Journal of ELECTRICAL ENGINEERING, VOL 57. NO 8/S, 2006, 62-65

NUMERICAL MODELING OF ACCURACY OF AIR ION FIELD MEASUREMENT

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An analysis of the electric state of air shows the presence of various ion sorts. The therapeutic effect of negative high-mobility ions of proper concentration is known. This positive effect was observed in caves that are used for speleotherapy. This article presents the capability of gerdien tube measurement methods for measuring ion concentration and present results obtained by the design of new type of gerdien tube.

Keywords: *a*ir ion, conductivity of air, gerdien tube

1 INTRODUCTION

Air ion concentration and composition belong to the frequently monitored parameters of the atmosphere [5]. Their influence on living organisms has been the subject of intensive studies. Earlier research has demonstrated the positive influence of light negative ions and air cleanness on human health. The Department of the Theoretical and Experimental Electrical Engineering of Brno University of Technology and the Institute of Scientific Instruments of the Academy of Sciences of the Czech Republic are involved in the research of ion field in office and living spaces. The objective is to increase the concentration of light air ions in these spaces. Another task is to set up a simulated therapy room, with conditions similar to speleotherapy caves. It sets the requirements for accurate measurement of ion field with good repeatability. The article deals with the design of gerdien tube and peripheral measuring devices. An optimal design is important for eliminating the inaccuracy of ion concentration measurement.

2 MEASUREMENT METHODS

Several methods are currently used to measure air ion fields: the dispersion method, the ionspectrometer method, the Faraday cage method, and the gerdien tube method, whose principle is shown in Fig.1 d_1 – inner electrode diameter, d_2 – outer electrode diameter, l –length of gerdien tube, M – air flow volume rate, v – air flow velocity, e – elementary charge of electron, positive air particle (ion), negative air particle (ion).The gerdien tube consists of two electrodes. There is an electric field between the inner electrode (the collector) and the outer electrode. The field is imposed by voltage source U. Air ions flow from the fan through the gerdien tube. Negative ions in the electric field impact the collector, and the current produced is measured by a pA-meter. The current measured is proportional to air ion concentration.

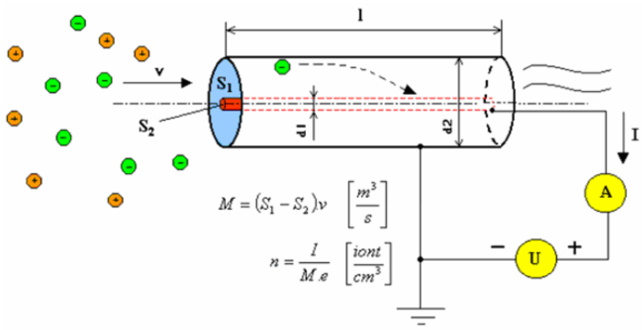

Fig. 1. Principle of gerdien tube method

The model of the measuring system is shown in Fig.2. The values measured carry systematical measurement errors. This is due to leakage currents and parasitic capacitances (modeled by I_{LEAK} in Fig.2) [6]. We have to consider leakage resistances R_{AK} of gerdien tube, leakage resistances and capacitance of the pA-meter input (R_{EH}, C_{EH}, R_{EL}, C_{EL}), insulation resistance (R_V) of the collector voltage source. The current measured is further affected by the input resistance of pA-meter and the input resistance of voltage source (R_U, C_U). To minimize the measurement error, R_{AK} ,and R_V should be much larger than R_I, and R_{EH}, and R_{EL} should also be much larger than R_{OUT}. Time constant $R_U C_U$ has to be much larger than the measuring time.

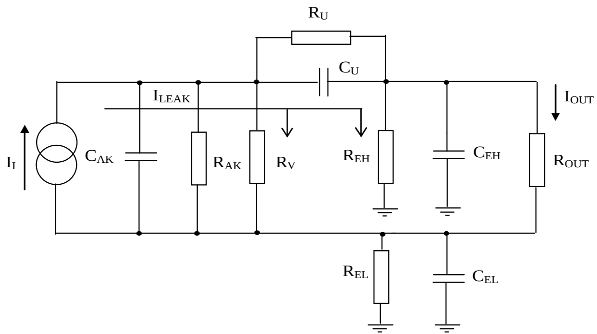

Fig. 2. Model of a system for measuring air ion concentration – the gerdien tube method

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ISSN 1335-3632 © 2006 FEI STU

3 NEW DESIGN OF GERDIEN TUBE

The inner and outer electrodes are elliptical in shape. This shape ensures that the flow of air is laminar. Air flow turbulence can distort the accuracy of measurement. The surface of the electrodes is required to be as smooth as possible. These aspects make the design of gerdien tube quite demanding (fine grinding, lapping, etc.). The new design of gerdien tube is shown in Figure 3, it was modeled with finite element method.

Fig. 3. New gerdien tube design

Since in the measurement of air ion concentration very small currents are detected, it is necessary to eliminate the influence of ambient electric charge. The influence of magnetic fields has to be minimized too.

4 WEAK CURRENT AMPLIFIER

The current flowing through the gerdien tube consists of ions. Current intensity depends on polarization voltage, on the dimension and parameters of gerdien tube, and on ion concentration. The specific current range for the designed gerdien tube is 10^{-10} A – 10^{-13} A.

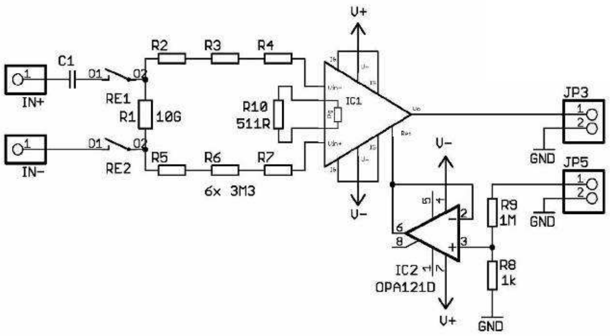


Fig. 4. Design of pA-amplifier

For the following measurement it is suitable to convert the current to voltage. Because the current is very weak, it is suitable to do this near the gerdien tube. The transimpedance configuration is used for the conversion and amplification in the first stage.

The transimpedance amplifier is realized with an INA 116 opamp. The INA 116 has a very low input bias current $I_{b,max}$ = 100 fA. The design of the amplifier is shown in Figure 4.

The first stage has transimpedance R_T = 10 GΩ. The second stage is a variable-gain amplifier. The gain is set by resistor R_G. Table 1 shows the values of gain, voltage and current for various gain resistors. The resulting current-to-voltage conversion constant can be set to 0.1 – 1 – 10 pA/V.

Table 1: Amplifier parameters

I_{IN}	U_M	U_{out}	Gain	R_G
[pA]	[V]	[V]	[-]	[Ω]
0,1	1m	1	1000	1M
1	10m	1	100	100k
10	0,1	1	10	10k
100	1	10	10	10k

5 PARAMETERS OF THE NEW GERDIEN TUBES

The gerdien tube of new design was compared with two others. Gerdien tube configuration and parameters are shown in Fig. 5-7. Measurement results of tube are shown in Fig. 8.

Fig. 5. UETE gerdien tube
M = 10,62 dm^3, v = 4,3 ms^{-1}, I_{leak} = 0,4 pA @ 150V

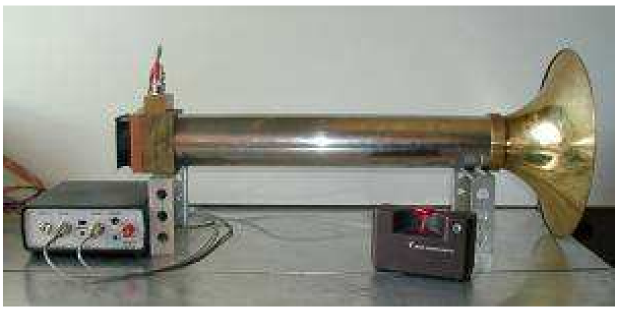


Fig. 6. ISI gerdien tube, M =12,14 dm^3, v = 3,75 ms^{-1}, I_{leak} = 0,3 pA @ 150V

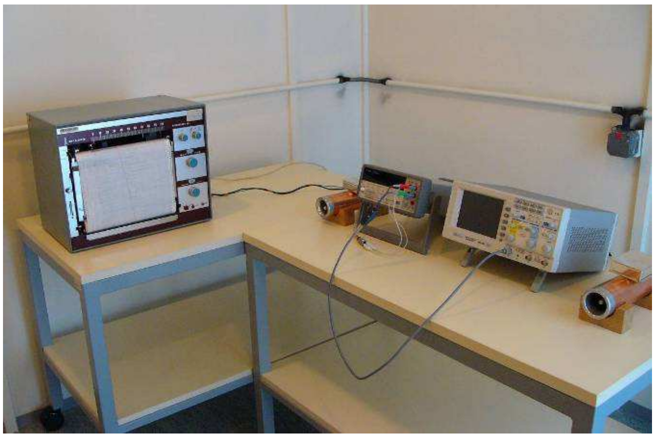


Fig. 7. New design of gerdien tube
M = 0,75 dm^3, v = 0,8 ms^{-1}, I_{leak} = 0,05 pA @ 150V

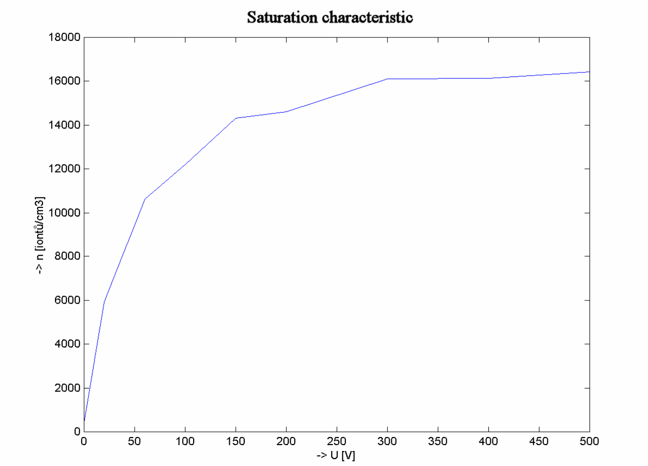


Fig. 8a. Results of measurment gerdien tube –saturation characteristic

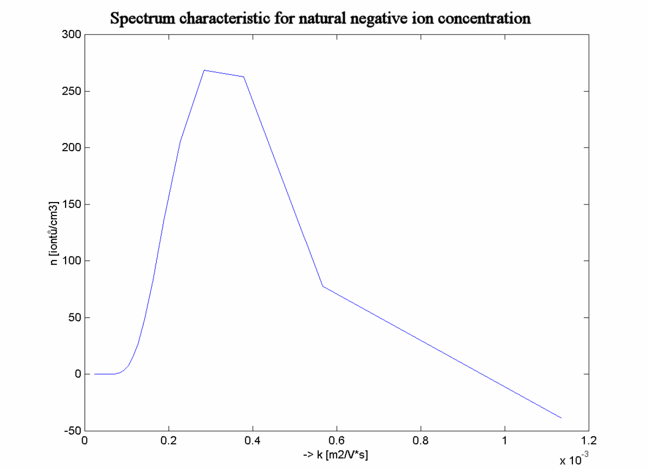


Fig. 8b. Results of measurment gerdien tube - spectral characteristic for natural negative ion concentration

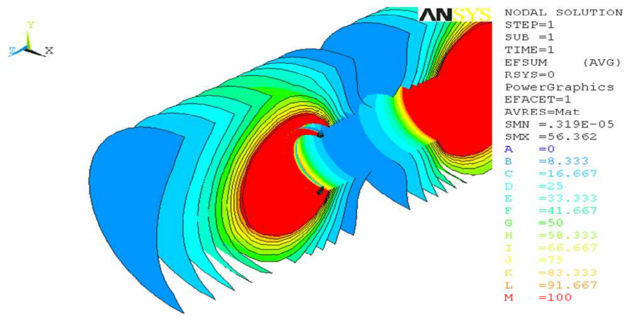
6 CONCLUSION

The new design of gerdien tube and the optimization of peripheral measuring devices have minimized the systematic error of measurement. The new system allows measuring air ion concentration with a sensitivity > 100 ions/cm^3. The ion mobility is in the interval 0.3 – 100 cm^{2}V^{-1}s^{-1}. The system will be used to measure ion field distribution in living and office spaces.

Very low leakage currents were achieved in the new design of gerdien tube. It allows higher sensitivity measurement. A long-term research task is to create an environment with suitable ion concentration and humidity in living spaces. The ion distribution in the environment will be simulated.

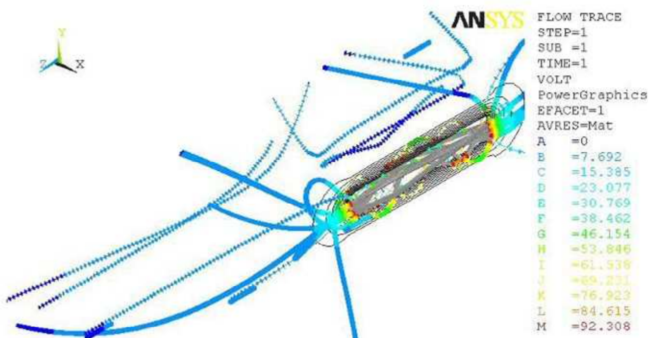
ANSYS system was used for numerical modeling of the gerdien tube. At the first, the distribution of electrical field in the vicinity of the tube was evaluated for increasing polarization voltage values. The output of the simulation is shown in Fig. 9a.

Next, it was examined the influence of the electrical field on the charge particles kinematics. The simulation was performed for various particle mass. Fig. 9b shows the trajectories of some particles in the vicinity of the gerdien tube. The results of this simulation give us the idea about relations between applied tube voltage, particle mass and air flow velocity. The relations are necessary for correct interpretation of real measurement results. The detailed results of the simulation are not presented due to limited scope of this paper. They will be published in the next articles related to this research.



q=1,6·10^{-19} C, m=9,1·10^{-31} kg, t=10^{-7} s, v=0 m·s^{-1} U=0,1 V

Fig. 9a. Electric field distribution in the vicinity of the gerdien tube



q=-1,6·10^{-19} C, -1,6·10^{-10} C m=9,1·10^{-6} kg, t=1,5 s,
v=9·10^{-6} – 0,09 m·s^{-1}, U=1000 V

Fig. 9b. Example of the trajectories of the two particle types

Acknowledgement

The paper was prepared within the framework of VUT Brno of the Czech Republic and with the support of the research plan MSM 0021630516.

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Received 8 November 2006

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