Maritime University of Szczecin

Faculty of Marine Engineering

Department of Physics and Chemistry

Physics Laboratory

Laboratory Description

Determination of cp/cv ratio

English version written by
dr Agata Kowalska

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Objectives:

- ➢ Understanding of basic gas processes.
- ➢ Performance of the pressure measurement using an open manometer.
- ➢ Determination of the adiabatic exponent.

Questions and problems to be solved:

- Ideal gas characteristics and ideal gas law.
- Four basic gas processes.
- Specific heat of ideal gases.
- What is the c_p/c_v ratio and what does it depend on?
- Pressure measurements by using an open and closed manometer.
- Explain why pressure changes in the tank are observed although the valve is closed?

Short description:

In order to determine the c_p/c_v ratio we use capacious tank, open liquid manometer, compressor and valve Z.

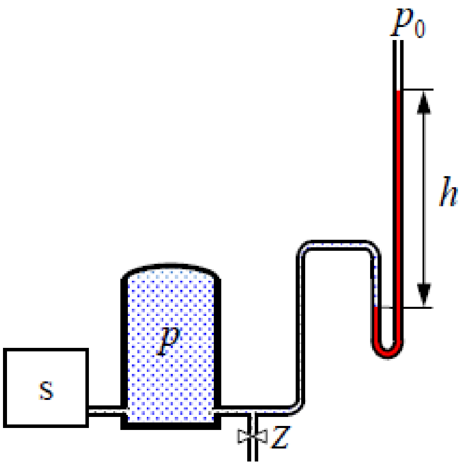

Fig. 1. Scheme of a measuring system used to determine the c_p/c_v ratio

At the beginning (state A) examined gas (air) fills entire volume of the tank V_0. Gas temperature T_0 and pressure p_0 is equal to the ambient temperature and pressure. Using the compressor we obtain the excess pressure in the tank until the difference of levels of liquid columns in both arms of the manometer is equal to about 0.8 m (state B). Afterwards we wait for 3 minutes. During this time, the air which was previously warmed in the adiabatic compression process, cools to the ambient temperature (state C). It results in a decrease of the level difference of the liquid in both arms of the manometer. We read the difference h_1 between liquid levels and calculate the actual pressure in the tank $p_1 = p_0 + \rho g h_1$.

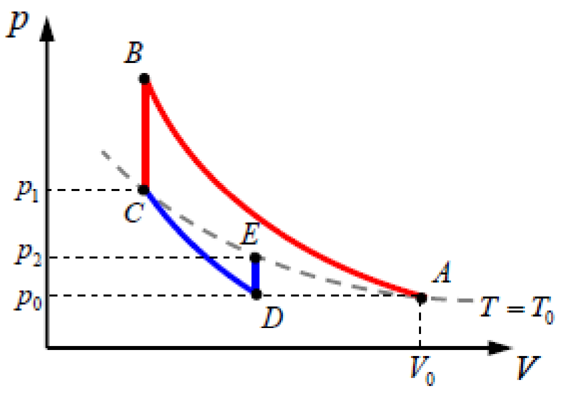

Fig. 2. Diagram of all thermodynamic processes taking place during the exercise

Afterwards we open the valve Z, allowing rapid, adiabatic gas expansion in the tank (state D). As soon as the pressure in the tank equals to the ambient pressure, we close the valve Z. Again we wait for 3 minutes. During this time, the air cooled in the adiabatic expansion process, reaches the ambient temperature (state E). At this time the gas pressure in the tank increases. As a consequence the difference of the levels of the liquid in both arms of the manometer increases up to the value h_2.. We calculate the pressure in the tank
$p_2 = p_0 + \rho g h_2$.
Points C and E lie on the same isotherm

$$pV = const. \tag{1}$$

because they correspond to the same temperature T_0. By differentiating this equation we get

$$pdV + Vdp = 0 \tag{2}$$

or after transformation

$$\frac{p}{V} = -\frac{dp}{dV} \tag{3}$$

Performing similar calculations for the adiabatic process

$$pV^{\kappa} = const\ , \tag{4}$$

which takes place between the C and D state, we find:

$$\frac{p}{V} = -\frac{1}{\kappa}\frac{dp}{dV}. \tag{5}$$

By comparing equations (3) and (5) and going to finite increments, corresponding to the experimental results, we get the relation:

$$\frac{\Delta p_{izot}}{\Delta V} = \frac{1}{\kappa}\frac{\Delta p_{ad}}{\Delta V}, \tag{6}$$

where: $\Delta p_{ad} = p_1 - p_0,\ \ \Delta p_{izot} = p_1 - p_2$.

After transforming the equation (6) we find the desired value of the coefficient κ:

$$\kappa = \frac{c_p}{c_v} = \frac{\Delta p_{ad}}{\Delta p_{izot}} = \frac{p_1 - p_0}{p_1 - p_2} \tag{7}$$

Literature:

1. Resnick R., Halliday D., Walker J., *Fundamentals of Physics*, John Wiley & Sons, INC (available editions).