2. Practical way of realization of adiabatic process

2.1 Introduction

Adiabatic process is carried out when amount of heat transfer is zero $Q_{1-2} = 0$ for each of state (i.e. 1 and 2) during the process (see figure). Based on this definition to realize the adiabate curve, any object must be equipped with a very good thermal insulator. For example, when the reservoir with gas is emptied by quick opening the valve, the adiabatic process needs perfect insulation. But, there is no ideal heat insulator in practice. Because of this adiabatic process can be made approximately, only. To define the approximation, the “Y” factor exists.:

$$Y = \frac{|Q_{z(1-2)}|}{|U_2 - U_1|} \tag{1}$$

Where:
$|Q_{z(1-2)}|$ - amount of total (positive or negative) heat transferred to the gas in time $\Delta\tau$,
$|U_2 \ - \ U_1|$ - total change of internal energy of gas during transfer from state 1 to 2,
If Y = 0, the real adiabatic process is carried out. For Y ≠ 0, the process is approximately adiabatic with accuracy of 1% or 0,1% etc., depends on quantity of Y.
All components of formula (1) must be known to define a level of approximation. It is not easy way to collect all of them. But it can be fully recognize when adiabatic process is carried out according to Clapeyron formula with heat capacity c_v = const. Within PV system, adiabatic process changes to polytrophic curve as follows:

$$pv^k = idem \tag{2}$$

Adiabatic exponent “k” is connected with c_v, c_p by:

$$k = \frac{c_p}{c_v} \tag{3}$$

In logarithmic diagram this formula changes to linear curve.

2.2 Objective of experiment

The aim of experiments are as follows:
• to give the answer – does adiabate of ideal gas is polytrope?,
• to check – does a decompression of reservoir wire the air is (approximately) adiabatic process,
• to calculate accuracy of realization of adiabatic process.

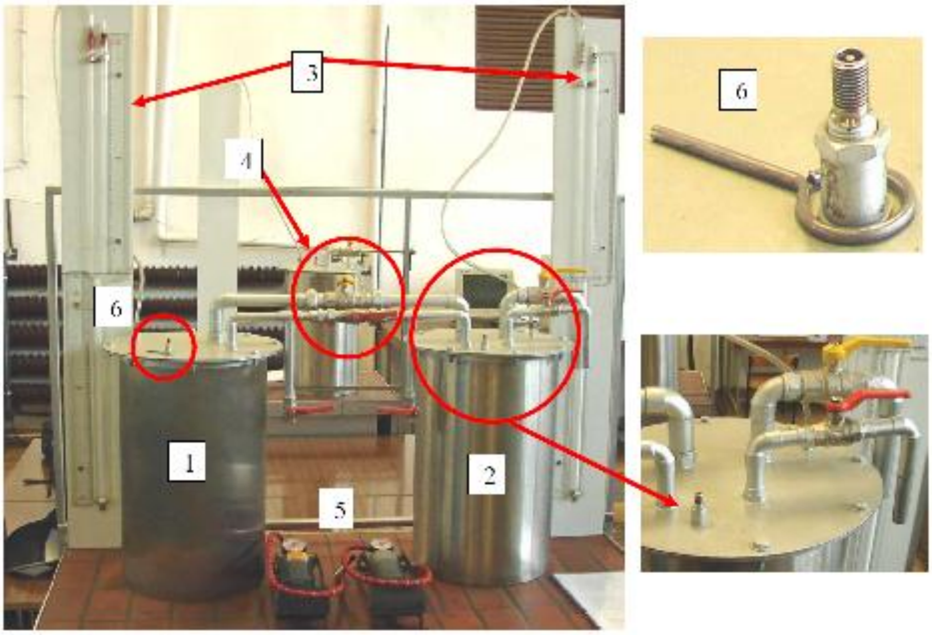

Fig 1 Measuring position. [1] tank A, [2] tank B, [3] manometers, [4] connecting valve A with B, [5] pump, [6] valve, [7] key

There are two tanks (called A and B)with constant volumes. Follow the curve of figure below, please.

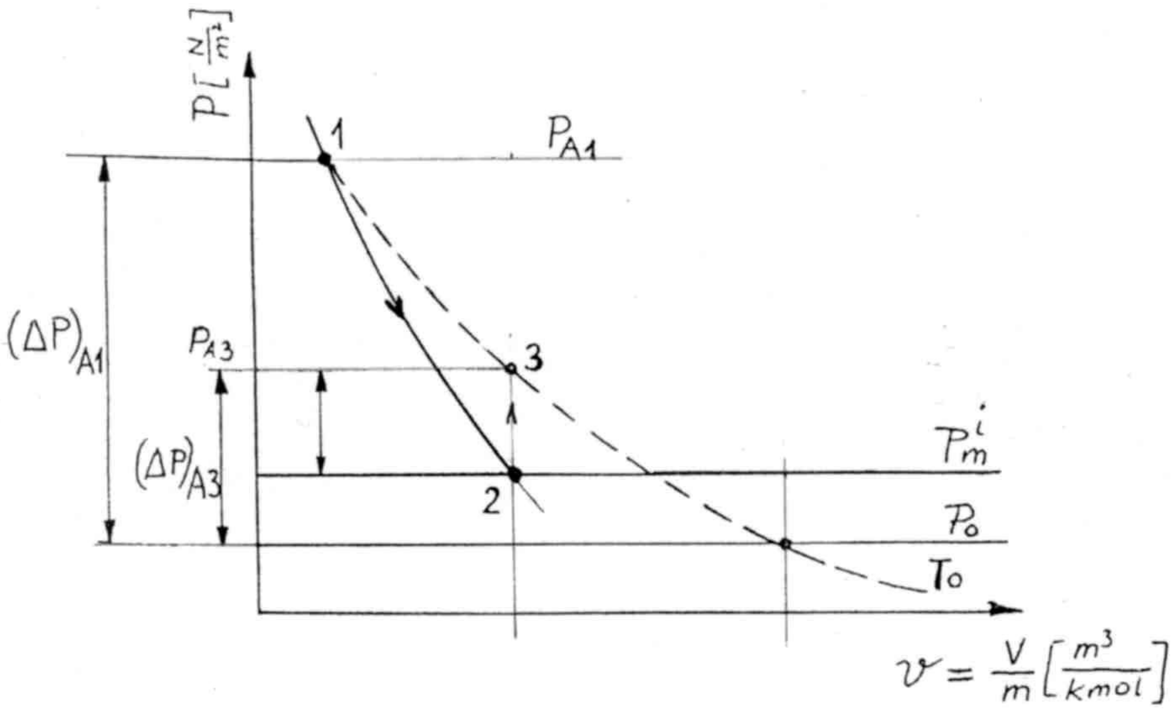

Fig 2 Decompression proves in tank called A

Step 1.

To fill two tanks A and B by ambient air to get an over pressures $\Delta p_{Ali}, \Delta p_{Bli}$ inside the particular tank, which are base for following dependence:

$$p_{Ali} > p_{Bli} \geq p_0 \tag{4}$$

Where:

p_0 ambient pressure

$p_{Ali} = p_0 + \Delta p_{Ali}$ and $p_{Bli} = p_0 + \Delta p_{Bli}$

After pumping (filling tanks by gas) temperature must be equal to the ambient:

$$t_{Ali} = t_{Bli} = t_0 \tag{5}$$

Step 2.
To open (for a moment – around one second) valve on the pipe joining both tanks. The fast air from the tank A to the tank B flow arises and end only when the pressure in both tanks equalize. Hence:

$$p_{A2i} = p_{b2i} = p_{mi} > p_0 \tag{6}$$

Then the temperatures reaches:

$$t_{A2i} < t_0 \; and \;\; t_{B2i} > t_0 \tag{7}$$

Notice!
Pressure pm is calculated by:

$$p_m = \frac{p_{A1} - p_{B1}}{2} \tag{8}$$

Step 3.
To close valve and wait until the temperature is in balance with ambient $T_{A3} = T_{B3} = T_o$
Then pressure can be measured $p_{A3} > p_{B3} > p_0$.

Experiment should be made several times for various values of pressure p_B and for the same amount of start pressure p_A.

Suitable formulas:

$T_2 < T_0$, $\quad p_{A2i} = p_{mi}$ (i=1,2,3,...,5)

$T_3 = T_0$ $\quad p_{A2i} > p_{mi}$

$p_0 v_0 = RT_0$ $\quad R = 0{,}287\, {}^{kJ}/_{kgK}$

$$p_m = \frac{p_{A1i} - p_{B1i}}{2}$$

$p_{A1i} = p_0 + (\Delta p)_{A1i}$ $\quad p_{B1i} = p_0 + (\Delta p)_{B1i}$

$(\Delta p)_{A1i}$ constant i.e. 800 mm H2O (it is important to be on the same adiabatic curve all time)

$(\Delta p)_{B1i}$- 0, 150, 300, 450, 600, mm H2O

$p_{mi} = \frac{p_0+(\Delta p)_{A1}+p_0+(\Delta p)_{B1}}{2}$ $\quad$ $p_{mi} = p_0 + \frac{p_0+(\Delta p)_{A1}+(\Delta p)_{B1}}{2}$

$p_{A3i} = p_0 + (\Delta p)_{A3i}$

States of gas „1", „2" are situated on adiabatic curve, means fulfill formulas as follows:

$p_{A1} v_{A1}^{w} = p_{A21} v_{A1}^{w} = p_{mi} v^{w}$ hence: $\frac{p_{A1}}{p_{A2i}} = \left(\frac{v_{A2i}}{v_{A1}}\right)^{w}$

States of gas „1" i „3" are situated on isotherm $T = T_o$, so it right that:

For $p_{A1} v_{A1} = p_{A31} v_{A3i}$ when $v_{A3i} = v_{A2i}$

Get $p_{A1} v_{A1} = p_{A31} v_{A2i}$ and $\frac{p_{A1}}{p_{A2i}} = \left(\frac{p_{A1}}{p_{A3i}}\right)^{w}$ or $\frac{p_{A1}}{p_{A3i}} = \left(\frac{p_{A1}}{p_{A3i}}\right)^{w}$

After mathematical operation:
$ln\frac{p_{A1}}{p_{mi}} = wln\frac{p_{A1}}{p_{A3i}}$ which can be farther converted into $\eta = w\zeta$

2.4 Elaboration of results

The results of measuring put to the table						
$(\Delta p)_{A1}$	800 mm H_2O					To set
$(\Delta p)_{B1i}$	0	150	300	450	600	To set
$(\Delta p)_{A3i}$						To measure
p_{mi}						To calculate
p_{A1}						To calculate
p_{A3i}						To calculate

Calculation:

$$\eta = ln\frac{p_{A1}}{p_{mi}}$$

$$\zeta_i = ln\frac{p_{A1}}{p_{A3i}}$$

Calculated values insert to the table below

$(\Delta p)_{B1i}$	0	150	300	450	600
η_i					
ζ_i					

Results give as a diagram $\eta = f(\zeta)$
If the points are situated near to the line, it is possible to define direction factor.
An amount of "*m*" is approximately adiabatic exponent "*k*" for ideal gas..
To determinate of accuracy of adiabatic curve use the formula as follows:

$$Y = \frac{Q_{z(1-2)}}{U_2 - U_1} = \frac{q_{z(1-2)}}{u_2 - u_1}$$

Because $w \neq k$ and $w = const$ (it is polytropic process), the heat of process can calculate by:

$$Q_{w1-2} = mc_w(t_2 - t_1)$$

And

$$c_w = c_\sigma - \frac{R}{w-1}$$

Since $U_2 - U_1 = mc_v(T_2 - T_1)$
Then

$$Y = \frac{w-k}{w-1}$$

For ambient air please take $k \approx 1{,}41$.

An example of test table

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Group …………………..date: …………………. hour:…………………….

Experiment set nr 1 (big valve)						
p_o, hPa/p_o, mm H_2O	/					
$(\Delta p)_{A1}$	800 mm H_20					To set
$(\Delta p)_{B1i}$	0	150	300	450	600	To set
$(\Delta p)_{A3i}$						To measure
p_{mi}						To calculate
p_{A1}						To calculate
p_{A3i}						To calculate

Calculated values η, ζ

$(\Delta p)_{B1i}$	0	150	300	450	600
η_i					
ζ_i					

Experiment set nr 2 (small valve)						
p_o, hPa/p_o, mm H_2O	/					
$(\Delta p)_{A1}$	800 mm H_20					To set
$(\Delta p)_{B1i}$	0	150	300	450	600	To set
$(\Delta p)_{A3i}$						To measure
p_{mi}						To calculate
p_{A1}						To calculate
p_{A3i}						To calculate

Calculated values η, ζ

$(\Delta p)_{B1i}$	0	150	300	450	600
η_i					
ζ_i					

Diagrams $\eta = f(\xi)$ for each experiment set (1 and 2).