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Investigation of Properties of Polymeric Filters "APRIS" in the Case of Air Purification: I. Filtration with a Flat Baffle

A. V. Klimov, V. V. Serdyuk, and L. A. Ashkinazi

ZAO "Academy of Applied Studies", St. Petersburg, Russia

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The filters "APRIS" applied to gas purification including the hydrogen from mechanical impurities. We carried out test benches of these filters for obtaining dependencies of an influence of such operational factors as flow, pressure, and density of the purified gas on a resistance of the filter cell "APRIS" for the following computation at designing cleaning arrangements.

The tests were conducted on the bench including an air balloon, a reduction gear, a body with filter cell, rheometer for measuring the volume air flow in a range of 5–25 l min^{-1}, a manometer with a scale from 0 to 25 kg cm^{-2} and an accuracy class of 0.6 for measuring a system pressure, an aqueous U-shaped manometer attached at the inlet and outlet of the filter cell body with a division value of 1 mm H_2O and with a range of the pressure drop measurement up to 2 mm H_2O, and two control cocks.

The filter cell was of a cylinder shape, 19 mm diameter and 45 mm height. Air passes through the filter cell along an axial direction.

The measurements of the pressure drop of the pipe section without the filter cell and including the filter cell under the fixed pressures: 1, 2, 4, 6, and 8 kg cm^{-2} and the air flow: 5, 10, 15, 20, and 25 l min^{-1} were performed. The filter cell resistance computed by a dif-ference between the pressure drop of the pipe section without the filter cell and the pressure drop of the same section with the filter cell at the same values of the pressure and the flow.

The Fig. 1 shows that the air resistance both of the pipe section and of the filter cell decreases in the course of growth of the pressure in the system at the fixed volume flow. It can be understood through the air compressibility: the air density increases along with the pressure growth that leads to increase in the air velocity at a fixed mass flow.

The effect of the resistance decrease at the further pressure growth diminished at the sufficiently high values of the pressure. Curves for the pressures of 8 and 9 kg cm^{-2} practically coincide at the control pressure rise up to 9 kg cm^{-2} in the pipe section with the filter cell.

The dependences of the filter cell resistance on the system pressure (Fig. 2) well expresses the set out above.

A dependence of the resistance on the velocity of the air passing through the filter cell under the standard conditions and not on the air volume flow should be reasonable considered. The air velocity in this case was calculated by equation (1):

$$W = \frac{Q}{S(P+1)}, \quad (1)$$

where W is air velocity, m s^{-1}; Q, the air volume flow, m^3 s^{-1}; S, the open flow area, m^2; P, excess air pressure in the system, bar.

The dependence of the filter cell on the air flow at the various pressures in the system is depicted in Fig. 3.

Obviously in this case all these curves are arranged with some deviations on the straight line that starts in an origin of coordinates.

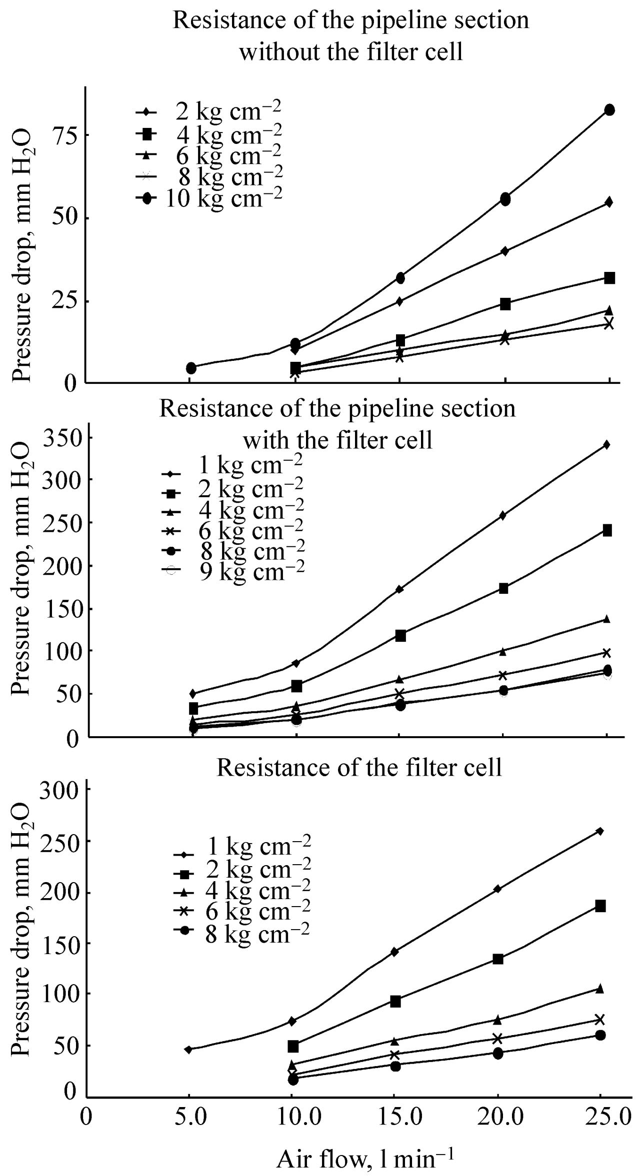

Fig. 1. Change in the pressure drop in the course of the "APRIS" filter cell test.

This straight line can be expressed by the following relation

$$\Delta P = a\,W, \tag{2}$$

where a is a coefficient that can be computed by the least-squares method using experimental data

$$a = \frac{\sum W_i\,\Delta P_i}{\Delta P_i^2} \tag{3}$$

Values of the coefficients for the various pressures of air in the system are presented in the Table 1.

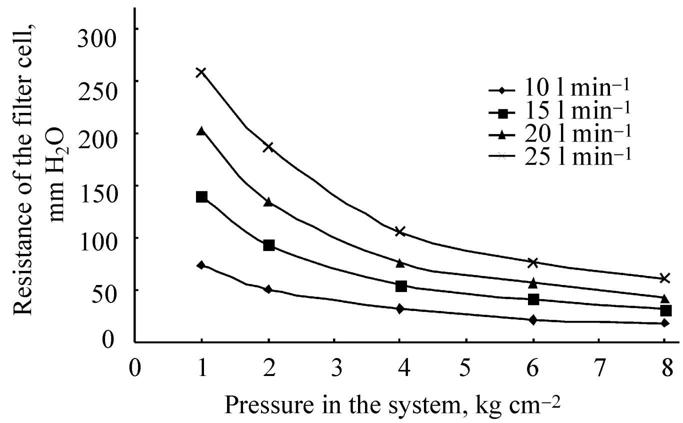

Fig. 2. Dependence of the filter cell resistance on the pressure in the system at the various air flow.

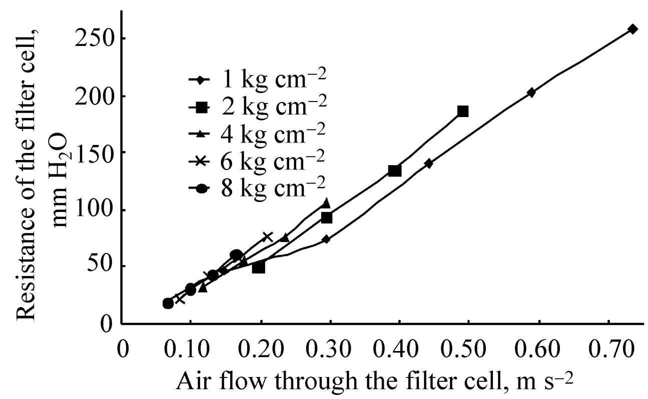

Fig. 3. Dependence of the filter cell resistance on the air velocity.

The experimental and computed characteristics are plotted for comparison on diagrams (Fig. 4).

The following characteristics for an average value a = 341.26 we depicted on Fig. 5.

We used Darcy's law for laminar flow of the liquid and gas in porous materials:

$$\Delta P = W\,\frac{\mu\,l}{K}, \tag{4}$$

Table 1. Values of the coefficient a

Pressure, kg cm^{-2}	Coefficient a
1.0	336.79
2.0	350.77
4.0	334.65
6.0	340.69
8.0	343.40
	An average value 341.26

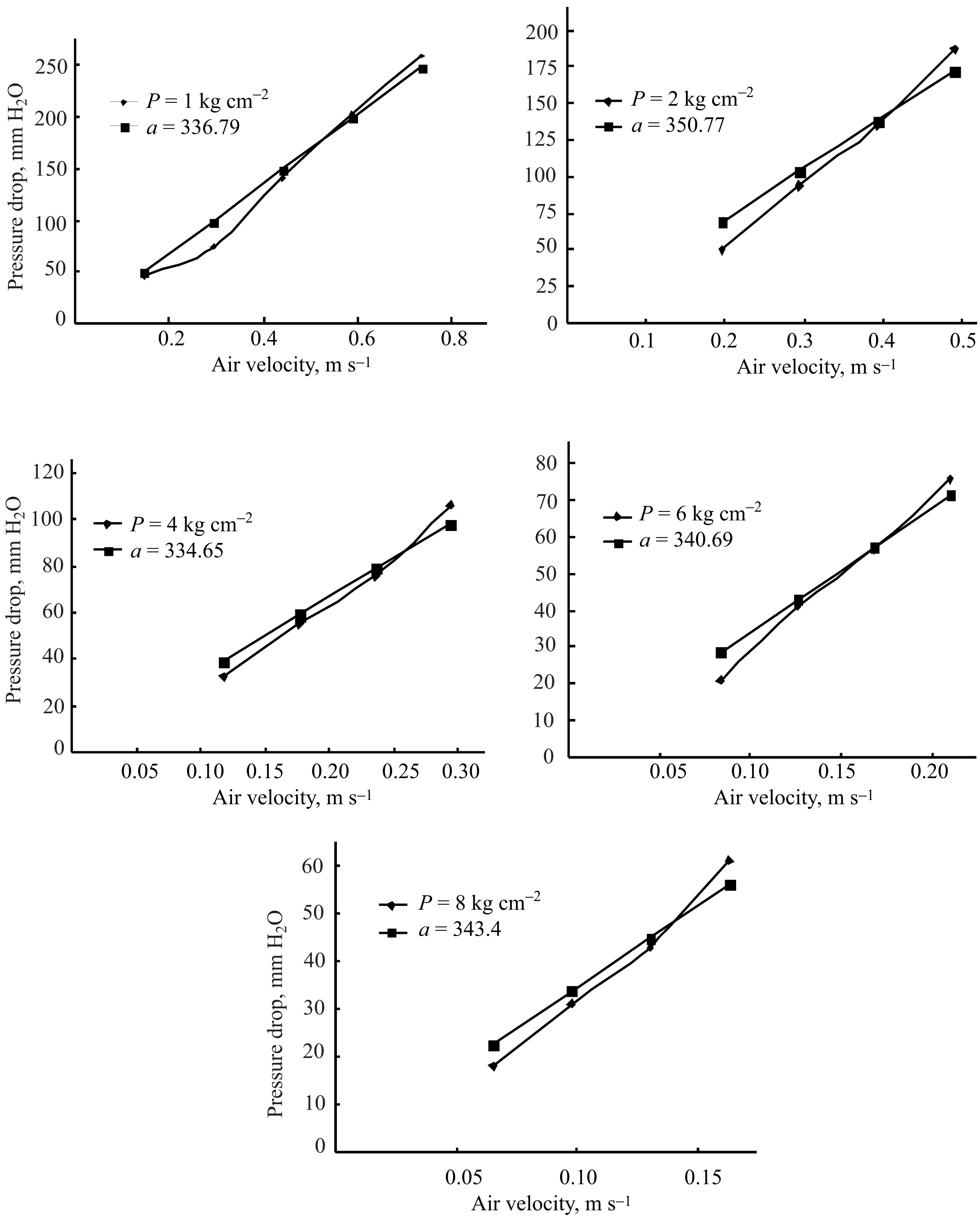

Fig. 4. Experimental and computed characteristics of the filters “APRIS.

where *m* is dynamical viscosity of the liquid and the gas; *l,* a thickness of material; *K* , the penetration coefficient taking into account structural characteristics of a porous body.

Regarding the obtained equation (1) we write:

$$a = \frac{\mu l}{K}, \tag{5}$$

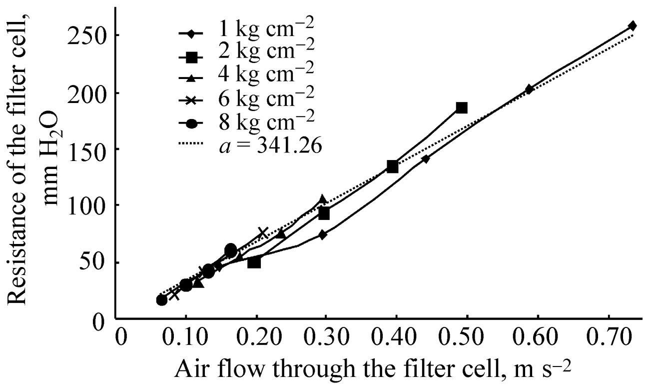

Fig. 5. Experimental and computed dependencies of the filter cell resistance on the air flow.

and

$$K = \frac{\mu\, l}{a}. \tag{6}$$

The dynamic viscosity of the gas depends on its properties and temperature excepting the pressure. The viscosity μ equaled to 180 μpoise at an operation under the room environment (20°C), the material thickness l was 0.045 m. The value of the coefficient a was 3.348 at the pressure measurement of the filter cell in kPa.

Earlier we did not take into account measuring the air flow in the porous structure of the filter cell. Actually the open flow area was less than the value of earlier used in the computations by the value of the material porosity, thus the filtration area S_f was computed by equation (7):

$$S_f = S\Pi, \tag{7}$$

where S was the geometrical area of the filter cell section through which the filtration occurred; Π, the porosity of the filter cell.

For the standard samples of the filter "APRIS" including also used in the given experiments, Π was 0.9. However in particular cases materials of the other porosity can be manufactured.

As a result taking into account the porosity, a was 3.013. The coefficient of the penetration computed by equation (6) was $K = 2.688$.

For computation using the Darcy's relationships the volume flow under the standard conditions was more preferable than the air flow velocity then an equation for calculation of the filter cell resistance at the filtration through the flat wall looked as

$$\Delta P = \frac{\mu\, Q\, l}{K\, S\, (P+1)}, \tag{8}$$

where ΔP was the filter cell resistance, kPa; l, the thickness of the filter layer, m; K, the coefficient of the penetration, $K = 2.688$; S, the filtration area of the filter cell, m^2; Π, was the porosity of the filter material, Π = 0.9; P, the overpressure in the system, bar; $(P + 1)$ was the absolute pressure, bar; μ, the dynamic viscosity of the medium, μpoise. However actually the filter cell was not of a flat shape but it was of a cylindrical shape considered in the further papers.

The dependence of the dynamic viscosity of the air and hydrogen is presented in Table 2.

Table 2. The dependence of the dynamic viscosity of gases (μpoise) on the temperature

Temperature, °C	0	20	50	100
Air	171	–	–	218
Hydrogen	85	88	94	103

CONCLUSIONS

(1) It was established that the filtering material "APRIS" is efficient for air filtration at the system pressure up to 0.9 MPa and at the air flow up to 5290 nm^3/h per 1 m^2 of the filtering surface.

(2) The experimental values of the resistance (the pressure drop) of a cylindrical sample of the filtering material "APRIS" at the air filtration through its flat surface in the axial direction were obtained at the system pressure in the range of 0.1 до 0.8 MPa and at the air flow of 25 l/min.

(3) It was established that the pressure increase in the system at the constant air flow measured under the standard conditions led to a some decrease in the resistance of the porous filtering material, the resistance change practically stopped at the increase in the system pressure more than 0.8 MPa.

(4) The coefficient of the penetration $K = 2.688$ for the fresh filtering material "APRIS" was determined.