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Theoretical Analysis Of The Hydrodynamic Characteristics Of Gas Flows And Their Significance In The Chemical Industr

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Abstract: The article explores the issues of studying the physical and chemical properties of secondary gases emitted into the environment from enterprises of the chemical industry and solving the problems of gas utilization on the basis of their taxability. The paper developed the theoretical justification of hydrodynamic forces acting on secondary gas in the chemical industry and the efficiency of the device.

Keywords: Throwing gases, purifying gas, hydraulic resistance, syomnik, coagulant, gas flow.

INTRODUCTION:

In the theoretical justification of the influence of the device's hydraulic resistance on cleaning efficiency, the following parameters are determined.

The calculation scheme of the device is shown in Figure 1.

Local resistance coefficients in the working elements of the device;

Total hydraulic pressure loss within the device;

Cleaning efficiency of the device;

Selection of secondary gas samples for research and conducting laboratory analyses of their absorption into the absorbent liquid.

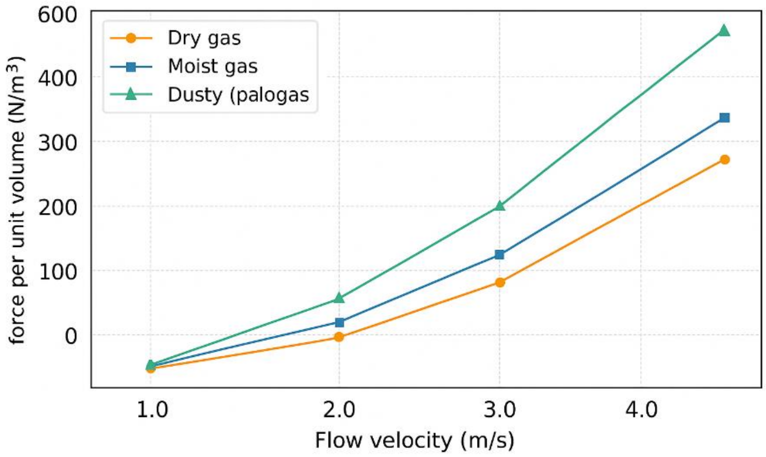

Figure 1. Relationship between hydrodynamic force and velocity under different gas conditions

Relationship Between Hydrodynamic Force and Velocity – for Dry, Moist, and Particle-Laden Gas Flows

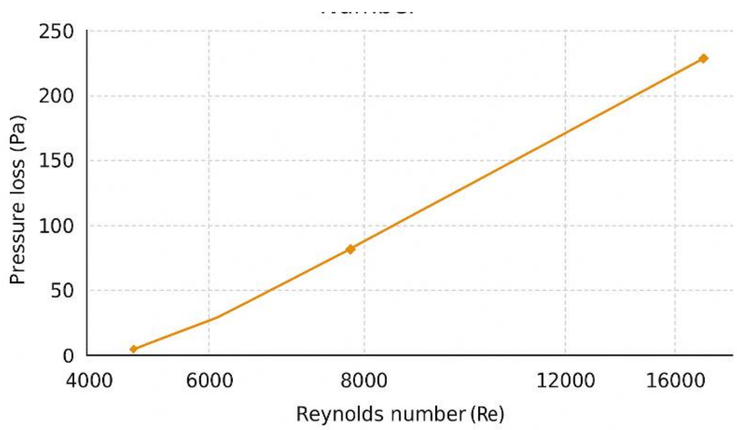

Figure 2. Relationship between pressure loss and Reynolds number

Relationship Between Pressure Loss and Reynolds Number – Depending on Flow Intensity. In devices designed for neutralizing secondary exhaust gases, it is essential to correctly establish the analytical and computational equations that describe the loads acting on the working elements as a function of gas velocity. This aspect serves as a key factor in determining the optimal parameters of the device's hydraulic resistance, the resistance coefficient of the working elements, and overall performance efficiency.

Although an increase in hydraulic resistance within the working elements enhances the cleaning efficiency, it simultaneously leads to a decrease in productivity. Consequently, the energy consumption required for gas purification rises.

The scrubber under investigation consists of a gas-guiding pipe (8) that directs the secondary gases and a rotary distributor (2) that imparts rotational motion to the gas flow within the liquid medium under the influence of flow energy. As the gas moves through the pipe, passes through the distributor's guiding orifice, and continues its movement within the liquid medium, it experiences hydraulic resistance.

The total hydraulic resistance acting on the gas within the device can be expressed, based on the computational equations provided in the literature [1–5 and others] and considering the A–A section of the calculation scheme (Figure 3), as follows:

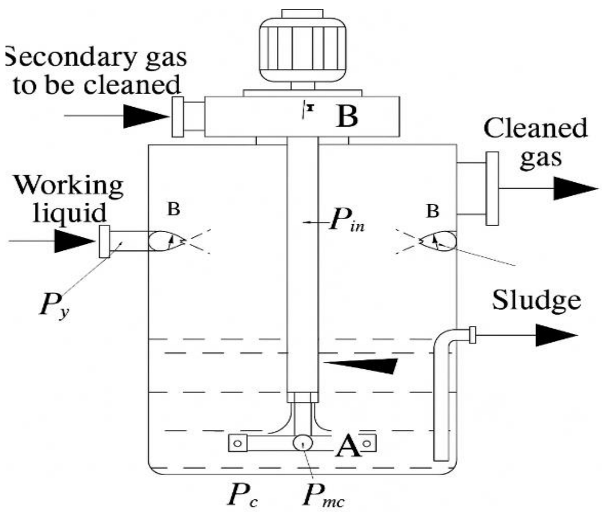

Figure 13. Schematic diagram for calculating the scrubber

The equation determining the overall hydraulic resistance of the apparatus can be expressed as follows, Pa:

$$\Delta P_{ум} = P_{йк} + P_{mc} + P_c \text{ ,Pa} \quad (1.1)$$

where P_{yk} is the pressure loss occurring during the movement of the secondary gas in the guiding pipe, which is

determined using the Darcy–Weisbach equation [4-10].
In this case, the equation can be written as follows, Pa:

$$P_{йк} = \xi_{йк} \frac{\rho_{ap} \cdot \upsilon^2{}_{йк}}{2} \text{,Pa} \qquad (1.2)$$

where υ_{yk} is the velocity of the secondary gas in the guiding pipe, m/s; ξ_{yk} is the local resistance coefficient of the guiding pipe, which is determined according to the following equation:

$$\xi_{йк} = \lambda \frac{l}{d_э} \qquad (1.3)$$

where *l*- is the length of the pipe, m; d_e is the equivalent diameter of the pipe, m;
λ is the Darcy coefficient, whose variation law has been found to depend on many factors when expressed by empirical equations. Based on the design features of the experimental apparatus, the Darcy coefficient in the equation was determined according to the Blasius law [4]. In this case, Equation (3) takes the following form:

$$\xi_{йк} = \frac{0{,}3164 l}{d_э \sqrt[4]{\mathrm{Re}}} \qquad (1.4)$$

By substituting Equation (1.4) into Equation (1.2), Equation (1.2) takes the following form, Pa:

$$P_{йк} = \frac{0{,}3164 l \rho_{ap} \upsilon^2{}_{йк}}{2 d_э \sqrt[4]{\mathrm{Re}}} \text{,Pa} \qquad (1.5)$$

P_{ts}- — is the pressure loss that occurs when the gas flow passes through the guiding orifice of the flow distributor (syomnik), which is determined by the following equation, Pa:

$$P_{mc} = \xi_{mc} \frac{\rho_{ap} \cdot \upsilon^2{}_{mc}}{2} \text{,Pa} \qquad (1.6)$$

where υ υ_{ts} is the velocity of the gas flow at the outlet of the distributor (syomnik) orifice, m/s;
ξ_{ts} is the resistance coefficient of the distributor orifice, which is determined using the experimental method proposed by B.A. Alimatov and I.T. Karimov, who investigated the dependence of the orifice resistance coefficient on the ratio of the orifice thickness to its diameter [5]. In this case, the calculation equation can be written as follows:

$$\xi_{mc} = \frac{\delta}{d_m} \qquad (1.7)$$

where δ is the thickness of the distributor (syomnik) orifice, mm; d_t is the diameter of the distributor orifice, mm.
By substituting Equation (1.7) into Equation (1.6), Equation (1.6) takes the following form, Pa:
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$$P_{mc} = \frac{\delta \cdot \rho_{ap} \cdot \upsilon^2{}_{mc}}{2 d_m} \text{,Pa} \qquad (1.8)$$

P_{ts} — is the pressure loss that occurs when the gas flow passes through the liquid medium, which is determined by the following equation, Pa:

$$P_c = \xi_c \frac{\rho_{ap} \cdot \upsilon^2{}_c}{2} \text{,Pa} \qquad (1.9)$$

where υ_s is the velocity loss of the gas flow when passing through the liquid medium, m/s;
ξ_s is the resistance coefficient of the working liquid acting on the gas flow, which can only be determined experimentally;
ρ_{ar} is the density of the secondary gas–air mixture, determined by the following equation, kg/m³:

$$\rho_{ap} = \rho_x + (\rho_г \cdot \gamma), \qquad (1.10)$$

where ρ_g is the density of the secondary gas, kg/m³; ρ_x is the density of the air, kg/m³; **γ** is the concentration of secondary gas in the air, %. By substituting Equations (1.8) and (1.9) into Equation (1.5), and then substituting the result into Equation (1.1), the equation takes the following form:

$$\Delta P_{ум} = \rho_{ap}\left(\frac{0{,}3164 l \upsilon^2_{йк}}{2d_э \sqrt[4]{\mathrm{Re}}} + \frac{\delta \upsilon^2_{mc}}{2d_m} + \frac{\xi_c \upsilon^2_c}{2}\right), \mathrm{Pa} \qquad (1.11)$$

Using the derived Equation (1.11), it becomes possible to determine the total hydraulic resistance of the apparatus.

The determination of the resistance coefficient ξ_s in Equation (1.9) is of a complex nature and requires consideration of various deviations.

Therefore, to simplify the process, we introduce a new equation for determining the resistance coefficient based on the ratio between the number of rotations in the open cycle and within the liquid medium under the influence of the gas flow force acting on the distributor (syomnik).

$$\xi_c = k\frac{n_{xб}}{n_{cб}}, \qquad (1.22)$$

where n_{xb} is the number of revolutions of the distributor (syomnik) under the influence of natural air pressure, rpm; n_{sb} is the number of revolutions of the distributor under the influence of water pressure, rpm; k is the correction coefficient, which is determined experimentally.

From this equation, it follows that an increase in water pressure or viscosity leads to an increase in the resistance coefficient.

Based on the factors mentioned above, by introducing certain modifications into Equation (1.11), the total hydraulic resistance of the apparatus can be determined as follows, Pa:

$$\Delta P_{ум} = \rho_{ap}\left(\frac{0{,}3164 l \upsilon^2_{йк}}{2d_э \sqrt[4]{\mathrm{Re}}} + \frac{\delta \upsilon^2_{mc}}{2d_m} + k\frac{n_{xб}\upsilon^2_c}{2n_{cб}}\right) \qquad (1.13)$$

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