THE ELECTRICAL CHARGING OF
SMALL PARTICLES AT LOW PRESSURES

Progress Report

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MASTER

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FOREWORD

This summary progress report together with the following two papers constitute the progress report for the current year:

- COO-1248-37. B.Y.H. Liu, K.T. Whitby and D.Y.H. Pui, "A Portable Electrical Aerosol Analyzer for Size Distribution Measurement of Sub-micron Aerosols", J. Air Poll. Cont. Assoc., 24:1067-1072 (1974).
- COO-1248-47. D. Sinclair, R. Countess, B.Y.H. Liu and D.Y.H. Pui, "Experimental Verification of the Theory of the Diffusion Battery", to be presented at the 1975 Annual Meeting of the Air Pollution Control Association, Boston, June, 1975.

In addition, the following papers describing previously completed research have been published during the current year. Copies of these papers are also herewith enclosed:

- COO-1248-38. H.C. Yeh and B.Y.H. Liu, "Aerosol Filtration by Fibrous Filters. Part I - Theoretical", J. Aerosol Sci., 5:191-203 (1973).
- COO-1248-39. H.C. Yeh and B.Y.H. Liu, "Aerosol Filtration by Fibrous Filters. Part II - Experimental", J. Aerosol Sci., 5:205-217 (1973).
- COO-1248-40. V.A. Marple and B.Y.H. Liu, "Characteristics of the Laminar Flow Jet Impactor", Env. Sci. & Tech., 8:648-654 (1974).
- COO-1248-42. B.Y.H. Liu and T.A. Ilori, "Aerosol Deposition in Turbulent Pipe Flow", Env. Sci. & Tech., 8:351-356 (1974).
- COO-1248-43. B.Y.H. Liu and D.Y.H. Pui, "Equilibrium Bipolar Charge Distribution of Aerosols", J. Colloid & Interface Sci., 49:305-312 (1974).
- COO-1248-44. B.Y.H. Liu and D.Y.H. Pui, "Electrical Neutralization of Aerosols", Aerosol Sci., 4:465-472 (1974).

EFFORT OF PRINCIPAL INVESTIGATORS

Prof. Liu devoted approximately 15% time to the project and Prof. Whitby approximately 5% time, during the current project year.

ABSTRACT

A series of experiments have been performed on the unipolar diffusion charging of aerosols. Unipolar positive ions produced by a corona discharge were used. The experiments covered a particle size range of 0.006 and 5 μm diameter and an $N_0 t$ product of 3×10^6 to 3×10^7 (ions/cc)(sec) where N_0 is the ion concentration and t is the charging time. Data are presented showing the median particle charge as a function of particle size for several different $N_0 t$ values. In addition, for particles in the ultrafine particle size range between 0.006 and 0.06 μm , the fraction of particles that are electrically charged following exposure to unipolar positive ions is determined. These data are being compared with the available charging theories.

PRELIMINARY PROGRESS REPORT ON THE EXPERIMENTAL STUDIES OF UNIPOLAR DIFFUSION CHARGING

During the current project year a series of experiments were performed on the unipolar diffusion charging of aerosol particles. The experiments covered a particle size range of 0.006 to 5 μm . The charging parameter $N_0 t$ was varied between 3×10^6 and 3×10^7 (ions/cc)(sec).

The experiments were performed using components from the commercial electrical aerosol analyzer shown in Figure 1. The aerosol used in the study was first exposed to unipolar positive ions in the cylindrical charger, and subsequently passed through a cylindrical mobility analyzer. The aerosol particles emerging from the mobility analyzer were then detected by one of three sensors, depending on the type of experiments performed and the size of the particles involved. For measuring the fraction of particles that are electrically charged in the 0.006 and 0.05 μm diameter range, a General Electric Condensation Nuclei Counter was used. For measuring the median particle charge in the 0.005 and 0.75 μm diameter range, an electrometer current sensor was used. For measuring the charge and charge distribution of aerosol particles between 0.75 and 5 μm diameter, a Royco PC 220 Optical Particle Counter was used.

The monodisperse test aerosols used in the experiments were generated by three separate techniques shown in Figure 2. For particles larger than 0.75 μm , a Berglund-Liu (1973) vibrating orifice monodisperse aerosol generator was used. The particles between 0.02 and 0.75 μm were generated by the electrical classification method described by Liu and Pui (1974). Moderately monodisperse aerosols between 0.006 and 0.03 μm were generated by the photochemical conversion of SO_2 gas into sulphuric acid droplets in the smog chamber. Aerosols generated by the electrical classification and the vibrating orifice principles were very monodisperse, and the geometrical standard deviations varied between 1.02 and 1.04. The aerosols generated by the smog chamber were only moderately monodisperse, with geometrical standard deviations of about 1.5.

Figure 3 shows the measured medium charge on the aerosol particles for several $N_0 t$ values. The particle charge is seen to vary from one elementary unit for particles near 0.03 μm diameter, to nearly 500 elementary units at the upper particle size limit of 5 μm . These experimental data are quite accurate, the estimated uncertainty in the measured particle charge being on the order of $\pm 5\%$.

In Figure 4 we show the results of measurement on the unipolar charging of ultrafine aerosols with diameters smaller than 0.06 μm . Since in this ultrafine particle size range multiple charging seldom occurs, the charging characteristics can best be described by presenting the ratio of charged to uncharged particles or its equivalent, the fraction of particles that are electrically charged. The results are shown in Figure 4 together with the theoretical values predicted according to the following simple kinetic equation previously derived:

$$f = 1 - \exp \left(- \frac{1}{4} \pi D_p^2 \bar{C} N_0 t \right)$$

where $\bar{C}$ is the mean thermal speed of the ions. More detailed comparison of these data with various theories will be performed during the remainder of the project year and during the next project year.

References

1. Berglund, R.N. and B.Y.H. Liu, "Generation of monodisperse aerosol standards" Env. Sci. Tech. 7:147-153, 1973.
2. Liu, B.Y.H. and D.Y.H. Pui, "A sub-micron aerosol standard and the primary absolute calibration of the condensation nuclei counter", J. Colloid & Interface Sci. 47:155-171.

Figure 1 Experimental system for studying the unipolar diffusion charging of aerosols.

Figure 2 Aerosol generation and detection techniques.

Figure 3 Median particle charge as a function of particle size for unipolar diffusion charging.

Figure 4 Fraction of particles that are electrically charged in unipolar diffusion charging.