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DEVELOPMENT OF AN EXPERIMENTAL PLANT OF A NON-NOZZLE POROUS FOAM GENERATOR FOR PRODUCING WITH FOAM GENERATING AND DEFOAMING STRUCTURES

Abstract. On the basis of studies of heat-mass exchange processes by boiling of pure liquids and with the addition of surface-active agents, a new class of non-nozzle porous foam generator for producing of air (steam) and mechanical foam was developed. The results of the experiment are generalized by the criteria equations of heat-mass exchange with an accuracy of ± 20% with respect to the processes of bubbling, foam generation, pseudo-fluidization and boiling. The combined action of capillary and mass forces for capillary-porous structures of the 3x0,4 type made it possible to boost the operating mode of the foam generator by 1,5-2 times and reduce the consumption of the foam generating agent and reduce the hydraulic resistance tenfold. The nozzle-free foam generators of air mechanical foam were designed along with its case, inlet and outlet nozzles, a set of grids and sprayer. They help to conduct foam generation processes with high effectiveness under low hydro-and-gas dynamic resistance. For further enhancement of the combined processes of gas mechanical foam and collecting micro-and-ultramicroscopic dust, a dust collector along with its case, inlet and outlet nozzles, a set of grids and sprayer was proposed, which is equipped with defoaming grid porous structure, whereas foam generating and defoaming structures are installed into in case consequently as per the dusty gas movement and sludge collector. Besides, each subsequent grid of foam generating porous structure is made with the increased size of cells following the cleanable gas; e.g. made of metal cells for clearance 0,08*0,14*1, and defoaming made of grids with decreasing size of cells following the cleanable gas, e.g made of metal cells for clearance 0,4*0,14*0,08.

Key words: porous foam generator, foam generation, foaming, defoaming, heat-mass exchange, capillary-porous structures.

Study of the heat and mass exchange of boiling pure liquids in capillary porous structures, development of control methods for these processes [1] allowed to summarize trials with pure foam and dust-foam flows and study a single equation for calculation of the heat and mass exchange with an accuracy up to ±20 % [2], whereby boiling processes, bubbling, pseudofluizidation and foam generation were summarized as well.

A new class of nozzle-free foam generators and foam-dust catchers along with bubbling capillary porous grids were invented [3], as well as foam generating and defoaming structures located vertically. Due to the controlling internal characteristics of two-phase flows [4] different types of foam-dust catchers were designed [5-13]. It is possible to increase effectiveness of dust-gas catching because of controlling geometry of microchannels of porous material [6], separation of flow into wave energy and gas (steam) energy [7, 11], forming generator with the help of power (without incoming flotation) [8], design of turbulizers as foam generating and defoaming structures using a joint action of gravitation and capillary forces, pressure and vibration forces.

In accordance with the article No.358012, 1972 a method of electrostatic gas cleanup was described where electrization of settling elements was produced using a tribo effect. This effect was used earlier, though during electrization of filter elements they had a conductive layer on their surface, which reduced

the electrostatic filtration component. The reviewed method describes that an effectiveness of electrostatic filters will be increased because it is recommended to implement electrization with the help of circulation of weight fine grained electrified agent in hollow settling elements.

Method of electrostatic gas cleanup as per the article No.358012, 1972 in terms of dust settling effectiveness exceeds the known methods. However, in comparison with the known methods, it has a low dust settling productivity.

Therefore, it is possible to increase the effectiveness of dust electrization in air flow by using a tribo effect. Though it requires solving a problem of dust cleanup productivity.

In addition to methods of gas cleanup from dust there is a method /article No. 247241, 1969/, where it is suggested to catch thin aerosol sprays with the help of charging aerosol spray particles when the electrostatic sprayed easily evaporating liquids are settled on them, hence a liquid vapor in a form of condensate will be re-used. Such method has an advantage over the method of dust catching by charging electrostatic sprayed water, because a mutual attraction of dust particles and drops of sprayed water leads to their adhesion and growth of particles along with charge neutralization.

A common disadvantage of electric methods is a minor size and porous structure of formed aggregation of dust particles. Under impaction, they can be easily destroyed. Low effectiveness of dust suppression process could be expected from settling of fine dust. Thus, it is required to develop a dust suppression method, which would allow significantly increase resistance to destruction of formed dust aggregation whilst processing an air dust flow by electric field with retention of high productivity of dust cleanup.

It is interesting to see the air dedusting method using porous blankets /article No. №368413, 1973/. In order to increase an effectiveness of dust catching, a dust flow goes through the parallel blankets that moist liquid. A moving air flow helps to vibrate blankets due to the irregular speeds. Dust particles located in air turbulent flow are being moisturized and coagulated. Fiber is moisturized by water supply to pipe frame where the blankets are fixed.

To achieve a required effectiveness of dust catching, it is necessary to conduct multiple test researches in various mode parameters, as well as to perform new design studies for forming an aerodynamic structure of air dust flow.

There is a dust suppression method based on enriched water steam. With a steam condensate, the area of low pressure is formed where all particles move and could be caught. The disadvantage of such method is its low effectiveness that is caused by unreasonable use of generated steam for the purposes of dust suppression. Besides, to achieve a required norm of dust content large steam resources are required, and that result in unreasonable costs for steam generation.

Similar method to the above-mentioned method is a method (article No.130461), where air dust flow is mixed with steam spray with further settling of steam-dust flow by the sprayed water.

Under such process, it is expected to obtain a low degree of dust catching. Condensate effect will be shown in unstable way, takes probabilistic nature depending on random contact of water sprayed drops with water steam molecules and will be determined by turbulence degree of air dust flow. Dust coagulation effectiveness is expected as minor in conditions of enriching air dust flow by steam. That is why water steam and sprayed water are used unreasonably, and there is increased consumption of steam and water.

When studying a movement of aerosol particles in the steam diffusion field it was evident that the aerosol particles are intensively remote from a cold surface. Aerosols with speed 1 m/s were put through the condenser of 0.5 m long and $5x10^{-3}$ m wide. Metal wall is washed by water with the temperature at condenser inlet 20°C and outlet about minus 70°C. Particle concentration was 1012 particles/m³. Catching degree varied in large limits 75-95%. Mechanism of the dust suppression process is based on two principles: I) condensate enlargement of aerosol particles like condensation nucleus; 2) directed movement of steam particles mainly towards a cold surface.

Mechanism of the dust suppression process is very complicated, though the main acting factors could be indicated such as Stefan flow of condensed steam as a driving force of aerosol particles. Also, it is enforced by the available diffusion, thermophoretic forces and convective flows, large particles are removed from flow due to the gravitation and centrifugal forces; some particles in air steam flow are minimized because of the coagulation process.

Study of the mechanism of dust suppression in the steam diffusion field requires further development, in particular, it is related to the enhancement of the steam condensation process, steadiness of liquid film distribution, development of new devices for feeding air dust flow by the enriched steam.

Some enhancement of the dust suppression processes could be achieved by additional power sources /article No.1032197, 1983/. It is suggested to charge water steam and dispersed water oppositely, whereas water should be previously magnetized. Steam is injected to a tank with hot mass, which goes through the electric field formed at the steam nozzle outlet. Steam-air-dust flow leaving a tank is condensed at sprayed drops of electrically charged and magnetized water.

Under the weight steam consumption equal to $7x10^{-3}$ kg/f and over, a relative air dust content reaches up to 3-6% and becomes self-simulated in relation to steam consumption. The increase of process effectiveness in the described condensate system of dust suppression occurs 1.5-2 times (probably in relation to condensate system without electric charge of steam, water and magnetization of water). Also, it is unclear how it impacts upon the process of water magnetization, and what contribution of electric charge separately for steam and water is.

The reached effect is explained by the fact that when oppositely electrically charged sprays of water and steam are injected to the dust source due to electric gravity forces between steam molecules and water drops it leads to more enhanced and ordered steam condensation at water drops. At condensate surface, a larger hydrodynamic flotation occurs rather than at non-charged aerosols, which directs to drops that collects dust particles and tends to their catch by drops. Due to that, massive dust particles are settled. Capture rate of dust particles by water drops also is increased due to minimizing forces of the surface tension of electrically charged drops.

The described method of dust suppression has an additional effect on settling dust particles. However, it is achieved by huge efforts as it requires the electric charge of steam, water, water magnetization that significantly complicates a condensate system of dust suppression, and extra costs for establishing electric fields and ensuring electrical safety of manpower.

Therefore, further theoretical and experimental studies of the dust suppression processes should be aimed at new design solutions that are based on the reviewed methods using evaporator-condensing multiphase systems of dust collection and surface-active agents.

Basically, in terms of the existing types of foam generating agents we could hope for the new aerodynamic diagrams and structures, which will determine a behavior of dust suppression process, significantly increasing a cleanup degree of dust flow, and become reliable and easy to fabricate and operate and meet safety requirements whilst operating the equipment [8-13].

Figure 1 demonstrates a new class of nozzle-free foam generator with foam generating capillary porous structure.

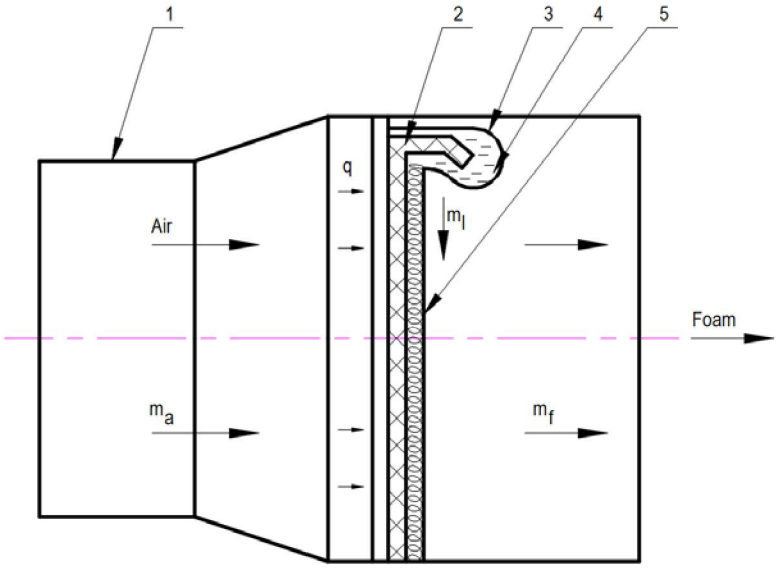

Figure 1 – Nozzle-free capillary porous foam generator of air (steam) mechanical foam:
1 – cylindrical case; 2 – capillary porous structure; 3 – spray device (feeding artery); 4 – foam generating solution;
5 – air (steam) – mechanical foam; ma, ml, ms – consumption of air (steam), liquid (foam generating solution), foam;
q – incoming (foam generating) flow energy density