DEVICE FOR FOG DENSITY CONTROL WITH MULTIPLE REFLECTIONS OF THE BEAM

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Abstract: *The current work is related to improving security by developing a new type of fog sensors and devices. We investigate fogs and their ability to absorb and clean various pollutants from air, including chemical, biological, radiological and nuclear (CBRN) agents. Fog can be used very effectively for counteraction to terrorist attacks and weapons of mass destruction, as well as for prevention of industrial accidents and disasters. We present a device developed by us – Fog Detector 3 (FD-3), which main purpose is to continuously monitor the atmospheric air and to produce analogue signal proportional to the density of any present aerosols, including water fog. The main components of the device, as well as their connections and way of operation are described.*

Keywords: DEVICE, FOG CONTROL, DROPLETS, AEROSOLS, DETECTION

1. Introduction

Atmospheric aerosols are a fundamental component of the air on our planet. They are represented by tiny particles of various sizes, physical and chemical properties. Aerosols play a crucial role in many climate processes [1] and affect them directly – such as formation of clouds, storms, etc. They also influence human health [2] and economy [3]. Harmful aerosol particles can be unleashed in the air in the case of industrial accidents or can be used for terrorist attacks [4, 5]. That is why it is very important to detect and identify different kinds of aerosol particles in real-time. Various techniques for aerosol detection have been developed – most of them are based on elastic scattering [6] or fluorescence detection [7]. Optical methods are also used, since they can provide information remotely. Light detection and ranging, for example, can perform 3D aerosol mapping over large distances [8]. This technique is mainly used for detection of biological aerosols by using elastic scattering [9] or ultraviolet laser induced fluorescence [10].

2. Prerequisites and means for solving the problem

Our work is related to a project with the acronym COUNTERFOG, which purpose is large-scale decontamination of facilities from chemical, biological, radiological and nuclear agents dispersed in air, which may occur in the case of terrorist attacks, industrial accidents or disasters, by using fog. For that reason, it is necessary to place devices, which continuously monitor the atmospheric air and alert the occurrence of dispersed agents, so that cleaning fog can be released. It is also required to assess if the fog has reached all areas, in order to stop releasing it, as well as to monitor its density. Such instruments are present on the market but they are quite expensive for our purposes, since we need a lot of them to be positioned at different sights. That is why we have designed and constructed several cheap versions of such devices and one of them is Fog Detector 3 (FD-3).

3. Solution of the examined problem

FD-3 is a cheap device, which allows continuous monitoring of atmospheric air and alerts when dispersed particles in the form of aerosols appear in it. It is small, inexpensive, it has a simple construction and is stable at various conditions. It has the capability to detect the presence of fog (which is also an aerosol in the form of tiny water droplets) and to assess its density. The principle of operation of the device is based on the spectrophotometric method. A beam of monochromatic light is passed through the investigated environment and its intensity is attenuated by the presence of pollutants. The device consists of three main blocks – an active block including a laser, an optical detector and a mirror; a passive block having just a mirror; and an alarm block, which alerts the presence of dispersed particles. The density of particles can be determined by attaching a voltmeter, which measures the signal from the optical detector. FD-3 operates with multiple reflections of the laser beam, so that more accurate and stronger signals can be measured.

4. Results and discussion

In this section we describe the principle of operation of FD-3, its technical implementation and main components.

4.1. Purpose and principle of operation

The main purpose of the device FD-3 is to continuously monitor the atmospheric air and to produce analogue signal proportional to the density of any aerosols, including water droplets in the form of fog. For this purpose a laser beam is used which is reflected several times on special mirrors before it falls onto the sensitive surface of an optical sensor. The density of the environment between the mirrors affects inversely the intensity of the beam. The intensity of the laser is converted in output analogue signal in the range 0÷3.9V. The general view of the three main components of our device is presented in Fig. 1.

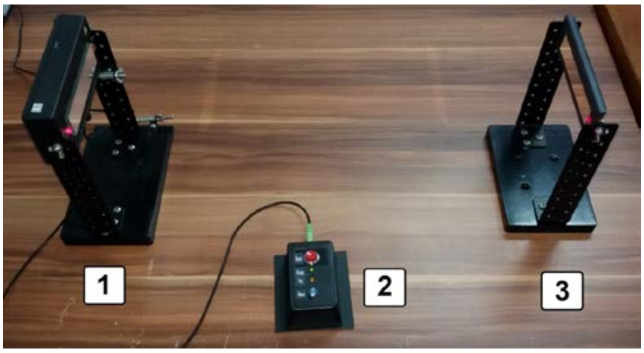

Fig.1 – General view of FD-3 and its main components

4.2. Main components

The device consists of:

- Active block with laser diode, optical sensor and mirror (position 1 in Fig.1);
- Passive block with mirror (position 3 in Fig.1);
- Alarm module with its connection cable (position 2 in Fig.1);
- Power adapter (12VDC 2A);
- Analogue voltmeter VA101A with its connection cable (used for calibration of the device and/or aerosol density assessment).

4.2.1. Active block

The active block is formed as a structure consisting of red laser diode (650 nm, < 5 mW) and optical sensor model WES103. The block is powered by a DC, 12V, 2A source. On its output the block generates analogue signal in the range 0÷3.9V, which is inversely proportional to the density of the examined aerosol. The laser beam's position is adjusted with two screw joints enabling rotation of the body of the active block on two orthogonal axes.

4.2.2. Passive block

The passive block is a mechanical assembly with one degree of freedom with respect to its base. A fixed mirror is attached to it.

4.2.3. Alarm block

The purpose of the alarm block is to detect the appearance of dispersed agents crossing the volume controlled by the device. It is triggered when there is an attenuation of the output signal under a certain threshold value ($U_{threshold}$=3.5V). Once activated, the alarm diode will blink until the "Reset" button is pressed. This threshold represents a coded constant in the program code of the microcontroller located in the active block. When a higher sensitivity is needed, this controller can be replaced with the provided spare controller. It is set to react under 3.7V.

4.2.4. Power supply block

The main purpose of the power block is to supply energy for the active block. It is powered from a standard AC network (220V 50Hz) and provides stable voltage 12V 2A on the output.

4.3. Connection of the components

The connection of the components should be done in the following order:

- The active block containing the laser diode, mirror and optical sensor, and the passive block with mirror are installed against each other at a distance in the range of 0.5÷1.5 meters. They can be placed either on a flat surface or on a rail on carriers or any other construction allowing the required positioning;
- The adjustment screws for rotation of the active block are placed at initial position (0° axial rotation);
- The mirror of the passive block is rotated in such a way that its plane is perpendicular to the base and also parallel the mirror of the active block;
- The active block and the passive block must be placed perpendicularly to the common rail (if there is such);
- The peripheral module for LED indication is connected to the coupling "Alarm LED" of the active block;
- The power adapter (12VDC/2A) is connected to the coupling "POWER" of the active block, after which is connected to the supply network;
- The voltmeter is connected to the output of the active block labelled "OUT";
- Now, the reflection of the laser beam from the mirrors must be adjusted (recommended number of reflections is 3 times):
    - The top adjustment screw of the active block is used for orienting the laser beam to the vertical center of the mirror on the passive block;
    - The bottom adjustment screw is used to acquire the needed number of reflections;
    - If needed, the above two steps should be repeated until the laser beam falls precisely onto the surface of the optical sensor. This can be judged from the shown voltage from the voltmeter. The positioning is good when the maximum value on the voltmeter is acquired;

The intensity of the laser beam can be regulated in such a way that the threshold of the output signal, in the absence of any aerosol, is 3.9V (Fig. 2). The intensity should not be increased over the point in which the sensor is saturated and the voltmeter reads 3.9V.

Fig.2 – Potentiometer for regulation of the laser intensity

4.4. Block scheme of the device

The block scheme of the device is shown in Fig. 3.

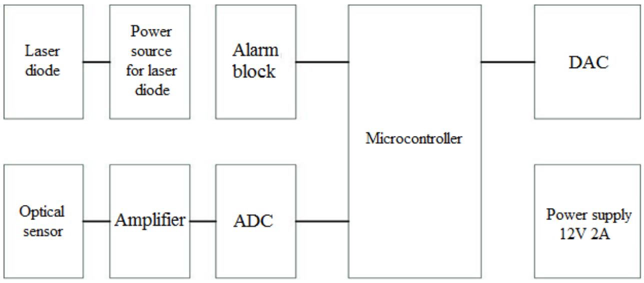

Fig.3 –Block scheme of FD-3

The power supply of the laser diode is accomplished by serially connected voltage stabilizer and current stabilizer. The laser diode is directed to the optical sensor as the beam crosses the field in which the density of water fog needs to be controlled. The incident light to the optical sensor generates analogue signal proportional to the intensity of the light. This signal is amplified and converted with ADC (analogue-digital converter) in the range 0÷4.096V before it is received from the microcontroller. The output signal, proportional to the attenuation of the light, is formed by the microcontroller via DAC (digital-analog converter) again in the range 0÷4,096V. In the cases when the output signal falls below 3.5V, the alarm block activates, in which case the blinking red LED indicates the appearance of mist. The diode can be turned off with the "Reset" button. On the alarm module there is an additional yellow diode which shows the dynamic state of the output signal –greater or smaller than 3.5V.

4.5. Working with the device

Once the laser beam is correctly directed to the optical sensor, the device is ready for work. The output signal is inversely proportional to the density of the fog. It can be monitored with the help of a voltmeter or it can be connected to additional hardware devices.

The alarm module (Fig. 4) can be used as a device for indication of fog/aerosol appearance in the controlled volume. Once activated, the alarm does not stop the signal blink LED labelled "ALARM" until it is stopped manually by pressing the "RESET" button. The LED labelled "POWER" signals for the correct operation of the alarm module when connected to the active block. The LED labelled "FOG" indicates dynamically for the current presence of fog – it lights up at certain values of the output signal, when there is presence of aerosol/fog.

Fig.4 –Alarm module to the device FD-3

The device is sensitive to displacement of the laser beam at the receiver. This is due to the fact that the laser beam is reflected multiple times and any slight misalignment of the emitter results in much greater misalignment on the receiver. To prevent such a malfunction, stable fixation should be provided. Such a problem may occur if the base is not at rest, if there are vibrations or any forces applied to the structure, etc.

Figure 5 shows a voltmeter connected to the FD-3 device.

Fig. 5. FD-3 device connected to a voltmeter

5. Conclusion

We have presented a small, inexpensive device, which can be used to detect the presence of dispersed particles in the form of aerosols by using multiple reflections of the emitted laser beam. The density of various types of aerosols, including water fog droplets, can be evaluated by simply attaching a voltmeter to the device and observing the signal intensity.

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