NEW CONSTRUCTION OF GERDIEN TUBE WITH ACTIVE SHIELDING AND ION-TRAP

Zdeněk Roubal
Doctoral Degree Programme (1), FEEC BUT
E-mail: roubalz@feec.vutbr.cz

Supervised by: Miloslav Steinbauer
E-mail: steinbau@feec.vutbr.cz

ABSTRACT

The light negative ions in air have positive influence on human health so measurement of their concentration is the object of interest. This paper deals with construction proposals for the gerdien tube (cylindrical aspiration condenser), which is one of the possible sensors of air ion concentration. With the described method of it is possible to measure the air ions in large range of mobility with good resolution.

1. INTRODUCTION

There are many problems with the measurement of air ions by gerdien tube method. The current of low order 10^{-10} to 10^{-13} A must be measured and it is necessary to ensure high measuring insulating resistances. There is a problem with multiple transits of measured ions through gerdien tube. It is necessary to take these aspects into account to provide sufficiently accurate measurement of air ions in the respect area.

To achieve the high insulating resistance the method of active shielding was proposed. By the numerical simulation of ion trajectories inside the tube and in its vicinity using Ansys software we have observed that a part of measured ions is transmitting thru the tube several times. This problem was consequently solved by adding a ion-trap to output of the tube.

2. STUDY

2.1. THE PRINCIPLE OF MEASUREMENT

Several methods are currently used to measure air ion fields [1]: the dispersion method, the ionspectrometer method, the Faraday cage method, and the gerdien condenser method, whose principle is shown in Fig.1.

The known amount of given air M is blown by fan thru the aspiration condenser. The condenser is polarized by a DC adjustable voltage U, so the electrical field with non-homogeneous intensity appears. Negative ion is attracted to positive inner electrode. By a ion impact to inner electrode the current I is generated. Because of the high value of inner impedance of the condenser and very small values of I, it is necessary to measure using electrometer. When the voltage U is high enough, the current I is saturated and is directly proportional to the air ion concentration, which can be obtain by solving the equation (1)

$$n = \frac{I}{M \cdot e}, \tag{1}$$

where

n	is the air ion concentration,	$(ions \cdot m^{-3})$
$M = S \cdot v$	is volume rate flow of air through the aspiration condenser,	$(m^3 s^{-1})$
$S = \pi\left(r_2^2 - r_1^2\right)$	is area of cross-section of the condenser,	(m^2)
r_2, r_1	are diameters of outer resp. inner electrode,	(m)
e	is a charge of electron $1{,}602 \cdot 10^{-19}$.	(C)

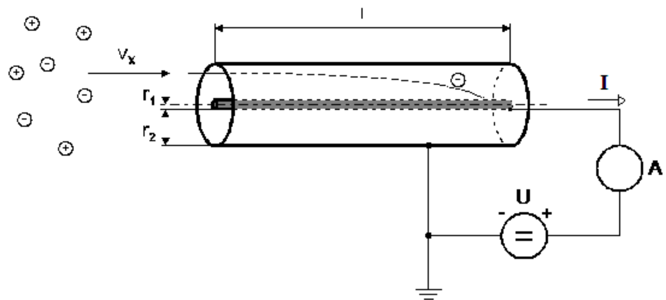


Fig. 1: The principle of the gerdien tube measurement method

2.2. EQUIVALENT CIRCUIT DIAGRAM

The measured values are burden with systematical measurement errors [3]. This is due to leakage currents and parasitic capacitances (modeled by I_{LEAK} in Fig.2).

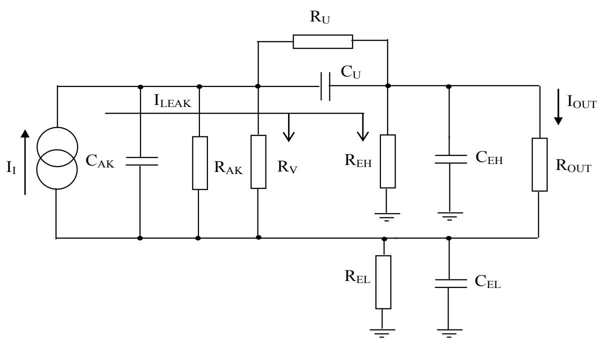


Fig. 2: Model of the gerdien tube for measurement of air ion concentration

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 polarizing voltage source. The current measured is further affected by the input resistance R_{OUT} of I/U converter and the input resistance of voltage source (R_U, C_U). To minimize the measurement error, R_{AK}, R_V, as well as R_{EH} and R_{EL} must be significantly higher then R_{OUT}. Time constant $R_U C_U$ has to be much larger than the measuring time.

2.3. MEASURING SYSTEM ON DTEEE

The circuit diagram of measuring current amplifier is shown in Fig. 3. The current flowing thru the gerdien tube is sensing on resistor R1 and amplified by the instrument electrometric amplifier INA116. This operational amplifier has very low input current 100 fA, thereby the systematic error is suppressed. By the relays RE3 and RE4 the gain coefficient can be switched so it is possible to measure in the wide band of air ions concentration values. INA116 has pins 2/4 and 5/7 connected to the input buffers which we use to active shielding of aspiration condenser and to eliminate earth-leakage currents on the PCB. Operational amplifier OPA121 is used as the source with low output impedance to offset compensation of INA116.

During the measurement process the INA116 offset is firstly set with relays RE1 switched off. Thanks to this compensation we can suppress the residual influence of the operational amplifier INA116 input currents. After this the capacitor C1 is charged by the voltage U_{POL} switching the RE2 relay on. In the next step relay RE2 switch off and relay RE1 switch on and the current from tube is measured. When changing the gain coefficient of OA INA116 it is necessary to set the offset again.

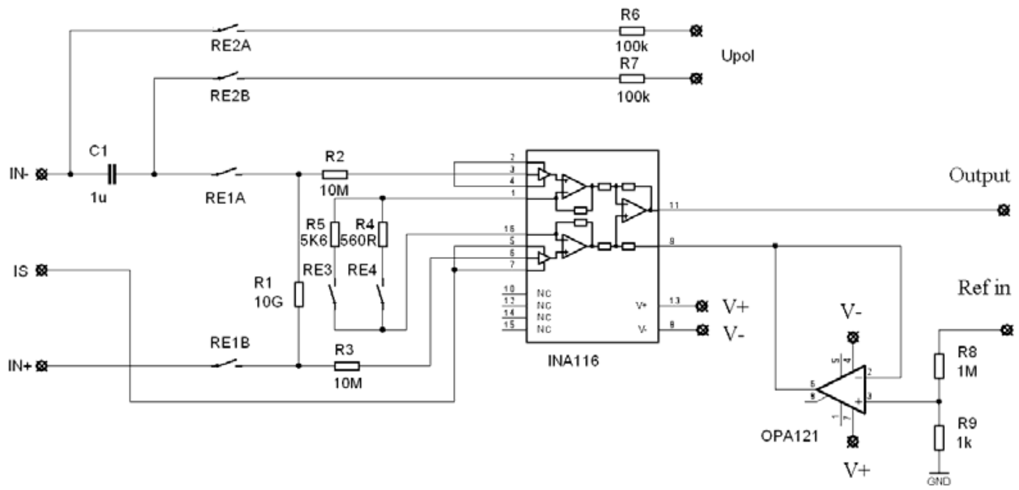


Fig. 3: The circuit diagram of measuring current amplifier

The output IS is used for active shielding of aspiration condenser as shown in Fig. 4. The active shielding increases the insulating resistance of bushing R_V and leakage resistance R_{AK} between the inner and outer electrode.

For the shielding of magnetic field generated near the fan is used the ferrite potty in a base of inner electrode and the permalloy belt closely under the aspiration condenser case.

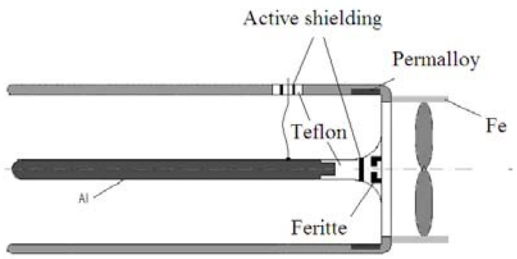


Fig. 4: Sketch of the gerdien tube construction details

For suppressing the switched magnetic field from the fan we enclose it in the steel ring. The electric field is shielded by a copper case of whole tube.

The above mentioned problem with multiply passing of some ions thru the condenser was investigated using numerical modeling [4]. We have used finite element method to model this situation in ANSYS software. In post-processing tool the trajectory of negative ion was identified and the interesting result was obtained. Some ions can fly through the aspiration condenser in several times, as is shown in Fig. 5.

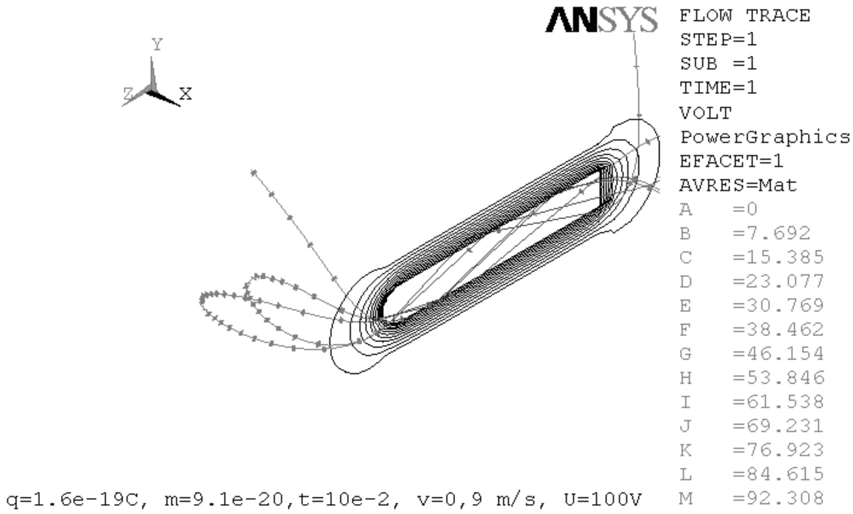


Fig. 5: Trajectory of light negative ions – numeric simulation results

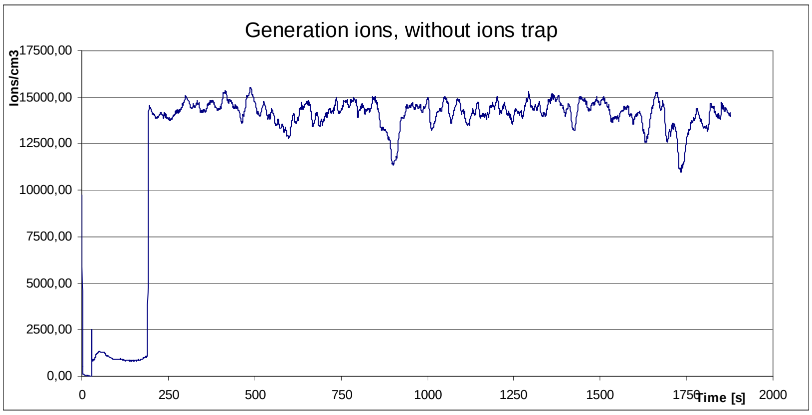
To avoid the multiple transitions of the ions there was added a ion-trap to output of the tube, which guarantees that all of the ions passed through the aspiration condenser will be captured ancd won't affect the measurement no more.

2.4. MEASURED RESULTS WITH THE GRIDS

The influence of the ion-trap was experimentally verified by a measurement of light air ions generated by an ionizer. The measurement was provided in a shielded room for suppressing unwanted disturbances. The leakage current of gerdien tube was compensated. Firstly, the measurement of a air ions of natural concentration in the room has been done for the both configurations – with the trap and without it. Next, the air ion concentration was measured when the ionizer was switched on. The results of measurement are shown in Fig. 6, without the trap on the top and with the trap on the bottom. The different between iont consentration without the ion-trap and with the ion-trap is average 1250 $ions \cdot cm^{-3}$. In the measurement without ion-trap is maximum peak to peak fluctuation 3200 $ions \cdot cm^{-3}$. With ion-trap after the stabilization is maximum peak to peak fluctuation 500 $ions \cdot cm^{-3}$

3. CONCLUSION

The paper describes an improved construction of gerdien tube with higher insulating resistance thanks to active shielding. There was confirmed the phenomenon of the ions with multiple transition through the gerdien tube. Using the ion-trap this phenomenon was significantly suppressed, which was experimentally verified.



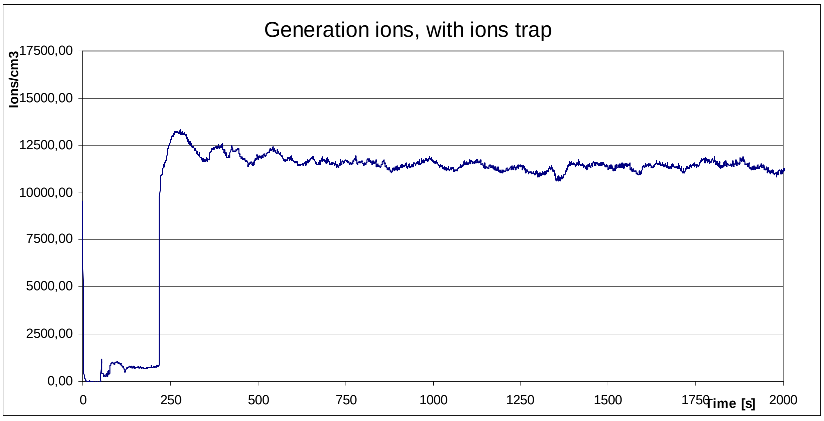


Fig. 6: The results of the air ion concentration without and with the ion-trap

REFERENCES

[1] ISRAËL, H. *Atmosphärische Elektrizität*. Akademische Verlagsgesellschaft Leipzig 1957

[2] CHARRY J.M., KAVET R. *Air Ions: Physical and Biological Aspects*, CRC Press, Inc. Boca Raton, Florida, 1987.

[3] SMUTNÝ, T. *Vliv obvodových prvků na přesnost měření iontových polí*: *Diplomová práce.* Brno: VUT FEKT, 2004.

[4] BARTUŠEK, K.; FIALA, P.; JIRKŮ, T.; KROUTILOVÁ, E. Experiments of Accuracy Air Ion Field Measurement. *PIERS ONLINE.* 2007. 3(8). p. 1330 - 1333. ISSN 1931-7360.

[5] STEINBAUER, M.; FIALA, P.; BARTUŠEK, K.; SZABÓ, Z. Experiments with Accuracy of Air Ion Field Measurement. In *PIERS 2008 Hangzhou.* Cambridge, The Electromagnetic academy. 2008. p. 1001 - 1005. ISBN 978-1-934142-04-2.