

1. Determination of heat capacities (specific heats) c_p (at constant pressure) and c_v (at constant volume) for ambient air

1.1 Introduction

The value of heat, which gives change of state of PVT system depends on type of process, means how the process is carried out. It is possible only for reversible processes, where path of phenomenon is fully specified. The heat can be defined by

$$Q_{1-2} = mc_{1-2}(t_2 - t_1) \quad (1)$$

where:

- Q_{1-2} - amount of heat between process states 1 and 2,
- m - mass of the gas,
- c_{1-2} - average heat capacity, taken from state of 1 and 2,
- T_2, T_1 - temperatures in state of 2 and 1 respectively .

Two types of specific heats take special roles in thermodynamics. There are: “ c_v ” – specific heat at constant volume state and “ c_p ” – at constant pressure, as follows.

$$C_v = \frac{Q_{v(1-2)}}{m(t_2 - t_1)} \quad (2)$$

$$C_p = \frac{Q_{p(1-2)}}{m(t_2 - t_1)} \quad (3)$$

To determine each of them all components of formulas should be measured using calorimetric method. It gives quite satisfied results for liquid and solid states, but for gas - too big errors are received.

There is a dynamic method (different than calorimetric one) to get right results for determination of heat capacity. This method bases on adiabatic expansion process. Formula of an adiabatic process is as follows:

$$pv^k = idem \quad (4)$$

where adiabatic exponent “ k ” is formulated by:

$$k = \frac{c_p}{c_v} \quad (5)$$

On the another hand the following relationship is existed

$$c_p - c_v = R \quad (6)$$

where: R – individual gas constant ($R = R_u/M$, R_u - universal gas constant, M – mole number, $R_u = 8,314 \text{ kJ/kmol K}$).

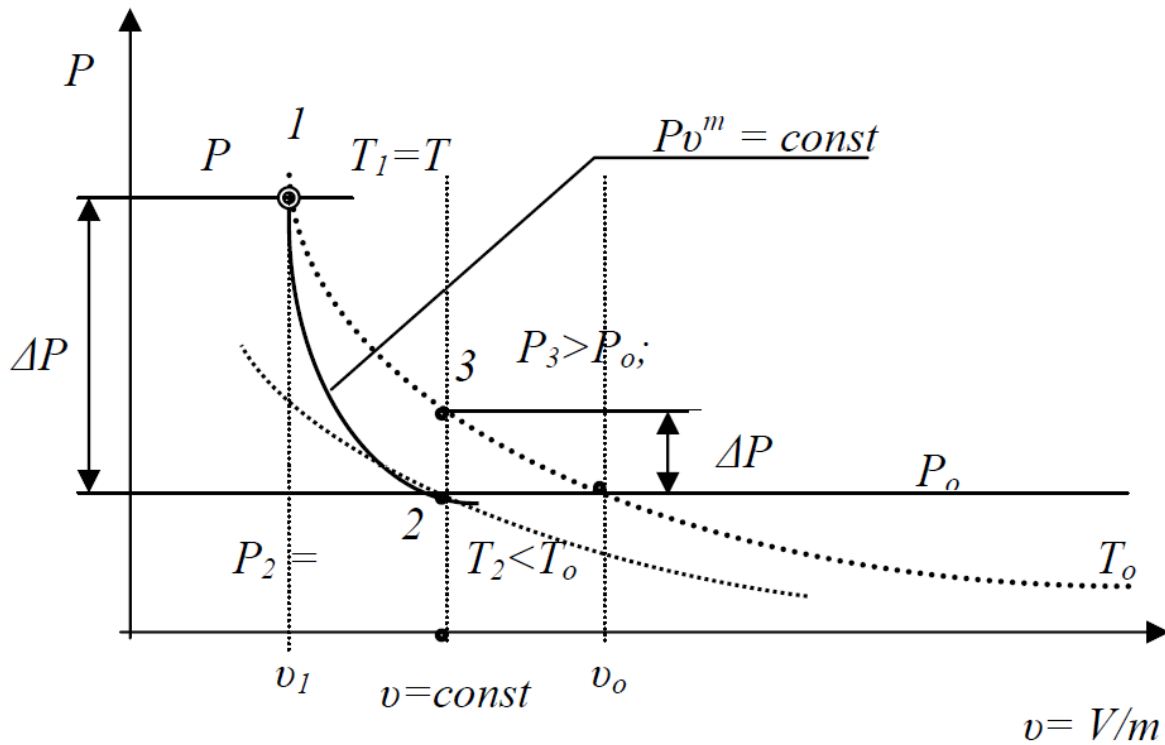
so:

$$c_v = \frac{R}{k - 1} \quad (7)$$

$$c_p = \frac{k}{k-1} R \quad (8)$$

1.2 Experiment description

There is a reservoir (tank) with constant volume and drain valve. To realize experiment follow curves on below figure, please.



Step 1.

To fill the tank by ambient air to the pressure value as $p_1 > p_o$ (p_o – ambient pressure). Air temperature at the beginning of process is as follows: $T_1 = T_o$.

Step 2.

To open (for a moment – around 1 second) the valve. The air flow to environment will be done. The pressure in reservoir drops to the amount $p_2 = p_o$, and temperature decreases to value $T_2 < T_o$.

Step 3.

After valve closing and before measuring the pressure in tank it is necessary to wait for temperature stabilisation inside of tank and ambient (balance between $T_3 = T_o$).

Step 4.

The pressure p_3 in reservoir can be measured $p_3 > p_o$.

The adiabatic process is basis for the dynamic method of determination of heat capacity. But during experiment some portion of heat is transferred to the tank. It means that process is near to adiabatic one but not ideal.

The factor “Y” helps to define the level of approximation to adiabatic process

$$Y = \frac{|Q_{z(1-2)}|}{|U_2 - U_1|} \quad (9)$$

where:

$|Q_{z(1-2)}|$ - amount of total (positive or negative) heat transferred to the gas in time Δx ,
 $|U_2 - U_1|$ - total change of internal energy of gas during transfer from state 1 to 2,

Notice !

$Y=0$ - real adiabatic process is carried out. For $Y \neq 0$, the process is approximately adiabatic with accuracy of 1% or 0,1% etc., depends on quantity of Y.

There is polytropic process for $Q \neq 0$. In this case, a polytropic exponent $w \neq k$ exists.

$$w = \frac{\ln(p_{1i}/p_0)}{\ln(p_{1i}/p_{3i})} \quad (10)$$

To define polytropic exponent it is necessary to set and measure some values of p_1 and p_3 :

$$p_{1i} = p_0 + \Delta p_{1i} \quad (11)$$

where:

i – number of experiment from 1 to 5,

Δp – excess pressure from the range of (0 – 1000 mmH₂O), i.e. 800, 650, 500, 350, 200.

1.3 Elaboration of results

1.3.1 To make calculation of m_i for each of test (Δp_i), then compute an arithmetic average by:

$$w_{av} = \frac{\sum_i w_i}{i} \quad (12)$$

1.3.2 To calculate c_{vm} and c_{pm} using formulas as follows:

$$c_v = \frac{R}{w_{av}-1} \quad (13)$$

$$c_p = \frac{w_{av}}{w_{av}-1} R \quad (14)$$

1.3.3 To compare values of c_{vm} and c_{pm} with c_v i c_p for adiabatic exponent $k=1,41$ (using formula (7) and (8)).

An example of test table

Lab_ 1 - Determination of heat capacities (specific heats) c_p (at constant pressure) and c_v (at constant volume) for ambient air

Group..... date: hour

Experiment set nr 1 (big valve)

N ^o	Parameter \ i	1	2	3	4	5
1	$p_o, Pa / p_o, mm H_2O$					
2	$zK mm H_2O$	800	650	500	350	200
3	Pi					
4	$Ap_3, mm H_2O$					
5	Pi					
6	M					
7	W_{av}					
8	C_{vm}					
9	C_{pm}					
10	C_v					
11	C_p					
12	c_{vm}/c_v					
13	C_p/c_p					

Experiment set nr 2 (small valve)

N ^o	Parameter \ i	1	2	3	4	5
1	$p_o, Pa / p_o, mm H_2O$					
2	$Ap_u mm H_2O$	800	650	500	350	200
3	Pi					
4	$Ap_3, mm H_2O$					
5	Pi					

6	M					
7	msr					
8	C_{vm}					
9	C_{pm}					
10	C_v					
11	C_p					
12	C_{vm}/C_v					
13	C_{pm}/C_p					