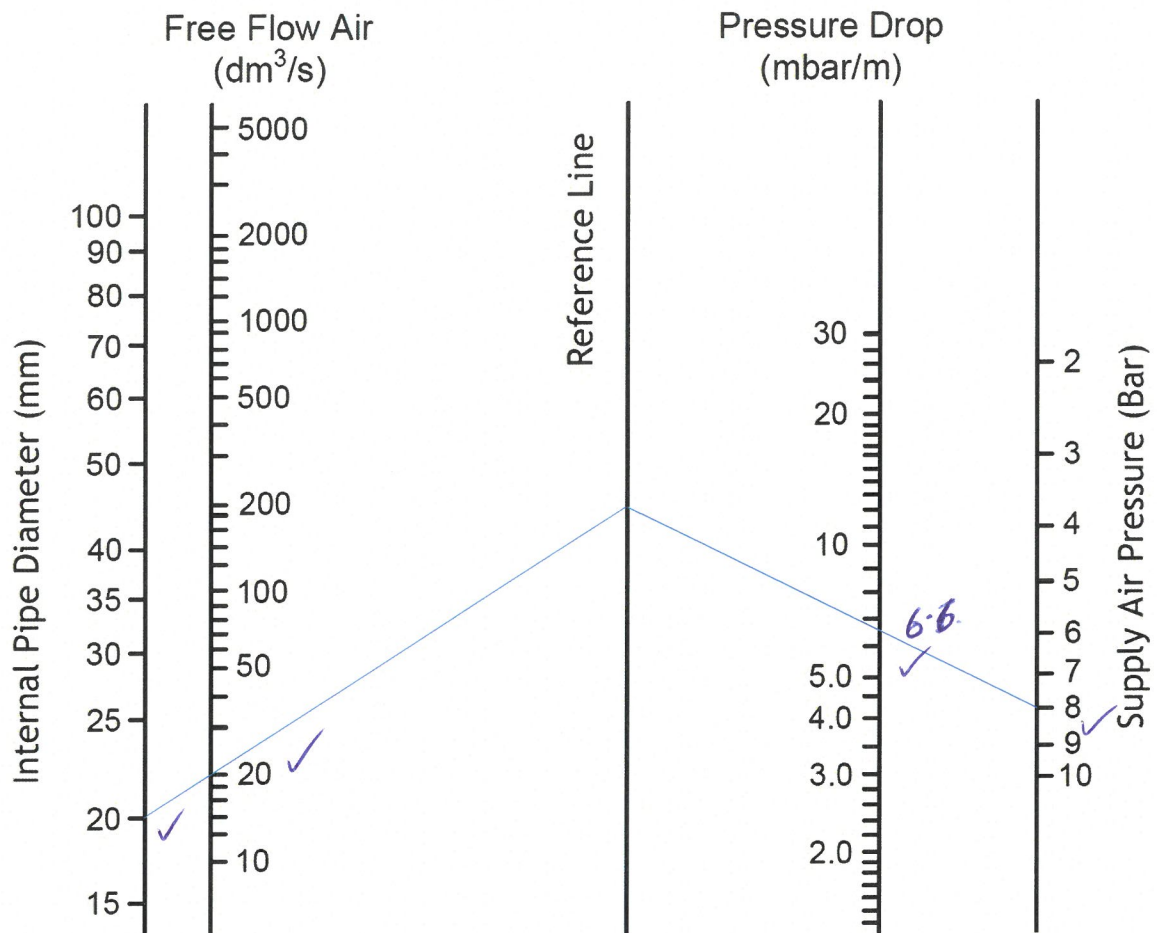


Figure 1 – Pressure Nomogram

$Z = 800 \text{ kPa}$

$Z = 800 / 100 \text{ Bar}$

$Z = 8 \text{ Bar}$

Pressure Drop (mbar/M) = 6.6

Pressure Drop of Whole Pipe Length = $6.6 \times 62\text{m}$

Pressure Drop of Whole Pipe Length = 409.2 mbar ✓

Pressure Drop of Whole Pipe Length = $409.2 / 10 \text{ kPa}$

Pressure Drop of Whole Pipe Length = 40.92 kPa

The task asks for the 'available pressure' - you need to subtract the loss from the initial 8 bar.

↳ 7.59 bar.

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

Equation 2 - Pascal's Law

$$F = P \times A$$

$$F = (40.92 \times 10^3) \times A$$

$$A = \pi r^2$$

Equation 3 - Area of a Circle

$$A = \pi 0.01^2$$

$$A = 314.16 \times 10^{-6}$$

$$F = (40.92 \times 10^3) \times (314.16 \times 10^{-6})$$

$$F = 12.8554 \text{ N}$$

Correct method, but as you have used 40.92 in place of 759 your $F = 12.8554 \text{ N}$. This should be 238.45 N.

2.3 Air Receiver

The flexible pipe is connected to a single acting, vertically positioned pneumatic cylinder of 76mm internal bore diameter.

Determine the maximum mass which could be lifted by this system.

Pressure of Pneumatic Cylinder = 800 kPa – 40.92 kPa

Pneumatic Cylinder = 759.08 kPa

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

$$F = P \times A$$

$$F = (759.08 \times 10^3) \times A$$

$$A = \pi r^2$$

$$A = \pi (38 \times 10^{-3})^2$$

$$= 4.536 \times 10^{-3}$$

$$F = (759.08 \times 10^3) \times (4.536 \times 10^3)$$

$$F = 3443.187 \text{ N} \quad \checkmark$$

$$F = m \times a$$

Equation 4 - Newton's Second Law

$$m = \frac{3443.187}{9.81}$$

$$m = 350.987 \text{ kg} \quad \checkmark$$

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✓
Wide range of info sources.
✱
Harvard 2009 style acceptable.

12