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GENERAL ENGINEERING AND MECHANICS

Building height determination by atmospheric pressure measurement

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The investigation present the methodology for determining the height of building structures using the barometric and thermal measurements for airs particles in the continuous chaotic motion movement related to the temperature interpreted as the thermal motion. During thermal movements the molecules are distributed in the volume according to the Earth's gravity. The methodology shows the possibility to evaluate the height of the structures in various thermal circumstances.

These two factors of the thermal motion and the Earth's gravity determine the distribution of the concentration of air molecules by the height [1, 2]:

$$n = n_0 e^{\frac{mgh}{-kT}}, \quad (1)$$

where n is the concentration of molecules at height h*;* n_0 *– the concentration of molecules on the Earth's surface;* k *– Boltzmann's constant; T is absolute air temperature; m is the average mass of an air molecule.*

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Formula (1) is obtained by assuming that the temperature T and the acceleration of free fall g do not change with height.

There is a directly proportional relationship between the pressure p and the concentration n of gas molecules [2]:

$$p = nkT \quad . \tag{2}$$

Formulas (1) and (2) show the dependence of pressure on height

$$p_h = p_o e^{\frac{mgh}{kT}} \quad , \tag{3}$$

p_h *and* p_0 *– atmospheric pressure at altitude h and at height* h *= 0 respectively.*

As can be seen from formula (3), pressure, like the concentration of molecules, decreases exponentially with height. Ratio (3) presents the used barometric formula.

Taking the logarithm of the barometric formula (3), it is easy to obtain the formula for altitude *h*:

$$\ln \frac{p_h}{p_0} = -\frac{mgh}{kT} \quad ,$$

or

$$h = \frac{kT}{mg} In \frac{p_0}{p_h} \quad . \tag{4}$$

Formula (4) is the working formula of this laboratory experiment.

The mass of an air molecule m is found from the formula:

$$m = \frac{M}{N_A} \quad , \tag{5}$$

where M = 0,029 kg/mol – molar mass of air, N_A *–Avogadro's number, thus*

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$$m = \frac{2.9 \cdot 10^{-2}}{6.02 \cdot 10^{23}} = 4.8 \cdot 10^{-26} \quad [kg].$$

The order of experimental steps was as following:

1. Go down with the barometer to the lowest floor of the building. Place the barometer on a horizontal section of the floor. According to the indicators of the barometer and thermometer, write down the values, respectively p_0 and T_0, the height, which we will consider to be zero.

2. Climb to the highest floor of the building and repeat the measurements. Record the value p_h and T_h at this height h.

3. Obtained values p_h and p_0 convert to CI with accuracy to 0.1 Pa.

4. Calculate temperature T as the arithmetic mean of temperatures at zero and maximum altitudes:

$$T = \frac{(T_h + T_0)}{2}.$$

5. Repeat the measurement according to points 1-4 for more times.

6. According to formula (4), calculate h the height in each case.

7. Calculate the average height value:

$$h_{av} = \frac{h_1 + ... + h_5}{5}.$$

8. Calculate the absolute error of each result:

$$\Delta h_1 = (h_{av} - h_1);$$
$$.....;$$
$$\Delta h_5 = (h_{av} - h_5).$$

9. Calculate the mean square deviation of the result using the formula:

$$\Delta h_S = \sqrt{\frac{\sum_{i=1}^{n} \Delta h_{i^2}}{n(n-1)}}.$$

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10. Calculate the absolute error of determining the height of the building using the formula:

$$\Delta h = t_c \Delta h_S$$

where t_c *– Student's coefficient for the small statistical samples.*

11. Record the result in the form:

$$h = h_{av} \pm \Delta h .$$

12. Determine the relative measurement error using the formula:

$$E = \frac{\Delta h}{h_{av}} \cdot 100\ [\%] .$$

The last formula gives us the relative error of the height measurement in percentage. The results of the experimental study are presented in the Table:

Table

Table of results of measurements and calculations

№	T_0, K	T_h, K	T, K	p_0, Pa	p_h, Pa	h, м	Δh_i, м	ΔS, м	Δh, м	E, %
1	293	291	295.5	97795	96140	58.29	0.58	0.498	1.84	37
2	293	291	292	96780	96115	59.03	1.37			
3	293	292	292.5	96790	96140	57.79	0.13			
4	293	293	293	96810	96180	56.09	1.56			
5	293	290	291.5	96785	96140	57.15	0.50			
Average.	293	292	293	96792	96143	57.06	0.83			

Conclusions

The results of the investigation methodology show the possibility of the express height built and hills structures evaluation with the use of barometers taking into account air thermal changes of the nearby media of objects with the obtaining of the experiment errors accuracy.

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