# Dust emissions' reduction into the atmosphere by environmental-engineering systems of small-size devices with counter-swirling flows (CSF)

*N.M.* Sergina[1], *A.A.* Sakharova[1], *V.N.* Azarov[1], *D.V.* Azarov[1], *M.A.* Nikolenko[2]

[1] Volgograd State Technical University, 400074, Volgograd, Russia
[2] Don State Technical University, 344000, Rostov-on-Don, Russia

**Abstract.** The article discusses the features of using environmental-engineering systems of small-size devices with counter-swirling flows (CSF) to reduce dust emissions into the atmosphere. The reasons for the decrease of the dust collection efficiency by CSF systems are analyzed. The layout diagram of the dust collection system with CSF devices and the organization of suction from the dust collector hopper are given.

## 1 Introduction

The vortex dust collector contains a cylindrical body with tangential nozzles for supplying primary and secondary streams of dusty gas, an axial nozzle for the output of purified gas in the upper part of the housing and a dust collector in its lower part. The inlet pipe of the primary gas stream is equipped with a swirl mounted at the inlet end of the gas duct outside the vortex dust collector body, and flow regulators are installed in the inlet tangential pipe of the primary and secondary dusty gas flows. This will allow adjusting the flow rate of gases entering the dust collector and the magnitude of the twisting parameters of the gas flows while maintaining the configuration and increases the cleaning efficiency for various types of dust [1].

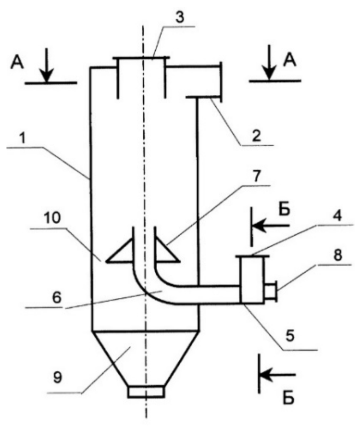


**Fig.1**. Vortex dust collector for pneumatic transport and aspiration systems [1]

The vortex dust collector comprises a cylindrical housing (1) with an inlet tangential nozzle (2) for supplying a secondary stream of purified gas and a nozzle (3) for outputting the purified gas. The secondary stream of the gas to be purified is introduced through the lower tangential pipe (4), a swirl (5), and a gas duct (6) with a baffle plate (7). The swirl (5) contains a hatch (8) for cleaning. The separated dust settles in a dust collector (9), passing through the annular gap (10) between the baffle plate (7) and the wall of the housing (1). The dusty primary gas stream is fed to a cleaning body (1) of the vortex dust collector through a tangential pipe (4). A passing swirl (5), the gas stream receives a helical direction of movement along a gas duct (6); the gas enters the separation space of the housing (1) of the vortex dust collector. The swirl (5) ensures the stability of the flow of the primary gas and the required angle of its opening in the separation space of the housing (1).

## 2 Results

Researches show that CSF devices have significant advantages over other centrifugal dust collectors:

– higher degree of fine dust particles' capture;
– lower sensitivity of the quantities' slip function to fluctuations in gas flow and dust concentration;
– less pressure loss in the device with a number of operating modes,
– ability to control the dust collection process by changing the relationship of gas flow rates and dust concentrations at the upper and lower entrances;
– ensuring the maximum diameter (defined as the diameter of particles trapped in the device with an efficiency of 50%) is less than that of other types device - the efficiency of trapping particles larger than 5-10 microns reaches 100% [2].

Along with the advantages one of the reasons for disadvantages of the CSF use is the requirements for more precise adjustment of the device and higher requirements for the quality control.

After analyzing more than 50 operating CSF devices and the reasons for their shutdown, it was found that if emergency stops of the dust collector are excluded according to technological requirements, the main one is clogging (overflow) of the hopper and the lower part of the separation chamber (above the bump plate). The main reason for this (up to 78% of cases) is failure, an airlock feeder accident (located under the device) with the subsequent and untimely termination of dust intake into the device. For example, it may happen in the absence of or automatic stop failure of the exhaust fan after the gateway feeder failure. In this case, the cleaning process which is quite laborious requires opening the airtight hatch and removing dust, powders are often already packed in the twist and the pipeline.

Another reason may be clogging of the horizontal supply section (pipe) to the lower entrance. The reason for this may be the arrival of heavier fractions of the material into the dust collector or a temporary decrease in the gas productivity of the fan or draft fan (for example, when a fabric filter, sleeve bag, or individual sections of the sleeve filter of the second stage are clogged). This leads, in both cases, to a situation where the gas velocity at the inlet to the lower inlet of the dust collector is lower than the speed of reliable transportation entering the CSF of the polydisperse material. Often, the cause of leakage is the ingress of a large solid particle into the airlock feeder.

One of the reasons may be an increase in the concentration entering the device when the mass flow rate of the incoming dust exceeds the mass flow rate of discharge. The cause of the malfunction is overflow. The failure of the lower entrance often increases the slip function, sometimes several times, because actually turns the CSF device into a cyclone, with an increased height separation chamber. It should be borne in mind that the recommended (conditional) speed (flow rate of incoming gas per unit cross-sectional area) for cyclones, as a rule, does not exceed 2.5 m/s, and for CSFs, this value is 3.5 - 5.0 m/s, which leads to an existing increase in pressure losses in the device, a decrease in the flow rate of gas entering the purification system, a decrease in the fractional purification function values, as well as an increase in dust emissions in the working area or failure to comply with the technological regulations [3].

Historically, all the devices with counter-swirling flows (CSF) can be divided into two types. The devices of the first type were developed on the basis of direct-flow dust collectors, while the secondary (upper) stream was initially supplied in the form of compressed air. The devices of the second type are based on the idea of cyclones. In this case, 65–70% of the dusty gas is supplied to the secondary (upper) entrance, and 30–35% of the gas enters the lower entrance.

The quality of gas purification in the device depends on the magnitude of the centrifugal force that emits dust particles from the flow, therefore, many authors developing vortex dust collectors pay much attention to the design of the input and secondary flows of the gas-dust mixture, the development of internal devices that allow increase the swirling of flows [3].

In order to increase dust collection efficiency and reduce energy costs, numerous researchers have proposed many improvements. The most important of them, according to Sazhin B.S. and Gudim L.I. [4], is equipment for inputting the primary gas flow by a swirl; replacing the nozzle supply of the secondary stream under high pressure by feeding this stream through a distributed inlet with a number of tangential nozzles or through another type of swirl under pressure not significantly different from the pressure of the primary stream; use as a secondary stream of the purified gas; replacing a profiled disk with a bump washer with optimal dimensions and location relative to the input of the primary stream. Changes were made in the design of the device body, separation zone, sludge discharge and clean gas outlet [3].

Sazhin B.S. in his works systematized and summarized the theoretical and experimental studies of CSF devices for the first time. By Kononenko V.D. [5] a CSF device was proposed, the feature of which is the design of the lower input. In his calculation model, the secondary stream, without mixing with the primary, passes from top to bottom to the level of the wallpaper washer, where it “flows” into the primary stream. The primary stream has only the internal part of the jet, the secondary one has the external. At the interface between the flows, it is assumed that the absolute values of the tangential velocity should be the same, and in the zones of the flows the average consumption speeds should be equal (to ensure the best dust separation). It is believed that the primary flow leaves the swirl in the form of a free swirling jet to the interface between the flows, and the secondary flow is in the form of a constrained swirling jet (swirling flow) [6].

The CSF devices, in which the direction of the flows creates a multidirectional twist, A. M. Kutepov and A. S. Latkin proposed to designate the CSF (opposite twist), in contrast to the CSF, that is, with a spiral swirl of flows [7]. Due to oppositely swirling flows, the twist in the CSFs sharply decreases, i.e. the hydrodynamic resistance of the device decreases, the abrasion of the walls by the material, and most importantly, the collision of oppositely swirling flows creates a more developed turbulent structure than in a cyclone device, which should lead to an increase in the speed of the process [3]. Such devices are used, for example, in the drying technique, but they are not considered in this paper. The designation of the CSF corresponds to the designation of the CSFs.

There are a number of works (by V.N. Azarov, S. A. Koshkarev, N. M. Sergina, V. N. Martyanov, B. T. Donchenko and others) related to design changes in the CSF devices and dust cleaning schemes using CSF . One of the important structural solutions is that to increase the reliability of the CSF device, the primary flow swirl can be moved outside the housing [8]. In addition, a number of devices with several upper inputs have been developed, for example, dust collectors (DC) [9, 10].

As noted above, an important feature of these vortex dust collectors is that the degree of purification depends on the ratio of primary and secondary flow rates and on the concentration of the solid phase in the dust and gas stream. For example, in the DC CSF and DC devices, optimal efficiency is achieved when the ratio of the flow rate supplied to the lower inlet of the device to the total flow to the cleaning range from 0.23 to 0.27. This requires a very precise regulation of the device and constant monitoring of their operation. To increase the stability of systems with vortex dust collectors, it was proposed to use preliminary separation of flows [11, 12]. In addition, the organization of suction from the bunker zone of the dust collector allows you to: prevent dust during unloading of the captured product from the device; reduce the absolute value of the pressure in the device, which, in turn, will lead to a reduction in dust knocking out; to exclude the installation of a gate feeder, which also provides a reduction in the amount of dust knocked out of the dust separator; to increase the reliability of the aspiration system by reducing the likelihood of clogging the dust collector [13].

As noted in a number of recent works, for small-size CSF devices, which include various modifications of CSF, DC CSF and others, the existing effect of the breakthrough of large particles [14, 15, 16].

One of the ways to increase the efficiency of cleaning emissions into the atmosphere from dust (to reduce dust leakage into the atmosphere) and to reduce aerodynamic drag in inertial dust collection systems with vortex devices with counter-swirling flows (CSF) is the organization of suction from the hopper of the CSF device [17]. One example of the implementation of such a solution is a dust removal system for emissions. In such a system, a reduction in dust leakage through the atmosphere (and a decrease in aerodynamic drag) is ensured by organizing suction from the hopper of the first-stage CSF device, as well as by supplying different-dust flows to the lower and upper inputs of the second-stage CSF device [18].

Figure 2 shows the layout of the dust collection system with the CSF devices when organizing suction from the hopper of the dust collector of the first stage.

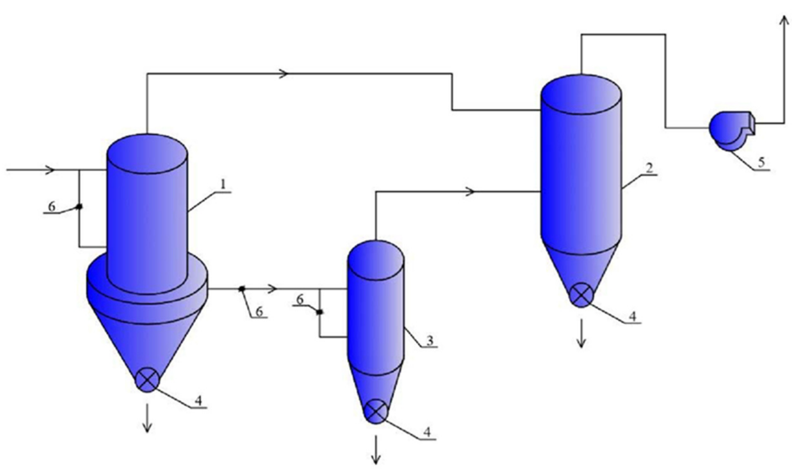


**Fig. 2.** An example of the layout scheme of the dust collection system with CSF devices in the organization of suction from the hopper of the dust collector of the first stage [17].

(1) - CSF device of the first stage; (2) - CSF device of the second stage;

(2) -additional dust collector CSF with smaller diameter;

(3) -sluice gates; (5) -fan; (6) -control valves

One of the factors that must be taken into account when arranging inertial dust collection systems with devices of different sizes, in addition to the properties of dust, the volume of gas to be cleaned, etc., should be considered the “leakage effect of large particles”.

## 3 Conclusion

Thus, experimental and computational studies have shown that low-efficiency CSFs are used to clean dust from return streams in order to reduce dust leakage in the main inertial dust collectors, for example, during suction from the hopper and in other cases, however, it is necessary to take into account the effect of leakage of large particles in small-size devices.

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