Multichannel Aerosol Spectrometer for Environmental Monitoring

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***Abstract*— *The description of the developed by us automatic Multichannel Aerosol Spectrometer "Masnik-A" are presented. "Masnik-A" system represents the optical/electronic automatic device for measuring of the concentrations and distributions of the sizes of liquid and solid aerosol particles of natural and artificial origin in laboratory and field conditions. Aerosol Spectrometer "Masnik-A" provides a range of measurement of the sizes of aerosol particles from 0.5 up to 40 µm (on a radius). It has 18 channels of the analyzer (graduations by the sizes) with a memory on the channel no less than $9x10^5$ particles. The limiting value of measuring concentrations (containing in 1 cm3 of the aerosol environment) makes no less $2x10^4$ particles. The instrument has possibility of obtaining the command of handle from external personal computer (PC), and also input of the results of measurements for further automatic processing by a specially developed program.*

***Keywords*— Liquid and solid aerosol particles; distant monitoring; aerosol formations of natural and artificial origin; aerosol sizes; capacity of memory.**

I. INTRODUCTION

In the sphere ecological researches of atmosphere takes an important place the study of the structural and physical features of the particles of liquid and solid aerosol formations. As they represent danger to normal habitability of man and other biological objects.

In researches of optical-electronic parameters of atmosphere an especially important place is occupied by measuring of descriptions of liquid and hard aerosol educations that are the special danger for the normal vital functions of man and other biological objects.

To hired description and principle of work of the multichannel aerosol spectrometer of "Masnik-A" worked out by us are driven, being an optical-electronic automatic device for measuring of concentrations and distribution on the sizes of liquid and hard particles of aerosol formations of natural and artificial origin in laboratory and field terms. The aerosol spectrometer of "Masnik-A" provides the range of measuring of sizes of aerosol particles from 0.4 to 40 µm (on a radius, overhead the fir tree of that can be extended to 100 µm). He has 18 channels of peak analyzer (gradations on sizes) with the capacity of memory on a channel no less $9x10^5$ particles. The maximum size of measureable account concentrations (contained in 1 cm^3 of aerosol test from surrounding space) makes no less $2x10^4$ particles.

The present report is devoted to the representation of working out method, developed by us, and instrumentation of monitoring of an atmospheric aerosol, under a title "Masnik-A". A multichannel aerosol spectrometer "Masnik-A" represent the optical-electronic automatic device for measuring the concentration and distribution of the sizes of liquid and solid aerosol particles of natural and artificial origin in laboratory and field conditions [1], [2].

A device has the opportunity of conclusion of results of measuring on the printing unit concerted with the interface of (IFSP) and to get management commands from the computer of type of Pentium through serial port of RS232. In PC it is possible to enter also the results of measuring for further automatic treatment on the specially worked out programs.

II. SHORT DESCRIPTION OF EQUIPMENT

The "Masnik-A" system provides a range of measurement of the sizes of aerosol particles from 0.5 up to 40 □m (on a radius). It has 18 channels of the analyzer (graduation by the sizes) with a memory on the channel no less than $9x10^5$ particles. The limiting value of measuring concentrations (containing in 1 cm^3 of the aerosol environment) makes no less $2x10^4$ particles. The instrument has possibility of obtaining the command of handle from external personal computer (PC), and also input of the results of measurements for further automatic processing by a specially developed program.

Structurally the spectrometer “Masnik-A” consists of two units: the optical-electronic unit (OEU), both unit of counting and handling (UCH) with PC, joint among themselves by a cable. OEU is installed immediately in the atmosphere (or in volume) where it is necessary to carry out researches of aerosol particles, and UCH with a computer can be placed in a premise, or in the auto-laboratory, length of cables between them can be up to 25 m. The optical scheme of the OEU is shown on the Fig. 1.

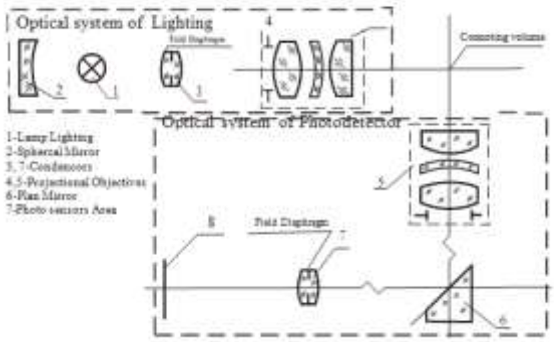

Fig. 1: Optical scheme of OEU aerosol spectrometer “Masnik-A”

The principle of the instrument is based on measurement of an emission power, scattered on aerosol particles. At the moment of passing each aerosol particle through countable volume of the instrument at the exit of the photo-detector (PEM-79), there appear are impulse electrical signals, the amplitude of which bears information about the sizes of particles [3].

The optical-electronic Unit consists of three main knots: Knot of Lighting with optics, the knot of the photo-detector with optics and the knot of aspiration, where the measured aerosol environment is soaked up. The main unit of the equipment ensuring reception of the initial information about the dispersion of aerosol particles is Optical Electronic Unit. The OEU consists of system aspiration, optical systems, power unit and preliminary processing of the information.

The optical systems of lighting and the Photo-detector (see Fig. 1) are intended for optical formation of the counting volumetric space with discrete change of its sizes, which is achieved by replacement field diaphragms, which are put on flat stuck together surfaces condensers.

The optical system of photo-detector is identical to system of the lighting, except that in which absence mirror, and on the location of a body of heat of a light source is located the adopted area of the photo-detector, in quality the photo-electronic multiplier (PEM-79) is used. The optical system of the lighting provides carry of the image of heat of a lump to area of counting volume which is taking place on an axis in taking of the aspiration system. From the aspiration system the jet of aerosol particles is directed to a bunch of the light beams. As a result of it, the aerosol particles getting in the most concentrated area of a light flow, scattered light, which part is going to the objective of the photo-detector system, through its field diaphragms. The field diaphragms of the lighting and the photo-detector systems allow allocating area of counting volume, within the limits of which there is an analysis of the sizes of aerosol particles and calculation of their quantities. The functional electrical scheme of the aerosol spectrometer is shown on Fig. 2.

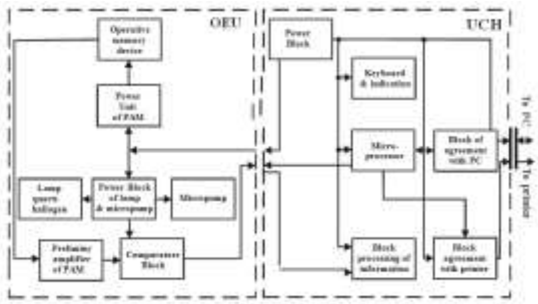

Fig. 2: Functional electrical block-scheme of aerosol spectrometer “Masnik A”

The pulse electrical analogous signals, from the photo-detector output amplify and transforms in a five-digit digital code and act to the block of processing of the information, which makes the peak analysis of pulses on 18 channels and registration them in view of the given restriction for discrimination on duration. The microprocessor makes initialization in all functional units of the spectrometer and processing of acting information. The results of measurements of the microprocessor are deduced on indication, and also, at the request of the operator, through the appropriate devices of interface are deduced on a seal and PC. The appearances of the OEU (a) and UCH (b) are shown on a Fig. 3.

Fig. 3: OEU (a) and UCH (b) aerosol spectrometer “Masnik-A”

Before natural measurements in atmosphere the optical graduation of a spectrometer “Masnik-A” on standard particles of polistirol latex is carry out [4]. The graduation characteristics (i.e. dependence of output signal amplitude from a size of aerosol particle) are introduced in the permanent memory of the system for the further using in automatic processing of the measuring results.

III. METROLOGICAL PARAMETERS OF SPECTROMETER “MASNIK-A”

Metrological attestation of multichannel aerosol spectrometer "Masnik-A" was conducted concordantly to the specially developed program АЕЛ2.851.002ПМА [5]. During attestation the metrological parameters of device, presented in the table 1:

Table 1: Metrological parameters of apparatus "Masnik-A"

The Name of Metrological parameters and unit of measuring	Possible Rejections
Relative error of producibility of calibration description of device during registration of monodispersible standard particles of aerosol no more	+_ 15%
Relative error of measuring aerosol particle sizes in the range from 0,4 to 40 µm (on a radius) no more than	+_ 20%

List of all facilities, terms and an order, and also description of the measuring setting, for realization of metrological attestation is expounded in [5].

For checking of calibration description of device for setting [5] the suspension of standard particles of polistirol latex was inundated in the generator of aerosols with a diameter from 3 to 4 µm. During work in the mode of automatic set and conclusion of information on the indicatory board of block of UCH and on a number printing device (NPD), from data of indicatory board labored for such degree of dilution of aerosol clean air that in times of a 30 sec. of display registered oneself no less than 1000 particles. Measuring was conducted in 5 cycles (i.e. information is a number of channel and amount of the registered particles) and written down on the ribbon of NPD on 5- lines. The similar measuring was conducted and for standard particles measuring 0.5 µm.

For every line of the got information relative frequencies of distribution of aerosol particles were calculated for every channel (i = 1÷18) of registration on a formula:

$$P_i\,(U) = N_i \,/\, N_0\,,$$

where N_i is a number of particles, registered in i channel; N_0 is a total number of the registered particles.

The mean value of relative frequencies of distribution was determined on a formula:

$$\overline{P_i(U)} = 1/n \sum_{i=1}^{n} P_{ij}(U)\ ,$$

where n - is a number of the registered information; j - is a number of lines.

On values of P_i (U) the number of modal channel (channel in that a value P_i (U) is maximal) was determined amplitude of output signal corresponding to the fashion of the got distribution on a formula was calculated:

$$U_0 = (U_m + U_{m+1})/2 - [(U_{m+1} + U_{m+2})/2]\ \overline{P_{m+1}}\ P_{m+1}\ - \quad -$$

$$[\,(U_m + U_{m-1})/2]\ \overline{P_{m-1}} \qquad (1),$$

where m - is a number of modal channel; U_{m-1}, U_m, U_{m+1}, U_{m+2} are values of thresholds signals discrimination (set at development of electronic charts) for channels with the numbers of m-1, m, m+1, m+2 accordingly; and are values of relative mid frequencies of distribution for channels with the numbers of m+1 and m-1, $\overline{P_{m+1}}$ and $\overline{P_{m-1}}$ accordingly. On the calibrating plot of spectrometer "Masnik-A" there is a diameter of particle (du), corresponding to the expected value U_0.

The relative error of producibility of calibration description of device is determined on a formula:

$$\delta_d = [(d_u - d_0)/d_0]\cdot 100\% \quad (2)$$

where d_0 is a nominal size of the applied standard particles of aerosol, µm. The rejection of producibility of calibration description of device appeared within the limits of ±15%.

For the estimation of relative error of measuring of sizes of aerosol particles, all operations, the stated, were executed higher, and for particles of sizes 0.5 µm.

For every line of the registered information, putting in a formula (1) instead of values and value P_{m+1} and P_{m-1} accordingly, on the calibration chart of device, for every line the value of du is certain, and it is chosen from the got row such du, for that $(d_u - d_0)$ maximally. According to a formula (2) the relative error of measuring of sizes of aerosol particles, is certain that appeared within the limits of ±20%.

At the change of ambient temperature from - 40 to 400 ^{0}C the additional error of measuring of aerosol particles sizes, does not exceed 20% from the measuring relative error.

IV. CONCLUSION

The typical characteristic feature of the developed by us aerosol Spectrometer is the using of complex changing field diaphragms, limiting the geometrical sizes of the instruments working volume in dependence from measuring counting concentrations of aerosol particles, as also contractions making of instrument is in two units OEU and UCH, that is provide the distant exploiting of instrument and safety of serving personal.

On the developed by us Aerosol Spectrometer received Patent AM, No 1807 A2, 15.06.2006.

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