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EXPERIMENTS OF ACCURACY AIR ION FIELD MEASUREMENT

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Abstract: *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 methods for measuring ion concentration and for ion spectral analysis.*

Key words: *Air ion, ion flow, condenser method*

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 condenser and peripheral measuring devices. An optimal design is important for eliminating the inaccuracy of ion concentration measurement.

1 MEASURING METHOD

Several methods are currently used to measure air ion fields: the dispersion method, the ionspectrometer method, the Faraday cage method, and the gerdien condenser method, whose principle is shown in Figure 1.Here is *d1* – inner electrode diameter, *d2* – outer electrode diameter, *l* –length of gerdien condenser, *M* – air flow volume rate, *v* – air flow velocity, e – elementary charge of electron, ⊕ positive air particle (ion), ⊖ negative air particle (ion).The gerdien condenser 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 condenser. Negative

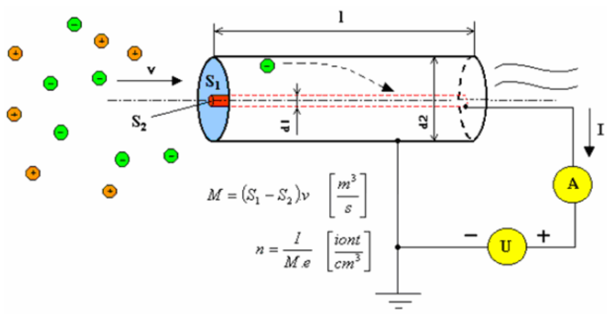

Fig. 1. Principle of gerdien condenser method

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. The model of the measuring system is shown in Figure 2. The values measured carry systematical measurement errors. This is due to leakage currents and parasitic capacitances (modeled by I_{LEAK} in Figure 2) [6]. We have to consider leakage resistances R_{AK} of gerdien condenser, 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_UC_U has to be much larger than the measuring time.

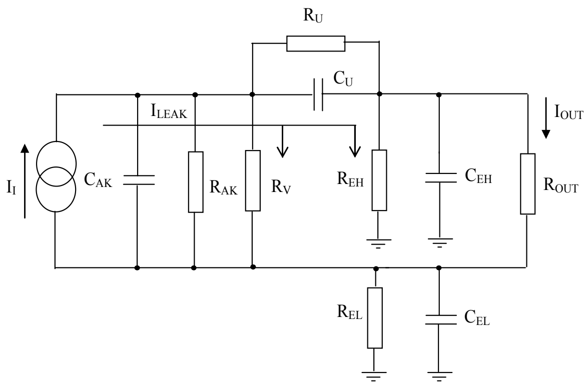

Fig. 2: Model of a system for measuring air ion concentration – the gerdien condenser method

2 NEW DESIGN OF GERDIEN CONDENSER

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 condenser quite demanding (fine grinding, lapping, etc.). The new design of gerdien condenser is shown in Figure 3.

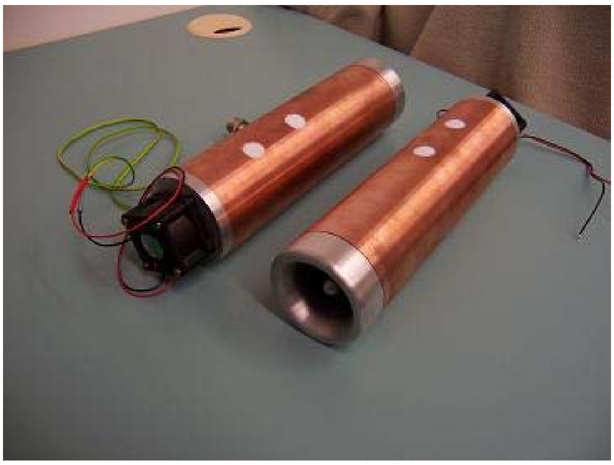

Fig. 3: New gerdien condenser

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.

3 WEAK CURRENT AMPLIFIER

The current flowing through the gerdien condenser is due to the ion concentration. Current intensity depends on polarization voltage, on the dimension and parameters of gerdien condenser, and on ion concentration. The specific current range for the designed gerdien condenser is 10^{-10} A – 10^{-13} A. 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 condenser. The low-level amplifier is realized with INA 116 – Figure 4. The INA 116 has a very low input bias current $I_{b,max}$ = 100 fA. The design of the amplifier is shown in Figure 5. The gain of INA 116 is set by resistor R_{10}

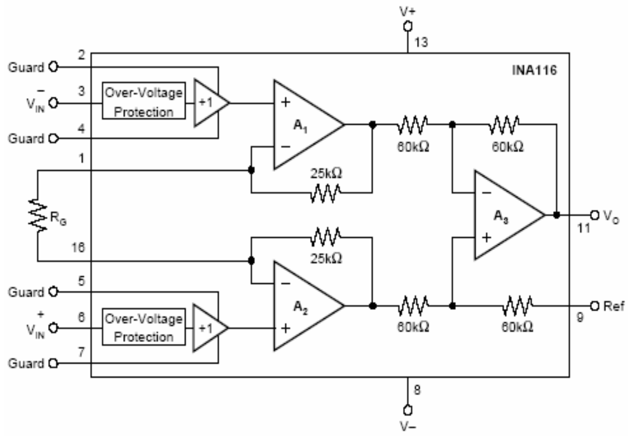

Fig. 4: Principal scheme of INA 116

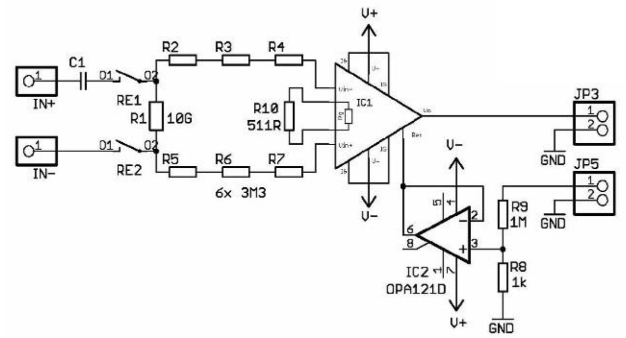

Fig. 5: Design of low-level amplifier

4 NUMERICAL MODELING

It is possible to carry out analysis of a MG model as a numerical solution by help of Finite element method (FEM). The electromagnetic part of the model is based on the solution of full Maxwell's equations. It was solved like simply electrostatic field , SOLID123. Solution is showed in Figure 6. In postprocessor was simulated many cases of ion position and its moving. This results showed to new facts in gerdien condenser design. The new knowledge were tested in many experiments and our measurement system had approximately 50% better characteristics. In Figure 7 is showed one effect of light negative ion inside of gerdien condenser. There are showed the non-primitive moving of one electron. Therefore the sensor has higher noise then sensor with filter.

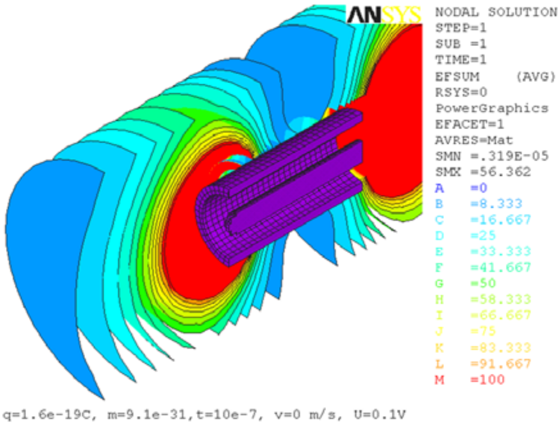

Fig. 6: Result – intensity of electric field E

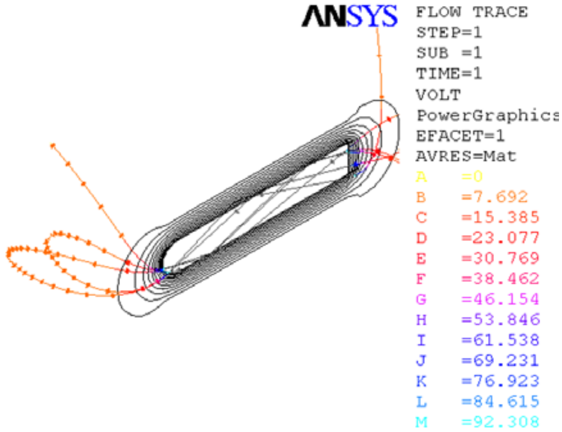

Fig. 7: Result – particle moving, trajectory of light negative particle

New design of gerdien condenser was made with filter for the specific particles. Result of new experiments are showed in Figure 8

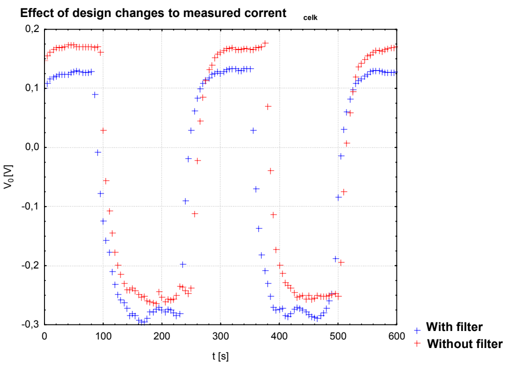

Fig. 8a: Result – characteristics of gerdien condenser with filter, time depend

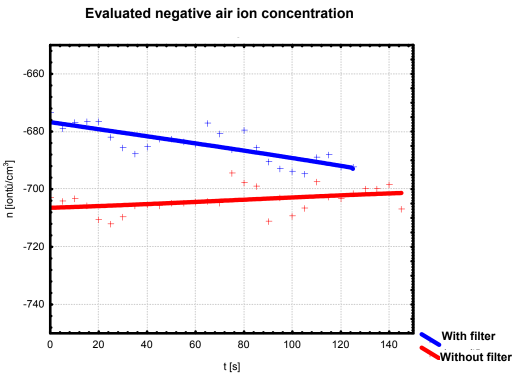

Fig. 8b: Result –characteristics of gerdien condenser with filter

5 COMPARISON OF GERDIEN CONDENSERS

The gerdien condenser of new design was compared with two others. Gerdien condenser configuration and parameters are shown in Figures 9 – 11. Measurement results of condenser are shown in Figure 12. Very low leakage currents were achieved in the new design of gerdien condenser. It allows higher sensitivity measurement. A long-term research task is to create an environment with suitable ionconcentration and humidity in living spaces. The ion distribution in the environment will be simulated.

Fig. 9: Gerdien condenser[5] (M=10,62 dm^3, v=4,3 ms^{-1}, I_{leak}=0,4 pA @ 150V)

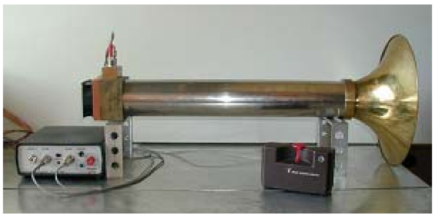

Fig. 10: Gerdien condenser[5] (M=12,14 dm^3, v =3,75 ms^{-1}, I_{leak}=0,3 pA @ 150V)

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

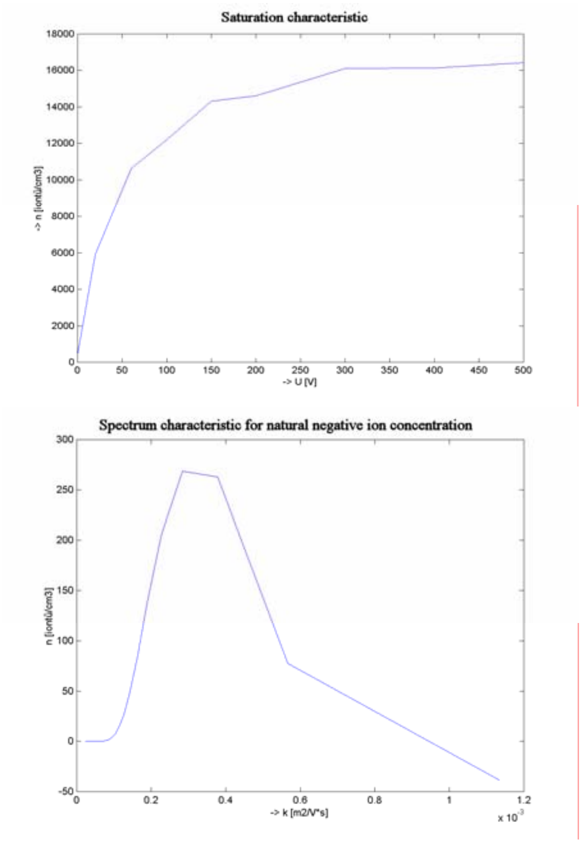

Fig. 12: Results of measurement gerdien condenser

6 CONCLUSION

The new design of gerdien condenser 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.

7 ACKNOWLEDGEMENT

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8 REFERENCES

[1] Bartušek, K.: Měření speleoterapeutických parametrů jeskyní pro lékařské účely. Interní text UPT AV ČR 1997.
[2] Buřival, Z.: Vliv prostorového náboje v atmosféře na znečištění vzduchu v technologických provozech. Knižnice odborných a vědeckých spisů VUT Brno.
[3] Spurný, Z.: Atmosferická ionizace. Praha. Academia 1985
[4] Puškeilerová, L.: Nové poznatky o měření volných záporných iontů v laboratorním prostředí.Příspěvek k VŠTČ FEI. Brno 2000
[5] Israël, H.: Atmosphärische Elektrizität. Akademische Verlagsgesellschaft Leipzig 1957.
[6] Smutný, T: Vliv obvodových prvků na přesnost měření iontových polí, Diplomová práce 2004 VUT Brno
[7] Kafka, V: Saturační a spektrální charakteristika iontového pole, Diplomová práce 2004 VUT Brno

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