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ANALYSIS OF THE THERMAL METHOD OF NEUTRALIZATION OF GAS STREAMS FROM ORGANIC MATTERS

Statement of a problem and its urgency

In Ukraine during 1990s volume of air waste releases had been decreased considerably because of setback in production. But since 2001 a tendency of the waste increase has been observed [1]. Data of State Statistic Committee of Ukraine indicate that there were 15549,4 thousand tons per 1990; 5908,6 thousand tons per 2000; 6615,6 thousand tons per 2005 [2]. Total amount of gaseous discharges per 2006 had made 7027,6 thousand tons, from which stationary sources, that represented by 11000 industrial enterprises, released 4822,2 thousand tons of hazardous pollutants (7,3% more than per 2005). It makes more than 130 kg per capita and several times more than developed countries have [2]. Hydrocarbons and volatile organic compounds emissions make more than 1000 thousand tons per annum. Among them stable organic pollutants are detected. The necessity of gas emissions cleaning is actual problem of today that appears constantly in the area of solution of ecological problems.

Objective

The analysis of the main method of neutralization of gaseous organic discharges was set as an object.

Basic material

There is the thermal method for the removal of pollutants from effluent streams discharging into the atmosphere, for gas cleaning and destruction of organic compounds and odoriferous substances. This method is realized in an afterburners or combustion devices (reactors, furnaces). It is used extensively because of simple construction of an apparatus and ease of service. But the method belongs to energy-intensive ones as the high-energy fuel for necessary temperature (650–1200ºC) maintenance is used. More often this method is applied for neutralization of industrial discharges that have compound composition.

The system of combustion devices or furnaces is considers as open one because there are constant material and energy input and output [3].

The method of thermal treatment of harmful substance, that can be oxidized, differs from other higher purification efficiency, absence of corrosive environment in the majority of cases and waste waters absence [4]. Meanwhile, the combustion must be complete; otherwise, intermediate products of combustion will form, which can be more dangerous than original substance. To achieve complete combustion requires an excess of oxygen, a sufficiently high temperature, sufficiently long residence time at this temperature, and high degree of turbulence to achieve intimate mixing of pollutant and oxygen (the three T's of combustion: temperature, time and turbulence). The required temperature ranges from 375 to 825ºC; some pollutant gases will be adequately destroyed at the lower temperatures, while virtually all organic pollutant gases will be destroyed at the higher temperatures if the other factors are suitable. An adequate residence time is of the order of 0.2 to 0.5 s. To achieve the high temperature, the afterburner normally must be separately fueled, so that the fuel must also be mixed with oxygen. An adequate degree of turbulence will generally occur if the gas velocity is in the range 4.5 to 7.5 m/s; in addition, turbulence can be promoted if the air and fuel are injected into the combustion chamber tangentially. The fuel must also burn completely without forming any pollutants [5].

The calculation of parameter toxicity at coal firing, combustion of gas, black oil and petrol has shown that the least background level owing to emission of harmful substances during combustion is observed at use of natural gas [6].

Oxygen concentration influences on completeness and velocity of the pollutants burn-out. The concentration of oxygen is 20,9 % in emissions (ventilation discharges), that is an air actually, the air that is polluted by dangerous substances. Thus its content is enough for maintenance of process of burning, but when the concentration of oxygen in the mixture of gas and air, which is neutralized, less than 17 % this process is decelerated owing to an influence of inert gases (nitrogen, dioxide of carbon) and water vapour. When the concentration is 14–14,6 % the flame dies away. In this case it is necessary to feed a combustion zone of free air. The process in a furnace is characterized by coefficient of surplus of air, which determines efficiency of the burn-out (temperature depends from the surplus of oxygen), the productivity of fuel (heightened supplying of the oxidant in composition of the polluted gases increases their specific amount, which can be neutralized at combustion of 1 $м^3$ of fuel) and stability of combustion (the availability of ballast admixtures decreases the intensity of transmission of molecules of the oxidant and its interaction with molecules of combustible substances that conducts to reduction of flame velocity and stability) [7].

With increase of concentration of pollutants and oxygen and with increase of temperature the time, necessary for complete neutralization, is diminished. The sufficient residence time is ensured due to increase in length of a furnace, modification of velocity of flow of the polluted gases, organization of the swirling flow of gases in cyclone or rotational furnaces.

For high-molecular organic compounds the temperature is usually 900–1000ºC and the time is less then 1 s [7]. The temperature has to be increased in case of presence of water vapour in discharging gases. All pollutants of a class of hydrocarbons are oxidized up to dioxide of carbon and water. By last of products of incomplete combustion of hydrocarbons burns off carbon monoxide as it is formed during combustion of hydrocarbons.

The method of achievement of high purification efficiency from organic substances is, except for increase of temperature, the adding of chemical oxidants, such as ozone and hydrogen dioxide (O_3 and H_2O_2). Besides it is important to take into account design features of a burner.

Thus, for realization of the process of thermal neutralization it is necessary to take into account features of influence of all major factors.

In general, the main distinctive characteristics among constructive features are the method of delivery of reacting air streams to a furnace, the method of heat recovery of combustion products.

The method of delivery of reacting air streams to a furnace differs subject to the content of oxygen in the polluted stream.

If the content of oxygen in the polluted stream is more than 17 %, contaminant gases proceed directly in a furnace and after mixing with natural gas burn in a furnace volume.

If the content of oxygen in the polluted stream is more from 5 to 17 %, contaminant gases proceed simultaneously through a burner to a furnace. The neutralization should be carried out in the equipment, which provides good intermixing and sufficient time of contact of hot products of combustion and waste gases. It is achieved due to tangential injection of waste gases in a furnace and formation in it of a vortex motion at the expense of increase in length of a combustion chamber. The waste gases with the content of oxygen is 5–17 % can be neutralized in furnaces of boiler aggregates. The method of neutralization of gases in boilers is effective at large values of combustion heat of waste gases, as allows increasing of steam generation.

Polluted gases go to furnace when the content of oxygen is less then 5 %, in the capacity of an oxidant is free air.

In the afterburners, burning polluted gases with the low content of oxygen, the necessary degree of intermixing and fast heating of waste gases by products of combustion of fuel should be supplied; otherwise zones with local lack of oxygen are formed, where the products of incomplete burning are accumulated. It can happen and at general surplus of an oxidant. For augmentation of residence time of gases in reactionary zone in furnaces a vortex motion of gases is created. But the equipment of such type is characterized by smaller purification efficiency, heightened cost of fuel and existence of products of incomplete burning.

The examples of such afterburners uneconomically use fuel, as waste gas can not be utilized as an oxidant. Therefore the heat utilization of off-gases is actual for an avoidance of thermal pollution. The similar afterburners can be used as furnaces of drying, heat-recovery boilers [7].

The economizers, economizers-condensers, evaporators and superheaters are used as apparatus for heat utilization of off-gases. It is necessary to take into account both design features of each heat-exchange apparatus, and composition of off-gas for an exact choice of constructional material. Increase of efficiency of heat utilization of off-gases and decrease of dimensions of heat-exchange apparatus are achieved by developed heat-exchange surfaces (tubes with spiral, parallel edges) [8, 9].

In dependence on a method of heat utilization of products of combustion there are such thermal reactors as:

afterburners without heat utilization,

afterburner with heat utilization for heat of the polluted gases or air, going to combustion. The hot combustion products go to tube space of a heat exchanger and return heat to the polluted gas. Then the heated gases reach the combustion chamber and go to the furnace [7].

Afterburner with heat utilization in other technological processes which do not influence on the processes of combustion (production a pair in heat-recovery boilers, drying, preheating of water and air for heating etc.) [5].

In that case mixture of the polluted gases is heated in the heat exchanger and then goes to the afterburner, where its temperature promotes behavior of process of combustion and neutralization of pollutants. Then exhaust gases pass through the heat exchanger and are discharged at a temperature somewhat above that of the inlet polluted stream. If this temperature is sufficiently above the ambient value, further heat recovery for some other purpose can be effected with a second heat exchanger [5].

Except for plants that use fuel for combustion of harmful organic compounds of discharging gas, the method of reburning of waste gas with the help of electrical heating under an operation of electromagnetic waves was developed. Thus oxygen and the pairs of solvents are heated more than the ballast nitrogen, therefore average temperature of combustion is lower, than usually, and the formation of oxides of nitrogen is excluded.

As one type of unconventional reactors is the chemical reactor on the basis of liquid rocket drive, which is characterized in small mass and dimensions and is convenient for building mobile modules in practice of solution of ecological problems, such as, neutralization of the toxic organic waste products. The application of the piston equipment is considered as chemical reactors, where there is a volumetric heat-up of gas, and the walls of the reactor remain cold. In reactors of a similar type series of experiments on neutralization of toxics also were carried out [10].

If the waste gases represent low-concentrated admixture of organic matters, known processes and plants do not provide their proper clearing of harmful matters. The equipment, capable to decide this problem, represents the low-temperature reactor working at direct contact of a coolant with a polluted gas stream [11].

Halogenated chemical matters are neutralized with use of plasma and microwave radiation, the detoxification of chemical matters takes place in apparatus of pulsating plasma. Temperature in a plasma reactor is in the range 2000–6000ºC [12, 13]. For example, clearing thermo plasma reactor for neutralization of dangerous organic ventilation discharges [14].

Conclusion

The thermal method of neutralization is acceptable for gas cleaning and destruction of organic matters, as a result of which the compounds are oxidized to dioxide of carbon and water; the range of sufficient temperature is 650–1200 ºC (at residence time no more than 1 s); the methods of delivery of polluted gases to reactor are different, subject to the content of oxygen in waste gases; there is variety of reactors distinguished on design and technological features. The thermal neutralization is expedient for combining with regenerative heat utilization.

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