Journal of Engineering Physics and Thermophysics, Vol. 72, No. 3, 1999

CLEANING OF AIR OF ETHYL ACETATE IMPURITY WITH THE AID OF A PULSED CORONA DISCHARGE

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UDC 537.535

The study presents experimental data for cleaning of gas–air mixtures containing ethyl acetate (EA) impurities with the aid of a pulsed corona discharge. A test laboratory bench for investigating cleaning of flue gases is described. Dependences of EA conversion on the discharge parameters and on the temperature of the initial gas–air mixture and the content of water vapor in it are given.

Cleaning of gas–air emissions of production enterprises has become an important ecological problem. Among promising cleaning methods is a plasmachemical method that employs a pulsed corona discharge (PCD) that initiates chemical reactions of decomposition of organic matter by producing highly active O and OH radicals in the nonequilibrium plasma of the discharge as a result of bombardment of molecules by high-energy electrons that appear in the forepart of the propagating streamer that forms the pulsed corona discharge.

The prospects of the method are largely determined by the structural simplicity of the reactor and the convenience of controlling the energy input to the discharge. Experimental data [1-6] indicate that use of a corona discharge for cleaning flue gases of nitrogen and sulfur oxides and a number of toxic organic compounds is highly economical and efficient.

Below we describe the experimental setup and results for cleaning of air of ethyl acetate vapor contained in gas discharges of some chemical enterprises with the aid of a PCD.

The experimental setup consisted of a system of air mixture preparation, a thermostated reactor, a high-voltage supply, and a system of gas sampling (Fig. 1).

From MK-12 microcompressor 1 of capacity up to 200 liter/h via rotameter 2 the air entered system of gas mixture preparation 3, where, as needed, it was dried or humidified and mixed with the vapors of organic compounds. On passing through sampling device 4 the air mixture was directed to reactor 5. Depending on the operating conditions of high-voltage supply system 6, either constant or pulsed voltage of positive polarity with an amplitude of up to 10 kV was fed to the reactor. The reactor temperature was stabilized by thermostat 7.

The reactor (see Fig. 2) consisted of two coaxial electrodes connected by flanges. The inner electrode was a Copel wire of diameter 0.2 mm, and the outer electrode was a stainless steel tube of diameter 16 mm and length 0.6 m. The reactor was provided with a constant-temperature jacket through which transformer oil was pumped from the thermostat.

The system of high-voltage supply included an ILGI-706 constant-voltage source, a discharger with a rotating electrode, and a pulse shaping circuit. The system generated voltage pulses of amplitude up to 10 kV with a front of 50 ns, a length of 150 ns, and a repetition frequency of 0.6 kHz. The electric energy put in the discharge was calculated from the discharge current and voltage determined by an S-122A oscillograph.

The concentration of the EA vapor was measured using an LKhM-8 chromatograph. Simultaneously, the concentration of ozone generated in the discharge was ascertained using an SF-26 spectrophotometer placed at the

Academic Scientific Complex "A. V. Luikov Institute of Heat and Mass Transfer of the National Academy of Sciences of Belarus," Minsk, Belarus. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 72, No. 3, pp. 584-586, May-June, 1999. Original article submitted March 3, 1998.

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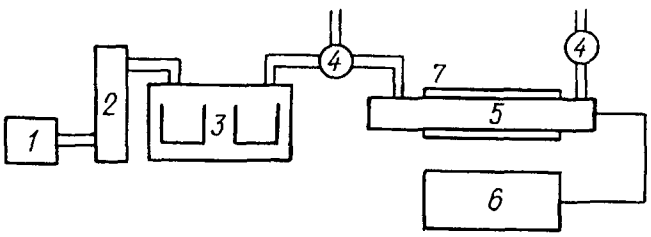


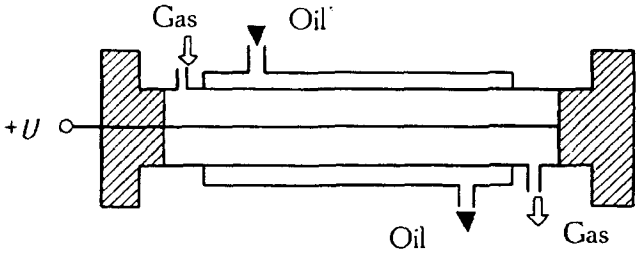
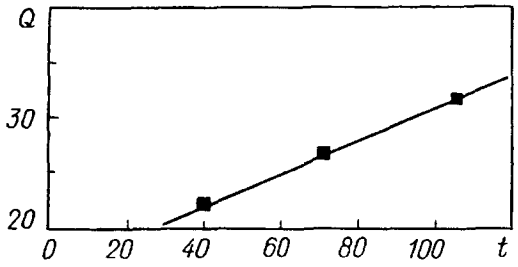


Fig. 1. Block diagram of the experimental setup.

Fig. 2. Schematic of the reactor.



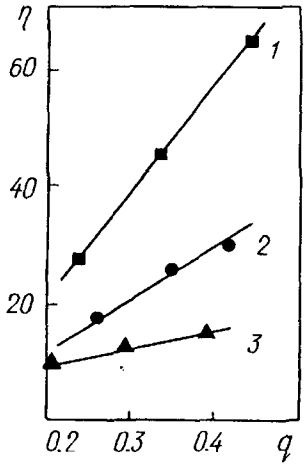


Fig. 3. Electric energy put in the discharge vs gas temperature. $Q \cdot 10^3$, J; t, °C.

Fig. 4. EA conversion as a function of the specific energy of the discharge in a gas mixture of different absolute humidity: 1) humidity $0.26 \cdot 10^{-3}$ g/m^3; 2) $4.0 \cdot 10^{-3}$; 3) 10^{-2}. η, %; $q \cdot 10^{-3}$, J/kg.

reactor outlet. Measurements were made for absorption of UV radiation at a wavelength of 254 nm. The absolute humidity of the gas was determined by measuring the "dew point."

To visually monitor the PCD combustion of the gas mixture at a high temperature, additionally a reactor was fabricated from a quartz tube 21 mm in diameter whose anode was a 0.2-mm-thick Copel filament and cathode a 0.4-mm-thick Nichrome wire coil wound with a 1 cm pitch. An electric heater was wound over the quartz tube in order to increase the gas temperature in the reactor.

Figures 3 and 4 present measurement results for EA conversion (conversion is the ratio of the EA volume concentrations at the reactor outlet and inlet) as a function of the reactor temperature and the specific energy put in the discharge for a mixture with different content of water vapor. The increase in the degree of cleaning with elevation of the gas temperature is linked with an increase in the initial value of E/N (because of the decrease in the gas density) and in the slope of the front of the discharge current pulse and with a rise in its amplitude and, accordingly, in the energy put in the discharge. As experiments reveal, an increase in the initial gas temperature from 20 to 100 °C increases the electric energy put in the volume discharge by more than 1.5 times.

An increase in the water vapor content in the gas mixture from 1.7 to 68% decreases the conversion from 70 to 10%. Here, the dependence of the conversion on the energy put in the discharge changes. As experiments demonstrate, the relation of EA conversion to the discharge power in a humidified mixture (68%) is less distinct than in a dried one (1.7%). The reduction in EA conversion with increase in the humidity is consistent with data of [4], which gives an account of experiments on cleaning of air of formaldehyde impurity with the aid of a nanosecond corona discharge.

Additional experiments performed in the quartz reactor revealed that with a constant supply voltage of 8 kV and with an increase in the gas temperature above 140 °C, i.e., with E/N larger than 66 Td, the discharge begins to convert to a spark one. Here, spark channels that significantly increase the discharge current originate in the highest-temperature zone. Introducing the EA vapor into the air "protracts" the spark formation, and here the glow discharge zone is reduced, i.e., the EA impurities behave like an electronegative gas.

To elucidate the degree of the effect of ozone on cleaning of air of EA impurity we conducted experiments on conversion of EA for the case of mixing of it with ozone outside the discharge zone. Their results indicate that the reaction of oxidation of EA by ozone does not occur at room temperature.

Thus, the experiments performed indicated the following:

1) a pulsed corona discharge in a wire-cylinder geometry can decrease the concentration of EA impurity in reaction gases of chemical enterprises, and here conversion can reach 70% with an energy consumption of 0.4 J/g;

2) a dominant role in EA conversion is played by the reactions of interaction with reactive O and OH radicals that form in the discharge zone of the pulsed corona discharge;

3) an increase in the relative humidity from 17 to 68% decreases conversion from 70 to 10%;

4) the increase in the degree of cleaning with rise in the temperature of the gas mixture results primarily from an increase in the energy put in the discharge;

5) ozone with an energy efficiency of about 12 g/kW·h can be generated in a pulsed corona discharge in the presence of EA; here, ozone forming in the discharge zone practically does not interact with EA impurities;

6) the energy characteristics of conversion can be improved by matching the wave resistances of the reactor and the power supply with a simultaneous increase in the plasmachemical efficiency of the process, which calls for a detailed study of the characteristics of a pulsed corona discharge in relation to the method of discharge feed and the composition of the gas mixture.

NOTATION

E, electric-field strength; N, number of particles per unit volume; η, ethyl acetate conversion; t, gas temperature; U, voltage; Q, energy put in the electric discharge; q, specific energy of the electric discharge.

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