The study of conical flow regulators: the effect of the diameter of the inlet/outlet ports

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For over 200 years, a significant increase in the average amount of rainfall has been observed - these amounts range from 80% to 140% of the long-term norm. This is especially the case between May and September, when there are numerous cases of sudden and extremely heavy rainfalls that cause local flooding. These extreme hydrological phenomena have a negative impact on water and sewage management. It is impossible to completely eliminate the effects of too much rainfall, but there are many ways to reduce them. Therefore, engineers are currently facing the challenge of protecting water and sewage management. For this reason, they create solutions that aim to regulate the flow of rainwater. One such solution is the design and implementation of hydrodynamic regulators of various shapes and sizes. A flow regulator is a device that is designed to maintain a constant outflow of a fluid, and to inhibit the flow when it reaches flow rates that are too high, regardless of changing temperature and pressure conditions (Ochowiak, 2016). Regulators are used in rainwater drainage systems. Their role is to prevent the flooding of urban areas and to protect treatment infrastructure against hydraulic overloads. They can also be used to regulate the amount of flowing water or sewage in water treatment plants and network facilities such as pumping stations, retention tanks, storm overflows and separators (Helman, 1998). The operation of flow regulators involves liquid being introduced into the device through the inlet port, and then it being directed to the conical chamber, where it is given a swirling motion. In this movement, the peripheral velocity increases as it approaches the axis of the cone, which in turn results in the formation of an air core. As a result of the centrifugal force, the pressure decreases towards the chamber axis and reaches the ambient pressure on the surface of the air core (Wójtowicz and Kotowski, 2008).

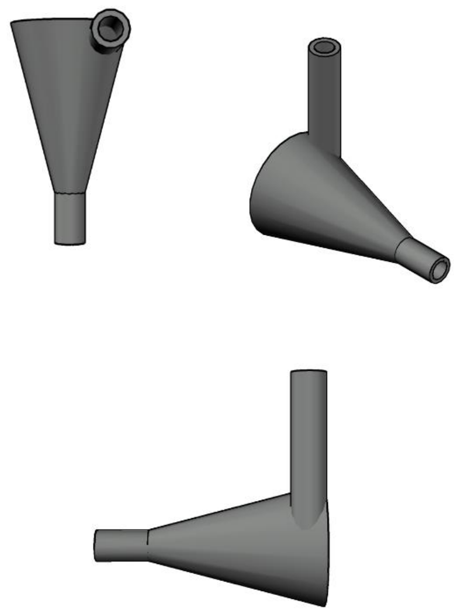

Figure 1. 3D model of a conical flow regulator.

Table 1. Characteristics of conical vortex regulators.

Series	d_1 (mm)	d_2 (mm)	h_c (mm)	μ	ζ
1	7.45	7.60	92.30	0.535	3.503
2	7.45	9.45		0.602	2.768
3	7.45	11.65		0.701	2.034
4	7.45	13.75		0.699	2.048
5	9.35	7.60		0.401	6.225
6	9.35	9.45		0.502	3.972
7	9.35	11.65		0.573	3.055
8	9.35	13.75		0.657	2.321
9	11.40	7.60		0.316	10.004
10	11.40	9.45		0.370	7.312
11	11.40	11.65		0.479	4.360
12	11.40	13.75		0.473	4.481
13	13.40	7.60		0.242	17.072
14	13.40	9.45		0.369	7.337
15	13.40	11.65		0.417	5.752
16	13.40	13.75		0.466	4.600

Flow regulators are designed and tested on a laboratory scale based on collected experimental data. In order to experimentally determine the characteristics of the liquid flow through the regulator, and to determine the values of the flow coefficient (μ) and/or local resistance coefficient (ζ) (Wójtowicz and Kotowski, 2008), 16 hydrodynamic regulators were designed and printed (Figure 1). They differed in terms of the diameters of the inlet ports d_1 and outlet ports d_2. The data regarding dimensions are listed in Table 1. The tests covered the range of heights of the liquid column from 0.1 m to 1.8 m. A specific volume of liquid flowing from the regulator at a specific liquid column height was collected into a measuring vessel, and the outflow time was also measured. The measuring vessel was then weighed. The results obtained in three measurement series were averaged. Based on the measurement data, the values of the volume flow of liquid flowing through the regulator were calculated while taking into account the liquid density $\rho = 998.23$ kg/m³ at 20°C. Based on the obtained results of the outflow coefficients μ, the dependences on the Reynolds number Re were determined:

$$Re = \frac{2 * \rho * Q}{\pi * \eta * r_1} \quad (1)$$

where: ρ – density (kg/m^3), Q – volumetric flow rate (m^3/s), η – dynamic viscosity coefficient of the water (kg/m·s), r_1 – radius of the inlet port (m).

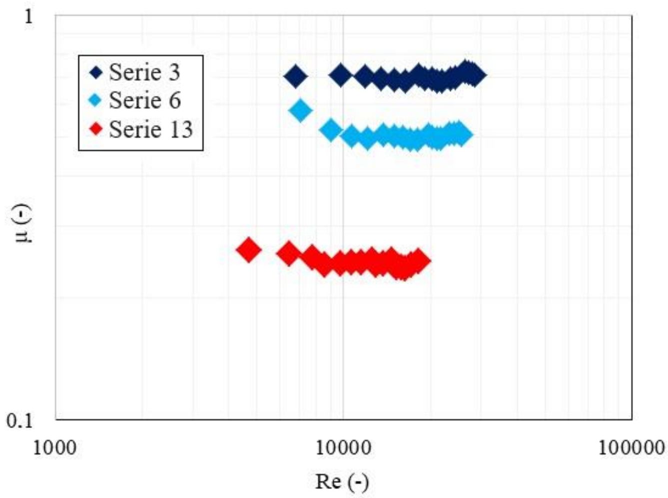

Figure 2. The dependence between μ and Re.

As the hydrostatic pressure increased, the amount of liquid flowing through the flow regulator increased. The flow coefficient values obtained during the tests ranged from 0.242 to 0.701. The two highest values correspond to the largest d_2/d_1 ratio. This means that an increase in the relative diameter of the outlet port leads to an increase in the flow coefficient. The analysis of the data presented in Figure 2 shows that in the case of large Reynolds numbers, the value of the outflow coefficient is practically constant. The results obtained in the above study may be an introduction to further work on models of flow regulators with different diameters of inlet and outlet ports. Ultimately, this may lead to the creation of a device that will be the solution to the growing problem concerning the regulation of water and sewage management.

References:

Helman M., Application of flow regulators in water and sewage management. Gospodarka Wodna, 11, 422-425, 1998.

Ochowiak M., The study of flow regulator equipped with the diaphragm. Inżynieria i Aparatura Chemiczna, 2, 64-65, 2016.

Wójtowicz P., Kotowski A., Model testing of conical vortex flow hydrodynamics regulators. Ochrona Środowiska, 30(3), 37-44, 2008.

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