1. Introduction

Fluids are used in a wide range of technical applications, varying from combustion systems to pneumatic applications. Knowledge in handling with fluids is therefore a important asset for engineering students.
The goal of this experiment is to gain insight into the basic characteristics of a gas. For understanding the following Boyle`s Law it is necessary to revise the two state variables pressure p and volume V of a gas. The pressure p in a chamber is defined as the sum of all acting forces per unit area of a gas or a gas mixture on the chamber wall. The volume V of a gas is defined by the space which it is occupying, for instance in a chamber.
Moving further to the actual law, which is under consideration, one of the basic laws for describing gases is the Boyle´s Law. This law was named after the anglo-irish chemist and physicist Robert Doyle in 1662. The Boyle`s Law can be derived by the ideal gas law. The ideal gas law states that the volume of a gas is connected to its temperature, its mass, the pressure and a constant R.

$$pV=mRT$$

Whereas the gas constant is R=0.287 kJ/kgK. The following conditions need to be assumed for an ideal gas:

1. The gas particles are considered as point masses
2. The diameter of the gas particles is much smaller than the average distance between the particles
3. The gas particles have ideal elastic impacts between each other and the wall.

As soon as the temperature are constant, volume only changes with the pressure of the gas. This is what Boyle's Law says.

$$V=k/p$$

So that the volume V is proportional to 1/p with the factor k.
During this experiment the constant k of Boyle`s Law will be derived from the test results. The gas used here is air.

1. Description of the instrument and technical scheme

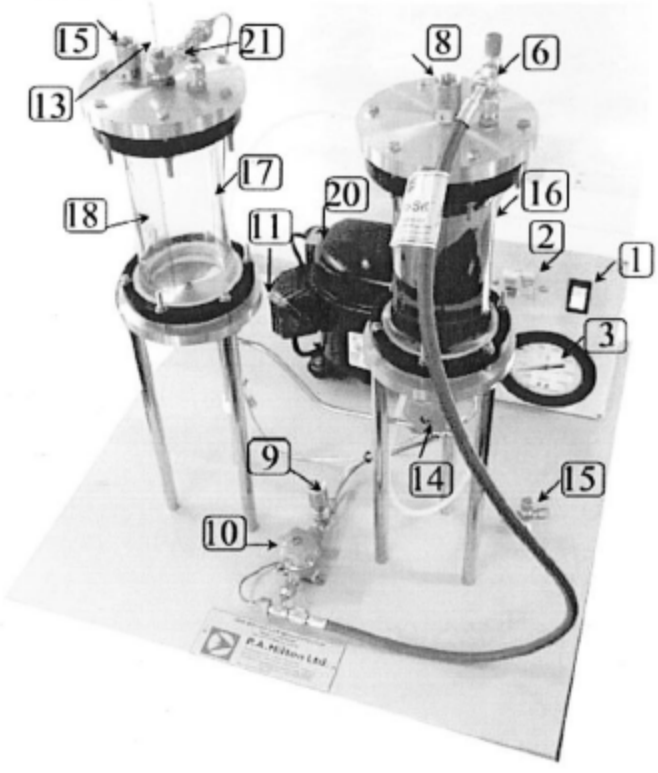
All parts of the experiment are equipped with number tags. These numbers will be used in this document together with the part names to be clear. Therefore see the pictures below.

The apparatus includes manly two chambers and a compressor. The right camber (16) is the fluid chamber and serves as a reservoir for a incompressible pressure oil. The oil is used to change the air volume in the left chamber (17) during the experiment. This one is the mesuring chamber. The pressure inside is displayed at the pressure gauge (3). Both cambers have couplings and valves on top. The valves (15) and (8) are needed for savety reasons while the couplings (21) and (6) do fit with the one end of the blue hose (12) that has a pin inside (make sure this one is closed tight, otherwise it will not open the coupling). The couplings can also be opend by a screw driver or a fingernail manualy (only if you are sure that there is no high pressure!!) by pressing the middle pin. The chambers are connected by a pipe that can be closed by a valve, the oil flow contol valve (14).

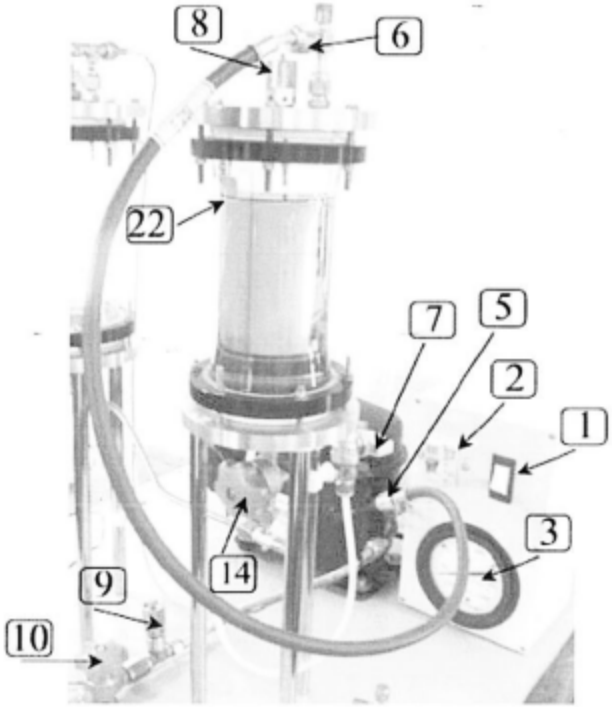
The compressor has two couplings, one where air comes out, the compressor discharge (4) and one where it is sucked in, the compressor suction coupling (5). The compressor discharge is connected to the pressurising control valve (10). Next to this valve there is the discharge coupling (19), where the hose (12) can be attached. These two couplings can be used to put pressure on each chamber or evacuate them. The compressor is switched on with the main switch (1).

1 mm of heights represents 0.005 L volume in both chambers. The permanent connection between the compressor discharge coupling and the mesauring chamber is for the pressure measurement and can be ignored in the flow sheet and operation of the apparatus.

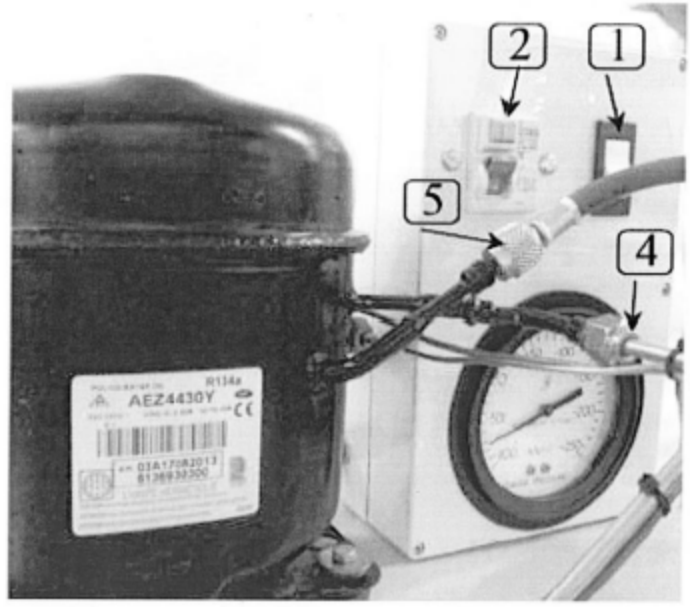
SCHEMATIC DIAGRAMS



Picture 1: Oil and Measuring Chambers



Picture 2: Oil chamber



Picture 3: Pressure gauge, compressor and transformator

2. Experimental procedures

Start point for each experiment:

Make sure that there has been no drastic temperature changes in the last hour before you start your experiment and rather will be during the experiment (Air con!!). The entire oil is supposed to be in the right chamber (16) and the pressure gauge must show 0 kN/m^2. To be sure the fluid chamber is also at atmospheric pressure push in the pin on the fluid chamber coupling (6). Place the Thermometer in the and don't move it during the experiment.

Experiment 1: below atmospheric pressure experiment

Open Valve (10), close valve (14) and connect the cranked end of the hose (12) to the coupling on top of the measuring chamber (21) and the other end to the compressors suction coupling (5). Now turn on the compressor and wait till the gauge shows approximately -50 kN/m^2. Stop the compressor and remove the knurled brass cap on the rear of coupling (6) on the fluid chamber to vent the chamber to atmosphere. Open the fluid flow valve (14) until the fluid reaches exactly 140 mm on scale of the measuring chamber (17) and close the fluid control valve (14). Disconnect the hose (12) from the measuring chamber and press the pin at the measuring chamber coupling (21) till the gauge shows 0 kN/m^2. Replace the knurled brass cap on the rear of coupling (6) on the fluid chamber. Now connect the hose to the couplings (5) and (6) and run the compressor for approx. 1 minute to reduce the pressure in the fluid chamber (16) to near vacuum.
The measuring chamber (17) now contains a known volume of air at atmospheric pressure and you can start your experiment from this point.
Record the starting pressure, starting air volume and temperature of the measuring chamber (17) and then carefully open the oil flow valve (14) to let oil flow back to the fluid chamber till the level at the measuring chamber has changed by 10 mm (= 0.05 L) on the scale and record the pressure, volume and temperature again. Repeat this procedure till the measuring chamber is empty and transfer your records to the given diagram. After the experiment restore starting conditions.

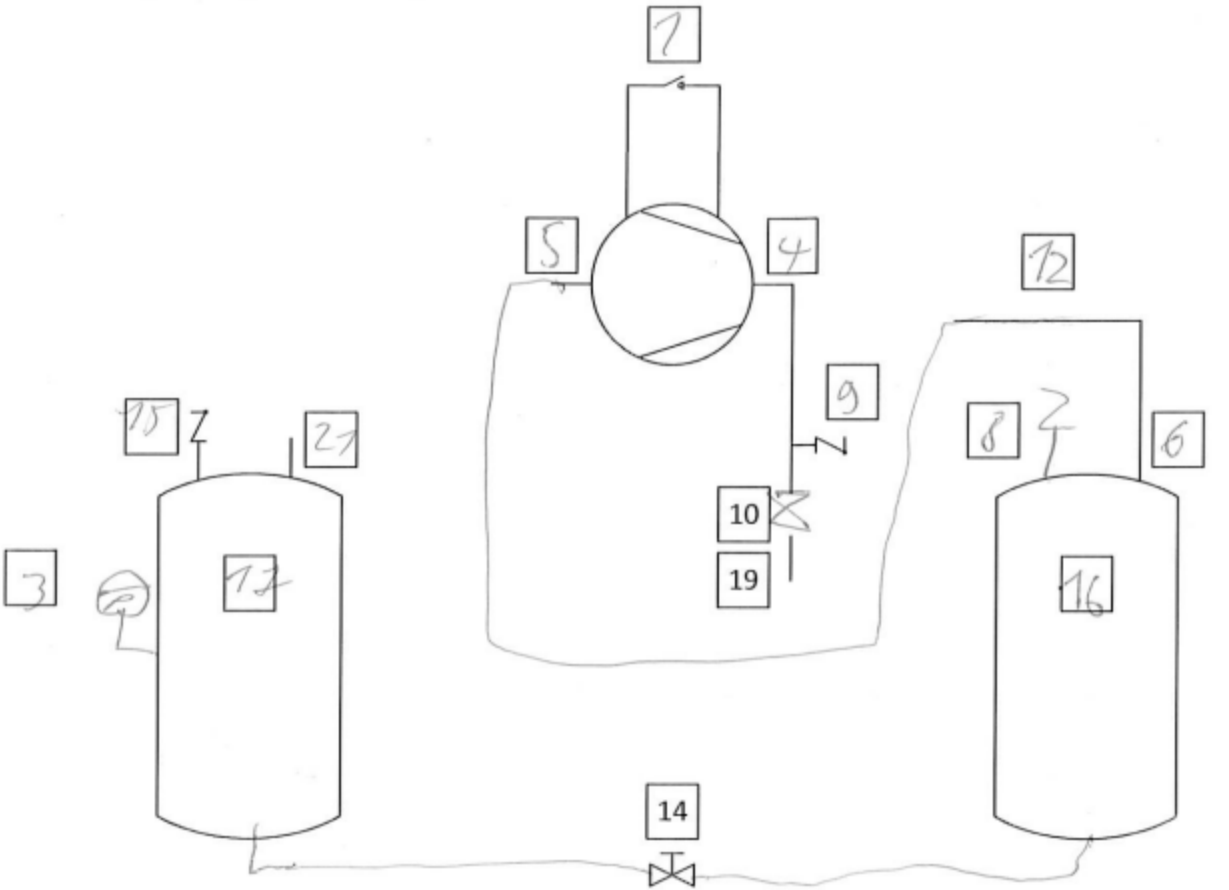
Experiment 2: above atmospheric pressure experiment

Make sure the oil flow valve (14) is closed and connect the cranked end of the hose to the fluid chamber coupling (6) and the other end to the discharge coupling (19) and close the air control valve (10). Now turn on the compressor. The relief valve (9) will vent and/or the compressor will turn off at a certain pressure. Now carefully open the air control valve (10) and close again after a short while. Open the oil flow valve (14) till oil level in the measuring chamber reaches 50 mm, then close valve (14). Now vent the measuring chamber by pushing the pin of the measuring chamber coupling (21). You can start your experiment from this point.
Record the starting pressure, starting air volume (level on scale) and temperature of the measuring chamber (17) and then carefully open the oil flow valve (14) to let oil flow into the measuring chamber (17) till the level at the measuring chamber has changed by 10 mm (= 0.05 L) on the scale and record the pressure, volume and temperature again. Repeat this procedure till the level at the measuring chamber is at 140 mm and transfer your records to the given diagram. If the pressure in the fluid chamber is insufficient, open the air control valve (10) again for a short while. After the experiment restore starting conditions and switch off the compressor.

3. Tasks and assignment

1. First you need to get familiar with the apparatus. Therefore complete the flow sheet for both operating states. Add all numbers and make a name list with these numbers of the apparatus parts.
2. Complete Experiment 1
3. Complete Experiment 2
4. Calculate the factor k from your diagrams. What is the difference between the two experiments and why does it occur? Hind: Calculate k from the ideal gas law and figure out which variable is different in the two experiments.
5. Redo both experiments in a way, that gives you the same slope for the above- and the below atmospheric pressure experiment.
6. Bring the apparatus back to start condition and make sure you leave the workspace as tidy as you found it in the beginning!
7. What are the conditions which have to be valid for using the Boyle`s Law?

Below atmospheric pressure experiment



Above atmospheric pressure experiment