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Numerical model of internal heat source capacity in desorption step of ETSA process☆

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Abstract

A new electrothermal desorption process in which the heat for desorption is generated inside adsorbent bed by passing an electric current through them (Joule's heat) is considered. The novel numerical model of volumetric internal heat source capacity in Sorbonorit 4 activated carbon bed, loaded with carbon tetrachloride or 2-propanol is developed on experimental basis. The quantitative relationships between a specific electric resistance $\rho(a,T)$ of the Sorbonorit 4 activated carbon bed and average VOC concentration in solid phase a, and average temperature of the bed T is determined. The capacity of the volumetric internal heat source in Sorbonorit 4 activated carbon bed depends on: electrodes supply voltage, concentration of adsorbate in the solid phase and temperature.

Keywords: Electrothermal temperature swing adsorption; Volatile organic compounds; Activated carbon

1. Introduction

Process of electrothermal temperature swing adsorption (ETSA) is a new method of volatile organic compounds (VOC's) removal from gaseous streams [1–4]. It is a cyclic adsorption process for separating strongly adsorbed species. Full adsorption cycle of the ETSA process consists of three following steps: adsorption, desorption by means of direct resistance heating of loaded bed (see Fig. 1) and adsorbent bed

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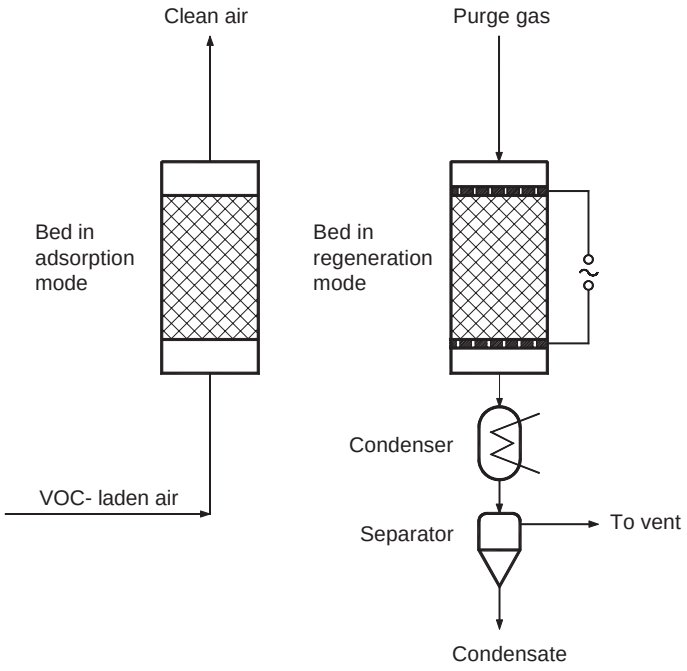

Fig. 1. A schematic diagram of the adsorption and regeneration steps of ETSA process.

cooling [1–7]. During direct resistance heating, the heat for desorption is generated inside the adsorbent particles by passing an electric current through them (Joule's heat). This operation is possible only if the adsorbent is an electric conductor or semiconductor as for instance activated carbon [8]. Direct and alternating current can be applied to adsorbent bed heating and process is controlled by supply voltage value [1]. A distinctive feature of this process is low consumption of the inert purge gas (e.g. nitrogen) passing through the column under desorption conditions [2–7]. The inert purge gas is used to washing up of desorbed component. It allows a considerable increase of the concentration of organic substances in a purge gas and enhancement VOC's recovery at relatively moderate cooling temperatures. In this process the directions of heat and mass fluxes are the same from solid particles to the purge gas. The desorbed components: 2-propanol and carbon tetrachloride were tested here in the ETSA process. These components were chosen because they are strongly adsorbed on activated carbon (AC).

In this paper, a mathematical model of internal heat source capacity is presented. A detailed description of the experimental set-up and procedure is reported elsewhere [6,7]. The basic element of this equipment was adsorption column with inside diameter equal 0.055 m and height was 0.27 m. The waste gas passes through an AC fixed bed where AC separates the VOC by adsorption. The cleaned gas is then vented to the atmosphere. During adsorption step, the experimental measurements of adsorption dynamics in temperature of 22 ± 2 °C were performed. The process was conducted up to full adsorbent bed saturation. The saturated bed was switched then to an electrothermal regeneration step. During the regeneration process, a very low amount of inert purge gas is passed through the adsorption bed and electrical power is supplied to the AC bed by means of sectional electrodes [3]. The concentrated vapor stream is then directed to a condenser where the VOC is separated from inert gas.