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Performance of Optimized TVOCs Sensor*

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Abstract

In this paper, an improved TVOCs (total volatile organic compounds) sensor construction was studied. Base on this new construction, the optimized flow rate, the responding character and the linear range of detector were studied. The effect of different electrode positions on the signal intensity was tested at different voltages. Compared with traditional PID – axial PID[3], the construction of this perpendicular PID could make the sensitivity loss decreased by a factor of 40 %. Especially, a newly adopted automatic cleaning technique was tested, which could decrease the drift greatly and make the signal of the detector almost unchanged after two weeks of continuous detection. Due to this new construction, the response time was decreased and the accuracy consequently was improved. When coupled with automatic cleaning technique, labor intensive daily calibration and frequent lamp cleaning were eliminated. The improvements in this new design made the detector more compatible with field uses.

Keywords: Photoionization detector, direct-reading and automated cleaning, total volatile organic compounds

1. Introduction

Photoionization detectors have several attractive features for use as direct reading instruments when evaluating exposure to organic materials, particularly solvents [1-4]. This detector is a compact yet high performance device, featuring excellent response characteristics and detection sensitivity on a ppb scale. It responds to a large variety of organic and some inorganic compounds, especially for aromatics[5] and unsaturated compounds[6], So TVOCs sensor normally battery-powered and without any heating facility, is used for fast in situ TVOC (total volatile organic compound) measurement without any GC separations, such as industrial hygiene, chemical process control, emergency chemical release response and environmental clean-up[7]. The need for such measurements increases as regulatory agencies begin to include TVOC limit in their indoor air quality guidelines. But for these measurements, there present new challenges resulting from the present construction and operation of PID.

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There are several primary problems related to traditional PIDs. Typically the sample gas flows directly towards the lamp and then exits the sides (shown in Fig. 1, it was called axial PID in this paper) and the distance between the two electrodes is relatively large [8,9]. Relatively high voltage is needed to achieve high electric field strength and high power consumption would make the miniaturization of axial PID difficult. As results, the response time and recovery time are longer due to large volume of ionization chamber; it's more susceptible to humidity because light has to travel further [10].

Another major drawback is drift resulting from contaminants, which are introduced with the sample and deposit on the optical window. Then the intensity of the UV light from the lamp is reduced. Because the sample stream is directed at the lamp window (in axial PID), the performance of the detector will eventually deteriorate below the acceptable level, and the quite expensive lamp must be replaced, or the window must be cleaned frequently. In the same way, the metallic electrodes also suffer from them resulting in unstable baseline current and increased noise signal.

In this paper, the perpendicular TVOC sensor was studied, which could overcome those problems mentioned above. It employed a new construction: the sample flew across the lamp window instead of towards the lamp window the way the axial PID used and adopted a new simple automatic cleaning technique, which decreased the drift greatly. Close-spaced electrodes needed lower voltage. Resulting from this new structure the response time was also decreased greatly. Comparisons between the characteristics of the two constructions were made. Improvements in the perpendicular TVOC sensor made the detector more compatible with in situ applications.

2. Theories

When a photon is absorbed by a molecule, which is then subsequently ionized, this phenomenon is called a photoionization [11,12]. The PID employs this principle. As illustrated in Fig. 1, the instrument includes an ultraviolet (UV) lamp which produces high energy photons having certain energy. The photons are directed into ionization chamber through an optical window. The photons collide with gases molecules and ionize those, whose IPs (ionization potential) are below the energy of the photons.

The ionization chamber contains a pair of electrodes - bias electrode and collector electrode (shown in Fig. 1). When a positive potential is applied, an electromagnetic field is created. The electron and positive ions are propelled to the electrodes. As result, a current i proportional to the gas concentration is produced, which can be expressed as [13]:

$$i = I_0 F \eta \sigma N L [VOC] \quad (1)$$

I0: the initial photon flux; F: Faraday; η: PI efficiency; б: the absorption cross-section of the substance; N: Avogadro's number; L: the path length. The product ηб is the PI cross-section, бi. So for a particular detector and lamp, the PID signal is proportional to ionization yield, absorption cross-section and molar concentration.

3 Experimental

3. 1 Construction and Design

In this study, two types of the detectors were used. One was the axial PID shown in Fig. 1 and another was the perpendicular PID shown in Fig. 2. The house of the detector was made of PTFE [14], which simplified the problem of making and adjusting electrical and gas lead connections to the device[6]. All the experiments were conducted at the temperature of about 20 ºC. The ionization chamber consisted of the lamp window, the collecting electrodes and various seals. The gas was pumped into the chamber by a miniaturized pump integrated with PID.