ACOUSTIC METER OF OZONE CONCENTRATION

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The acoustic type ozone meter designed to measure ozone concentration at the output of compressor type ozonators has been proposed. The ozone concentration is measured as a dependence of sound speed propagation on the density of the gas media. Increasing the density of the gas medium, the speed of sound is decreased, respectively. It was shown that the speed of sound would fall with increasing the ozone concentration. The possibility of this device to measure the concentration of various gases in the air was shown.

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INTRODUCTION

It is well known that ozone is used primarily for disinfection purposes. Since ozone has been considered a hazardous material it concentration needs to be accurately measured and monitored [1]. Ozone meters are used in environmental technology as well as in industrial processes [2, 3]. The operation of ozone meters is based on chemical, physical-chemical and physical measuring principles. Among the physical methods, the most widely used are optical absorption analysis based on the absorption of ozone in some areas of the electromagnetic spectrum (UV, visible and infrared areas of the spectrum) [4]. Unfortunately, devices based on this method tend to be cumbersome and have sufficiently high prices.

Acoustic meters are used to determine the concentration of gases depending on the specific weight and can be used for ozone concentration monitoring. There are several types of acoustic gas analyzers. For example, an acoustic gas analyzer in [5], consists of a camera, an acoustic resonator length equal to an odd number of half wavelengths of sound, filling holes for the working gas, as well as the source and the sound receiver. The acoustic analyzer is an electronic circuit generator of sound frequencies, sound and reception circuit and frequency measurements. This device provides a sufficiently high accuracy measurement of concentration of industrial gases.

The other group of acoustic meters are the devices that use the principle of measuring the resonant frequency of the sound in chamber (cuvette) filled with a controlled gas. Such devices have limited accuracy due to low Q factor resonators. The higher quality factor is provided by the Helmholtz resonators however their use does not allow to provide continuous measurements and has some technical difficulties.

In this article, the novel acoustic gas meter has been developed for determining of ozone concentration is described.

1. DESIGN AND OPERATION OF ACOUSTIC METER

The principle of the device for measuring the ozone concentration is based on measuring the speed of sound, depending on the density of the gas. The ozone density differs from the density of the air, which makes it possible to record the difference in the speed of propagation of sound vibrations and this difference may be negligible. The measurement is based on the change in the oscillator frequency with an acoustic feedback in the cell, and in turn fills the air with the gas. Ozone concentration is proportional to the difference between the oscillator frequency to the cuvette filled with ozone-air mixture or air-filled. The speed of sound in gases is determined by the formula

$$c = \sqrt{\frac{\chi p}{\rho}} = \sqrt{\chi RT}, \qquad (1)$$

where

c – the speed of sound in gas (m/s);

χ = cp / cu –adiabatic value;

ρ – gas density (kg/m³);

p – gas pressure (N/m²);

R – gas constant (J/kg·K);

T – gas temperature (K).

Thus, an acoustic gas analyzer comprises a working chamber (acoustic resonator) with an odd number of half-waves, the sound source and the receiver mounted at the ends of the chamber. Acoustic oscillator with positive feedback through Q cuvette is constructed in order to stabilize the oscillation amplitude. Due to the sufficient quality factor of the resonator, a high stability of the sine wave signal is reached. The schematic diagram of the acoustic gas meter is presented in Fig. 1.

The operation of the device controls provide the microprocessor unit. The microcontroller is realized on the base of an integrated circuit PIC18F2550 produced by Microchip Technology Inc.

At relatively low cost, such microcontroller ensures the realization of all the necessary functions of the device [6]. They include the timing of the microprocessor; the choice of operation modes, and measurement of the concentration, an indication of the current parameters and timing.

The device comprises an acoustic resonator with a transmitter and receiver of acoustic oscillations, a compressor, a solenoid valve, an air dryer, the destructor for the decomposition of ozone injected and other components (Fig. 2).

The air from the industrial premises or an ozone-air mixture produced by the generator of ozone, is entered

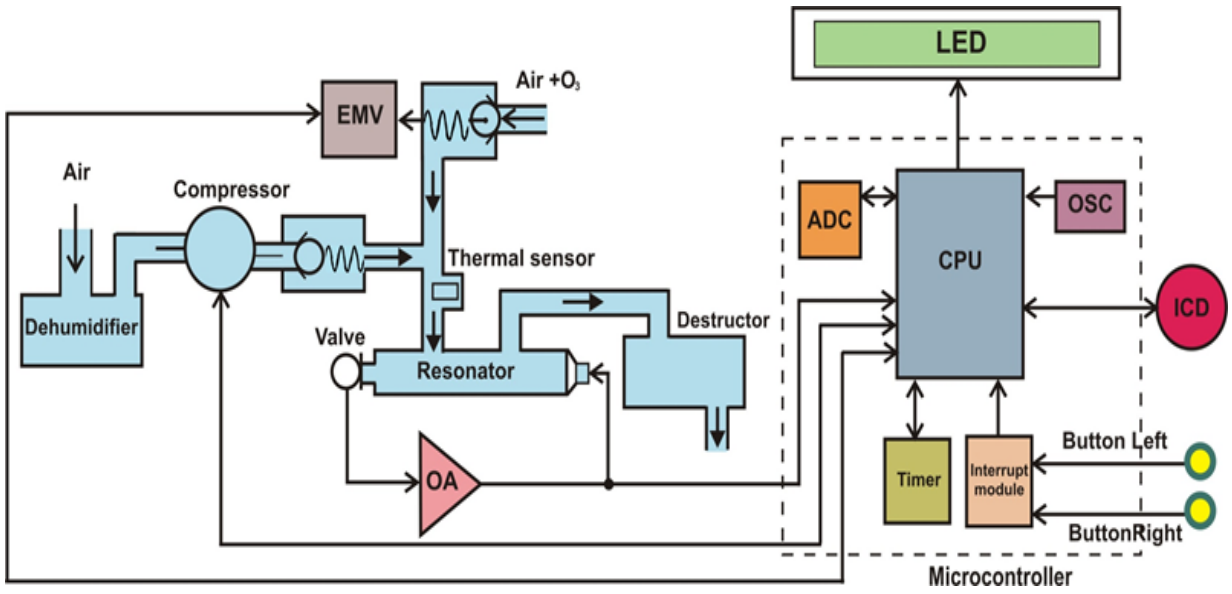

Fig. 1. Schematic diagram of the acoustic gas meter EMV – solenoid valve; ADC – analog digital converter; CPU – central processor unit; ICD – in-circuit debugger; LED – light-emitting diode; OA – operational amplifier; OSC – external oscillator 4 MHz

alternately in the acoustic resonator through a solenoid valve. The signal from the output of generator is fed to the input of the microcontroller via limiter-amplifier (Fig. 3).

Fig. 2. Acoustic meter main view

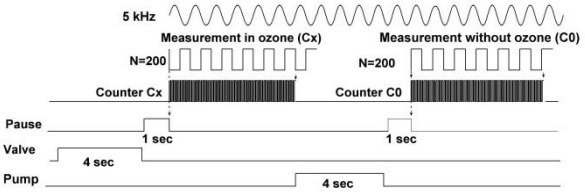

Fig. 3. Time diagram of the acoustic meter

2. MEASUREMENTS OF OZONE CONCENTRATION

Measurements of ozone concentration begin with the opening of the electromagnetic valve and filling the resonator with ozone-air mixture. After establishing of the resonance the measurement cycle begins. The microprocessor (MP) calculates the time required to complete 200 cycles of oscillation in the resonator. Such measurements are made 10. The value of each measurement is stored in the memory array and averaging array elements.

The valve on command from the MP is activated and closes an air compressor which blows resonator with the air. After 2 seconds, the same measuring cycle is repeated for air. Further, determining the frequency difference between the air and the air-ozone, the ozone concentration is calculated, the value of which is displayed on the digital indicator.

Due to the negligible time of ozone concentration measuring the heating of the resonator can be neglected.

To provide temperature compensation of the measurements in a controlled flow the sensor is installed. Sensor's readings are analyzed under the program of the microcontroller.

Device calibration is accomplished by comparing its readings with industrial meter readings. In this case they must be connected to one source of ozone.

As reference standard, an American ozone meter M454 produced by Teledyne Advanced Pollution Instrumentation Inc. was used. While scanning the measured concentrations range the collected data was stored in memory of the microcontroller. This array is used for the analytical calculation of measured concentration by installed software of the microcontroller.

Software module is created in the environment of development MPLAB IDE in a specialized language C18, designed to program the microcontrollers [7].

The described device has the following parameters:

Range of measured concentration – 1…99 mg/l;
Measurement time – 5 s;
Dimensions – 165 x 95 x 58 mm;
Weight – 400 g;
Power consumption – 15 W.

CONCLUSIONS

The acoustic type ozone meter designed to measure ozone concentration at the output of compressor type ozonators has been proposed. Ozone concentration is measured on the base of dependence of sound speed propagation on the density of the gas media. The ozone meter is controlled by the PIC18F2550 microprocessor-based controller produced by Microchip Technology Inc. The original software was developed. The meter is easily reprogrammed for monitoring of other gases by simply reload the database of gas concentration in depending on the speed of sound propagation in the tested environment.

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АКУСТИЧЕСКИЙ ИЗМЕРИТЕЛЬ КОНЦЕНТРАЦИИ ОЗОНА

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Описан акустический измеритель озона, предназначенный для измерения концентрации озона на выходе озонаторов компрессорного типа. Концентрация озона измеряется как зависимость распространения скорости звука от плотности газовой среды. При увеличении плотности газовой среды скорость звука будет уменьшаться. Установлено, что скорость звука будет падать с увеличением концентрации озона. Показана возможность данного устройства для измерения концентрации различных газов в воздухе.

АКУСТИЧНИЙ ВИМІРЮВАЧ КОНЦЕНТРАЦІЇ ОЗОНУ

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Описано акустичний вимірювач озону, призначений для вимірювання концентрації озону на виході озонаторів компресорного типу. Концентрація озону вимірюється як залежність поширення швидкості звуку від щільності газового середовища. При збільшенні щільності газового середовища швидкість звуку буде зменшуватися. Встановлено, що швидкість звуку буде падати зі збільшенням концентрації озону. Показана можливість даного пристрою для вимірювання концентрації різних газів в повітрі.