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FLOW METERS WITH VERY GOOD PERFORMANCES

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Rezumat. *Se prezintă calculul teoretic al unui debitmetru brevetat, atât din punct de vedere termodinamic cât şi aerodinamic, precum şi precizia de măsurare a debitului de aer în orice condiţii meteorologice. În acelaşi timp remarcăm că debitmetrul propus, prin poziţia sa de amplasare, nu are pierderi de sarcină.*

Abstract. *We present the theoretical calculus of a patented flow meter, concerning such the thermodynamic and aerodynamic calculus, as well as the offered precision to measure the flow of the air in any meteorological conditions. In the same time we remark that the proposed flow meter, by its positioning, has not loss of head.*

Keywords: Gas flow meters, Gauging of gas flow meters, Thermodynamic and aerodynamic calculus, Offered precision calculus, Flow meter without pressure loss

1. Introduction to present our special flow meter

In this work we shall present the theoretical support of a gauge flow meter, patented in the year 1989 [1], studied in any works [2-5] and schematic represented in the figure 1.

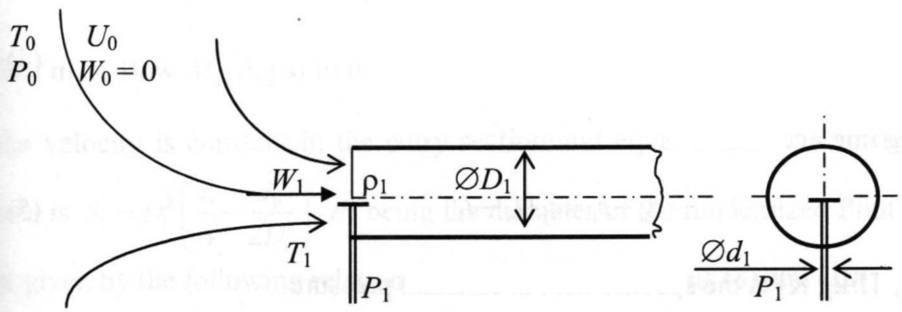

Fig. 1. The physical magnitudes of the aspired air in a pipeline foreseen with a special tube at the entry.

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Applying the **first principle of Thermodynamics** for the open systems, between the points 0 and 1, we can write

$$q_{01} - l_{01} = h_1 - h_0 + \frac{1}{2}\left(W_1^2 - W_0^2\right) + g\left(z_1 - z_0\right) \text{ [J/kg = m}^2\text{/s}^2\text{]}, \tag{1}$$

where q_{01} [J/kg] is the heat and l_{01} [J/kg] the mechanical work, changed by the air

with the exterior medium in his evolution between the points 0 and 1, h [J/kg] is the specific enthalpy, W [m/s] the air velocity, g [m/s^2] being the gravitational acceleration and z [m] the level in the gravitational terrestrial campus.

Taking into account that such the transferred heat as well the mechanic work are nulls ($q_{01} = l_{01} = 0$), the expression of the first principle reduces to the Bernoulli equation for a current line:

$$h_1 - h_0 + \frac{1}{2}\left(W_1^2 - W_0^2\right) + g\left(z_1 - z_0\right) = 0 \tag{2}$$

For the other hypotheses accepted:

$$W_0 = 0,\ z_0 \cong z_1 \text{ the gas being light} \tag{3}$$

and using the relations (2) and (3) we obtain

$$W_1 = \sqrt{2\left(h_0 - h_1\right)} \tag{4}$$

and taking into account that

$$h_0 - h_1 = c_p\left(T_0 - T_1\right) \tag{5}$$

where c_p [J/kg K] is the specific heat at constant pressure.

Using the relations (4) and (5), results

$$W_1 = \sqrt{2c_p\left(T_0 - T_1\right)} \tag{6}$$

The **gas state equation**, applied in the points 0 and 1, has the form

$$P_{0,1} = \rho_{0,1}\Re T_{0,1}, \quad \text{with} \quad \Re = \frac{P}{\rho T}\left[\frac{\mathrm{N}}{\mathrm{m}^2}\frac{\mathrm{m}^3}{\mathrm{kg\,K}} = \frac{\mathrm{J}}{\mathrm{kg\,K}}\right] \quad \text{and} \quad \rho_{0,1} = \frac{P_{0,1}}{\Re T_{0,1}}, \tag{7}$$

where $\Re$ [J/kg K] is the gas constant.

Considering that between the points 0 and 1 the air has an isentropic evolution, therefore

$$\rho_1 = \rho_0 \left(\frac{P_1}{P_0}\right)^{1/\mathrm{k}} \tag{8}$$

and using the equations (7) and (8), one find that

$$T_0 - T_1 = T_0\left[1 - \left(\frac{P_1}{P_0}\right)^{\frac{\mathrm{k}-1}{\mathrm{k}}}\right] \tag{9}$$

and using the relations (6) and (9), results

$$W_1 = \sqrt{2c_\mathrm{p}T_0\left[1 - \left(\frac{P_1}{P_0}\right)^{\frac{\mathrm{k}-1}{\mathrm{k}}}\right]} \tag{10}$$

The mass flow $\dot{M}_1$ [kg/s] in the entry section in the pipeline, in the hypothesis that the velocity is constant in the entry section and equal with W, also the interior aria is $S_1 = D_1^2\left(\frac{\pi}{4} - \frac{d_\mathrm{P}}{2D_1}\right)$, d_P being the diameter of the modernized Pitot's tube, it is given by the following relation, using also the equations (8) and (10)

$$\dot{M}_1 = \rho_1 S_1 W = \rho \left(\frac{P}{P}\right)^{/} S\, T^{/} \sqrt{2c\left[1 - \left(\frac{P}{P}\right)^{-}\right]} = \frac{P}{RT^{/}}\left(\frac{P}{P}\right)^{/} S \sqrt{2c\left[1 - \left(\frac{P}{P}\right)^{-}\right]} \tag{11}$$

the above equation (11) necessitating one measure of the temperature and two measures of static pressure.

To calculate the absolute relative precision with which one obtain the flow value, we shall apply the natural logarithm to the relation (11), obtaining

$$\ln \dot{M}_1 = \ln \frac{P_0}{\Re T_0^{1/2}} + \frac{1}{\mathrm{k}} \ln \frac{P_1}{P_0} + \ln S_1 + \frac{1}{2}\left\{ \ln 2c_\mathrm{p} + \ln\left[1 - \left(\frac{P_1}{P_0}\right)^{\frac{\mathrm{k}-1}{\mathrm{k}}}\right]\right\} =$$

$$= \ln P_0 + \left(\ln \Re + \frac{1}{2}\ln T_0\right) + \frac{1}{\mathrm{k}}\left(\ln P_1 + \ln P_0\right) + 2\left(\frac{\pi}{4} - \frac{d_\mathrm{P}}{2D_1}\right)\ln D_1 + \qquad (12)$$

$$+ \frac{1}{2}\left\{ \ln 2c_\mathrm{p} + \ln\left[1 - \left(\frac{P_1}{P_0}\right)^{\frac{\mathrm{k}-1}{\mathrm{k}}}\right]\right\}$$

and in continuation by differentiation of the magnitudes dependents of the measured errors, considerate positive, we shall have the following equation

$$\frac{\delta \dot{M}_1}{\dot{M}_1} = \frac{\delta P_0}{P_0} + \frac{1}{2}\frac{\delta T_0}{T_0} + \frac{1}{\mathrm{k}}\left(\frac{\delta P_1}{P_1} + \frac{\delta P_0}{P_0}\right) + 2\left(\frac{\pi}{4} - \frac{d_\mathrm{P}}{2D_1}\right)\frac{\delta D_1}{D_1} + \frac{\mathrm{k}-1}{2\mathrm{k}} \frac{\left(\frac{\delta P_1}{P_1} + \frac{\delta P_0}{P_0}\right)}{\left[\left(\frac{P_1}{P_0}\right)^{\frac{1-\mathrm{k}}{\mathrm{k}}} - 1\right]} \qquad (13)$$

Introducing the fixed values:

$P_0 = 1{,}013$ mb = 101,325 Pa, $T_0 = 300^\circ C = 573.15$K, k = 1.4, $d_\mathrm{P} = 3$mm $D_1 = 0.1$m and the measuring precisions of different magnitudes: $\delta P_0 = 0.1$ mb = 10 Pa, $\delta P_1 = 0.1$ mmwc = 1.01972 Pa, $\delta T_0 = 0.02^\circ C = 0.02$ K, $\delta D_1 = 0.01$ mm, we have obtained from the equation (13) the following equation

$$\frac{\delta \dot{M}_1}{\dot{M}_1} \cong \frac{0.1\mathrm{mb}}{1{,}013\mathrm{mb}} + \frac{1}{2}\cdot\frac{0.02^\circ C}{300^\circ C} + \frac{1}{1.4}\left(\frac{1.01972\ \mathrm{Pa}}{P_1} + \frac{0.1\mathrm{mb}}{1{,}013\mathrm{mb}}\right) +$$

$$+ 1.57\frac{0.01\mathrm{mm}}{100\mathrm{mm}} + 0.143\frac{\left(\frac{1.01972\ \mathrm{Pa}}{P_1} + \frac{0.1\mathrm{mb}}{1{,}013}\right)}{\left(\frac{101{,}325\ \mathrm{Pa}}{P_1}\right)^{0.2857} - 1} \qquad (14)$$

For different values of the pressure P_1 in the equation (14) we have represented in the figure 2 the variation of the relative error of the measured mass flow rate.

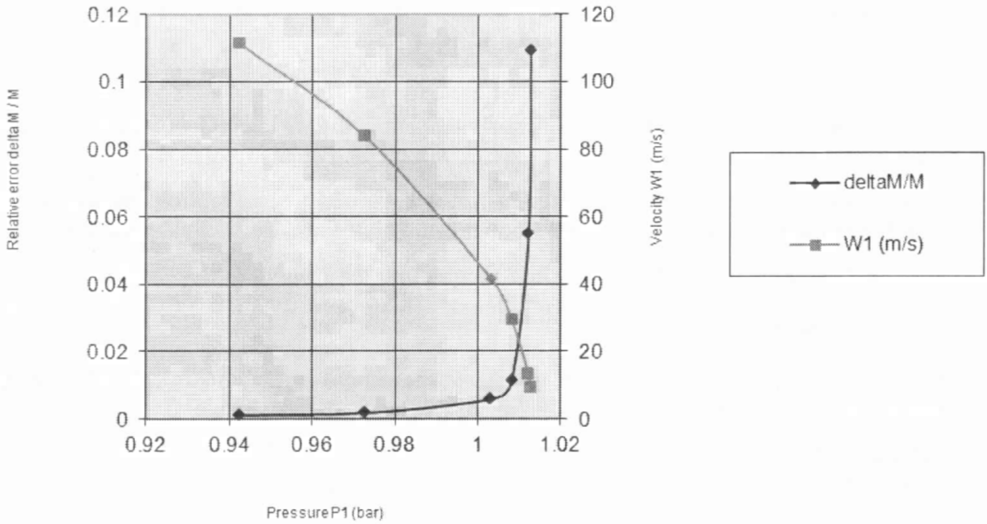

Fig. 2. Dependence of the relative error $\delta \dot{M}_1 / \dot{M}_1$ and velocity W_1 on the presure P_1.

Conclusions

We consider a very good precision with respect of that offered by the other type of flow-meters.

R E F E R E N C E S

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