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**HNC Instrumentation Engineering
Pneumatics & Hydraulics Assignment 1**

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✓
well organised.

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Correctly
formatted.

Introduction

Through this assignment, I aim to introduce the key aspects of pneumatic and hydraulic systems and how they compare. The assignment will cover the following areas of pneumatics and hydraulics – power sources, pressure regulation, pressure drops, forces, gas laws. This will be achieved through both calculations and research.



*No page numbers
to relate to your
ToC + Figures.*

Task 1.1

Pneumatic vs Hydraulic Systems

The main difference between the two types of fluid power is the substance they utilise in order to operate their system. Hydraulic systems require pressurised liquid such as water or oil for transmission whereas pneumatic systems require compressed gas or air. This is a deciding factor for many users based on how the system is going to be used.

Pneumatic systems contain components like filters, regulators and lubricators to ensure that the air travelling through the system is of sufficient pressure and free from any contaminants. The filter should be drained regularly, and the regulator set to the lowest possible pressure that's still capable of maintaining the specified rate for the system. Solenoid-operated valves will also be seen throughout the system and are in place to control the direction of air flow. In such a configuration, piping is used to transport air in different directions based on the position of a shuttle inside the SOV. When energised, a magnetic field is produced inside the SOV, and this is what pulls the shuttle in either direction which in turn blocks air from travelling in any other direction. Below, a basic diagram of a SOV can be seen:

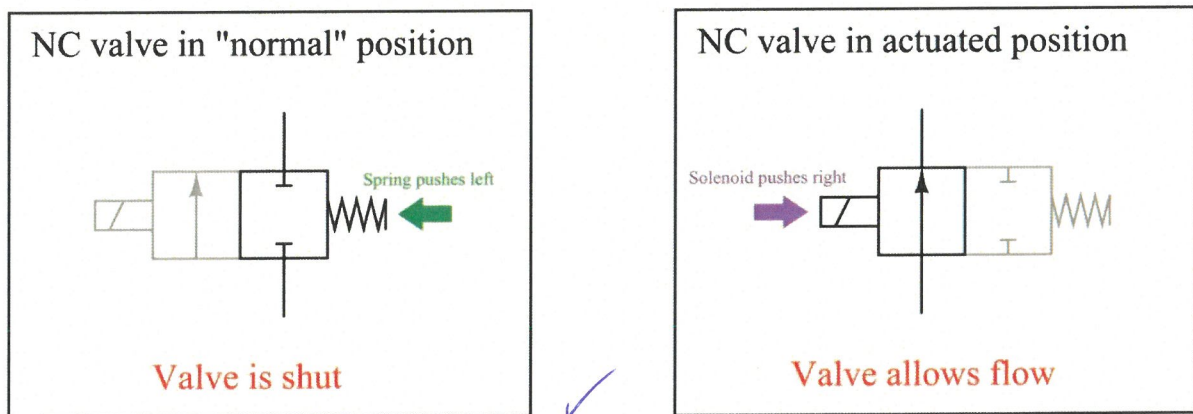


Figure 1 - SOV Diagram (Discrete Control System Elements, 2024)

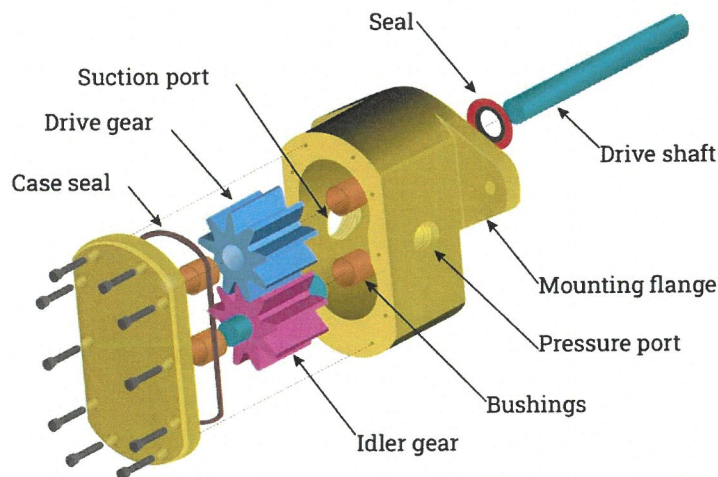
A common application of a pneumatic system on the refinery is a set of solenoid-operated valves configured with level switches. For example, when a high-level alarm on a drum is activated, an electrical signal will be sent to the SOV which switches the position of the shuttle inside and allows air to pass through to a steam valve causing a turbine to start pumping out the level inside the drum. Pneumatic systems typically max out at 80-100 psi making it preferable in situations like this where not a lot of pressure is required to carry out the task effectively.

Great example

↳ photo/diagram would bolster your writing

The hydraulic system is much more complex than the pneumatic system requiring a reservoir, filter, pump, motor and cylinder to operate correctly. This method of fluid power is useful in lifting heavy equipment due to the amount of pressure that can be produced by a hydraulic system. As Pascal's Law states, "A pressure change occurring anywhere in a confined incompressible fluid is transmitted throughout the fluid such that the same change occurs everywhere." Meaning that when fluid is pressurised, it acts on every part of a vessel creating a force which can then be applied to performing a task such as lifting a heavy load. Another way in which hydraulics can be used in a system is within a pump. The pump pulls a vacuum at its inlet, which forces fluid to travel from the reservoir toward the inlet line. Depending on the type of pump that is being used, a specific mechanical action will then push the fluid from the inlet line to the outlet, forcing it into the system. These types of systems are capable of working with much larger pressures when compared to pneumatics, making them desirable in industrial applications such as pumps and compressors. Most hydraulic systems will have no trouble working within the pressure range of 1000-5000 psi with some specific applications exceeding this. Below is a diagram displaying the components of one of the many types of hydraulic pumps, a gear pump:

reference?



IQSdirectory.com

Figure 2 - Hydraulic Gear Pump (Industrial Quick Search, 2024)

The cleaner, more environmentally friendly option of the two is the pneumatic system. A leak inside this system should only result in the emission of air whereas a leak inside a hydraulic system would more than likely result in the ejection of hydraulic fluid. This type of fluid is harmful and can result in diseases such as dermatitis developing if control measures aren't put in place such as wearing PPE and practising good pipe fitting technique to avoid leaks. Fluids used within the hydraulic system should be contained and disposed of appropriately after use to avoid contaminating nearby areas.

Dermatitis is a well recognised issue, what other hazards/harms are there?

Task 1.2

Positive Displacement Compression

One method used to deliver compressed air to a pneumatic process system is known as positive displacement compression and a piece of equipment that operates using this method is known as the rotary screw compressor. The method consists of drawing air into a compression chamber and then blocking this air from the inlet. Once the air is inside, the chamber slowly decreases in area resulting in the internal air pressure being increased. This continues until the pressure reaches its specified maximum range when it is then released via a valve. From the chamber, the compressed air is sent to the outlet line ready for use in the process system. In particular, the rotary screw compressor operates by utilising two internal rotors that turn in opposite directions. As they rotate, the air becomes trapped between them, and the housing's internal pressure begins to increase until the maximum pressure is reached. It's at this moment that the air disperses toward the outlet line. To avoid producing more heat than is necessary, a compressor with an internal cooling system can be installed to reduce the temperature of the air post-compression. This system works by cooling the air to an ambient temperature before sending it to the outlet line. In this case, it would be wise to compress the air isothermally rather than isentropically, as the latter requires more energy to keep the temperature at a minimum level.

Due to the compressor operating within a clean room, it is important that no contaminants are produced and released into the atmosphere. As well as this, the clean room in this scenario is temperature-controlled making it necessary for us to limit the amount of heat being dissipated by the compressor. Along with an internal cooling system, the build-up of heat during operation can be further reduced with the help of an air conditioning system. Clean rooms consist of an air-conditioning system to ensure the air inside is constantly flowing, a way to reduce the risk of contaminants forming. For our application, it will be worth installing an HVAC system as this will control not only air conditioning but also heating and ventilation within the clean room. It is important that the system we install also contains an HEPA filter as this will remove fine particles and microbes from the air that might be produced during the compressor's running.

There is a set of standards for clean rooms known as the clean room classification system 'ISO 14644-1'. The room is rated from ISO-1 (the cleanest) through to ISO-9 (least clean) based on how clean it needs to be. The classification is decided by the amount and size of contaminating particles within a cubic meter of air. It's important to consult the requirements of the clean room before deciding on a conditioning system to install.

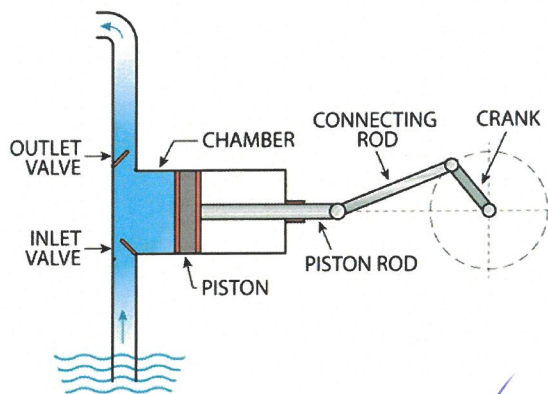
Task 1.3

Positive Displacement Pumps

A positive displacement pump operates by repeatedly reducing the area of a chamber in which fluid sits until a significant pressure is built. It is at this pressure when the fluid is released via the outlet. This operation is cyclic and can be carried out using a variety of different components although it is likely that these components fall under the general category of either reciprocating or rotary.

One type of reciprocating pump is known as the piston pump which consists of an inlet valve, outlet valve, chamber, piston and rod to name a few. These components work together through two phases, known as the suction phase and compression phase, to produce a pressurised fluid efficiently.

yes, with gaskets.
The first stroke of the piston pulls a vacuum from the inlet valve drawing in any fluid that resides there. As the vacuum is drawn, this enables the inlet valve to open whilst maintaining the closed position of the outlet valve. The fluid pulled in by the vacuum then sits inside the chamber where it awaits the 2nd stroke. Once pressure has built up inside the chamber, the piston rod carries out its 2nd stroke where it is sent back the way it has just come forcing the inlet valve closed. Simultaneously, this pushes the pressurised fluid in the chamber toward the outlet valve, forcing it open in the process. This cycle is repeated continuously at the rate set by the user.



Discussion is not overly-detailed on the construction, but diagram is concise.

Figure 3 - Piston Pump (Chesterton, 2024)

One type of rotary pump is known as a vane pump. Rather than the backwards and forwards motion required by the reciprocating pump, this rotary pump operates by utilising a set of vanes that rotate continuously to compress the fluid. The vane pump is made up of inlet holes, outlet holes, sliding vanes and an off-centered drive shaft. ✓

In this operation, fluid from a dedicated reservoir is forced through the inlet holes and into the chamber by the atmospheric pressure acting on it. Once inside the chamber, the fluid then collects within the gaps between vanes which are connected to the pump's drive shaft. ✓ An important note is that these vanes are also pushed against the wall of the chamber therefore creating a seal. Due to the position of the drive shaft relative to the chamber, as it rotates, the chamber wall presses in against these vanes further decreasing the area between the vane and the wall. This decrease in volume has an inverse effect on the pressure of the fluid, increasing it to the point of its highest pressure when it is discharged from the outlet line found at the other side of the chamber. ✓

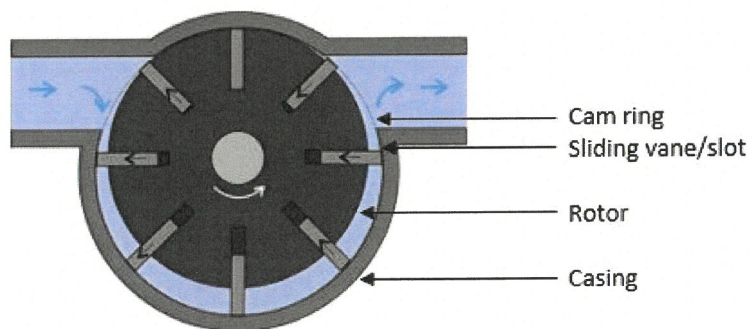


Figure 4 - Sliding Vane Pump (Michael Smith Engineers, 2024) ✓

What pressure/flow rates can you expect from these type of pumps?

Task 1.4

Controlling Pressure Within Pneumatic & Hydraulic Systems

Pneumatic systems must provide an appropriate amount of air to the application it is supplying. This means that air throughout the system should be monitored and controlled constantly to ensure that enough is being produced but also remaining at a safe amount to avoid over pressuring. All pneumatic systems should be fitted with an air regulator attached to the supply side of the system to minimise the likelihood of the system over pressuring. The air regulator can be adjusted via a screw to set a maximum amount of air from the supply into the system. Tightening this screw will increase the amount of pressure and loosening it will decrease the amount of pressure. This should be set based on the requirements of the application. ✓

Pneumatic controllers can also be adopted when trying to maintain a certain pressure within a system and focus on proportional, integral and derivative elements to control this. First, a variable signal is received by the controller and compares this variable value to the setpoint. The controller then processes the variable signal based on the setpoint value and delivers an output. It is essentially a balancing act between all elements to try and keep the amount of air flowing as close to the setpoint as possible. Below is a graph and table displaying how a system responds to a pneumatic controller when each element is introduced. This example is used to control temperature although the principles for pressure remains the same: ✓

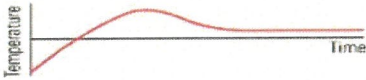
Control mode	Typical system responses	Advantages/disadvantages
On / off		• Inexpensive • Simple • Operating differential can be outside of process requirements
Proportional P		• Simple and stable • Fairly high initial deviation (unless a large P-band is chosen), then sustained offset • Easy to set up • Offset occurs
Proportional plus Integral P + I		• No sustained offset • Increase in proportional band usually required to overcome instability • Possible increased overshoot on start-up
Proportional plus Derivative P + D		• Stable • Some offset • Rapid response to changes
Proportional plus Integral plus Derivative P + I + D		• Will give best control, no offset and minimal overshoot • More complex to set up manually but most electronic controllers have an 'autotune' facility. • More expensive where pneumatic controllers are concerned

Figure 5 - PID Control (ECampus Ontario, 2024)

In a hydraulic system, a pressure-compensated flow control valve can be adopted to control variable pressure and maintain a constant flow rate within the system. For example, when the load acting on the system is larger, the pressure is already sufficient so the spool inside of the control valve opens to maintain this pressure. On the other hand, when the load acting on the system becomes smaller, the spool pushes against the spring and closes off to increase the pressure inside the system and keep the flow rate constant. This is useful when delivering hydraulic fluid to a system that consists of fluctuating loads. ✓

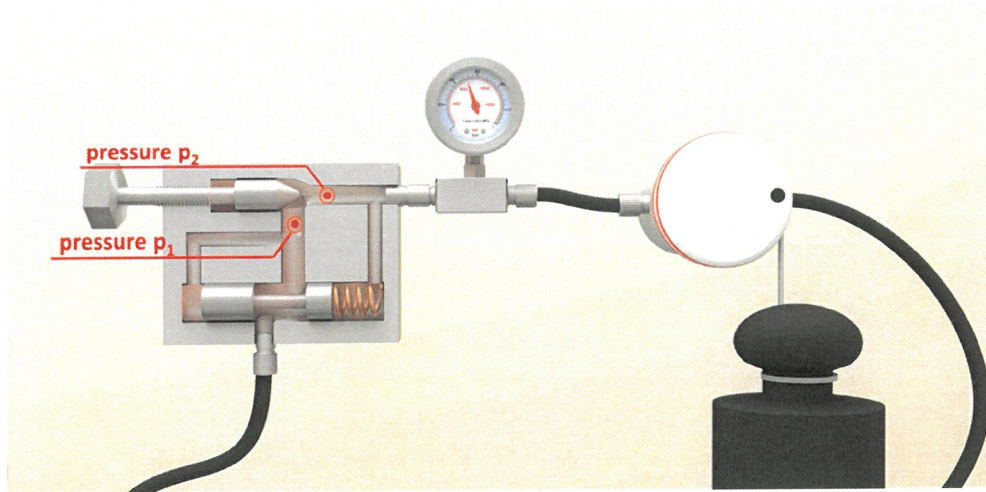


Figure 6 - Flow Valve Controlling Larger Load (Youtube, 2021)

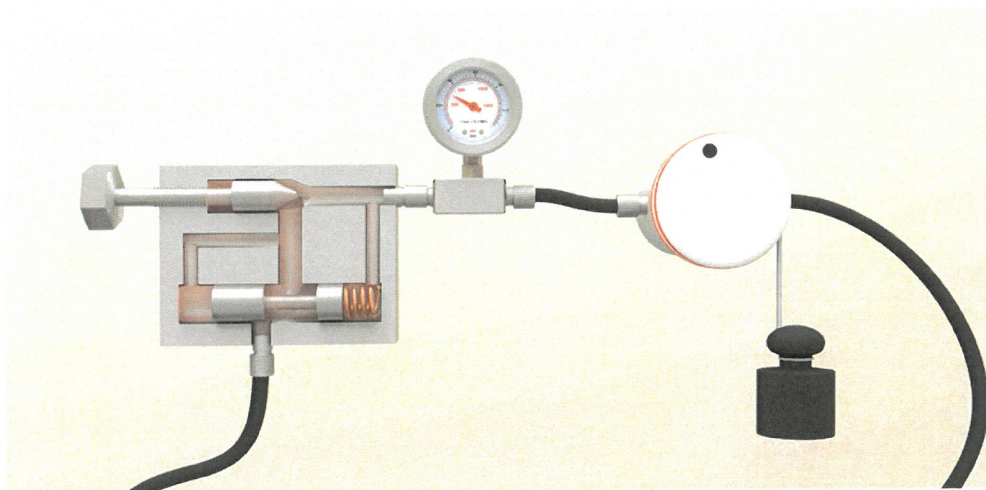


Figure 7 - Flow Valve Controlling Smaller Load (Youtube, 2021)

Good consideration towards maintaining pressure rather than relief.

Task 2.1

Compressor

Conditions

$$T_1 = 20^\circ\text{C}$$

$$P_1 = 101.325 \text{ kPa}$$

$$V_1 = 25 \text{ m}^3/\text{min}$$

Stage 1

$$T_2 = 40^\circ\text{C} \quad (w)$$

$$P_2 = 510 \text{ kPa} \quad (x)$$

$$V_2 = ?$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{(101.325 \times 10^3) \times 25 \times (40 + 273)}{(20 + 273) \times (510 \times 10^3)}$$
$$= 5.3 \text{ m}^3/\text{min} \quad \checkmark$$

Figure 8 - Compressor Stage 1 Calculations

Stage 2

$$T_2 = 40^\circ\text{C}$$

$$P_2 = 510 \text{ kPa}$$

$$V_2 = 5.3 \text{ m}^3/\text{min}$$

$$T_3 = 72^\circ\text{C} \quad (y)$$

$$P_3 = 900 \text{ kPa}$$

$$V_3 = ?$$

$$V_3 = \frac{P_2 V_2 T_3}{T_2 P_3} = \frac{(510 \times 10^3) \times 5.3 \times (72 + 273)}{(40 + 273) \times (900 \times 10^3)}$$
$$= 3.31 \text{ m}^3/\text{min} \quad \checkmark$$

Next calculations.

Figure 9 - Compressor Stage 2 Calculations

Task 2.2

Pipe Losses

Conditions

Diameter = 20mm

Length = 62m

Flow = 20 dm³/s

Pressure = 900 kPa (z)
= 9 bar

Pressure drop = 5.8 mbar/m
= 0.0058 bar/m

0.0058 × 62 = 0.36 bar

9 - 0.36 = 8.64 bar ✓

$P = F/A$

$F = P \times A = \frac{8.64 \times 10^5 (\pi \times 0.02^2)}{4}$

= 271.4 N ✓

Good method.

Figure 10 - Pipe End Pressure Calculations

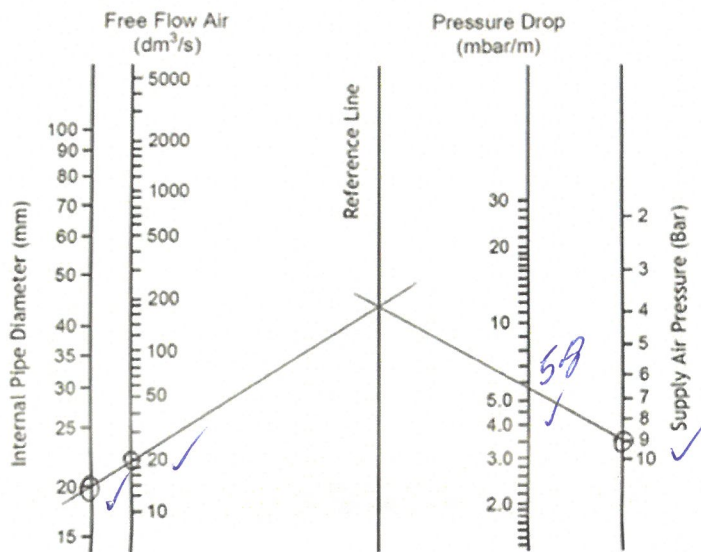


Figure 11 - Nomogram Determining Pneumatic Force of Air at Pipe End

Task 2.3

Air Receiver

$$F = P \times A$$
$$= 8.64 \times 10^5 \left(\pi \times \frac{0.076^2}{4} \right)$$

$$= 3919.5 \text{ N} \quad \checkmark$$

$$F = m/a$$

$$= 3919.5 / 9.81$$

$$= 399.54 \text{ kg} \quad \checkmark$$

Figure 12 - Maximum Mass Calculation

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+ Wide range of information.
- Where have these been used in the report?
In-text citations needed.
Harvard 2006 style acceptable. ✓