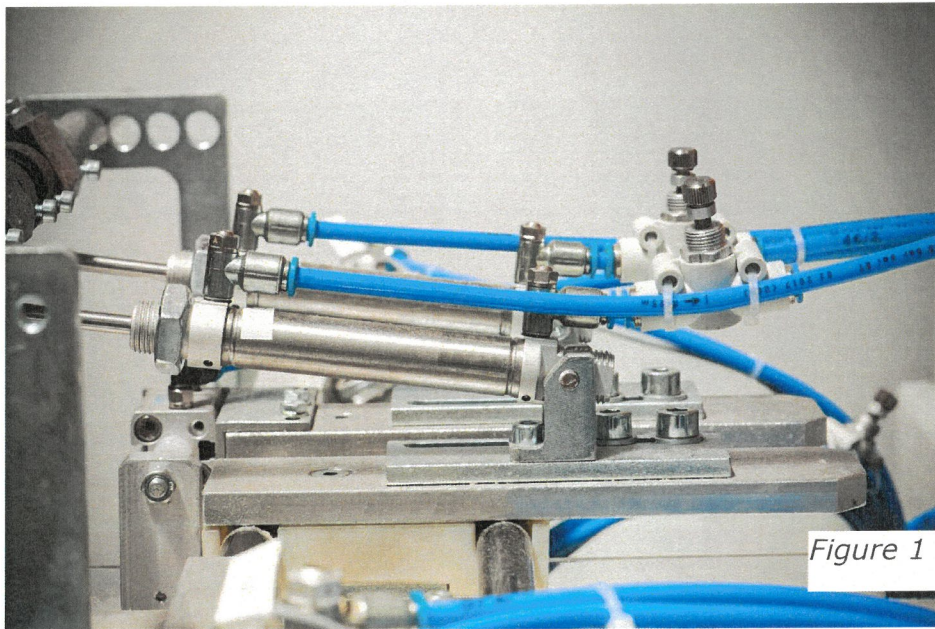


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J.M.

PNEUMATICS & HYDRAULICS PCEE4010

Year 2- HNC Instrumentation Engineering



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Prifysgol Cymru
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University of Wales
Trinity Saint David

Good format.

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List of figures
should be here,
not in appendix.

?

INTRODUCTION

The following assignment will inform the reader regarding Pneumatic and Hydraulic systems, and how they compare to one another. It will cover information such as operating principles, design features, air compressions, displacement pumps and pressure control, among other information. There are also some calculations such as flow rate, force and mass in Task 2.



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TASK 1 – PRIME MOVERS AND CONDITIONING

Operating Principles

Both Hydraulic and Pneumatic systems rely on the principle of fluid power (hydraulic compresses liquid, pneumatic compresses a gas) to achieve a desired outcome, to transmit power, such as activation of an actuator. This compression of the fluid enables a pressure to be output, and pressure is “the amount of force exerted on a unit area of a substance”, (Mott & Uttener, 2015). There are similarities between both systems, such as the operating principles, but there are also many differences.

For example, due to the nature of hydraulic oil, it is near incompressible, whereas pneumatic air is compressible, with the result of this being the Pneumatic systems are used where a quick output response, low load and a lower level of accuracy are required. Hydraulic systems are used more commonly where the load is much greater, and the need for accuracy in operation is required, and it achieves this due to the oil not being compressible. Compressibility is defined as “the change in volume (V) of a substance that is subjected to a change in pressure on it”, (Mott & Uttener, 2015).

Figure 2

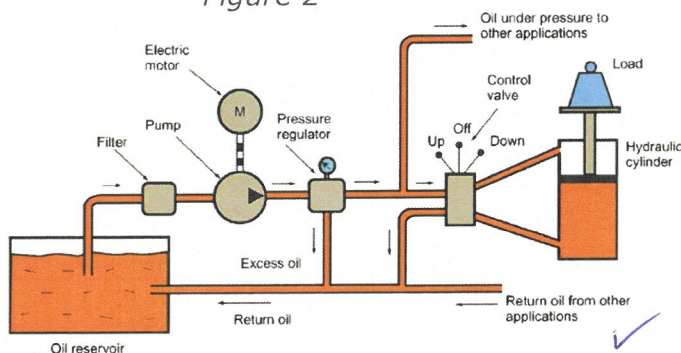
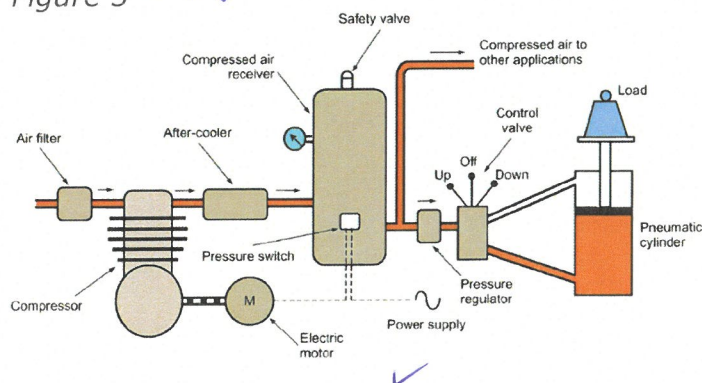


Figure 3 – Figure labeling missing.



As the two figures above show, both types of system use the same layout principles, with a supply of air / fluid coming into the system, being filtered and regulated, with the actuator having both an open and closed port in both applications. One notable difference is, the Pneumatic application has a feed to other application, so one energy source (compressor) has the ability to supply more than one system. This is achievable as a pneumatic system operates at a much lower pressure as opposed to a hydraulic system. Also, it is best practice for a Hydraulic system to be in a closed loop principle, one supply for one system, as this type of application operates at a much greater pressure. Another noticeable difference is that Figure 3 (Pneumatic),

* I do not know which page this info has originated from, see comment on reference list.

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has an air receiver tank, whereas the Hydraulic system uses a reservoir. The main reason for this variance, is because the pneumatic system will constantly use the supplied air and need topping up, whereas the Hydraulic system is a closed loop of fluid, and no liquid oil should be lost under normal working conditions. Lastly, the pressure regulator / pressure relief valve is common to both systems. The purpose of such a component is to ensure the overall system pressure doesn't not exceed a set value, where it could cause damage to the components or other equipment or people around it.

↳ how?

Both Hydraulic and Pneumatic are widely used throughout industry, ranging from petrochemical to food and drink manufacturing. Different applications depend on the above operating principles discussed, and for example, a Pneumatic system would be used in industries where cleanliness is important, such as laboratory or food/ beverage manufacture, as the only substance that could leak is air! Opposingly, Hydraulic systems are slightly more industrial, with the possibility of oil leakage, so these types of systems are used in industries such as oil and gas, transportation and storage etc. Hydraulic systems can also deal with a greater mass on the actuating end, making it perfect for more heavy industry. Due to the compression of air being fairly easy, Pneumatic systems are great for the handling and packing of consumer-based products, due to the lower operating pressures, "the pneumatic cylinders operate at a much lower pressure than the hydraulic cylinders. Therefore, the pneumatic cylinders are made of aluminium", (Salam, 2022), and speed of actuation, making it an ideal system for food manufacturing and the Fast-Moving Consumer Goods market in general.

As with any type of system in industry, fluid power comes with its own risks and legislation all user maintainers should follow. Some Safety legislation that covers all pressurised systems include the Pressure Equipment Safety Regulations 2016, and the Pressure Systems Safety Regulations 2000. Both these regulations were put in place to ensure employers and manufacturers are clear on what is expected of them when designing, building and supplying a pressurised system.

↳ such as?

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Air Compression

There are many types of air compression available, and the application required impacts the choice made for a business. Figure 4, below right, shows the various types of compressors such as screw, vane, diaphragm etc. For the requirements of the pneumatic system in question, the BOGE SLF Screw Compressor would be an ideal choice, data sheet can be found in the appendix. This compressor is a screw type, meaning the “compressor uses two rotors (helical screws) to compress the air, there’s a female and a male rotor”, (Watterson, 2018). The rotors force ambient air from the air inlet, through a cavity, and increasing the pressure on the output side. Figure 5, below, shows the overall screw unit of a screw compressor.

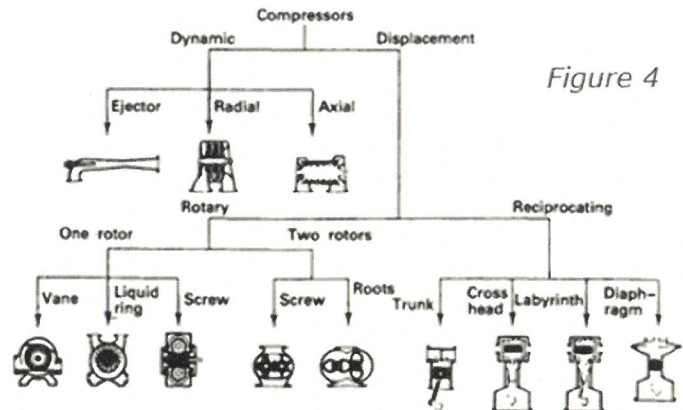


Figure 4

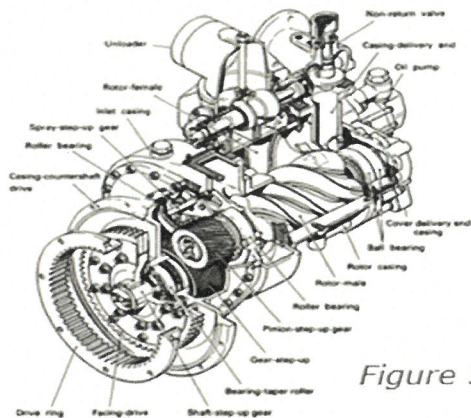


Figure 5

Alongside the production of compressed air, it is also possible to condition the air that is being processed. For example, the processed air can be temperature regulated, with the BOGE SLF mentioned above, using a frequency-controlled cooling fan to ensure optimum air temperature. It is also common for the air to be dried after compression, and doing so helps reduce running and maintenance costs, helps prevent corrosion within the system, ensures no damage to the actuators through pitting or causing seals to go brittle, and provide a moisture free air supply. It is pivotal to filter the air as it progresses through the compressor, especially filtering for any contaminants such as oil, as “the most common problem is oil in the compressed air”, (Watterson, 2018).

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Positive Displacement Pumps

In mechanical engineering there are many components used to obtain various outcomes. Pumps are used in a wide range of industries from petrochemical, food and drink and water treatment. But we can also categorize pumps by their type, not just their application, for example there are positive displacement pumps, centrifugal pumps, diaphragm pumps and so on.

Positive displacement pumps have a wide range of use, and their design ensures any fluid going in, only goes out. The way the pump moves fluid is by drawing the substance into the main cavity / chamber under vacuum, and as the pump completes the cycle, the fluid in the vacuum is forced out of the chamber under pressure, and out of the outlet port. This design allows such a pump to have a predictable flow rate, consistent pressure, lower rate of mechanical wear and wide range of viscosity capabilities. There are still some downsides to such a design, like frequent maintenance intervals, restriction to flow, requirement to purchase other OEM parts (relief valve etc) and more expensive than other alternatives.

Some common applications of positive displacement pumps include high viscosity substances, such as paint, oil, sediment, foods and more!

- you have not identified two types of positive displacement pump, (e.g. internal gear, external gear, vane, variable vane, piston, rotary piston.)
- + construction and general working principles are correct.

A pump diagram would be beneficial. + typical pressure/flow rates.

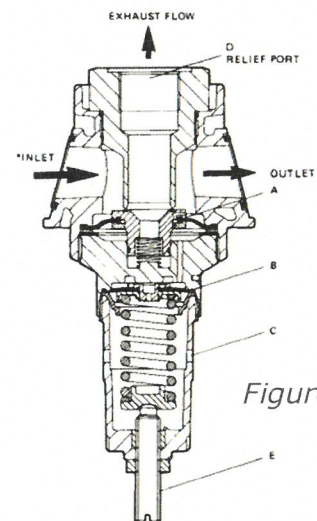
★ This is a very nice introduction, but when you are limited on words it is better to get straight into answering the question.

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Pressure Control

As with any system in industry, there needs to be controls and limits in place to ensure the optimum efficiency and safety of a system. This is heightened with regards to fluid power such as hydraulic and pneumatic, pressure control is of utmost importance. A system going over the designated safe working pressure, could be not just costly, but deadly. There are multiple components used within systems that allow them to operate at safe working pressures, such as PRV's (pressure relief valves), regulators, dump tanks and so on. With relation to a typical pressurised system, the main regulation on pressure would be at the outgoing side of the source (compressor / reservoir), and on any air receiver tanks.

For example, there would be a PRV on the outlet side of the air compressor, to allow any excess air to be dumped if over pressure, and again on the air receiving tank there would be a PRV. There would also be a check valve, or one way valve, ensuring pressure cannot re-enter the air source from the output side. Regulating valves are vital in controlling varying level of pressure in different stages of the system, and “ensures that the pressure in the system (or a part of the system) is not exceeded”, (Barber, 1997). Pressure relief valves, or PRV's, are normally closed valves that operate when a set pressure is exceeded, “It opens and exhausts fluid when the system pressure exceeds its design pressure by a selected amount”, (Barber, 1997). Figure 8, below, shows a typical PRV, which will operate should the throughput pressure be enough to disrupt the fixed spring, discharging out of Exhaust flow labelled.



In relation to the BOGE SLF mentioned above, they also do ancillary products such as the BLS leak stop, a device which can be fitted and detects any leaks when the system is idle, for example. This is not necessarily control, but certainly monitoring.

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TASK 2 – CALCULATIONS

Figure 4 and figure 5, below, shows a table of common formulae used when undertaking mechanical equations, some of which has been used below to obtain the required results.

Formula	Formula symbols	Units
Acceleration = $\frac{\text{change in velocity}}{\text{time taken}}$	$a = \frac{v - u}{t}$	m/s^2
Linear velocity	$v = \omega r$	m/s
Angular velocity	$\omega = \frac{\theta}{t} = 2\pi n$	rad/s
Linear acceleration	$a = r\alpha$	m/s^2
Relationships between initial velocity u , final velocity v , displacement s , time t and constant acceleration a	$v^2 = u^2 + at^2$ $s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$	m/s m $(\text{m/s})^2$
Relationships between initial angular velocity ω_1 , final angular velocity ω_2 , angle θ , time t and angular acceleration α	$\omega_2 = \omega_1 + \alpha t$ $\theta = \omega_1 t + \frac{1}{2}\alpha t^2$ $\omega_2^2 = \omega_1^2 + 2\alpha\theta$	rad/s rad $(\text{rad/s})^2$
Momentum = mass $\times$ velocity		kg m/s
Impulse = applied force $\times$ time = change in momentum		kg m/s
Force = mass $\times$ acceleration	$F = ma$	N
Weight = mass $\times$ gravitational field	$W = mg$	N
Centripetal acceleration	$a = \frac{v^2}{r}$	m/s^2
Centripetal force	$F = \frac{mv^2}{r}$	N
Density = $\frac{\text{mass}}{\text{volume}}$	$\rho = \frac{m}{V}$	kg/m^3
Work done = force $\times$ distance moved	$W = Fs$	J
Efficiency = $\frac{\text{useful output energy}}{\text{input energy}}$		
Power = $\frac{\text{energy used (or work done)}}{\text{time taken}}$ = force $\times$ velocity	$P = \frac{E}{t} = Fv$	W
Potential energy = weight $\times$ change in height	$E_p = mgh$	J
Kinetic energy = $\frac{1}{2} \times \text{mass} \times (\text{speed})^2$	$E_k = \frac{1}{2}mv^2$	J

Figure 7

Formula	Formula symbols	Units
kinetic energy of rotation = $\frac{1}{2} \times \text{moment of inertia} \times (\text{angular velocity})^2$	$E_k = \frac{1}{2}I\omega^2$	J
Frictional force = coefficient of friction $\times$ normal force	$F = \mu N$	N
Angle of repose, θ , on an inclined plane	$\tan \theta = \mu$	
Efficiency of screw jack	$\eta = \frac{\tan \theta}{\tan(\alpha + \theta)}$	
SHM periodic time $T = 2\pi \sqrt{\frac{\text{displacement}}{\text{acceleration}}}$	$T = 2\pi \sqrt{\frac{x}{a}}$	s
$T = 2\pi \sqrt{\frac{\text{mass}}{\text{stiffness}}}$	$T = 2\pi \sqrt{\frac{m}{k}}$	s
simple pendulum	$T = 2\pi \sqrt{\frac{L}{g}}$	s
compound pendulum	$T = 2\pi \sqrt{\frac{I_G + h^2}{gh}}$	s
Force ratio = $\frac{\text{load}}{\text{effort}}$		
Movement ratio = $\frac{\text{distance moved by effort}}{\text{distance moved by load}}$		
Efficiency = $\frac{\text{force ratio}}{\text{movement ratio}}$		
Kelvin temperature = degrees Celsius + 273		
Quantity of heat energy = mass $\times$ specific heat capacity $\times$ change in temperature	$Q = mc(t_2 - t_1)$	J
New length = original length + expansion	$L_2 = L_1 [1 + \alpha(t_2 - t_1)]$	m
New surface area = original surface area + increase in area	$A_2 = A_1 [1 + \beta(t_2 - t_1)]$	m^2
New volume = original volume + increase in volume	$V_2 = V_1 [1 + \gamma(t_2 - t_1)]$	m^3
Pressure = $\frac{\text{force}}{\text{area}}$ = density $\times$ gravitational acceleration $\times$ height	$p = \frac{F}{A}$ $p = \rho gh$ $1 \text{ bar} = 10^5 \text{ Pa}$	Pa

Figure 8

Compressor

NTP= 20°C 101.325KPa > 80degrees C

25cubic metres / min > 500Kpa

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \quad V_2 = V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{101.325 \times 10^3 \times 50 \times (80 + 273)}{(20 + 273) \times 500 \times 10^3} = 12.2 \text{ m}^3/\text{min}$$

Stage 1-

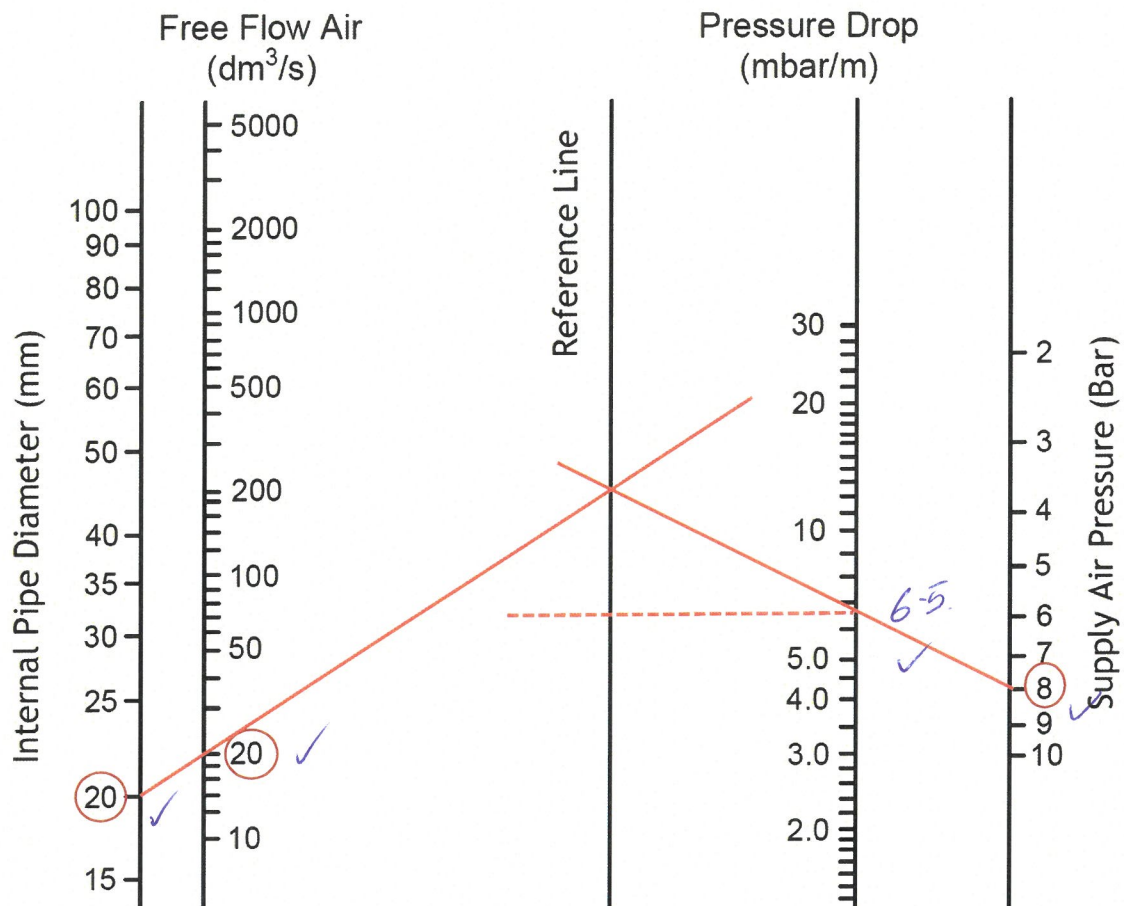
$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} = \frac{101.325 \times 10^3 \times 25}{(20 + 273)}$$

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{101.325 \times 10^3 \times 25 \times (45 + 273)}{(20 + 273) \times 540 \times 10^3} = 5.09 \text{ m}^3/\text{min} \quad \checkmark$$

$$V_3 = \frac{P_2 V_2 T_3}{T_2 P_3} = \frac{540 \times 10^3 \times 5.09 \times (75 + 273)}{(45 + 273) \times 800 \times 10^3} = 3.76 \text{ m}^3/\text{min} \quad \checkmark$$

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Pipe Losses



After losses at end of pipe 6.5mbar per metre

6.5mbar x 62meters = 403 milli bar after 62 meters

Total loss = 0.403 bar after 62 meters

Pressure after losses = 8bar- 0.403bar= 7.597bar ✓

Pneumatic force = Area X Pressure

Pressure = Force / Area

$$CS\ AREA = \frac{\pi \ 20mm^2}{4} = 314.16mm^2/0.314m^2$$

Good, clear method.

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F= Pressure / Area

$$\frac{7.597 \text{ bar} \times 10^5}{0.31416 \text{ m}^2} = 238.67 \text{ N} \quad \checkmark$$

Air Receiver

Force = Pressure x Area

Cylinder 76mm what can it lift at 1.4bar ?

Force= P x A

$$\text{Force} = \left(\frac{1 \times \pi \times 0.0762^2}{4} \right) \times 7.597 \times 10^5 = 3464.511 \text{ N} \quad \checkmark$$

Force= Mass x acceleration

Mass= Force / Acceleration

$$\text{Mass lifted} = \frac{3464.511}{9.81} = 353.16 \text{ kg} \quad \checkmark$$

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* Reference duplication for varying page numbers of the information source is not needed. One reference list entry. The page numbers should follow the in text ~~refer~~ citations in the report.

e.g. on page 5 of your report.

... of a substance (Mott & Uttener, 2015, pp. 26).

Harvard 2008 style acceptable.

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Evidence of wider reading. ✓

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APPENDIX:

Data Sheet 1- CAS, B. (2019) *Boge Screw Compressor S-3 Series, Boge Compressed Air Systems*. Available at: https://www.boge.com/sites/default/files/006_en_s-3_data_201006_0.pdf (Accessed: 18 January 2024).

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Figure 8- Bird, J.O. and Ross, C.T.F. (2020) 'Revision Test 8', in *Mechanical engineering principles*. Abingdon, Oxon: Routledge, pp. 293–294.

Should be in figure list.

When appendix information is included – insert the datasheet as it ~~is~~ is relevant to the reader.