THE INVESTIGATION OF THE ELECTRIC FIELD OF WIRE-PLATE ELECTROSTATISTIC PRECIPITATOR BY DIELECTRIC WIRE METHOD

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Abstract

An axially moving dielectric wire is placed in a parallel position to the corona wire of the precipitator. After measuring the saturation line charge acquired by the dielectric wire in the field, the local electric field strength is calculated by means of a relation deduced by author in a previous paper.

Changing the axial speed of the wire, it is possible to obtain different distributions of the acquired line charge, depending on the ionization times. These distributions permit to effect an analogy with particles charging in short ionization times or by pulse corona discharge.

By placing dielectric wire perpendicularly to the corona wires it is simulated the trajectory of an air suspended particle wich is charged while passing through electrostatic precipitator area (not taking into account the particle trajectory deviation in the field). It is presented the distribution of the electric line charge with wich the dielectric wire was charged, plotted for different axial speeds.

1. Introduction

Corona discharge is the phenomenon that is the basis of such equipment as electrical precipitators, electrophotographic machines, electrostatic separators, static elimination systems. For an optimal operation of the equipment, in all these discharges, it is important to know the electric field distribution, the space charge distribution and the particle charging.

The first study, based on small conducting and insulating spheres falling through the discharge, was performed by Pauthenier (1). Cooperman (2), Penney and Hewit (3), Lagarias (4), also measured the strength of the electric field for corona monopolar air dicharge by means of the charge acquired by ballistic probes passing through the system.

Penney and Matick (5), Bertini and Operto (6), Sampuran - Singh and Coventry (7), explored the field using a thin wire probe connected to a high impedance voltage measuring device. A variable potential is applied to the probe. The potential of the probe equalizes the potential of its surroundings when the current between the probe and corona discharge is zero.

Masuda and Nonogaki (8), Dubard and Masuda (9) measured the field using a cylindrical bipolar type current probe.

Tassicker's method of the boundary probe for measuring the current density and electric field strength (10) is used by Collins (11), Gallo and Lama (12), Horenstein (13) and improved by Selim and Waters (14).

The optical methods for the electrical measurement of high voltage fields (15) are especially based on Kerr (16) and Pockels effects (17).

2. Basic principle of the method.

A wire with the radius *a*, placed in a uniform electric field E_o gets polarized. The equations of the external and internal potentials written in cylindrical coordonates are known (18), (19).

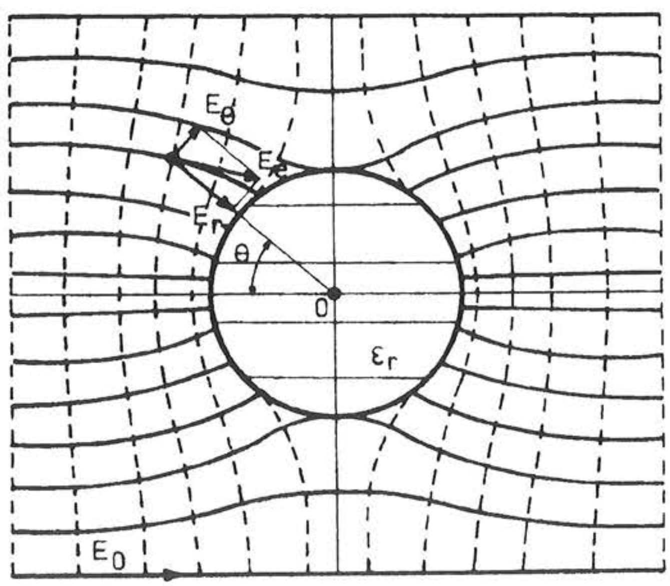
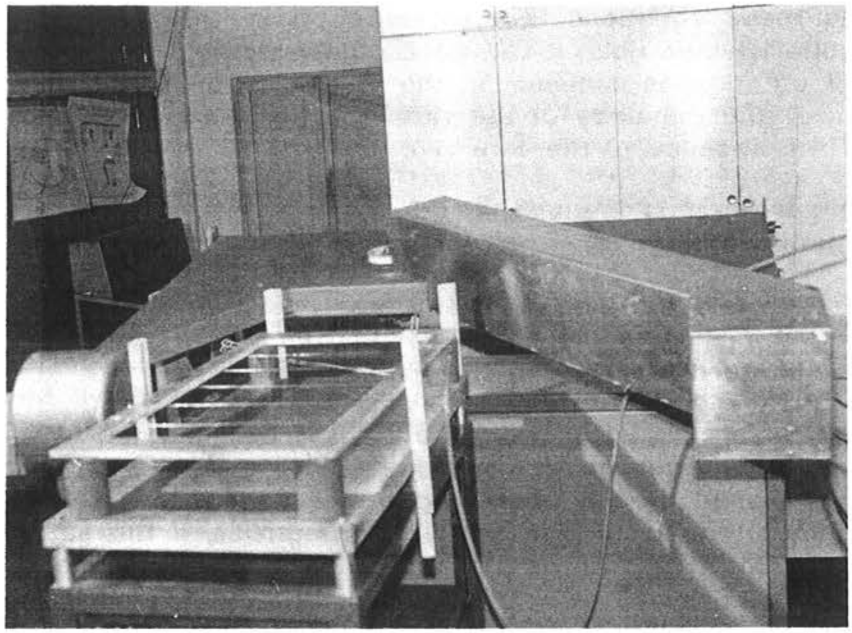


Fig.1 Dielectric wire in a uniform electric field: equipotential lines, field lines and external electric field components.

The term

$$\frac{\varepsilon - \varepsilon_o}{\varepsilon + \varepsilon_o} = \frac{\varepsilon_r - 1}{\varepsilon_r + 1} = A \qquad (1)$$

(a)



(b)

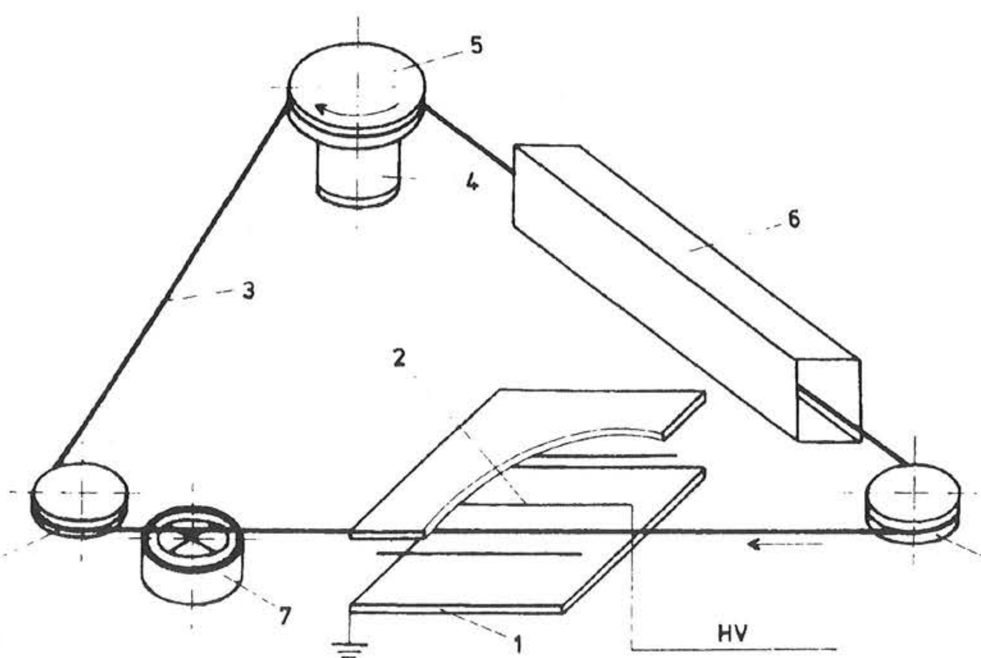


Fig. 2. (a) The measuring equipment; (b) Block diagram of the measuring equipment. 1. grounded plates (in a upper grounded plate removed); 2. high-voltage supplied corona wire; 3. dielectric wire; 4. electric motor; 5. drum; 6. neutralization tunnel; 7. generating voltmeter; 8. guining rolls.

contained in these equations is a measure of the distortion created by the wire within the initial electric field. It can be demonstrated that the distortion of the initial electric field potential is minimum in the case of a dielectric wire, since the lower ε_r is, the lower the influence of the term that is to be substracted from the local potential in the absence of the wire (20).

From the initial potential equations, the external electric field components E_r and E_Θ can be deduced (Fig. 1).

In the case of an electric field with ionic space charge (corona discharge) the ions moving along the lines of the electric field which converge to the dielectric wire, transfer the charge to the wire at the impact moment.

The charging ends completely when the electric field created by the line saturation charge σ_{ls} is finally equal to the maximum electric field $E_{r\,max}$ at $\Theta=0$, at the wire surface ($r=a$). Based on this reasoning one can deduce a relation which enables the calculation of the local electric field strength E_0, if the saturation line charge σ_{ls} acquired by the dielectric wire in the field, is previously measured. (20)

$$E_0 = \frac{\sigma_{ls}}{2\pi\,\varepsilon_0\,a\,(1 + A)} \qquad (2)$$

3. Measuring equipment

Figure 2 presents the measuring equipment. The corona discharge system, consisting of corona wires 2 and grounded plates 1, is mounted on a table which can be moved horizontally by a helicoidal shaft, driven by an electric motor (not figured). Between these electrodes there is generated a corona discharge, which is the object of our investigations.

In fact, the measuring equipment is mounted on a tipped-up plate. The dielectric wire 3, is set in an axial motion by the drum 5, mounted on a shaft of an electric motor 4. The speed of the dielectric wire can range between 0.2 and 15 m/s.

The acquired charge of the wire length element during the motion through the corona discharge is measured by means of the generating voltmeter (field mill) 7.

The dielectric wire charges electrically both when passing through the investigated corona discharge and when frictioning the guiding rolls 8 and the drum 5, therefore, for the accuracy of the measurement, it is necessary to discharge it before entering the discharge area. The neutralization tunnel 6 is meant to neutralize all the electric charge accumulated on the wire. Inside this tunnel there is an ionizer, consisting of a row of needles fed at 6 kv, 50 Hz and a row of grounded electrodes, among which a low intensity corona discharge takes place. This discharge generates, in the neighbourhood of the wire, an ionized region, rich in positive and negative ions. The dielectric wire charge attracts the ions of the opposite sign and neutralizes itself. In this way, at any speed, the dielectric wire enters the investigated corona region completely discharged.

The mobile table and/or the tipped-up plate are moved till the dielectric wire arrives in that position of the corona discharge where we want to perform the measurements. Then the dielectric wire is put into motion, the corona wires are supplied and the measurement of the line wire charge is performed.

4. Investigations regarding the wire-plate electrofilter

There was investigated a reduced corona discharge area of a wire-plate electrofilter, wich consists of a few corona wires (spaced at 140 mm, connected to high voltage V=30kV, negative) and grounded plates. Within this investigation the local electric field strength results from the summing up of the Laplacian field and the field created by ionic space charge.

A first set of measurements was performed by placing the axially moving dielectric wire parallel to the corona wire (Fig. 3). A quarter of a quadrant was investigated (hatched area), taking into account the symmetry of the system. The saturation line charge σ_{ls} acquired by the dielectric wire in the field was measured, and the local electric field strength was obtained by means of relation (2). The distribution of the electric field strength is presented in Fig. 3.

As we have expected the maximum electric field strength is found to be close to the corona wire, in the meridian plane. After passing through a minimum value the field increases again, as we get closer to the grounded plates. Mention must be made of the important decrease of the electric field strength between the corona wires.

The measurements were performed with an axial speed of the dielectric wire of 0.2 m/s,the width of the investigated area is 0.42 m and the corresponding charging time is 2.1 seconds.

By mentaining the paralell position of the dielectric wire to the corona wires, placed in an axial plane, but by changing the dielectric wire speed, it is possible to obtain different charging times and corresponding line charges acquired by the dielectric wire (Fig. 4).

The curves have the same shape with the curves of the speed of the particles field charging presented by White (21), based on Pauthenier's relation of particles field charging versus ionization time (1).

For short ionization times (about 0.1-0.4 seconds) the line charge aquired by the dielectric wire in the neighbourhood of the corona wire is more important than the line charge acquired in the rest of corona discharge.

Close to the grounded plates (Y=90mm, Y=95mm) the saturation line charge of the dielectric wire is reached in about 0.2 - 0.3 seconds, but in the neighbourhood of the corona wire it takes a longer time to reach the saturation line charge, approximately 1-2 seconds (not figured). The same thing can be observed in the curves of Fig. 5. In proportion as the ionization time increases, the acquired line charge of the dielectric wire close to the corona wire, has a more important increasing compared to the acquired line charge of the dielectric wire near the grounded plates.

If the dielectric wire is placed perpendicular to the corona wire and parellel to the grounded plates, as shown in Fig. 5, one may consider that the dielectric wire represents the trajectory of an air suspended particle, which is charged while passing through the corona discharge area (without taking into account the charged particle trajectory deviation in the field).

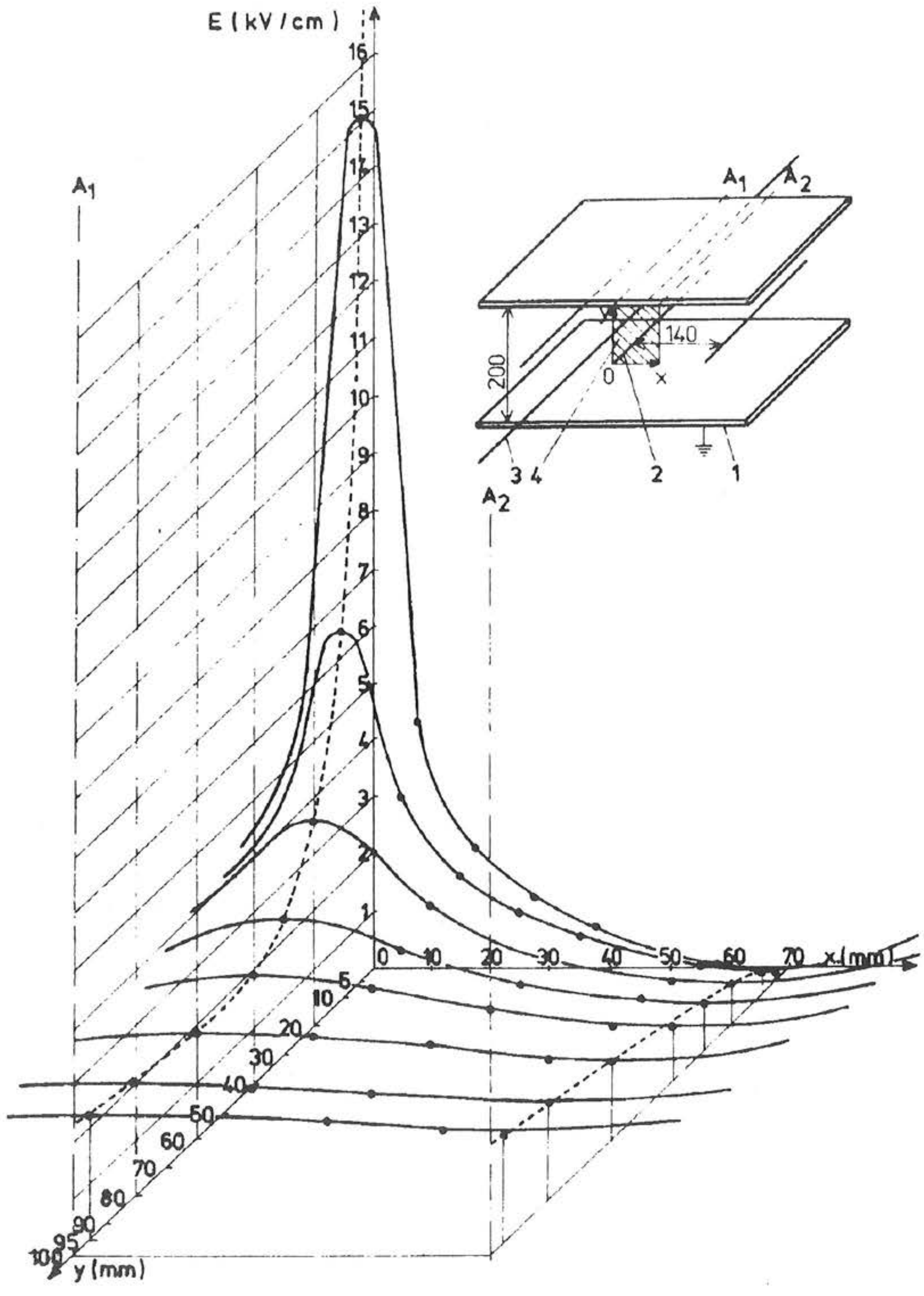


Fig. 3. Distribution of the electric field strength of the wire-plate electrofilter. 1. grounded plates; 2. corona wire, Φ1.2mm, V=30kV, negative; 3. dielectric wire, Φ0.5mm; 4. explored area.

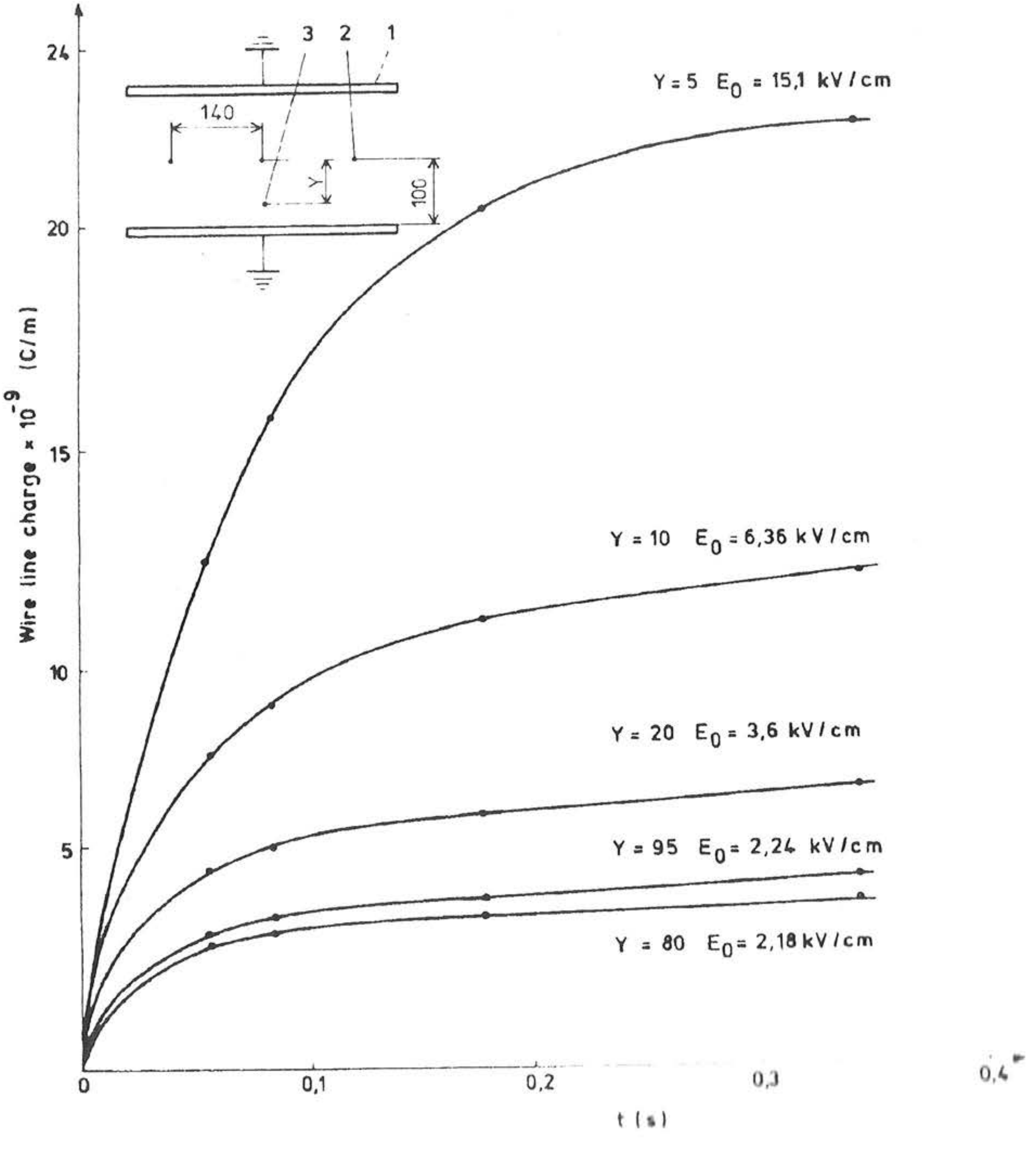


Fig. 4. Acquired line charge of moving dielectric wire, placed in the axiall plan, parallel to corona wire, as a function of charging time. 1. grounded plates; 2. corona wire, Φ1.2mm, V=30kV, negative; 3. dielectric wire, Φ0.50mm.

2. P. Cooperman, "A New Technique for the Measurement of Corona Field Strength and Current Density in Electrical Precipitation", *AIEE Transactions,* Part I, March 1956.

3. G. W. Penney, J. G. Hewitt, "Some Measurements of Abnornal Corona", *AIEE Transactions,* Part I, july 1958.

4. J. S. Lagarias, "Field-Strength Measurements in Parallel-Plate Precipitators", *AIEE Transactions,* Part I, September 1959.

5. G. W. Peney, R. E. Matick, "Potentials in D-C Corona Fields" *AIEE Communications and Electronics*, May 1960.

6. S. Bertini, A. Operto, G. Sciutto, "Electric Potential Measurements in Gasuous Insulating Materials by Corona Probe in a Controlled Ebvironment", *I.E.E.E. Transactions on Instrumentation and Measurement*, vol. I.M.-29, no. 2, June 1980.

7. Sampuran-Singh, P. F. Coventry, J. Dalmon "A Study of Electrostatic Precipitation Process-Electric Field Measurements", *Journal of Electrostatics*, 10, 1981.

8. S. Masuda, Y. Nonogaki, "Sensing of Back Discharge and Bipolar Ionic Current", *Journal of Electrostatics*, 10, 1981.

9. J. L. Dubard, S. Masuda, "Measurements of the Interelectrode Space Potential in Electrostatic Precipitators", *Journal of Electrostatics, 19 (1987).*

10. O. J. Tassicker, "Boundary Probe for Measurement of Current Density and Electic Field Strength, with Special Reference to Ionised Gases", *Procedings of IEE*, Vol. 121, no. 3. March 1974.

11. L. F. Collins, S. A. Self, D. D. Shearer, "Point-Source Corona Current Distribution in an External Field", *IEEE Transactions on Industry Applications*, Vol. IA-14, No.6, Nov/Dec. 1978.

12. C. F. Gallo, W. L. Lama, "The Lateral Distribution of Current from Wire to Plane Coronas", *IEEE Transactions on Industry and General Applications*, vol. IGA-7, nr. 3, May/June 1971.

13. M. N. Horenstein, "Peak Sampled Vibrating-Reed for the Measurement of Electric Fields in the Presence of Space Charge", *Review of Scientific Instruments*, 54(5), May 1983.

14. E. O. Selim, R. T. Waters, "Static Probe for Electrostatic Measurement in the Presence of Space Charge", *IEEE Transactions on Industry Applications*, Vol. IA-16, No. 3, May/June 1980.

15. R. E. Hebner, R. A Malewski, E. C. Cassidy, "Optical Methods of Electrical Measurement at High Voltage Levels", *Proceding of IEEE*, Vol.65, No.11, November 1977.

16. P. D. Thacher, "Optical Effects of Fringing Field in Kerr Cells", *IEEE Transactions on Electrical Insulation*, Vol. EI 11, No. 2, June 1976.

17. K. Hidaka, T. Kouno, "A Method for Measuring Electric Field in Space Charge by Means of Pockels Device", *Journal of Electrostatics,* 11(1982).

18. C. I. Mocanu, *Teoria cîmpului electromagnetic*, Editura Didactică şi Pedagogică, Bucureşti, 1984.

19. E. Durand, *Electrostatique*, Masson et C-ie, Paris, 1966, Tome III, 245, 246.

20. D. D. Botez, "Experimental Investigation of the Ionization Region of the Two-Stage Electric Filter, by Dielectric Wire Method", *Journal of Electrostatics*, 27 (1992).

21. H. J. White, *Industrial Electrostatic Precipitation*, Addison-Wesley, 1963.

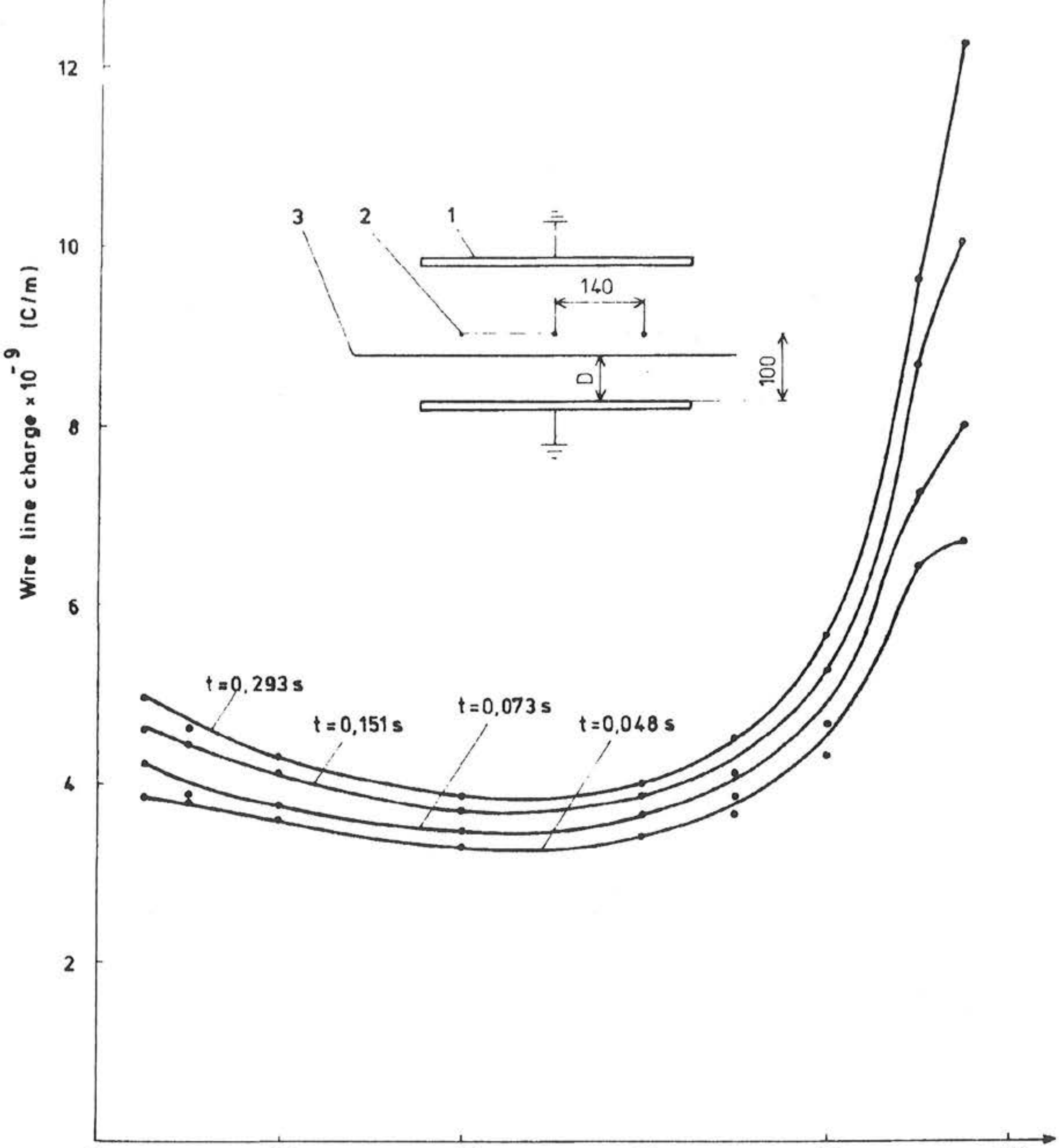


Fig. 5. Distribution of acquired line charge of axilly moving dielectric wire, placed perpendicular to corona wire, for different charging times. 1. grounded plates; 2. corona wire Φ1.2mm, V=30Kv, negative; 3. dielectric wire, Φ0.5mm.

The distribution of the electric field strength along the path, parallel to axis x, covered by the dielectric wire, can be deduced from the distribution presented in Fig. 3, as a curve with maximum and minimum values. An element of dielectric wire will acquire in each elementary covered area a charge proportional to the local electric field strength, local density of the ionic space charge and the charging time in this elementary area. The final acquired line charge results from the summing up of the accepted charge in each elementary area, after its passing through the whole corona discharge. The distribution of the acquired line charge as a function of the distance to the grounded plates, plotted for different charging times, is given in Fig. 5.

One may notice that in the neighbourhood of the corona wire line charge of the dielectric wire has a maximum value, which, after passing through a minimum value, increases again, reaching another maximum value, close to the grounded plates.

In the case of the wire-plate type electrofilter the particles which are passing close to the corona wire are charging with a bigger charge than the particles which are passing in the rest of the corona discharge area, for the same ionization time (namely all particles passing through the electrofilter have the same speeed, that of the surrounding gas). For long ionization times (t > 2 seconds) the particles which enter the corona discharge close to the corona wire, are charging with a charge bigger than the charge of the particles entering the rest of the corona discharge.

5. Conclusions

The method of the axially moving dielectric wire, makes possible the investigation of the plane-parallel symmetry corona discharges, the field lines distortion being negligible.

But for dissimilar calculating relations, the charging mechanism of the dielectric wire in the field, is similar to that of particle charging. There follows that by processing and interpreting the experimental results, we can draw conclusions concerning particles charging in equipment such as electrofilters, electrostatic separators.

The measurements are sensitive to the temporal local changes of the electric field strength caused by variations of the local ionic space charge.

The method offers the possibility to investigate even the corona discharges with relative low voltages (a few kilovolts) and small interelectrodes and electrodes dimensions (a few centimeters), due to the reduced size of the dielectric wire and to its sensibility.

By this method one can measure the line charges acquired by the dielectric wire in ionization times from a few seconds to a few hundredths of second (and shorter) and to infer on particle charging in symilar situations.

References

1. M. M. Pauthenier and M. Moreau Hanot, "La Charge des Particules Spheriques dans un Champ Ionise", *Journal de Physique et Radium*, tome 3, 12, 1932.