

MECHANICAL INJECTORS FOR SUPPLY OF LIQUID TO GAS CLEANING EQUIPMENT

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Abstract. Nomogram to select the mechanical injectors (used for gas treatment devices). Operational reliability and efficiency of wet apparatus to a large extent due to the correct choice of atomizing devices (jets). In technology gas treatment in most cases, preference is given to a mechanical (hydraulic) injectors. This paper presents the main parameters (consumables and energy), mechanical injectors, the most ubiquitous in the technique of gas cleaning, and given the approximate estimate of the size generated in the process of spray droplets. All jets (except for variable) are designed to work with liquids in which the concentration of suspended solids of up to 500 mg/l at the grain size less than 0,5 mm. Adjustable jets works reliably when the concentration of suspended solids in the liquid up to 100mg/l. The paper was obtained by approximating the dependence. Based on the approximation depending nomogram was constructed for the case of spraying water at $\rho=1000 \text{ kg/m}^3$ and $v=10^{-6} \text{ m}^2/\text{s}$, where the experimental data medium sized water droplets in the spray. Were found to be linear droplets size d_k , which allow us to calculate the efficiency of gas cleaning from suspended particles in wet scrubbers.

Keywords: injectors, gas-cleaning apparatus, scrubbers, mechanical injectors, nomogram, droplets.

1. Introduction

In order to protect the air basin from harmful industrial and exhaust discharges, there is extensive use of gas washers (scrubbers). The expediency of their use is confirmed not only in cleaning gases from suspended particles, but also simultaneous cooling, moistening (drying) of gases, and also absorption of gas admixtures. The operational reliability and efficiency of wet equipment (hollow injector scrubbers, Venturi scrubbers, ejection equipment, etc.), whose operating principle is based on the reaction of a gas stream with droplets of sprayed liquid, caused to a considerable extent by correct selection of atomizing devices (injectors).

In the majority of cases in gas cleaning technology preference is given to mechanical (hydraulic) injectors that are the most economical, simple and reliable. However, when fine dispersion of considerable volumes of liquid is required, for example, in gas evaporation cooling scrubbers, pneumatic injectors are used.

The main parameters (flow rate and energy) parameters are given in this work for mechanical injectors, that are most widespread in gas cleaning technology, and an approximate estimate is given for the dimensions of droplets generated during atomization. We consider the types of mechanical injectors shown in Fig 1 and their main characteristics (Table 1).

2. Materials and methods

2.1. The types of mechanical injectors and their main characteristics

This paper presents the main parameters (consumables and energy), mechanical injectors, common in the art of gas purification, and given the approximate estimate of the size generated in the process of spray droplets.

Flow characteristics are determined by nozzle heads way structural factors, and depend little on the physical properties of the spray liquid and environment (GK Lebedyuk 1976).

Consider the types of mechanical injectors, showing in (Fig 1), and their main characteristics (see table 1).

Considered mechanical injectors, the principle of operation can be divided into four classes: inkjet, jet-percussion, rotary and centrifugal-jet .

Jet nozzle. Nozzles of this type are cylindrical nozzle (or several nozzles), which yields a liquid jet, which decays into droplets and forms a torch sprayed liquid with a small angle at the vertex. By the jet are also fan-jets, in which on the front side of the slotted or channels. Sometimes an outlet attached to an elongated shape, thereby resulting liquid forms a flat jet of a fan, which is then disintegrates into droplets.

Jet attack jets. These nozzles atomization occurs outside the body during the impact of the jet nozzle of a

special sprinkler, located against the opening. The most widely used jet injectors drums with ring reflectors, representing Corps, ending significant diameter hole. Attached to the body from the outside holders with a number of reflectors. The inner diameter of the first in the course of the liquid ring reflector slightly smaller bore nozzles, and the outside-more. Liquid coming out of the nozzle, reflector splits into two streams: one stream (axial) passes through the opening of the reflector and the second struck his bevelled edges, spreads over the surface of the ring. Axial flow after the first reflector meets the second and also splits into two streams. (AN Chokhonelidze 2002).

Centrifugal atomizer. Liquid to the outlet of the centrifugal nozzle gets intensive rotational movement of the camera twist, where it comes from the tangential channel or channels of screw insertion. Typically, these jets are called, respectively, tangential and helical (swirl). In the exit nozzle of the nozzle the liquid moves as a film along the channel

wall, while the centre completes the so-called 'swirl'. Arising out of the nozzle film becomes unstable, forming a torch in the form of a hollow cone. Centrifugal-jet nozzles are different from the centrifugal bilateral input in these fluids. Part of the liquid is supplied through the inclined peripheral channels insert or fed tangentially into the chamber swirl, forming a rotating flow. Another part is supplied as a continuous stream through the central hole. (Uzhov 1972; Pazhi 1979). The diameter of the solid stream should be somewhat larger than the inside diameter of the rotating flow in the nozzle jets, then by viscous forces, rotating fluid will be spinning the central jet, forming a single stream, which is dispersed at the nozzle exit, forming a solid cone spray. Disintegration of the central jet also contributes to the intense turbulence that occurs in the collision of flows.

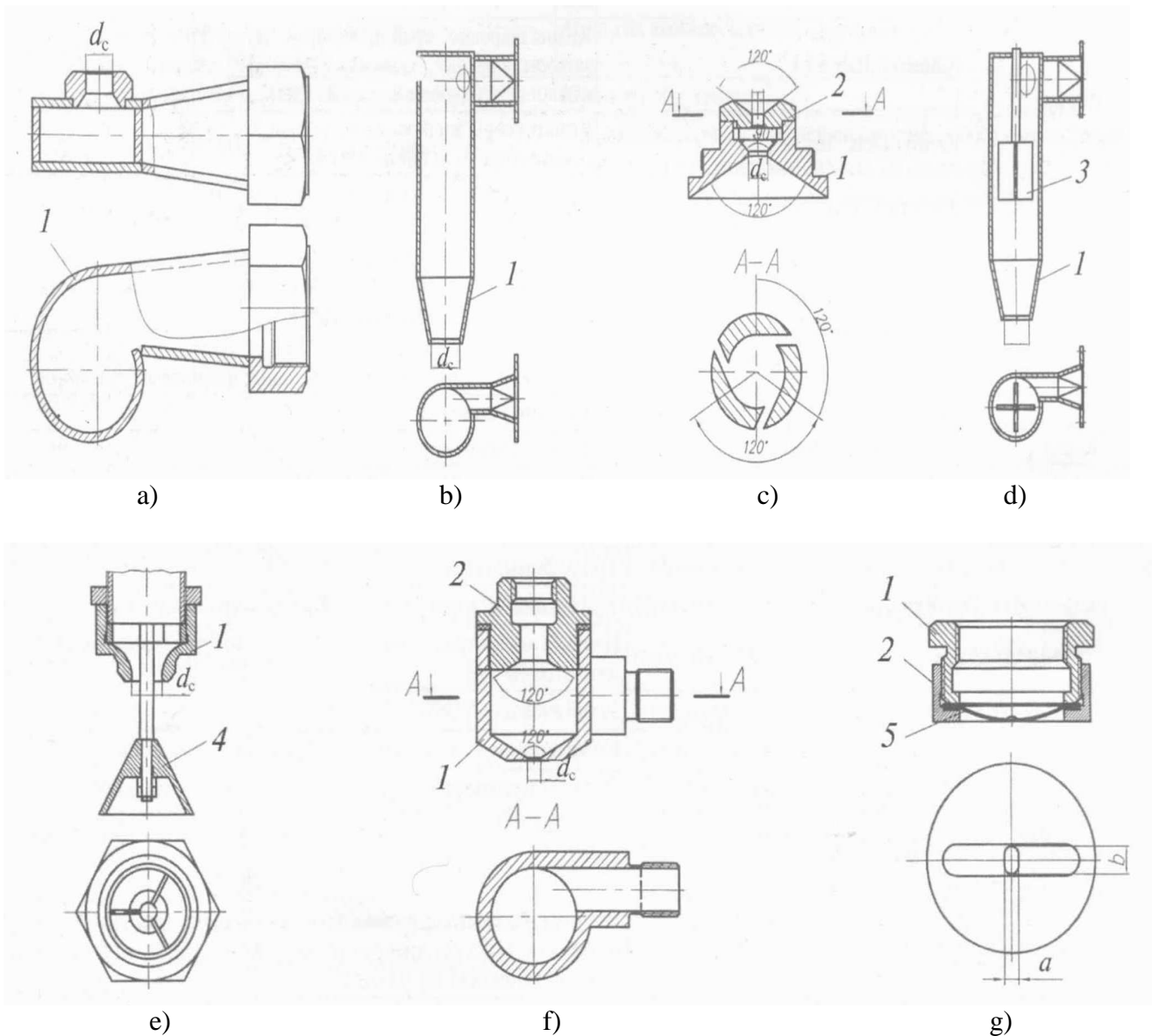


Fig 1. Diagrams of mechanical injectors: a) spiral; b) elongated centrifugal; c) centrifugal-jet; d) elongated with a filled spray; e) shock-jet; f) centrifugal controlled; g) flat-spray; 1) body; 2) cap; 3) bush; 4) reflector; 5) membrane

Table 1. Characteristics of mechanical injectors

Injector type	Field of application	Shape of atomized spray	Flow rate coefficient	Liquid pressure p , MPa	Nozzle diameter d_c , mm	Atomized liquid productivity V , m ³ /h	Spray opening angle a , °
Spiral	Hollow scrubbers, Venturi tubes	Hollow cone	0.5-0.7	0.05-0.50	12.0-25.0	0.3-100.0	60
Elongated centrifugal	Hollow scrubbers, irrigation of large size gas conduits	Hollow cone	0.433	0.02-0.30	15.0-60.0	3.0-100.0	70
Centrifugal-jet	Hollow packed scrubbers, Venturi tubes, dust washing from electrode surface in electric filters	Filled cone	0.6-0.8	0.15-1.0	4.0-24.0	0.5-35.0	60-80
Elongated with filled flare	Packed scrubbers, washing of dust from surfaces, Venturi tubes with large throat cross section	Filled cone	0.433	0.04-0.30	15.0-60.0	0.3-100.0	70
Impact-jet	Packed scrubbers, irrigation of vertical walls for film creation, creation of liquid canopies for spark extinction	Hollow cone	0.7	0.04-0.36	14.0-48.0	2.2-100.0	6-120
Flat flare	Slot Venturi tubes, wet lamellar electric filters, scrubbers with injector gas supply	Continuous flat flare	0.7	0.3-1.0	ba 1 0.75-8-6	0.03-4.50	30-120
Centrifugal regulated	Scrubbers with variable gas supply (evaporation cooled hollow scrubbers)	Hollow cone	Depends on degree of regulation K $K = 1.0-0.35$	0.15-2.00	4.0-14.0	0.27-5.00	From 60° with $K = 1$ to 120° with $K = 8$

Degree of regulation K , which is the ratio of the maximum liquid flow rate to the minimum, varies within the limits 1-8.

2.2. Approximate dependence

All injectors (with the exception of regulated) are designed for operation with liquids within which the concentration of solid suspensions is up to 500 mg/liter with a grain size of not more than 0.5 mm. A regulated injector operates reliably with a solid suspension concentration in liquid up to 100 mg/liter. The kinematic viscosity of the atomized liquid ν should not exceed $25 \cdot 10^{-6}$ m²/sec.

Injector flow rate constants for a liquid are calculated by the equation:

$$V = \frac{\pi}{4} \cdot d_c^2 \mu \sqrt{2 \cdot p / \rho} \quad (1)$$

Where V is liquid flow rate, m³/sec; d_c is nozzle diameter, m; μ is liquid flow rate coefficient; p is spray pressure, Pa; and ρ is liquid density, kg/m³.

In order to calculate the average linear droplet dimension d_k generated during atomization by mechanical injectors an approximation relationship recommended in (Valdberg, 1988) is used:

$$\frac{d_k}{d_c \cdot \sqrt{\mu}} = 385,5 \text{ Re}^{-0,74} \quad (2)$$

where $\text{Re} = d_c \sqrt{\mu v / \nu}$ is Reynolds criterion; v is liquid discharge rate from the injector nozzle, m/sec.

Discharge rate v was calculated by the equation:

$$v = \sqrt{2p/\rho} \quad (3)$$

The approximation relationship is effective in the range of values $4 \cdot 10^4 < \text{Re} < 15 \cdot 10^4$. With $\text{Re} > 15 \cdot 10^4$ the ratio $\frac{d_k}{d_c \cdot \sqrt{\mu}} = \text{const}$ and it does not exceed 0.05.

3. Results and discussion

A nomogram (Fig2) has been constructed on the basis of the approximation relationship for the case of water atomization with $\rho = 1000$ kg/m³ and $\nu = 10^{-6}$ m²/sec, within which experimental data are provided for average size water droplets during atomization, obtained in (Valdberg 1988; Geller 1965; Khavkin 1976), under conditions corresponding to nomogram plotting (p , μ , v). An experimental curve is plotted in (Fig 2), to the right of which there is a region of values $\text{Re} > 15 \cdot 10^4$, within which the value of d_k is found by the expression

$$d_k \sim 0,05 d_c \sqrt{\mu}. \quad (4)$$

The values of d_k obtained make it possible to calculate the efficiency gas cleaning from suspended particles in wet t catchers, and also gas cooling processes.

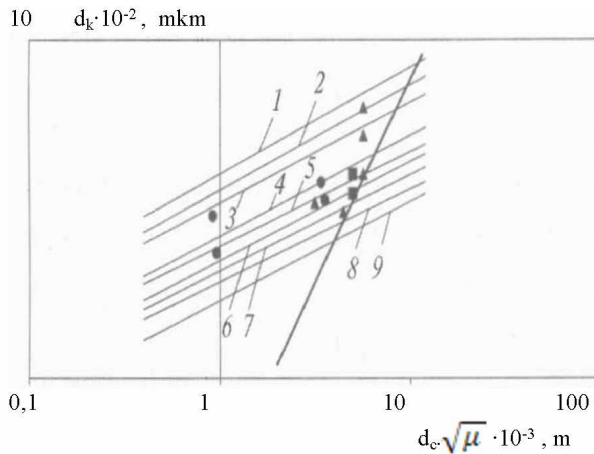


Fig 2. Nomogram for determining the linear dimensions of the drops:

- 1) with $P = 0.06$ MPa,
- 2) with $p = 0.08$ MPa,
- 3) with $p = 0.1$ MPa,
- 4) with $p = 0.2$ MPa,
- 5) with $p = 0.25$ MPa,
- 6) with $p = 0.3$ MPa,
- 7) with $p = 0.4$ MPa,
- 8) with $p = 0.5$ MPa,
- 9) with $p = 0.6$ MPa.

▲ - from the work (Valdberg 1988); ● - from the work (Geller, 1965); ■ - from the work (Khavkin, 1976).

4. Conclusion

1. Based on approximate dependence is built on nomogram (Fig 2) for a sputter of water at $\rho = 1000$ kg/m³ and $v =$

10^{-6} m² / s, at which swarm experimental data medium-sized water droplets in the spray.

2. Nomogram for determining all the parameters of mechanical injectors.
3. The values obtained d_k allow us to calculate the efficiency of gas cleaning from suspended particles in wet scrubbers and cooling gas process.

Reference

- Chokhnelidze, A. N.; Galustov, V. S. 2002. Guide to Spray irrigation and kapleulavlivayuschim devices. M: *Energoatomizdat*, 608.
- Geller, Z. I. 1965. Fuel oil as fuel. MM: *Nedra*, 496.
- Khavkin, Y. I. 1976. Centrifugal atomizer. L.: *Mashinostroenie*, 168.
- Lebedyuk, G. K.; Galustov, V. S. 1976. Atomizing device in gas purification apparatus *TSINTIHIMNEFTEMASH*, 14.
- Pazhi, D. G. 1979. Atomizer. M.: *Chemistry*, 216.
- Uzhov, V. N.; Valdberg, A. J. 1972. Wet gas cleaning filters. Publisher chemistry. Moscow. 74.
- Valdberg, A. Y.; Savitskaya, N. M. 1988. Overall estimation of dispersion of the spray hydraulic nozzles. *TOKHTA*, 23(5): 689–692.
- Вальдберг, А. Ю.; Мошкин, А. А.; Каменщиков, И. Г. 2003. *Образование туманов и каплеулавливание в системах очистки газов [Formation of mists and drops' collecting in the systems of cleaning of gases]*. Москва: Издательский Дом «Грааль». 256.