AIR ION OBSERVATORY AT TAHKUSE: INSTRUMENTATION

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Introduction

The system is designed for continuous recording of atmospheric electrical and meteorological parameters at an observation station. It is installed at Tahkuse village situated 27 km NE from Pärnu, Estonian SSR, USSR [1,2]. The design of the system is based on the research in [3,4,5]. In addition to the air ion mobility spectrum in a wide range of $3*10^{-4}...3\ cm^2/(V*s)$ the system is able to measure and record basic meteorological parameters, electric field strength, intensity of atmospherics, etc.

General layout of the system

Principal components of the system are depicted in Fig.1.

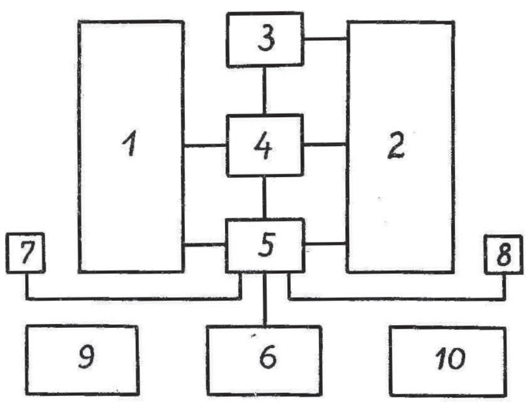

Fig. 1. Block-diagram of the system

The air ion mobilities are measured by a six-channel (1) and a ten-channel (2) spectrometer (abbreviations S-6 and S-10, respectively). One of the measuring capacitors of S-10 is equipped with a charger (3) to obtain some extra information about aerosol particles. Direct voltage for each measuring capacitor (MC) is provided by the voltage supply (4) controlled by the controller (5). Besides the control of the components of the system the controller is responsible for the reception and tranmission of signals. The controller is operated by an Elektronika D3-28* computer (6). The computer program controls the measurement, preliminary data processing and storage.

In addition to the spectrometers, the system has sensors for meteorological parameters (7). The control panel (8) is used to control the display of current results and, if necessary, to change operation modes. Both spectrometers are in the same air tract (9) with a common fan. As a precaution against possible power cuts the computer, the controller, and the voltage supply have an autonomous power supply (10). The above devices, excluding the meteorological sensors, are enclosed in a thermally insulated stable-climate chamber which makes it possible to use the equipment throughout all four seasons.

Six-channel air ion spectrometer

The measuring capacitor of S-6 is identical to the one described in [5]. The electrometric amplifiers are described in [6]. The feedback circuit of the amplifier consists of parallel resistor (about 1 TΩ) and capacitor (about 50 pF). The exact values of resistance and capacitance are determined for each amplifier.

S-6 has six collector electrodes, the respective channels are numbered from 0 to 5 according to the air flow.

The incoming air flow is divided into two parts by a preliminary capacitor. The outer coaxial layer is deionized, while the central flow passes through retaining its natural condition. To ensure efficiency of the preliminary capacitor, the polarity and value of the voltage are chosen in line with the recommendations in [7,8].

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* Henceforth the originally Cyrillic letters used in the designations of apparatus types have been transliterated into the Latin alphabet.

The total flow rate is 9900 cm^3/s. The flow rate of the outer deionized layer is 8200 cm^3/s. Limiting mobilities for each channel can be computed by means of the geometrical average of the total flow rate and the outer layer flow rate (this average is 9000 cm^3/s). Air ion spectrum will be presented in mobility bands (subintervals) with boundaries close to the limiting mobilities. The boundary mobilities are presented in Table 1.

Table 1

Boundary mobilities of S-6, in $cm^2/(V*s)$

Channel No		0	1	2	3	4	5
at 47.5 V	from	2.5	2.0	1.6	1.26	1.0	0.8
	to	3.2	2.5	2.0	1.6	1.26	1.0
at 150 V	from	0.8	0.63	0.5	0.4	0.32	0.25
	to	1.0	0.8	0.63	0.5	0.4	0.32

The limiting mobility of the preliminary capacitor is two times lower than the minimum limiting mobility of the MC.

An approximate description of the dependence of the signal on the mobility inside subintervals can be given by a triangular graph where maximum sensitivity is located in the geometrical centre of a subinterval and where sensitivity decreases towards the limits of the subintervals [9].

Ten-channel air ion spectrometer

Basic characteristics of S-10 are idential to those published in [3]. The only significant modification are preliminary capacitors added at the entrances to MCs. These preliminary capacitors give the spectrometer the characteristics of a differential spectrometer of the second order [9]. The preliminary capacitor is depicted in Fig. 2.

Electrodes 1 and 3 are grounded, electrode 2 is given DC voltage. The air between electrodes 1-2 and 2-3 is deionized, whereas the air passing electrode 1 retains its natural condition. In S-10 (as well as in S-6) effective filtration is achieved by the selection of voltage polarity and value on electrode 2 in accordance with the recommendations in [7,8].

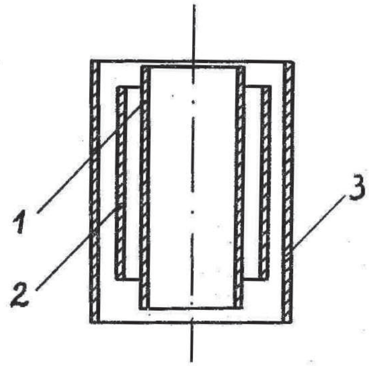

Fig. 2. Preliminary capacitor for S-10. 1,2,3 - the electrodes.

S-10 has two measuring capacitors: MC_i for small and intermediate ions (channels 6...10) and MC_l for large ions (channels 11...15). The voltage on MC_i is 406 V, the total air flow rate is 4750 cm^3/s, the flow rate of the outer layer is 2350 cm^3/s and the geometrical average of the flow rates is 3340 cm^3/s. The voltage on MC_l is 890 V, the total flow rate is 1210 cm^3/s, the flow rate of the outer layer is 600 cm^3/s and the geometrical average of the flow rates is 850 cm^3/s.

The boundaries of the mobilities for S-10 are presented in Table 2.

Table 2

Boundary mobilities of S-10, in $cm^2/(V*s)$

Channel No		6	7	8	9	10
MC_i	from	0.4	0.15	0.07	0.032	0.015
	to	∞	0.32	0.15	0.07	0.032
Channel No		**11**	**12**	**13**	**14**	**15**
MC_l	from	0.007	0.0032	0.0015	0.0007	0.00032
	to	0.015	0.007	0.0032	0.0015	0.0007

Channel 6 has integral characteristic, while the other channels are differential with approximate triangular apparatus functions [9]. The limiting mobilites of the preliminary capacitors are 8 and 4 times smaller than the respective minimum limiting mobilites of MC_j and MC_l.

Charger

The charger makes it possible to control the charging of aerosol particles in order to obtain extra information on the size spectrum of the atmospheric aerosol and on electrical parameters of the atmospheric aerosol. A computer program can turn the charger on/off. Depending on the program, the charger can charge particles either with negative or positive small air ions.

The charger was to meet two main conditions. First, it had to guarantee an opportunity for theoretical calculation of the aerosol particle charging processes in the device. Second, it has to achieve a good approximation to an ideal unipolar diffusion charging of particles with small air ions. As a basis for the attainment of these two aims the theoretical model of ideal transverse charger proposed in [10] was used.

The layout of the charger is illustrated in Fig. 3.

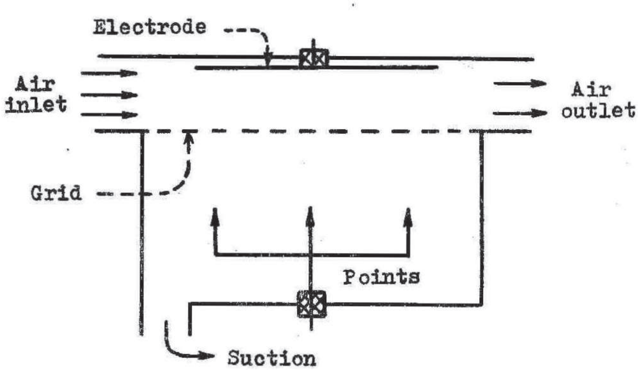

Fig. 3. Diagram of the charger

From above the charging zone is limited by a plane electrode connected with an electrometric amplifier, from below it is limited by a plane grid through which small air ions are fed. The length of the zone is 20 cm, the width is 12 cm and the heigth is 5 cm. The flow rate of inlet air is about

1500 cm^3/s; the flow rate of outlet air is about 1200 cm^3/s. Approximately 300 cm^3/s is sucked away through the grid. The suction is carried out in order to suppress the transport of corona products into the charging zone. The voltage between the electrode and the grid is 200 V, the respective field strength is 40 V/cm. When the net is dust-free, and the voltage on the points is 3 kV, the value of the dimensionless charging parameter α (cf.[10]) is approximately 20, or $n_0 t$ is approximately $8*10^6$ s·e/cm^3. When the net is contaminated with dust and/or hair the value of the parameter α decreases.

The actual value of the dimensionless charging parameter is computed using the effective value of the strength of small air ion current through the upper electrode of the charger which is obtained and recorded by the system.

Voltage supply

The voltage supply provides the measuring capacitors, the preliminary capacitors, and the charger with high-stability voltages of 400 V, 890 V, 1.8 kV and 3 kV.

Stabilized direct voltage is obtained by the rectification of HF voltage provided by a stabilized generator. Final stabilization is carried out by means of parametrical stabilizers on corona stabilitrons SG301S and SG302S.

A voltage of 890 V on the measuring capacitors is given by one and the same highly-stable supply through a voltage divider with a total resistance of 61 MΩ.

The voltage supply is controlled by a controller which turns it on/off and switches the polarities. For physical switching of high voltage a special relay is used.

Controller and control panel

The controller used in the present system is an analogy of the device described in [4]. The controller comprises a control block, a relay commutator for analog signals, an analog-digital converter (ADC), a protection circuit for the electrometric amplifiers of the spectrometers, triggers and relays for commutation, a timer, and a preliminary amplifier with an amplification coefficient of 100.

According to the commands of a Elektronika D3-28 computer the controller performs various functions: controls the shorting of relay switches at the input of the electrometric amplifier through the protection circuit, switches the voltages of the preliminary and measuring capacitors and of the charger, performs commutations necessary for regular zero-control of several sensors.

According to the commands of the computer the controller obtains signals from different sensors and from the electrometric amplifiers of the spectrometers, subsequently the signals are transformed into a code and transmitted to the computer.

The control panel is used for the selection of operation mode and for current indication of results on the display of the computer, as well as for labeling the record.

To suppress noises the controller is connected to the computer via a unit of galvanic isolation.

The measurement range at the input to the ADC is -10 V...10 V. The digitization increment is 5 mV for signals with an absolute values higher than 1 V and 0,5 mV for the signals with absolute values lower than 1 V. A preliminary amplifier with an amplification coefficient of 100 can be added to any measuring channel.

The measurement time for one channel is about 20 ms, whereas the span cannot be reduced due to the inertia of the electromagnetic relays of the commutator.

Air tract

The inlet opening for the investigated air is in the southern side of the observatory building, at a height of 5 m from the ground. Protection against precipitation is provided by a metal shelter. A metallic channel with a cross section of 0.02 m^2 leads the air to the two spectrometers (S-6 and S-10). The time of air travel in the channel is about 1.5 s. To suppress turbulence the channel is provided with lengthwise walls as well as with directing blades at bends and at the outlet. The channel grows narrower in the direction of the flow.

The flow is created by a sucking fan. Distribution chamber at the inlet end of the fan provides calibrated air flows through MCs (S-6, MC_i, MC_l) and the charger. To suppress the effect of wind on the flow rate the outlet of the fan takes place at the same side of the building with the inlet.

Autonomous power supply

The device for uninterrupted power supply consists of a reference 50 Hz generator, a low frequency amplifier, a power supply, and floating batteries.

Before being used by the load connected to the device the signal of the reference generator is amplified by a 200 W amplifier with automatic adjustment of output voltage to 220 V. The generator and the amplifier operate on the mains (220 V) through the power supply and floating batteries with a voltage of 24 V and a capacitance of 120 Ah.

The computer, the controller and the voltage supply are fed through the above device. It ensures the stabilization of short-term fluctuations in the voltage supplied from the mains, it also warrants the integrity of the program and automatic resumption of operation after power cuts lasting less than 3 hours.

Sensors

According to functions the sensors of the measurement system can be divided into three groups: the sensors of meteorological parameters, the sensors of atmospheric electricity parameters, and the sensors monitoring technological parameters of the measurement system itself.

The first group comprises the sensors of:

(1) direction and velocity of the wind (anemorhumbometer M63M-1 [11] with a supplementary device for electrical output);
(2) relative humidity of the air (hygrometer GS-210 and a hair hygrometer equipped with a potentiometric converter);
(3) the temperatures of the air and earth (graduated temperature-sensitive resistors MMT-4 with a nominal resistance of 15 kΩ);
(4) atmospheric pressure (a unified sensor of pressure, system KRAMS [11,12]);
(5) meteorological visibility RDV-2([11,12]);
(6) total radiation (thermal electrical pyranometer M-80M [11]).

The sensors of temperature and humidity are in a channel provided with a fan and situated near the inlet of the main air tract. The photometric unit of the sensor RDV-2 is in a special shelter at a height of about 2 m, the prism reflector with an additional metallic protection shield is elevated on a concrete support pillar to a height of 3.5 m; the support with the reflector is 100 m away from the photometric unit RDV-2. The sensor of wind direction and velocity is at the top of a 10 m support.

The second group is made up a Pole-2 field strength sensor [13] and a sensor of close thunderstorms. The latter has been built on the analogy of the KRAMS-system sensor [12], it has two sensitivity limits for thunderstorms at a distance up to 10 km, or 30 km, respectively. These sensors have been positioned separately from each other and from the other sensors in accordance with their operational requirements.

The sensors of the third group, monitoring the technological parameters of the system, comprise the sensor of current strength of the charger, the sensor of minimal voltage from the mains, and the sensor of temperature in the thermal-insulation chamber.

The above set of sensors is open to alteration and addition as the controller can cope with 12 additional sensors.

The computer program controlling the system is thoroughly described in the present volume [14].

Acknowledgements

The above measurement system would not have materialized without the efforts of the whole staff of the Air Electricity Laboratory at Tartu University. The authors express their sincere gratitude to their colleagues at the Laboratory as well as to Y. Georgiyevsky, R. Sepp, T. Sinimäe, V. Smirnov and M. Sulev.

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ОБСЕРВАТОРИЯ АЭРОИОНОВ ТАХКУЗЕ: АППАРАТУРА

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Р е з ю м е

Аппаратура, предназначенная для регистрации атмосферно-электрических и метеорологических величин, содержит шестиканальный и десятиканальный спектрометры подвижности аэроионов, источник высокостабильных напряжений, контроллер, ЭВМ "Электроника Д3-28", автономный источник питания и ряд датчиков. В настоящее время осуществлена регистрация спектра подвижности в диапазоне от $3*10^{-4}$ до 3 $см^2/(В*с)$ в 20 фракциях, а также основных метеорологических величин.