Pearson BTEC Level 5 Higher Nationals in Engineering (RQF)

Unit 63: Industrial Services

Unit Workbook 2

in a series of 4 for this unit

Learning Outcome 2

Compressors

edexcel
Approved Centre

Contents

INTRODUCTION

Investigate the applications and efficiency of industrial compressors.

- *Industrial compressors:*
    - o Types and applications of industrial compressors.
    - o Role of intercoolers, dryers and air receivers.
    - o Efficiency and performance of air compressors.
    - o Hazards and faults: safety consideration and associated legislation.

GUIDANCE

This document is prepared to break the unit material down into bite size chunks. You will see the learning outcomes above treated in their own sections. Therein you will encounter the following structures;

Purpose	Explains *why* you need to study the current section of material. Quite often learners are put off by material which does not initially seem to be relevant to a topic or profession. Once you understand the importance of new learning or theory you will embrace the concepts more readily.
Theory	Conveys new material to you in a straightforward fashion. To support the treatments in this section you are strongly advised to follow the given hyperlinks, which may be useful documents or applications on the web.
Example	The examples/worked examples are presented in a knowledge-building order. Make sure you follow them all through. If you are feeling confident then you might like to treat an example as a question, in which case cover it up and have a go yourself. Many of the examples given resemble assignment questions which will come your way, so follow them through diligently.
Question	Questions should not be avoided if you are determined to learn. Please do take the time to tackle each of the given questions, in the order in which they are presented. The order is important, as further knowledge and confidence is built upon previous knowledge and confidence. As an Online Learner it is important that the answers to questions are immediately available to you. Contact your Unit Tutor if you need help.
Challenge	You can really cement your new knowledge by undertaking the challenges. A challenge could be to download software and perform an exercise. An alternative challenge might involve a practical activity or other form of research.
Video	Videos on the web can be very useful supplements to your distance learning efforts. Wherever an online video(s) will help you then it will be hyperlinked at the appropriate point.

With rotary compressors, there is an eccentric rotor featuring a number of spring-loaded vanes, the rotor rotates within a cavity and the combination of vanes and cavity form pockets of differing sizes. A gas is inputted into the system at a steady flow rate, entering one of the large pockets and, as the rotor spins, the size of the pocket decreases, this causes the pressure within that pocket to increase. The whole process is usually lubricated with oil, so this must be separated from the compressed gas after compression. See below for a graphical representation of this setup:
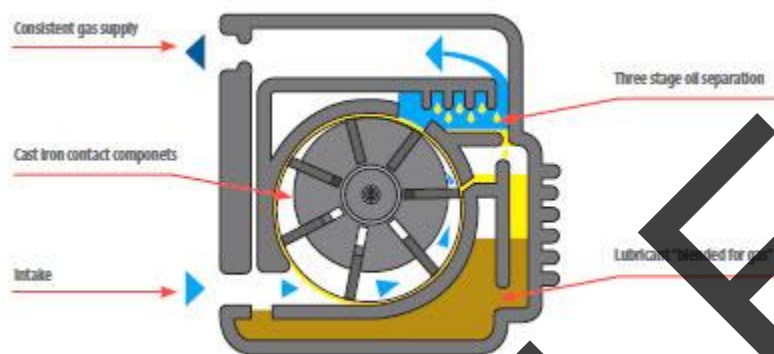

Figure 1.2: *Rotary Vane Compressor*

The following video also offers a clear explanation of the workings of a vane compressor:

Video

https://www.youtube.com/watch?v=L30JpM8Lv_A

The other main compressor type is the reciprocator and in direct contradiction to the rotary vane type, the flow is pulsating. A piston moves side to side and compresses the fluid in one stroke, forcing it through a delivery port, whilst during the other stroke, the fluid is taken in. Oftentimes, the piston is double ended so as to increase the efficiency of the operation, leading to input and output at both ends. As with a rotary/valve compressor, this reciprocating process is lubricated with oil, therefore reducing wear and aiding compression efficiency, the lubricating oil should either not be in contact with the gas or be removed after compression.
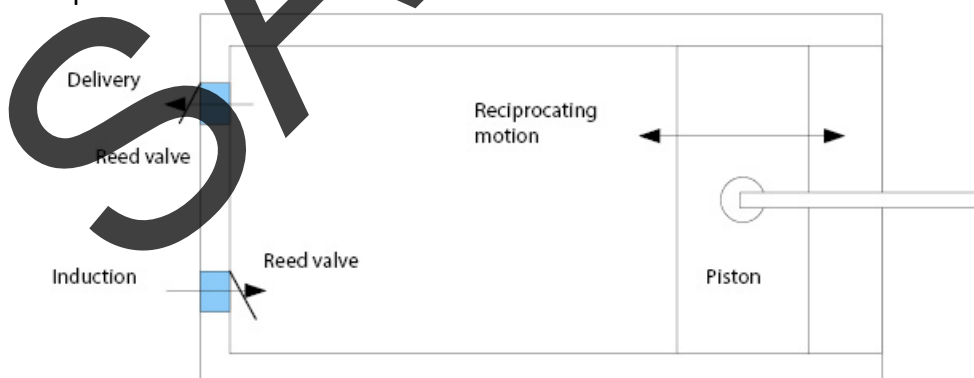

Figure 1.3: *Reciprocating Compressor*

The following video offers an explanation of the workings of a reciprocating compressor:

Video

https://www.youtube.com/watch?v=ITCu7gNMicc

Both the reciprocator and rotary/vane type compressors work via **positive displacement** of some mechanical linkage which reduces volume. There are another family of compressors, known as **dynamic compressors**, which depend on the momentum and inertia of the gas being compressed, i.e. the pressure increase occurs whilst the gas is flowing. In these types of compressor, an impeller uses rotating blades to increase the velocity of the gas, this gas is then rapidly slowed which causes an increase in pressure. The main types are shown below:
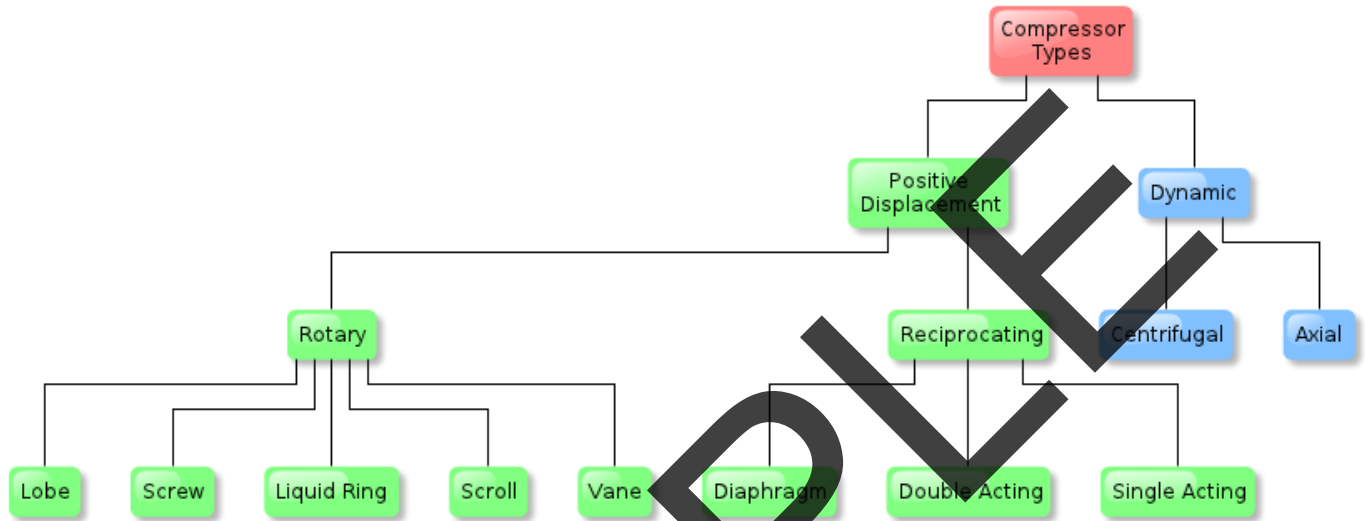

Figure 1.4: *Compressor Types*

There are two types of dynamic compressor, axial and centrifugal, and whilst the axial is not usually used in industry, the centrifugal is. An axial compressor uses turbine blades to force gas into an ever-reducing area, whereas a centrifugal compressor draws air into the centre of an impeller before accelerating it outwards towards its perimeter diffuser plate and outlet, whereby the velocity is drastically decreased.
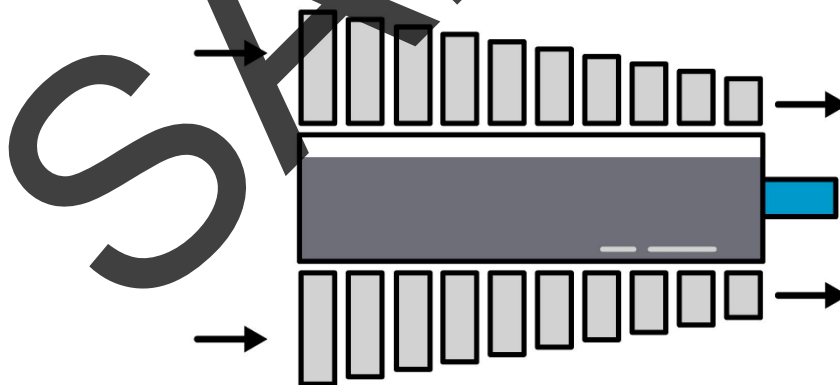

Figure 1.5: *Dynamic Axial Compressor*

The following video gives a good overview of axial compressor workings:

Video

https://www.youtube.com/watch?v=Il27VvHu-s0

$$(101000)(2.0)^{1.3} = (450000)(V_2)^{1.3}$$

$$248691.17 = 450000(V_2)^{1.3}$$

$$0.55 = (V_2)^{1.3}$$

$$\sqrt[1.3]{0.55} = 0.63$$

Final Volume = 0.63m³

Challenge

Work out the isothermal work, polytropic work and isothermal efficiency of the physics classroom piston system.

Video

See the following video for further explanation and examples of these equations:
https://www.youtube.com/watch?v=-GZoMyKDOrg

It may also be useful to determine the **volumetric flow rate** of the gas in a compressor; the volumetric flow rate of any substance is really just the volume of substance which passes per unit of time and is measured in m³ per second or sometime cubic feet per second. Expressed simply as the following equation:

$$\dot{v} = \frac{\Delta v}{\Delta t}$$

(Equation 1.6)

Commonly, in industry, compressors are rated with a volumetric flow rate at a certain pressure – compressors may have more than one pressure setting that they are capable of operating at. An example may be: 11 cfm @ 7.5 bar.

In industry, the **volumetric efficiency** of a compressor is also often used as a performance indicator. The volumetric efficiency of any compressor is essentially the ratio of the amount of gas entering the compressor compared to the amount leaving it. In **reciprocating compressors**, there are clearance gaps between the piston and its surrounding, leading to in efficiencies in the system. These clearance gaps are necessary in order for the compressor to actually function and so this type of compressor cannot, even in theory, be 100% efficient.

With a reciprocating compressor, there are essentially four different stages to the whole process. We have previously been looking at examples in a simplified way, considering essentially only two stages, i.e. the pre-compression and post-compression. In reality the stages are as follows:

Stage 1-2: The gas is compressed by the piston, decreasing volume and increasing pressure. *(Considered, only as either isothermal or polytropic in our examples).*

Stage 2-3: The gas is delivered to the next process through a discharge valve, (possibly to an inter-cooler or further compressor). Volume decreases slightly again as pressure remains constant.

Stage 3-4: The discharge valve is closed, the intake vale is opened ready to start the whole process again, pressure decreases, and volume increases slightly.

Stage 4-1: Gas is supplied to the compressor at initial pressure conditions, volume increases as the piston moves to accommodate it.

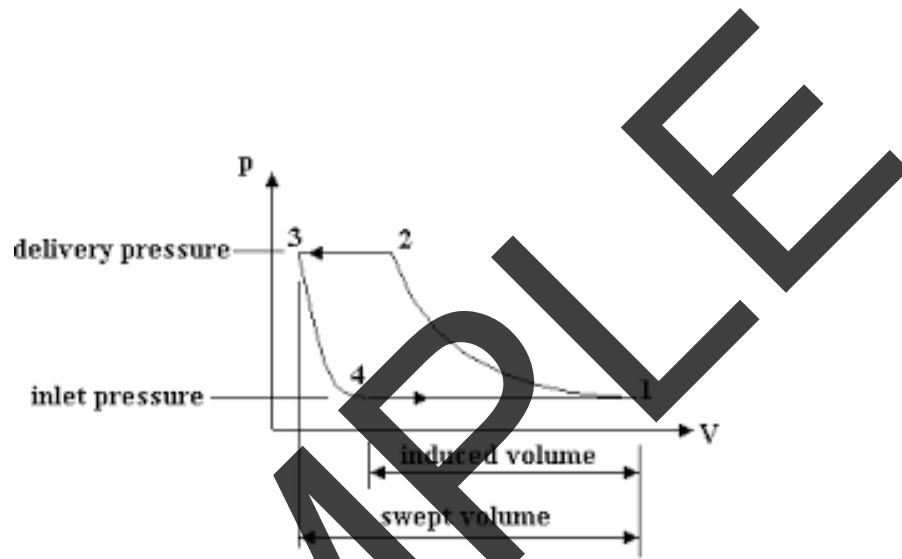These stages can be represented on a PV diagram as follows:

Figure 1.8: Reciprocating Compressor PV Diagram

In order to determine the volumetric efficiency of such a reciprocating compressor, the following equation is used:

$$\eta_{Volumetric} = \frac{Induced\ Volume}{Swept\ Volume}$$

(Equation 1.7)

Challenge

Using your own research, find out how this equation is derived.

All compression processes can be thought of in these essential basic terms, although if there is more than one compression operation then this adds another layer of complexity. Don't panic though, you can simply work out the performance characteristics of each operation separately!