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EXAMINATION OF THE PROTECTION FACTOR WITH A LASER PHOTOMETER

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Abstract: *The work presented below deals with the modernization of the method for testing the protection factor of a protective mask against sodium chloride (NaCl) aerosols. The aim of the work is to show the possibility of modernizing the method which, unlike the existing method with a flame photometer (FP), uses a laser photometer (LP). The reason for this is the dependence of the accuracy of the method on the operation of the FP, which uses the combustion of hydrogen gas for its operation. Problems occur with changes in the hydrogen-oxygen concentration required for flame maintenance and FP operation, as well as the quality of hydrogen, which cannot be influenced. The main challenge in establishing the method is to find the ideal characteristics of the laser light source that enables the detection of aerosol NaCl particles and all other particles, especially carbon particles, whose number and concentration vary during the test, should be negligible, so filters for masking the photometer are not necessary for the operation of the new method. The function of the new method must meet the measurement of NaCl mass concentrations up to 15mg/m*^{3}*, and the measurement sensitivity is 5ng/m*^{3}*. The certified device FIELD MAX ii was used to adjust and detect the wavelengths of the laser photometer as well as to determine the required power of the laser light source.*

Keywords: *flame photometer(FP), laser photometer(LP), protective mask, mySql data base.*

1. INTRODUCTION

As indicated in the abstract, the aim of the paper is to show the possibility of modernizing the method for testing NaCl aerosol particles behind a protective mask, that is, the method for checking efficiency. First, an adequate concentration of the test aerosol must be provided. From a 2% solution of sodium chloride reagent in distilled water, the aerosol generator produces an aerosol of sodium chloride. One large Collison atomizer is used, requiring an air flow of 100 l/min at a pressure of 7 bar. The atomizer and its housing are integrated into a channel that maintains a constant flow of air. To ensure complete drying of the aerosol particles, it may be necessary to heat or dehumidify the air. The mean indoor sodium chloride concentration should be (8 ± 4) mg/m^3, with a variation not exceeding 10% throughout the effective working volume. The particle size distribution was determined as an equivalent aerodynamic diameter of 0.02 µm to 2 µm, with a mass mean diameter of 0.6 µm.

In the following, the examination and checking of the concentration and size of the particles was carried out. When the reference values of the number and size of particles were obtained, a check was performed on a flame photometer with different mask samples.

A flame photometer serves as a valuable tool for accurately measuring the concentration of sodium chloride inside a face mask. To ensure the suitability of an instrument for this purpose, several key performance characteristics must be considered. First, the instrument should be specifically designed for the direct analysis of sodium chloride aerosols. Moreover, it should have the ability to measure NaCl aerosol concentrations ranging from 15 mg/m^3 to 5 ng/m^3. In addition, the total aerosol sample required by the photometer should not exceed 15 l/min. Moreover, the response time of the photometer, excluding the sampling system, should not exceed 500 ms. Finally, it is necessary to minimize the response to other elements, especially carbon, since its concentration varies during the respiratory cycle. This can be achieved by ensuring that the bandwidth of the interference filter does not exceed 3 nm and by incorporating any necessary sideband filters. Figure 1 shows the used flame photometer that was used to collect data during this research.

It is important to note that a constant flow of air is maintained, which is filtered multiple times and without admixture of carbon and admixture of water or dirt in it. Air without condensate is delivered from the screw compressor, and after purification and dehumidification at a constant temperature of 22°C, it is delivered to the

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flame photometer.

All measurement results were directly entered from the instrument or microcontroller into the MySql database, from which, after processing and statistical processing, the graphs and tables presented in the paper were obtained.

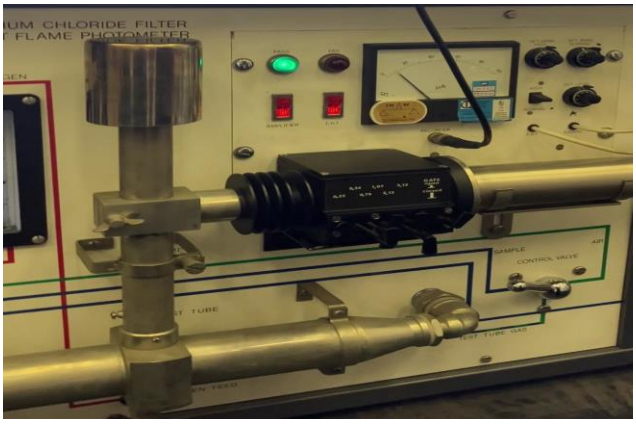

Figure 1. Flame photometer (FP)

2. FP MEASUREMENTS

After the fulfillment of the necessary conditions and calibration of the apparatus, the measurement of samples with the presence of NaCl particles and clean air for different filter levels was performed. Table 1 shows the values measured on the instrument (FIELD MAX ii.), for measuring the power and wavelength of light when burning clean air.

Table 1. Measurements power on a flame photometer during air combustion

Air					
N.o.	Filters	Average	STD	Min	Max
1	0	16.87n	235.7p	15.7n	17.4n
2	0.22	2.944n	152.1p	2.399n	3.399n
3	0.34	-645.5p	135.6p	-999.8p	-299.9p
4	0.75	-2.835n	102.2p	-3.099n	-2.599n
5	1.07	-5.075n	79.06p	-5.299n	-4.799n
6	2.13	-6.318n	115.2p	-6.698n	-5.899n
7	3.13	-6.774n	93.74p	-7.098n	-6.498n

The next step is to measure the value of the light level after burning the NaCl particles, when using different filters.

Table 2. Measurements power on a flame photometer during NaCl combustion

Sodium particles					
N.o.	Filter	Average	STD	Min	Max
1	0	21.97u	246.9n	21.09u	22.59u
2	0.22	6.334u	169n	5.799u	6.698u
3	0.34	1.569u	145.6n	1.1u	2u
4	0.75	-2.002u	102.4n	-2.299u	-1.7u
5	1.07	-4.519u	114.5n	-4.799u	-4.199u
6	2.13	-6.174u	123.8n	-6.498u	-5.899u
7	3.13	-6.746u	88.07n	-7.098u	-6.498u

Legend in tables 1 and 2 the following symbols have meaning:

u for micro**, n** is the symbol for nano, **p** for pico.

From the tables shown, the differences in measured values can be clearly seen when using clean air, that is, when burning particles of a mixture of air and NaCl. The difference in power ratio is several thousand times. This can also be seen with the naked eye when burning air without NaCl particles, the flame is imperceptible light blue, while when burning NaCl particles the flame is very yellow and very visible.

3. THE WORKING PRINCIPLE OF LP

The continuation of the research is related to the replacement of the flame photometer with a laser photometer: The plan is to place laser diodes in the vacuum tube on the front side, which will be the light source, then the light should be refracted through convex mirrors between which the sample with Nacl is brought. By passing the laser beam through the particles of air and NaCl, further detection is performed on a photo transistor that measures the level of particles in the sample. During the research, a large number of experiments were conducted with different wavelengths of the laser diode. The schematic view of the solution is presented in Figure 2.

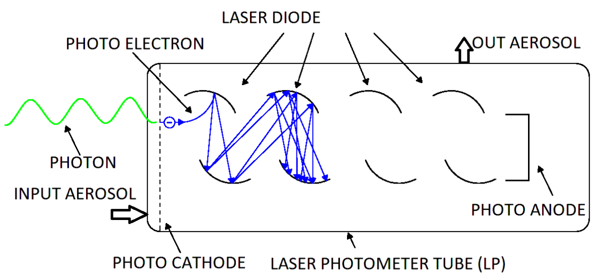

Figure 2. Laser photometer (LP)

In this research, the COHERENT OP-2 VIS photo probe element was used for signal collection

Figure 3. Photo detection probe

In addition to this probe, measurements were also made on various photo elements (photo transistors, photo diodes, photo resistors), but the parameters were more or less within approximate limits, which depended more on the accuracy of the probe than on the particular type of element used.

4. GRAPHS

In this chapter, graphs of measurement results obtained on the photo probe for different values of power and wavelength of the laser diode will be presented. All measurements were performed under the same conditions at the same concentration of NaCl aerosol and the same particle size as well as at the same humidity of the reagent entering the laser photometer. Figure 4 shows a graph for a laser diode with a wavelength of 200 nm and a power of 0.3 mW. We can see that only a very small part of the changes shown in the amplitudes in the 248 data points is registered on the graph.

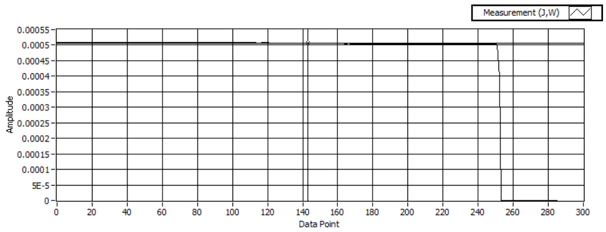

Figure 4. Graph for laser diode 200nm

Figure 5 shows a graph for a laser diode with a wavelength of 400 nm and a power of 0.3 mW. It can be seen that the change in amplitude between 90 and 120 data points is registered on the graph.

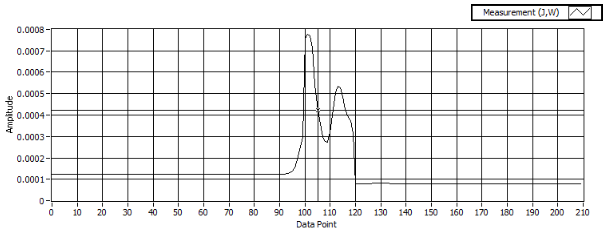

Figure 5. Graph for laser diode 400nm

Figure 6 shows a graph for a laser diode with a wavelength of 500 nm and a power of 0.3 mW. It can be seen that a large number of changes are registered on the graph through the entire scale of data points shown at amplitudes between 1 and 192 data points.

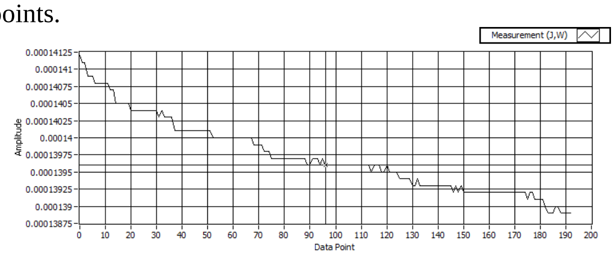

Figure 6. Graph for laser diode 500 nm

Figure 7 shows a graph for a 600nm laser diode with a power of 0.3mW. It can be seen that the change in amplitude between 130 and 210 data points is registered on the graph.

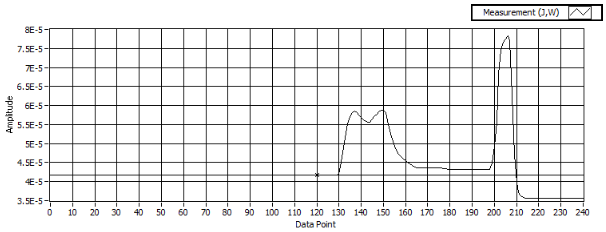

Figure 7. Graph for laser diode 600nm

Figure 8 shows a graph for a 700nm laser diode with a power of 0.3mW. It can be seen that the graph registers a large number of very frequent changes throughout the entire scale of data points displayed at amplitudes between 1 and 1, which last until the end of the measurement. On this graph, you can also see the highest power measured on the entire sensor range. This wavelength gives the best classification and the best reading for the presence of NaCl cells.

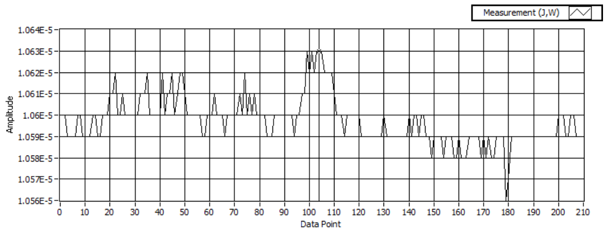

Figure 8. Graph for laser diode 700 nm

Figure 9 shows a graph for a laser diode with a wavelength of 800 nm and a power of 0.3 mW. It can be seen that changes in the range from 1 to 79 data points and amplitudes between 140 and 270 data points are registered on the graph.

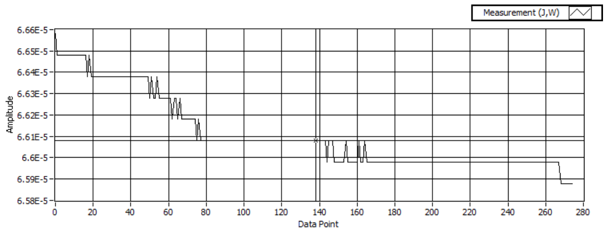

Figure 9. Graph for laser diode 800 nm

Figure 10 shows a graph for a laser diode with a wavelength of 900 nm and a power of 0.3 mW. It can be seen that the change in the range of 1-140 data points and the amplitude between 140 and 320 data points are registered on the graph. The displayed amplitudes are random with symbolic values in the reading, so when choosing this laser diode, one does not get a clear picture of the concentration change in relation to the power of the signal reading on the photometric sensor.

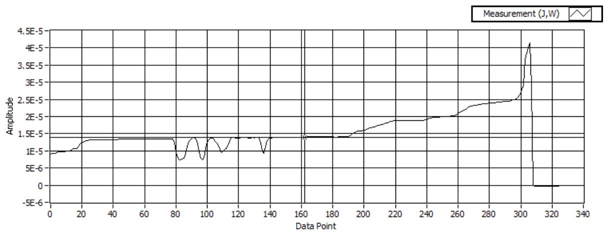

Figure 10. Graph for laser diode 900 nm

5. CONCLUSION

We hope that with this research we have made a contribution to the modernization of the method for measuring the effectiveness of protective masks in real conditions. The research showed the possibilities of using LF as a substitute for PF. The results obtained by measurement give the same or more precise data than using the previous system. Due to the simpler use of more precise results and resistance to external influences, it is recommended to use the LF application for efficiency measurement. The continuation of the research will refer to the possibility of replacing the testing reagent Nacl with Paraffin oil and finding the ideal values of power and wavelength of the laser diode for precise measurement. The possibility of using several laser diodes of different wavelengths and powers at the same time during the detection of these two types of reagents is being checked.

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