The Electric Charge on Sprayed Oil Droplets 3 (The Mechanism of Electrification of Sprayed Oil Droplets)

The Electric Charge on Sprayed Oil Droplets III

(The Mechanism of Electrification of Sprayed Oil Droplets)

Ken MIYAGI

In order to investigate the mechanism of electrification of sprayed oil droplets, using two kinds of lubricating oil, the electric charge of sprayed oil droplets were measured. The measurement was carried out using Millikan's oil drop method, and the dependence of the quantity of the charge on oil droplets upon the friction between the droplets and air, upon the friction between oil and the oil vessel of atomizer before spraying, and uopn the air-pressure in spraying, was investigated.

The results of measurement showed that the friction and the spraying -pressure do not give any definite effect on the electrification of oil droplets. This fact suggests that the electrification of oil droplets occurs when oil breaks up into droplets.

1. Introduction

In the previous experiment, it was shown that the larger electric charge of the sprayed oil droplets depends on the kind of oil sprayed: using Corvus oil, no charge larger than 10e was observed, using Alcaid oil, charge larger than 60e was observed but no charge larger than 100e was observed. Futhermore, using SAE 20 w, charge larger than 400e was observed.[1]

According to R. A. Millikan, when oil is sprayed into droplets, the droplets are strongly charged by the frictional process involved in blowing the spray.[2] On the other hand, it has been said that the electrification of liquid droplets occurs in breaking-up of a mass of liquid into droplets.[3] It seems that the electification of sprayed oil droplets is possible in the following processes: (1) heavy friction between oil and air at the moment of spraying, (2) light friction between the oil droplets and air and ion -capture by the droplets in their path from the atomizer to the electrode after spraying, (3) friction between oil and the oil vessel of the atomizer before spraying, and (4) breaking up of oil into droplets.

When all kinds of oil are sprayed, many droplets with various charge, viz. $\pm e$, $\pm 2e$, $\pm 3e, \cdots\cdots, \pm ne$, are produced, and the charge of small quantity can be found in certain droplets of any oil. For the larger charge, however, the quantity of the charge depends on the kind of oil. Therefore, in this experiment, the droplets with larger charge only were selected for measurement, and two kinds of lubricating oil, SAE 20W with paraffin hydrocarbon structure as the main constituent and Alcaid oil with naphthene hydrocarbon structure as the main constituent, which has been used in the previous experiment, were selected as oil samples, because their coefficients of viscosity are approximately equal.

Table I

	Density (gr/cc)	Coeff. of viscosity (cp)
SAE 20W	0.883 (at 23°C)	194 (at 23°C)
Alcaid oil	0.907 (at 23°C)	190 (at 23°C)

2. Experimental

The experimental apparatus which had been used in the previous experiment excepting the vinyle-pipe, through which the droplets was led into a glass pipe on the electrode from the atomizer, and oil vessel of the atomizer, was used in this experiment (see Fig. 1).

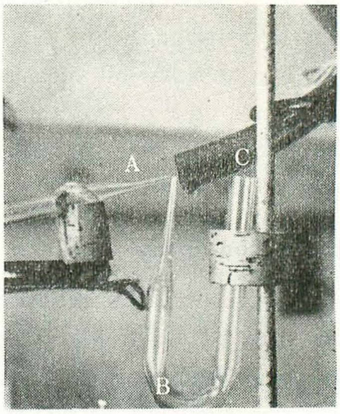

Fig. 1 Atomizer
A: glass nozle
B: oil vessel
C: vinyle-pipe

In this experiment, in order to investigate the effect of friction between oil and oil vessel, two oil vessels were used, one with long capillary tube of 16 cm in length and 0.09 cm in diameter, and the other with short capillary tube (see Fig. 2). In order to investigate the effect of light friction between the droplets and air upon the electrification of the droplets and the effect of ion-capture of the droplets, two vinyle-pipes were used, one of 130 cm and the other of 55 cm in length and each of 1.5 cm in diameter.

Using these pipes, the traveling paths of droplets amount to 150 cm and 75 cm, respe-ctively, when 20cm, the length of the glass tube on the electrode, is taken into consideration. Futhermore, in order to investigate the effect of spraying-air-pressure upon the electrification of the droplets, a manometer was connected to the rubber tube which connects a hand-air-pump and the glass nozle of the atomizer. Before the measurement, the applied voltage was chosen suitably so that the length of the time t_u which the droplets with larger charge require to move up-ward through the fixed distance ℓ in the electric field may be feasible for measurement. These voltages were 20V for SAE 20W and 150V

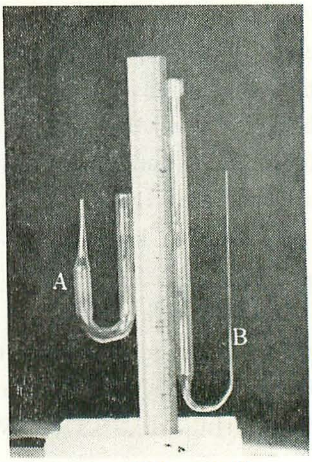

Fig. 2 Oil vessels

for Alcaid oil, and two electrode were fixed at the distance of 0.636 cm. At the measurement, the droplets which move up-ward and down-ward too slowly were not measured, because the velocities of these droplets might be affected considerably by slight motion of air in the electrodes. The largly charged droplets' t_u and t_d, which are the time-length of up-ward movement in the electric field and of down-ward movement under the gravity through the fixed distance ℓ in the electrodes, respectively, were measured and plotted in t_d-t_u plane (see Fig. 3 to Fig. 8). The measurement were carried on at the room-temperatures between 23°C, 24°C, and 27°C.

3. Results and Discussion

The results of measurement were compared with the curves which were represented by the following equation,

$$t_u = \frac{(k/g)\, t_d}{(t_d)^{3/2} - k/q,},$$

where

$$K = 9\sqrt{2}\,\frac{\pi \eta^{3/2} \cdot \ell^{3/2}}{E(\sigma-\rho)^{1/2} \cdot g^{1/2}},$$

t_d : fall time through distance ℓ cm under the gravity
t_u : rise time through distance ℓ cm in the electric field
η : viscosity of the air $(=1.84\times10^{-4}$gr/cm sec)
ℓ : fall and rise distance of droplets (=0.082cm)
E : electric field strength in e.s.u.
g : accelaration of gravity (=980cm/sec^2)
ρ : density of the air (=0.0012 gr/cc)
σ : density of oil (=0.907 gr/cc Alcaid oil, =0.881 gr/cc SAE 20W),
q : electric charge of droplets in e.s.u.

which is derived from Stokes's law, and the electric charge of droplets was estimated roughly. Fig. 3 shows that the estimation of the electric charge of the droplets in this way is not unreasonable. In the figure, t_d and t_u of the droplets of 1e, 2e, and 3e and the theoretical curves of 1e, 2e and 3e, respectively, are shown.

In Fig. 4 to Fig. 8, the curves corresponding to q=60e and 30e for Alcaid oil and q=400e and 200e for SAE 20W are shown.

(1) The Effect of Friction between Oil and Oil Vessel

Using two vessels, the electric charge of droplets of Alcaid oil and SAE 20W was measured. If the electric charge of droplets depends upon the friction, the electric charge using the oil vessel B must be larger than the charge using the oil vessel A, but the results of the measurement showed that there is no definite difference between vessel A and B (see Fig. 4a and 4b). There is a slight difference between Fig. 5a and 5b showing the results for Alcaid oil, and the result shows that the electric charge of droplets using the oil vessel A is larger

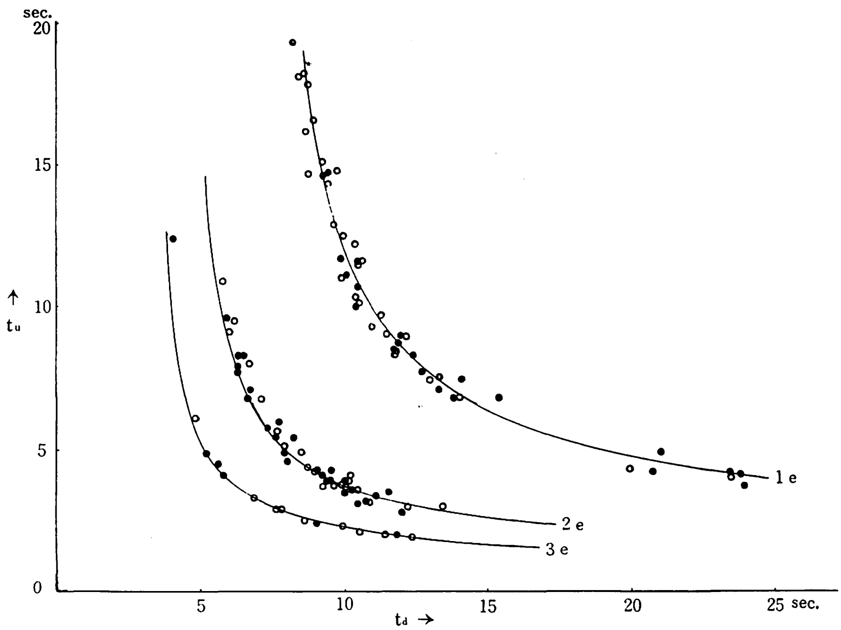

Fig. 3 t_d and t_u of the droplets of Alcaid oil at 1800V and the theoretical curves of 1e, 2e and 3e
○: positively charged ●: negativelv charged

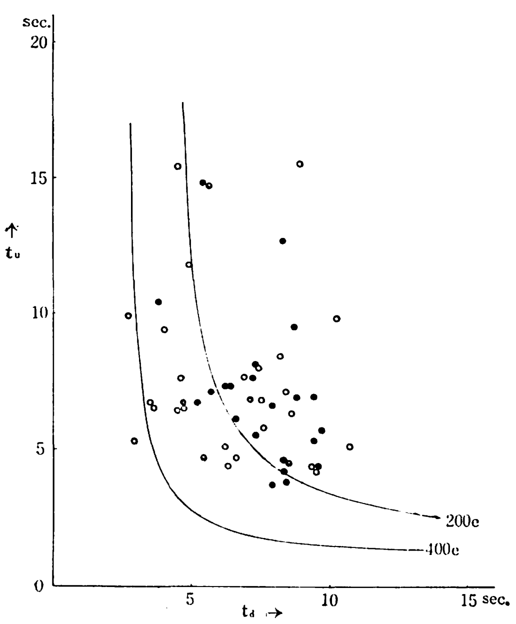

Fig. 4a t_d and t_u of the droplets of SAE 20w at 20V, using oil vessel A
○: positively charged
●: negatively charged

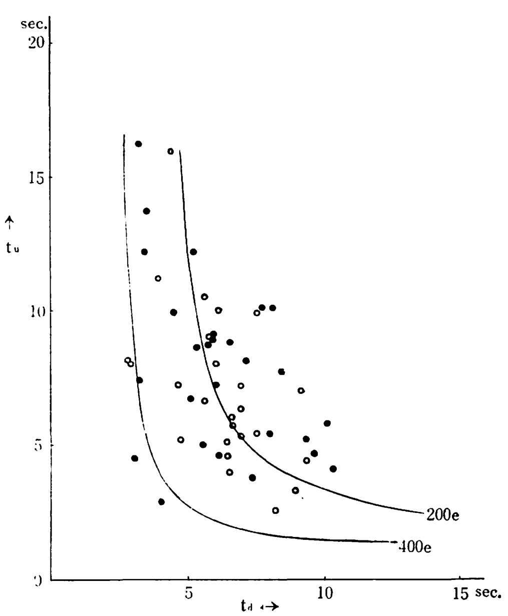

Fig. 4b t_d and t_u of the droplets of SAE 20W at 20V, using oil vessel B
○: Positively charged
●: negatively charged

than the charge using the oil vessel B, contrary to what was mentioned above. Since the slight difference seems to be due to the fact that the number of measured droplets was not large enough, it would disappear if the number of droplets measured were increased.

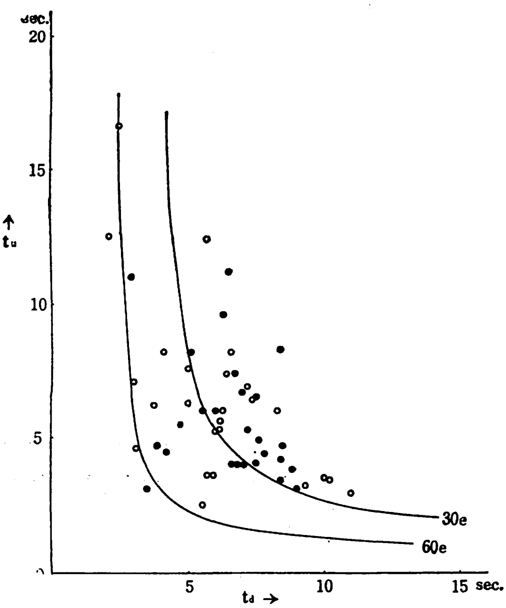

Fig. 5a t_d and t_u of the droplets of Alcaid oil at 150V, using oil vessel A
○: positively charged
●: negatively charged

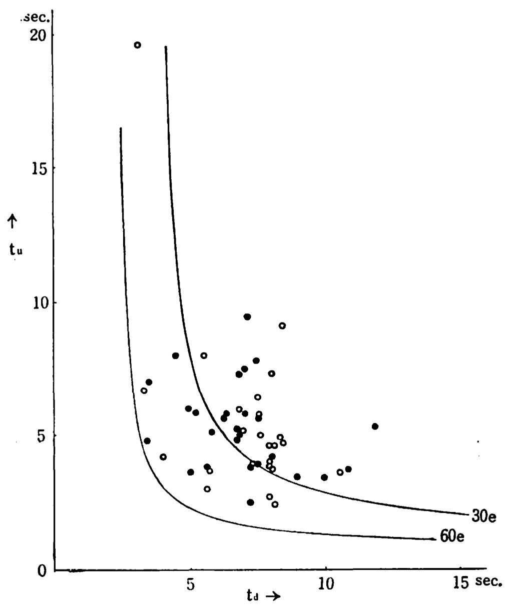

Fig. 5b t_d and t_u of the droplets of Alcaid oil at 150V, using oil vessel B
○: positively charged
●: negatively charged

(2) The Effect of Friction between the Oil Droplets and Air and the Effect of Ion-capture of Droplets

The measurement was carried out using two vinyle-pipes. Through this measurement, the oil vessel A was used. The results of the measurement using SAE 20W are shown in Fig.6a and 6b, the results of the measurement for Alcaid oil in Fig.7a and 7b. Both results of the measurement for two kinds of oil using two vinyle-pipes of different length show that the electric charge of droplets with shorter vinyle-pipe are slightly larger than those with longer one, but the difference could be neglected by the reason stated in (1).

The effect of ion-capture of droplets upon their electric charge can hardly be expected by the following reason. The radius of the observed droplets in this experiment was of the order of 10^{-4} cm : therefore the cross-section of the droplets is of the order of 10^{-8} cm^2. As it is said that there are about 10^3 pairs of ion per c.c. in the air,[4] the probability of ion-capture of the droplets in their path is insignificant.

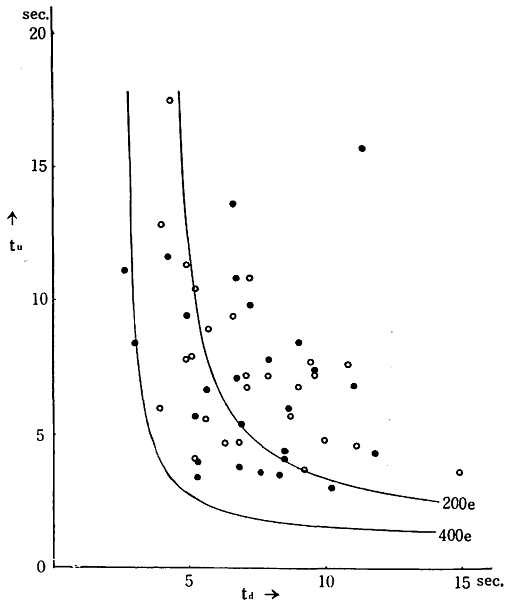

Fig. 6a t_d and t_u of the droplets of SAE 20W at 20V, using longer vinyle-pipe
○: positively charged
●: negatively charged

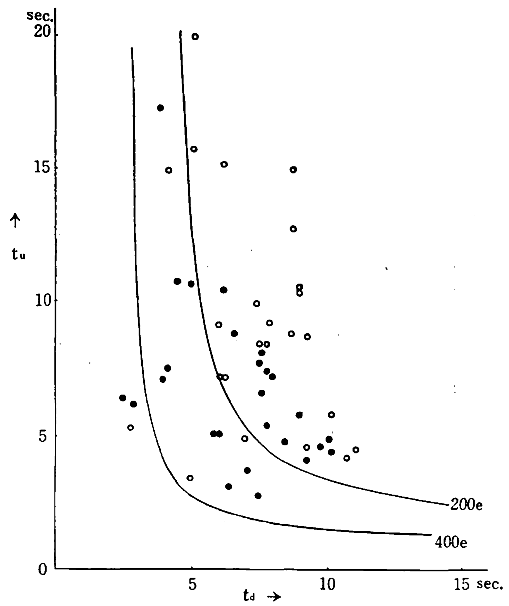

Fig. 6b t_d and t_u of the droplets of SAE 20W at 20V, using shorter vinyle-pipe
○: positively charged
●: negatively charged

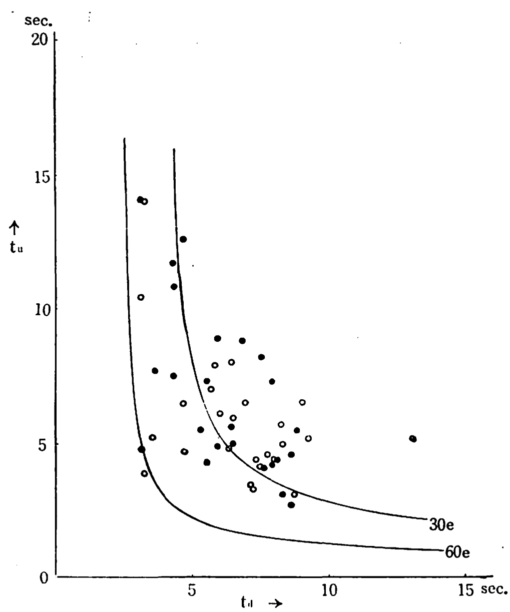

Fig. 7a t_d and t_u of the droplets of Alcaid oil at 150V, using longer vinyle-pipe
○: positively charged
●: negatively charged

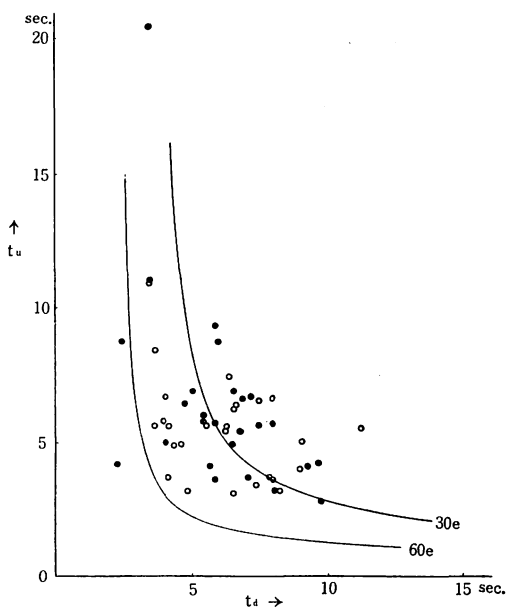

Fig. 7b t_d and t_u of the droplets of Alcaid oil at 150V, using shorter vinyle-pipe
○: positively charged
●: negatively charged

(3) The effect of the Strong Friction between Oil and Air at the time of Spraying

In order to investigate the effect of the frictional process involved in blowing the spray upon the electric charge of droplets, oil was broken up into droplets with different air-pressure. Fig. 8 shows the result of measurement with so weak pressure that oil breaks up barely into droplets. At that time, the manometer connected with a hand-air-pump showed the pressure differed from atmospheric pressure by about 6 cm Hg. Excepting the measurement shown in Fig. 8, all measurements were carried on under the pressure difference of about 16cm Hg to 20cm Hg from atmospheric pressure.

No definite difference between Fig. 5b, 7b and Fig. 8 seems to exist in spite of the difference in spraying-pressure of these measurement. Therefore, it may be reasonable to conclude that there is no effect of the frictional process involved in blowing the spray upon the amount of efectric charge of sprayed oil droplets.

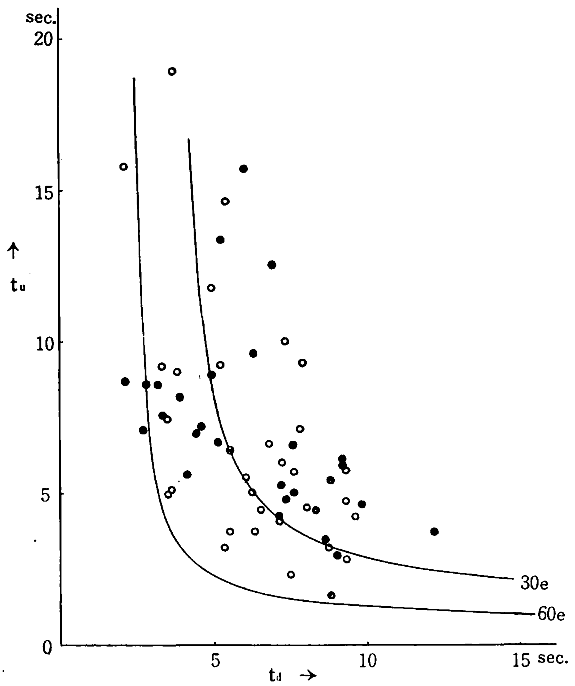

Fig. 8 t_d and t_u of the droplets of Alcaid oil at 150V, sprayed with weaker pressure
○: positively charged ●: negatively charged

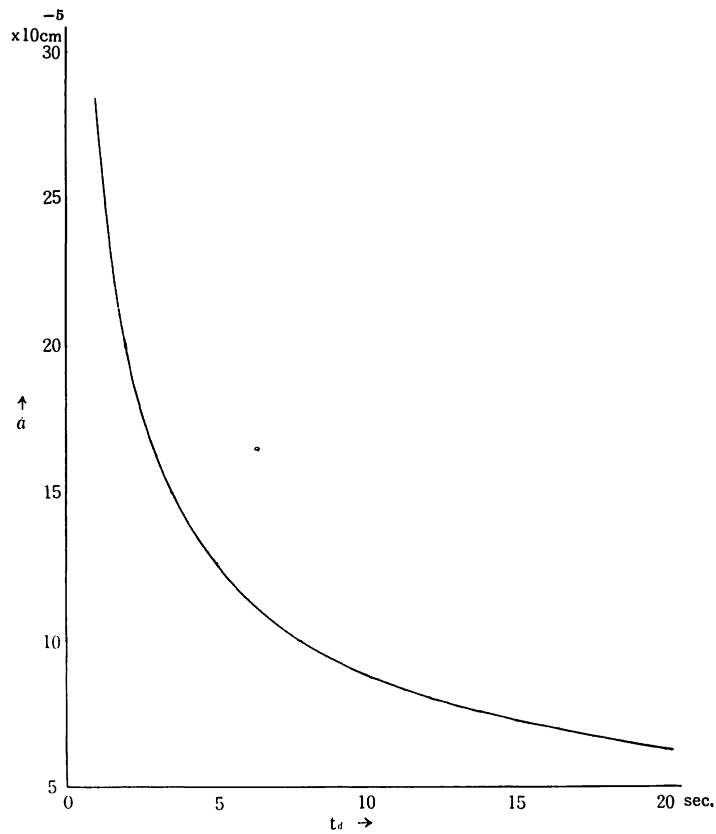

Fig. 9 Relation between radius of droplet a and t_d, calculated by Stokes law

4. Conclusion

The results of the experiment show that there are no definite effect of the length of the capillary of the oil vessel, the length of the vinyle-pipe and the air-pressure of spraying; that is, the frictiction between oil and the oil vessel, the friction between the sprayed oil droplets and air in the vinyle-pipe, ion-capture of the droplets in their path, and the friction between oil and air at the moment of spraying, do not affect effectively the electric charge of sprayed oil droplets. Therefore, it might be concluded that the larger parts of the electric charge of sprayed oil droplets are generated in breaking up into droplets.

Reference

(1) K. Miyagi: Bull.Arts anb Sci. Div., Ryukyu Univ. (Math. anb Nat. Sci.) 8 (1965)
(2) R. A. Millikan: Electrons (+anb−) proton,…………
(3) S. Taneya: J. J. A. P. 2 (1963)
(4) Y. Hatta: Gaseous Discharge (in Japanese), (Kindai Kagaku-sha, Tokyo, 1960)