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USING THE SYSTEM OF FINE PURIFICATION OF GASES IN THE DISPOSAL OF INDUSTRIAL AND DOMESTIC WASTE

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The paper solves the problem of the inertial method of sedimentation of dust particles (or liquid droplets), which is based on changing the direction of gas movement with particles suspended in it. Really one of the most serious environmental problems facing humanity is environmental pollution by domestic and industrial waste. These wastes mostly have such undesirable properties as toxicity, carcinogenicity, mutagenicity, corrosion, reactionary ability and fire danger. It is known that the effectiveness of any gas cleaning system is determined by its ability to remove small particles from the gas stream. To obtain a solution to this problem, we considered the possibility of separating heterogeneous gas mixtures by developing the fine purification of gases based on a gradient separator. The system of fine gas cleaning on the basis of a gradient separator is designed to clean gas streams from dispersed particles, separate aerosols, sublimates, and separate heterogeneous gas mixtures into separate components.

Keywords: *gradient separator, domestic and industrial wastes, small particles, separation limit*

Introduction

Currently, strict rules and conditions are being introduced on placement and equipment of landfills for warehousing and disposal of hazardous waste in industrially developed countries. In recent years, the problem of toxic waste disposal has become relevant in the Republic of Belarus, the Russian Federation, the Republic of Kazakhstan and other CIS countries which coincide with the level of its importance worldwide. It is connected with the international strategic trend on comprehensive "greening" of the environment as the factor compensating the degradation of the environment due to industrial development as well as the increasing danger to the population from the accumulation of highly toxic and infected production and consumption waste.

The most common method of processing hazardous organic waste is incineration. For these purposes, industrial thermal devices are widely used, for example, asphalt or cement furnaces, steam boilers, circulating fluidized bed furnaces, rotary kilns. At a temperature of 1000-1200 °C in such furnaces and devices, afterburning of the formed volatile organic compounds is carried out in secondary chambers with additional fuel and oxidizer supply. In some cases, air is enriched with oxygen to increase temperature in burners.

Fire method of waste neutralization and recycling is the most versatile, reliable and effective along with others. In many cases, it is the only possible way to neutralize industrial and domestic waste. This method is used for the disposal of solid waste in any physical condition: liquid, solid, gaseous and pasty. Along with the burning of combustible waste, the fire method is also used for the disposal of non-combustible waste. In this case, waste is exposed to high-temperature (more than 1000 °C) products of combustion.

Incineration is the controlled process of oxidation of solid, liquid or gaseous combustible waste. During combustion, carbon dioxide, water and ashes are formed. Sulfur and nitrogen, contained in wastes, form various oxides during combustion, and chlorine is reduced to HCl. In addition to the gaseous products, solid particles are also formed from the combustion of waste such as metals, glass or slag which require further recycling or disposal.

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This method is characterized by high sanitary and hygienic efficiency. The field of the fire method applications and wastes that can be neutralized by this method are constantly expanding. They include waste from organo-chlorine production, basic organic synthesis, production of plastics, rubber and synthetic fibers, oil refining industry, forestry, chemical-pharmaceutical and microbiological industry, mechanical engineering, radio engineering and instrument-making industry, pulp, and paper production and many other industries.

The conducted researches [1-3] demand a critical approach to fire neutralization of toxic waste due to the possibility of the formation of extremely harmful compounds afterwards: dioxins and furans. The disadvantage of fire neutralization is also the use of additional fuel (usually natural gas), which significantly increases the volume of exhaust gases, and therefore significantly increases the load on the gas cleaning system, its size, and material capacity.

In industry, mechanical, electrical and physicochemical methods of gas purification are used [7, 10]. Mechanical and electrical cleanings are used to trap solid and liquid impurities from gases, and gaseous impurities are captured by physical and chemical methods. Mechanical purification of gases is carried out by the sedimentation of impurity particles by gravity or centrifugal force, by filtering through fibrous and porous materials and by washing with water or other liquid. The simplest, but an ineffective and rarely applied method is by the sedimentation of large dust by gravity in so-called dust chambers. The inertial method of sedimentation of dust particles (or liquid drops) is based on the change of direction of gas flow with weighed particles in it. Since the particles density is about 1-3 thousand times more than the gas density, they continue to move by inertia in the previous direction and separate from gas.

1. The gradient separator

The possibility of separation of heterogeneous gaseous mixtures gives opportunities not only to prevent harmful gas emissions, but also to use these components as technological raw materials. It is important to mention that the device separates gaseous mixtures as, for example, oil and water are separated in liquids. The device cannot divide homogeneous gaseous mixtures into components, for example, air into its components (as, for example, it is impossible to separate water and alcohol).

In fact, the efficiency of any gas purification system is determined by its ability to remove small particles from the gas flow, since the problem of removing large particles is basically solved to date. A feature of the gradient gas purification method is the fact that devices have a separation limit which is the zone of large particle sizes. There are reasons to assume that such devices operate at the molecular level in the zone of small particle sizes, i.e. they can remove particles of one molecule size from the flow. The basis for such an assumption is the experiments on laboratory installations while working with various smokes – tobacco smoke is much easier to remove from the flow because it is the thinnest among other smokes. In addition, when working on a pilot plant, sulfur dioxide was derived from the total gas flow, which is possible only if the device works at the molecular level.

Of course, the conducted researches are not enough to make a final conclusion; however, theoretical assumptions indicate that separators, that use a gradient method of gas purification, are capable to extract particles one molecule in size from the gas flow. The system of fine purification of gases on the basis of the gradient separator (figure 1) is intended for cleaning of gas streams from dispersed particles, separation of aerosols, sublimates, a division of heterogeneous gaseous mixtures into separate components.

The dusty gas flow, which is a mixture of gases and weighed particles, moves into the inlet confuser 1, containing 2 equal-profile sites "a" and "b", where the flow is accelerated. On the site "b", the gas flow is provided with an additional impulse of twisting by the guiding device 2.

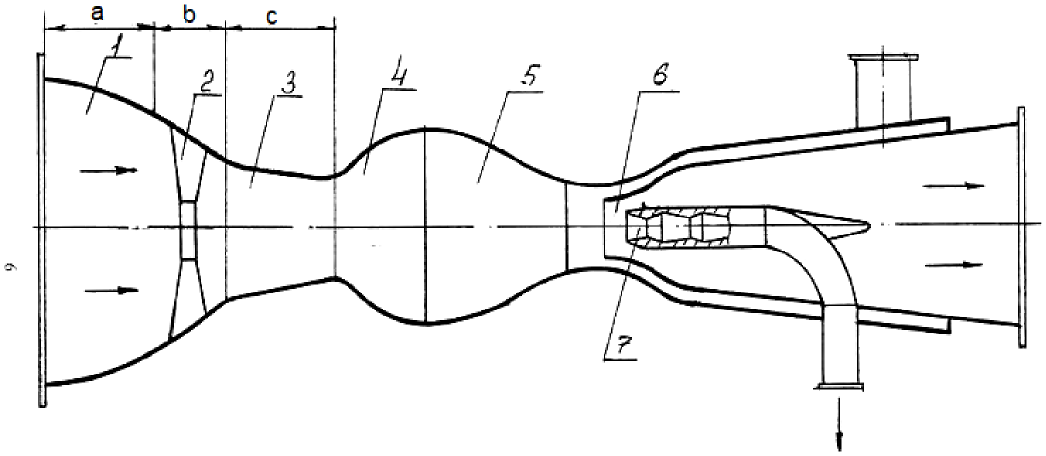

Fig.1. Scheme of the gradient separator

In a confuser 1, gas flow is accelerated, twisted, keeping the laminar structure of a stream. The laminar flow is provided by monotonously increasing the tangential and axial acceleration following these conditions in a confuser 1:

On the site «a»: $\frac{dF_i}{dl_i} = const_1$, On the site «b»: $\frac{dF_i}{dl_i} = const_2$,

where F – cross-sectional area of the channel; dF – increment along the area; l – site length; dl – increment along the length.

These constants are determined experimentally, depending on the properties of the gas flow (temperature, viscosity, density). Next, the gas flow enters the confuser 3 where the acceleration is continued under the condition $\frac{dF_i}{dl_i} = const_3$. The third constant is also determined experimentally.

From the confuser 3, the gas flow enters the twisting nozzle 4 where it is provided with a new twisting impulse. The geometry of a nozzle is calculated by the formula:

$$D_i = \sqrt{D_{i-1}^2 + \frac{\Delta l_i \cdot c_0 \cdot D_0^2}{\sqrt{(c_0^2 - 2a_0 l_i - l_i^2 \cdot k)^3}} \cdot (a_0 + kl_i)} \quad (1)$$

where D_i – the diameter of the i-th cross section of a nozzle; Δl_i – the difference between the distances between the ith and the (i-1)th sections; c_0 – the initial gas velocity at the entrance to the nozzle; a_0 – the acceleration of the flow at the entrance to the nozzle; $k = \frac{a_0}{l}$ – specific increment of acceleration per unit length of the nozzle.

At the exit of the diffuser 4, the gas flow is inhibited due to the geometry of the twisting nozzle. After carrying out the first 3 stages of the flow acceleration, it's twisting with the preservation of the laminar structure, the flow moves into the separation channel of the gradient separator where the flow acceleration is continued in the parabolic confuser 5, then flow is twisted in the nozzle 6.

At the same time, the dusty gas mixture is sucked through the dust-collecting pipe 7 along the channel axis, aligning the velocity and acceleration of the flow along the channel section which prevents turbulence. Gases with high density are removed through the peripheral-radial suction. The condition is, herewith, always fulfilled – the smaller the particle size, the closer to the center its trajectory passes, the easier it is to remove such particles from the gas flow. Therefore, it is impossible to record the presence of particles at the exit from the gradient separator on highly dispersed two-phase flows.

2. Processes in the gradient separator

The physical phenomenon that resembles the operation of the gradient separator is known to be a tornado. In nature, when a tornado occurs, it is observed in the form of a trunk, which is due to the suction of dust into the discharged core of the rotating gas mass. A similar process takes place in the gradient separator. The presence of a laminar structure of the gas flow, on condition of intensive rotation, allows the removal of components such as sulfur dioxide, fluorine, chlorine (from the periphery of the channel), water vapor, gaseous sublimates (from the center of the channel) from the total flow of industrial gas emissions.

Dimensions of the gradient separator allow it to be installed directly in the bypass flue gas ducts of production lines. The gradient separator is completely erosion-free since the dust is collected in the center of the separation channel and never comes into contact with the construction elements, including the central suction path. Energy consumption for gradient separation is comparable to the energy consumption for the implementation of known methods. The next element in the presented purification system will be an inertial vacuum dust collector, a technological machine for the deposition of dust particles taken from the central section of the gradient separator.

The remaining elements of the gas purification system on the basis of the gradient separator are standard: a condenser, steam jet ejectors, regulating and shut-off valves. Under the action of the smoke exhauster, the flue gases from the steam generator through the bypass flue gas duct are directed to the gradient separator (figure 2). In the separator, dust is concentrated to form a dust cord which is sent to the rough and fine purification bunkers through the central suction where its deposition occurs. Gas is pumped out from the bunkers and the central suction with the help of steam jet ejectors and is then released directly into the atmosphere.

This research work shows the results of the study on the degree of trapping the ashes from coal combustion in an inertial vacuum dust collector. The diagram of this process is presented in figure 3. The principle of operation of the inertial vacuum dust collector is based on a number of effects observed during the gas flow in a so-called negative voltage state ("NV state"). Thus, the particles can enter the channel, but cannot exit. The gas is in this state if the blasting device, that drives it, is located at the exit of the installation. In this case, the gas becomes stretched, and the effects are observed that cannot be explained by the molecular-kinetic theory of gaseous state:

- two jets of gas in the "NV state" do not have any effect on one another (transparent to each other) when crossed at an angle of 90^0.

– if two jets intersecting at an angle of 90^0 are in the "NV-state" and transport dispersed particles, then after crossing the jets, all particles go to the jet with higher velocity.

- if a high-speed gas jet transports dispersed particles and borders with a stationary gas mass, then that gas mass is a "pump" for particles, i.e. such a mass sucks the particles into itself.

The gas to be purified is sent to the booster nozzle (a). The flow speed of gas particles increases at the exit of the booster nozzle through the inlet pipe because of its constriction, and the gas is stretched and goes into a negative voltage state. The dusty flow passing through section 1 has a velocity greater than the flow in section 2. But the particles in this flow also have high velocity, hence greater kinetic energy, which allows them to overcome section 2 along the tangent and rush in the form of д. When the dusty gas flow moves along the rotary chamber, it contacts the sedimentary grid located in the lower part of the rotary chamber, behind which is the stationary gas mass. Particles from the high-speed flow pass into this mass and are deposited in the bunker; however, not all particles are deposited.

Some of them go to the exit of the device and, falling under the influence of the inlet jet, are again sent to the rotary chamber of the system.

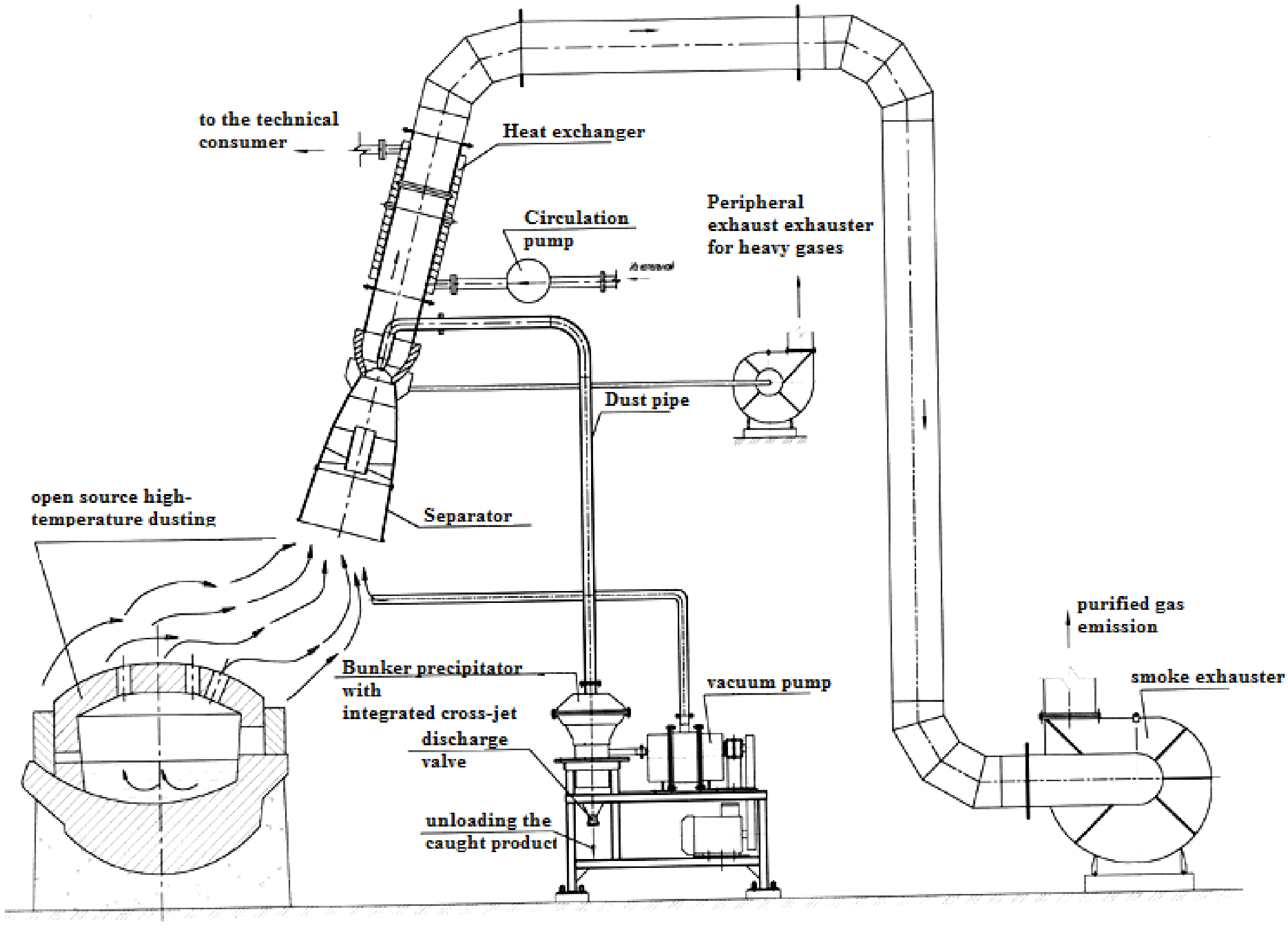

Fig.2. Installation diagram of the gradient separator

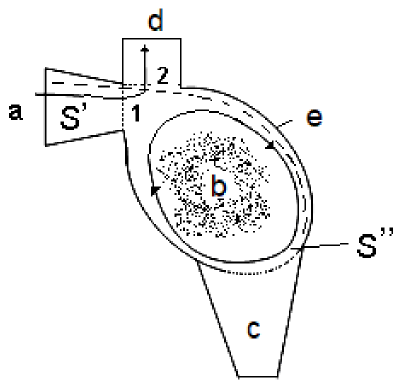

Fig.3. Diagram of the inertial separator dust collector model

There, an aerodynamic trap arises, i.e. particles can get into the rotary chamber of the device but cannot get out of it and are completely deposited in the bunker at the end. For the gas coming out of the rotary chamber, the inlet jet is a filter consisting of gas layers (layers of the filtering material) that is as efficient as cloth filters. The speed of particles decreases as they move, and the pressure gradients in the collecting chamber and the trap are leveled off, making necessary conditions for the particles to fall into the collecting chamber itself. The remaining particles (a small part) fall into the aerodynamic trap, accumulate in it and eventually fall into to the collecting chamber “c” due to the gravitational force. Herewith, the distance S’ - S’ determines the place of the particle deposition of a certain size.

Conclusion

The observation of particles falling into the collecting chamber confirms what was described earlier. Only a small fraction (less than 2-3 %) of the particles is attracted to the flow and is carried back into the aerodynamic trap.

The second important aspect of operability of the gas purification device is its erosion safety. In the inertial vacuum dust collector, the current of two-phase flow is formed in such a way that particles cannot overcome an interface and move not touching the walls until the zone of sedimentary grids.

Specific equipment is needed for each type of raw material depending on its characteristics: the temperature of ignition and combustion, burning time and others. Domestic waste is represented by more than 1,700 different components; therefore, selecting necessary equipment and a combustion device is essential. Those purchased abroad are only suitable for sorted, drier (with a moisture content of 7 %) garbage; domestic one has a moisture content of 46-50 %.

Chemical (gas) and physical (ash and slag) under burning constitute 27-29% when traditional technologies are applied to domestic waste. Thus, incomplete combustion products are released into the air. Carbon monoxide is formed during the combustion of the plastic packaging. Carbon monoxide causes various diseases in the presence of chlorine gas and phosgene and emitted dioxins and furans. It is not possible to extract these components from flue gases using standard filters. Ash and slag from single-stage combustion have poisonous concentration. Therefore, the use of the proposed fine gas purification system is quite relevant.

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