A Study on the Fate of Negative Ions (Electrons) in the Flowing Air

Hiroyoshi Iida and Tokusaburo Koshijima
Training Division, National Institute of Radiological Sciences, Chiba, Japan

Research Code No.: *200*
Key Words: *Ion, Life time of ion, Ionization current, Recombination, Flowing air velocity*

運動気体中における電離負イオンの挙動

放射線医学総合研究所養成訓練部
飯 田 博 美　越 島 得三郎

（昭和53年8月21日受付）
（昭和53年10月20日最終原稿受付）

一定流速で流れる空気中に電離によつて生じたイオンの挙動を調べるため内径10cm のダクト中に流速0.4〜3.0m/s で空気を流し，ダクトの中心軸に置いたアルファ線源の下流での電離電流を円筒形電離箱によつて測定した．線源がないときの電流（バックグランド電流）が小さく，また塵埃がイオンを吸着するには数秒以上の時間を要するため測定に及ぼす空気中の塵埃の影響は無視し得ると考えられる．電離箱電圧と電流との関係では電流は電圧の増加と共に大きくなるとは限らず，電離箱外壁とダクト間に電位差のある場合には低流速時に電圧の上昇と共に電流は減少した．流速と電流との関係においても同様に，電流はある流速で最大値を示しその後は流速が高くなるに従い減少した．特に低電圧のときにその傾向が著しい．これらはイオンまたは電子が電離箱に入る前にダクト・電離箱外壁間の電界に捕捉されること，高流速では電極に捕えられる前に電離箱を通りぬけてしまうこと，などに依るものと考えられる．線源と電離箱間の距離による電流の変化から，0.42m/s の流速で1cm 当り約0.5%のイオンが再結合することが推論された．

Object

Ionization of the air by radiation is applied to some apparatus such as static electricity remover, smoke detector, etc. in which the ions produced in flowing air play an important role. Although the ionization of the static air by radiations is well known until the present time, we have little information on the ionization of flowing air.[1)2)] The purpose of the present study is to determine the fate of ion in the flowing air by measurement of current in ionized air with a device designed for the experiment.

Experiments

The main part of the experimental device is the cylindrical ionization chamber of 100 mm in

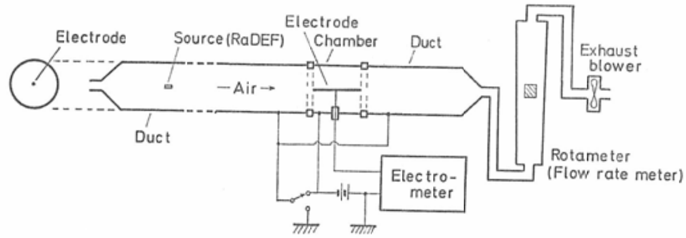

Fig. 1. Experimental schematic diagram for measuring ionization current in flowing air.

both diameter and length with an insulated electrode of 6 mm$\phi \times$100 mm as an ion collector, and the chamber is connected with the ducts of the same diameter (Fig. 1). The alpha particles from the RaDEF source which was electrodeposited on both sides of a silver plate of 3 mm in thickness and 25 mm in diameter (341 and 323 dps [Bp] on each side) was used for production of ion pairs. The radiation source of RaDEF was placed at the axial point in the duct and both the circular surfaces were kept in parallel with the axis direction of the duct. The measurement of ionization current was made using an electrometer of Ohkura Electric Model I-3045 connected to Model I-2080.

When the radiation source of RaDEF was shielded with aluminium foil of about 10 mg/cm^2 in thickness, the ionization current produced by the beta particles from RaDE showed about 0.1% of the current by the alpha particles. From this, the contribution of the beta particles to ionization current could be neglected. The space between the ionization chamber and the source can be varied at an interval of 10 cm. The duct was connected in series with a rotameter for measuring flow rate and a exhaust blower. Maximum flow rate was 1.37 m^3/min that epuivalent to 2.91 m/s of the air velocity in the duct.

Results and Discussion

Without radiation source of RaDEF, very little background current was observed. It is suggested that natural ions and ionized dust that flow into the chamber is much less than the ions which produced by the alpha particles from RaF. Besides, the produced ions are hardly adsorbed by dust in air, since the ions flow into the chamber within one second after they are produced.[2] Therefore, it may be said that the dust in air have no considerable effect on the ionization current.

We obtained the following three main findings, using such a device.

First, the response of the ionization current to the voltage was investigated under the condition that there was a potential difference and no one between the duct and the chamber wall. Here, the source was placed at a distance of 20 cm from the entrance face of the chamber and the air flowed with a constant velocity. As shown in Fig. 2, in the absence of a potential difference between the duct and the chamber wall, the ionization current increased with increasing voltage and showed a tendency of saturation. On the contrary, Fig. 3 shows that in the presence of a potential difference, the saturation curves fell down as the applied voltage increased, remarkably at a lower air velocity.

A possible interpretation might be offered for it that ions are interrupted by the electric field between the duct and the chamber wall before they flow into the chamber.

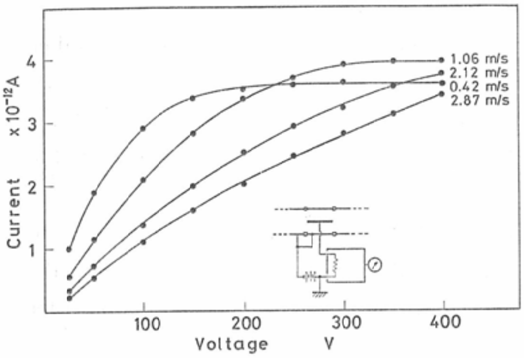

Fig. 2. Ionization current in flowing air at air velocity of 0.42 to 2.87 m/s, in the absence of a potential difference between the duct and the chamber wall.

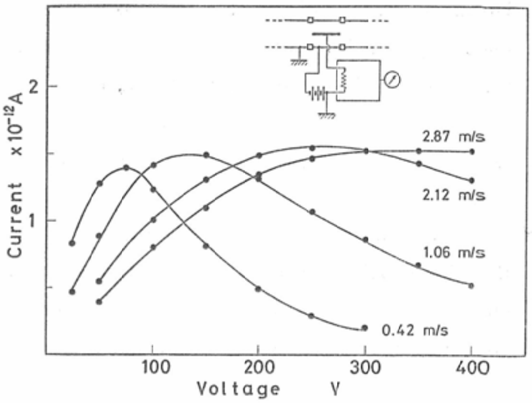

Fig. 3. Ionization current in flowing air at air velocity of 0.42 to 2.87 m/s, in the presence of a potential difference between the duct and the chamber wall.

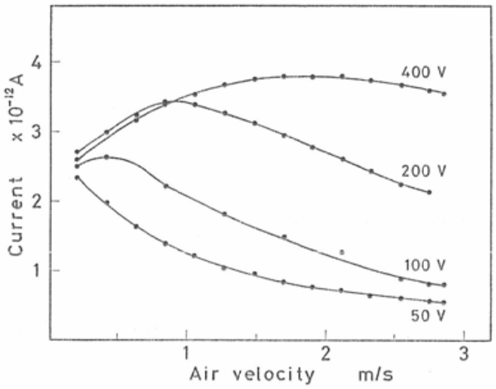

Fig. 4. Current—air velocity characteristics, in the absence of a potential difference between the duct and the chamber wall.

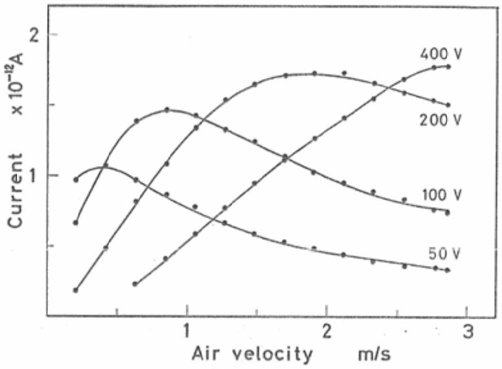

Fig. 5. Current—air velocity characteristics, in the presence of a potential difference between the duct and the chamber wall.

Secondly, we investigated the response of the ionization current to the air flow velocity. When the source was placed over 10 cm away from the chamber, no ionization current was observed until the air was flowed by operating the exhaust blower. Consequently, the ionization current was measured at a distance of 50 cm from the source. Under the condition that there is no potential difference between the duct and the chamber wall, the ionization current did not always increase with increasing air velocity, and took a maximum value at a certain air velocity as shown in Fig. 4. On the other hand, Fig. 5 shows that the current versus air flow velocity curves under the condition that there is a potential difference between the duct and the chamber wall. These curves yielded a maximum current at a certain velocity is a similar manner as those shown in the Fig. 4.

It seems reasonable to expect that the current increases with an increase in the air velocity.

However, the initial increase in current was followed by a decrease with increasing air velocity, remarkably at a low applied voltage. For this decrease, it is considered that the number of ions, other than those collected in the electrode, increases as the air velocity increases, particularly in the weak electric field. That is, the ions will not easily collected in the weak electric field and at the high air velocity. These all the characteristic relations were scarcely affected by the distance between the source and the chamber.

Lastly we examined the variation of the ionization current due to the distance from the source to the chamber, under the condition that there was no potential difference between the duct and the chamber wall (Fig. 6). Four hundred volts, the maximum voltage in this experience, was applied for collecting the electrons as many as possible which flow into the chamber.

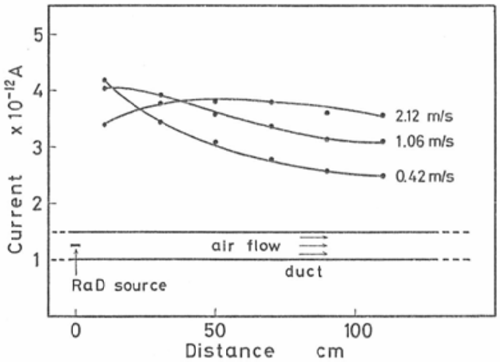

Fig. 6. Th variation of the ionization current due to the distance from the source to the chamber.

At the velocity of 0.42 m/s, the current can be adepuately approximated by the following epuation

$$I = 4 \exp(-0.0047 d)$$

where I is the current and d is the distance. From this relation, it may be concluded that the electrons were decreased by about 0.5% for 1 cm greatly by recombination and also in part by collision with duct wall.

In order to elucidate the fate of positive ions formed in the flowing air, further experiment is being carried out on the same device.

(Part of this work was presented at The 37th Annual Meeting of Japan Radiological Society, 1977 and The XIV ICR, 1977.)

Reference

1) Tsuge, M., Ogawa, K. and Sakai, K.: Relation of atmospheric contamination with air ions, Mitsubishi Denki Giho, 40: 462—466, 1966

2) Watanabe, H., Kaneko, F., Tamoto, E., Tanigawa, H., Hara, J., Tabata, N., Saito, H., Hirayama, K. and Ogawa, T.: Air-iongenerators for air conditioning and their application to Mido building, Mitsubishi Denki Giho, 40: 448—455, 1966