Air Ion Counter Design Using Gerdien Condenser

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Abstract. Air is a mixture of gases including nitrogen, oxygen, water vapour, carbon dioxide etc. which are ionized. We live in the ocean of air ions. Actually ions are nothing but atoms or molecules which have lost or gained electrons. These ions are counted with the help of new model based on cylindrical capacitor designed by Gerdien. We have designed and developed air ion counter using operational amplifier AD549JH which has very low input current and low input offset voltage. The fan fixed at one end of the cylinder sucks the air then similar charged ions are repelled by the outer electrode. Further, these ions travel towards the central electrode to form a very small current of the order of pA. The current measured is proportional to the air ion concentration. Particularly, to calibrate and measure air ion concentration, the current to voltage converter is used. The complete instrumentation necessary to measure ions consists of Gerdien condenser associated electrometer and bias voltage supply. Data acquisition is done with the help of digital voltmeter, personal computer by using Rishcom software. This instrument gives opportunity for comprehensive measurement of air ions. It is low cost instrument and can be used to measure positive and negative ions for different atmospheric conditions.

Keywords: Gerdien condenser, air ions, operational amplifier, aerosol, digital voltmeter.

1. Introduction

The small, intermediate and large ions are the generally classified as Atmospheric ions. The electrical conductivity of air is associated with the presence of these ions moving in an atmospheric electric field. Natural radioactivity, cosmic rays, waterfalls, Gamma rays and wind action produces natural air ions (1-2). We have designed and developed a small air ion counter indigenously at the department of Physics, Arts, Commerce, Science College, Palus India.

In 1901 Ebert invented first ion counter and in 1905 Gerdien developed new ion counter which has become the standard instrument for measuring air ions and conductivity (3). Now a days most of air ion counters uses this technology. Hatakeyama et al. (1958) developed a radiosonde instrument which consists of a Gerdien condenser for the measurement of electrical conductivity and electric field in the upper atmosphere (4). Higazi et al., (1966) used a Gerdien condenser made of brass with 5.4 cm internal diameter and 35.6 cm long outer electrode and inner electrode 25.4 cm long and 8 mm in diameter (5). Widdel et al. (1976) utilized a Gerdien probe cylinder made of aluminum electroplated with nickel (6).
Aplin (2000) used a Gerdien condenser for measurement in atmospheric air consisting of a central electrode made of stainless cylinder as the outer electrode (7).

The main objective of this research is to introduce a new air ion counter using Gerdien cylindrical condenser which is used for determination and measurement of small air ions in the atmosphere. These positive and negative air ions are measured distinctly.

2. Instrumental Description

The instrument used in this study i.e. small air ion counter contains a Gerdien condenser. This condenser is protected from external fields by a coaxial cylinder which is fixed around the outer electrodes with Bakelite Spacers between them.

The dimensions of Gerdien condenser are:

2.1 (Dimensions of Gerdien condenser)

| Description                          | Size     |
|--------------------------------------|----------|
| Diameter of outer electrode          | 0.035m   |
| Diameter of inner (central) electrode| 0.008m   |
| Length of outer electrode            | 0.25m    |
| Length of inner (central) electrode  | 0.22m    |

![FIGURE 1: Schematic diagram of the Gerdien system in current measurement mode BNC B supplies the bias voltage, BNC A measures the ion current and its outer connection is driven by the current amplifier.](image)

The inner electrode is coaxially supported inside and outer electrode is supported with the help of Teflon legs which is good quality insulator with volume resistivity exceeding 1018 Ohm- cm (Keithley 1992). The condenser is made from brass sheet and chrome plate. A suction pump fitted at the end of coaxial structure is used to suck the air through condenser (8). By adjusting voltage of suction pump, air
flow rate in the condenser can be varied. The air meter (Anemometer model AM-4201) is used to measure air velocity in the condenser. The accuracy of air meter is 0.005m/s. The non-magnetic stainless steel grid is used to separate the inner electrode from the fan electrostatically. The central electrode is electrostatically separated from the fan by a non-magnetic stainless steel grid. The collecting electrode is at virtual ground potential because of very high input resistance of the femto ampere meter. An operational amplifier AD549JH was utilized for the conversion of initial current to the potential signal which is stored in data logger and in computer (9).

For fixed bias voltage, the ion current flowing through the inner (central) electrode is proportional to the ion concentration (10). After each bias, voltage is switched on and settling time is allowed before sampling of ion current is begun. Noise may be considered in an electrical sense when many disturbance of an electrical nature produce noise in receivers. To avoid this noise effect, the amplifier is kept inside the aluminum box.

![Diagram of the apparatus](image)

**FIGURE 2:** CE-Central (inner) electrode, OE-outer electrode, ESS- Electrostatic shield made of Teflon, V- fan, PSS- Power supply, DMM- Digital voltmeter, DL-Data logger, PC-Personal computer, ADC549JH-operational amplifier, GND-Ground

### 3. Calibration

The calibration of the amplifier is done in the laboratory using resistive method of generating small current with a mili volt (by using 1.5 volt battery supply and potentiometer) Calibrator and TΩ resistance. The current flowing through the Gerdién tube consists of ions. Current intensity depends on polarization voltage, on the dimensions of tube, ion concentration (Viitanen et al., 2006) (10). The mean value of the velocity v is measured with velocity meter AM-4201.

The flow rate is (Ø) is given by,

\[ \Theta = \pi v (r_o^2 - r_i^2) \]

Where \( r_o \) – radius of outer cylinder, \( r_i \) – radius of inner cylinder

The air ion concentration (N) is given by,

\[ N = I / (e \Theta) \]
Where $I$ – Input current, $e$ – charge on ion $= 1.6 \times 10^{-19}$C.

In the market, several types of amplifiers are available for the measurement of atmospheric current. But, the atmospheric current is very small. Therefore, separate electrometer is essential to measure the small magnitude of current. The instruments with 1fA resolution are commercially available. However, they are bulky and their calibration is quite expensive which are unsuited for field work. During measurement of such small currents (Hatakeyama et al., 1958), the effects frequently considered as negligible in other circumstances which are relative to the signal such as leakage current.

**FIGURE 3:** (a) Shows I-V relationship and (b) shows calibration of amplifier

**FIGURE 4:** (a) Calibration curve and (b) shows new instrument
To measure small currents (AD549JH) operational amplifier is used by converting it into a voltage, which is related to input current. This opamp is suitable for applications which requires very low input current as well as low input offset voltage.

Skill is required while obtaining null offset. Low leakage currents were achieved in this design to increase the accuracy. This is one attempt to develop and design new air ion counter using Gerdien cylindrical condenser.

4. Conclusion

Air ions are nothing but all airborne particles which has charge and electrical conductivity. Air ions in the atmosphere usually differ from the ions in solution. In this case, the energy is needed for their formation. This paper presents a design of small air ion counter for small positive as well as negative air ions having diameter < 1.45 nm and mobility range > 0.77* 10^-4 m²/Vs. The positive and negative air ions are measured with the single Gerdien condenser. Sensitivity of this device is greater than 45 ions per cubic cm. Data acquisition is done with the help of digital voltmeter, personal computer by using Rishcom software. This instrument gives opportunity for comprehensive measurement of air ions. It is low cost instrument and can be used to measure positive and negative ions for different atmospheric conditions. Further designs could be related to automatic measurement of air ions.

5. References

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