# The Electric Charge on Sprayed Oil Drops 2

# The Electric Charge on Sprayed Oil Drops II

Ken MIYAGI

Dependence of the quantity of the electric charge on sprayed oil drops upon the physical conditions at spraying and physical properties of the oil used was investigated. Using Millikan's oil drop method, fall time $t_d$ and rise time $t_u$ of oil drops were measured and then the quantity of the electic charge on the drops was estimated.

Five kinds of lubricating oil with naphthene hydrocarbon structure as main constituent (these will be referred to as oils of group A, hereinafter) and other five kinds of lubricating oil with paraffin hydrocarbon structure as main constituent (these will be referred to as oils of group B, hereinafter), were sprayed to make the drops.

The results of measurement showed no dependence of the electric charge on the drops upon the physical conditions at spraying and physical properties (except electric properties) of the oil used, but showed a definite difference between the quantity of charge on the drops of the oils of group A and the quantity of charge on the drops of the oils of group B.

## 1. Introduction

When all kinds of oil are sprayed, many drops with various electric 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 drops of any oil, but for the larger charge, the quantity of the charge depends on the kind of oils. This makes the measurement of the larger charge significant.

It was shown in the previous experiment with some kinds of oil that the larger the coefficient of viscosity of the oil, the larger the quantity of the charge on the drops of the oil[1]. In that experiment, however, no attention was paid to the structure of the main constituent of the oils, unsatisfactory coaxial rotating cylinder viscosimeter was used, and some other oil was used as olive oil unknowingly.

In this experiment, using five kinds of oil with similar structure, viz. the oils of group A, and other five kinds of oil with similar structure, viz. the oils of group B, the charge on drops was measured and compared, and the measurement of the coefficent of viscosity of the oil was done by using Brookfield type viscosimeter.

## 2. Experimental Procedures

a: Measurement of the electric charge of oil drops.

Millikan's oil drop method was used to measure the electric charge on the drops. Two thick brass plates with a pin-hale in the top plate were used as

electrodes. These plates were separated by two bake-lite strips of 0.636 cm. in thickness. Oil was sprayed by a hand air pump, and the drops were brought, through a vinile-pipe of about 1 m. in length, into a glass tube of 15 cm in length and 3 cm in diameter which was vertically mounted on the top plate. First, after spraying the oil, some larger oil drops which fell freely through the distance of 0.082 cm. within the time of 15 or 16 sec. were observed using a microscope with two parallel hairs, since the motion of the smaller drops were affected by the movement of air. Next, the voltage was so applied to the electrodes in each measurement that the rise time of the drops might fall into convenient range for measurements. This means that for the drop with larger charge, a lower voltage was applied, and for the drops with smaller charge, a higher voltage was applied. Under the fixed suitable voltage for a given oil, fall time $t_d$, through the distance 0.082 cm., and rise time $t_u$, through the same distance, of drops were measured by repeating oil spraying, and the results were plotted. In this way, the measurements of ten kinds of oil were carried out (see Fig. 3··· Fig. 12).

Besides, the similar measurements were carried out under different humidity, at different temperature of oil and at different pressure of spraying.

b: Measurement of density, surface tension and coefficient of viscosity of oil.

As density of oil is necessary in determination of the quantity of the electric charge, its measurement was carried out in various temperature using Baume's Hydrometer (see Fig. 1 and 2). Surface tension of oil was measured by Du Nory tensionmeter (see Table 1). Measurement of the coefficient of viscosity of oil was carried out in various temperature of oil using Brookfield type viscosimeter (see Fig. 13 and 14).

Table 1

| Substance | Surface Tension dyn/cm at 20° C | Substance | Surface Tension Syn/cm at 20° C |
|---|---|---|---|
| Corvus oil | 36.2 | SAE 10W | 36.8 |
| Alcaid oil | 38.2 | SAE 20W | 37.8 |
| Winter Black oil | 38.7 | SAE 30W | 38.6 |
| Algol oil | 37.7 | SAE 40W | 38.6 |
| Ursa oil | 39.3 | SAE 50W | 38.6 |

## 3. Sample

As the object of this work was to investigate some relationship between the electric charge on the drops and the property of oil, oils of two groups, each of which has similar chemical structures respectively, were used. One was a group of lubricating oils which mainly consist of naphthine hydrocarbons; corvus, alcaid, winter black, algol, and ursa oil. The other was a group of lubricating oils which mainly consist of paraffin hydrocarbons; RPM the premium motor oil HD SAE 10 W, 20 W, 30 W, 40 W, and 50 W. These oils are sold by Caltex Co. USA.

## 4. Results and Discussion

According to Stoke's law,

$$\frac{4}{3}\pi a^3(\sigma-\rho)g=6\pi\eta a v_d, \tag{1}$$

$$\frac{4}{3}\pi a^3(\sigma-\rho)g+6\pi\eta a v_u=qE. \tag{2}$$

where $a$: radius of the drop
$\sigma$: density of oil drop (see Fig. 1 and 2)
$\rho$: density of the air (=0.0012 gr/cc)
$\eta$: viscosity of the air ($=1.79\times10^{-4}$gr/cm, sec)
$g$: accelaration of gravity (=980 cm/sec$^2$)
$v_d$: fall velocity of drop
$v_u$: rise velocity of drop
$E$: electric field strength in e. s. u.
$q$: electric charge of drop in e. s. u.

Using equation (1) and (2), eliminating $a$, and replacing $v_d$ and $v_u$ with $t_d$ and $t_u$ according to $v_d=l/t_d$ and $v_u=l/t_u$, we get

$$t_u=\frac{(K/q)\cdot t_d}{(t_d)^{3/2}-K/q}. \tag{3}$$

where

$$K=9\sqrt{2}\,\frac{\pi\eta^{3/2}\cdot l^{3/2}}{E(\sigma-\rho)^{1/2}\cdot g^{1/2}}, \qquad E=\frac{V}{300d},$$

where $l$: fall and rise distance of drop (=0.082 cm)
$t_d$: fall time through distance $l$
$t_u$: rise time through distance $l$
$V$: applied voltage in volt
$d$: distance between two electrodes (=0.636 cm)

Equation (3) represents an algebraical curve with two asymptoes; $t_u=0$ and $t_d=(K/q)^{2/3}$.

As $E$ is constant for a given oil, a curve corresponds to a value of $q$.

The curves are shown in Fig. 3, 4 ··· and 12.

In these figures, magnitudes of the electric charge on the oil drops can be roughly estimated by comparing the curves with plotted points.

It follows from the results of measurement that;

(1) The coefficient of viscosity of the oil does not give any definite effect to charging of oil drops of either group. Corvus oil in group A is the only exception.

(2) There is a definite difference in larger electric charge assumed by the drops of oils of two groups. Namely, the larger electric charge of drop of oil of group A is less than 100 e, while that of oil of group B is about 400 e. The definite difference in charge could be attributed to either the difference in chemical structures of the main constituent of the oils, or the small amount of some organic substances which are added to the oils of group B to make the quality of the oil

better.

(3) The results of the measurement of the electric charge of oil drop under different humidity, at different temperature of oil, and at different pressure of spraying oil showed no definite change in the charge of drop. So the results of the measurement for this part are not especially given in this paper.

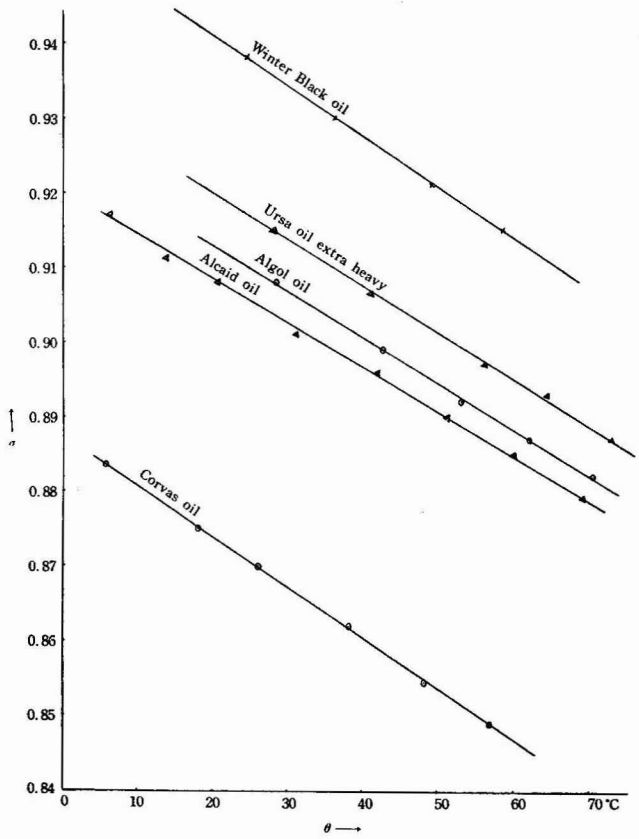


Fig. 1. Density of oils of group A vs. tempe.

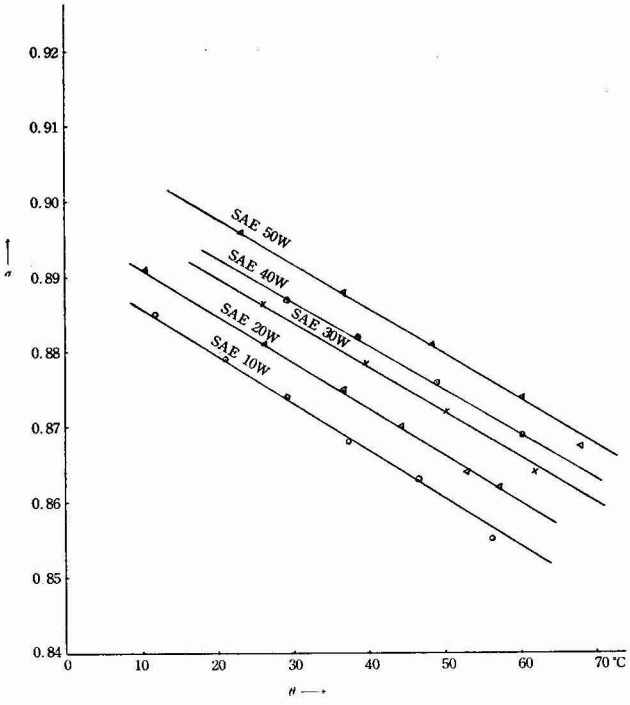


Fig. 2. Density of oils of group B vs. temp.

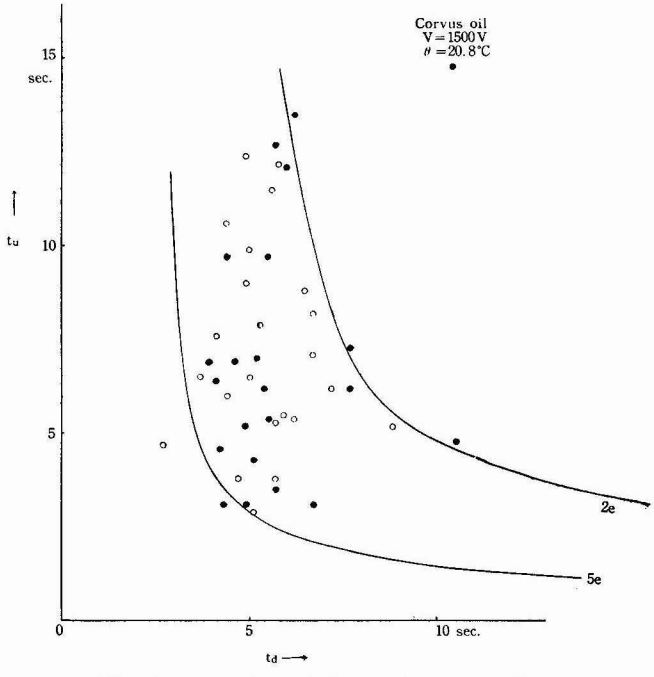


Fig. 3. $t_d$ and $t_u$ of drops of corvus oil
○; Positively charged drops.
●; Negatively charged drops.

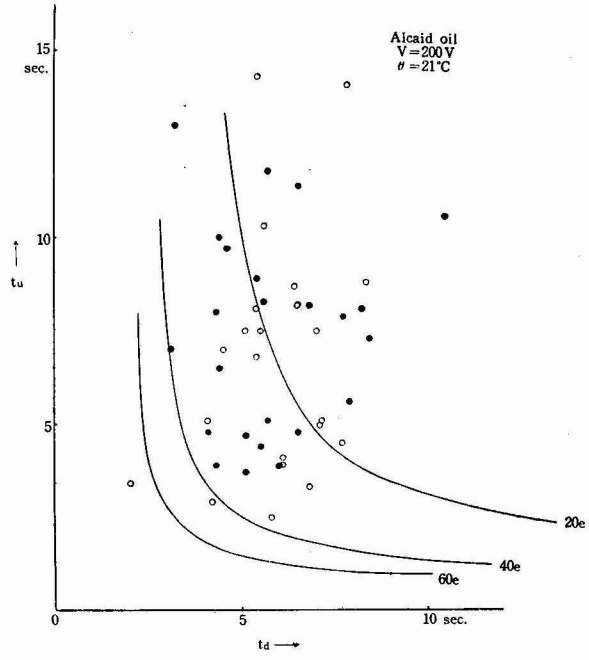


Fig. 4. $t_d$ and $t_u$ of Alcaid oil
○; Positively charged drops.
●; Negatively charged drops.

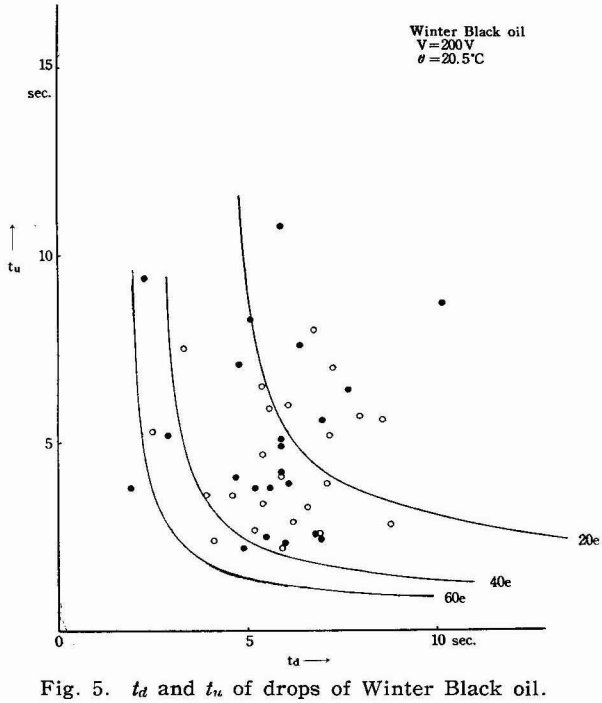


Fig. 5. $t_d$ and $t_u$ of drops of Winter Black oil.
○; Positively charged drops.
●; Negatively charged drops.

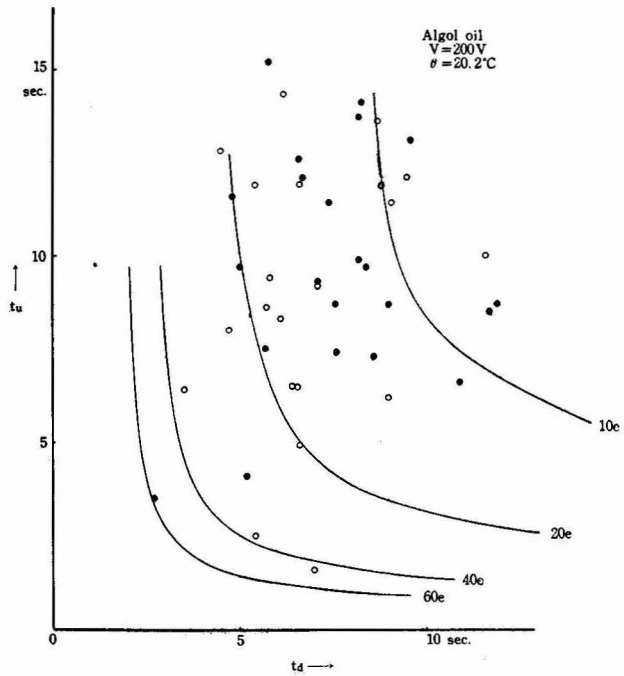


Fig. 6. $t_d$ and $t_u$ of drops of Algol oil.
○; Positively charged drops.
●; Negatively charged drops.

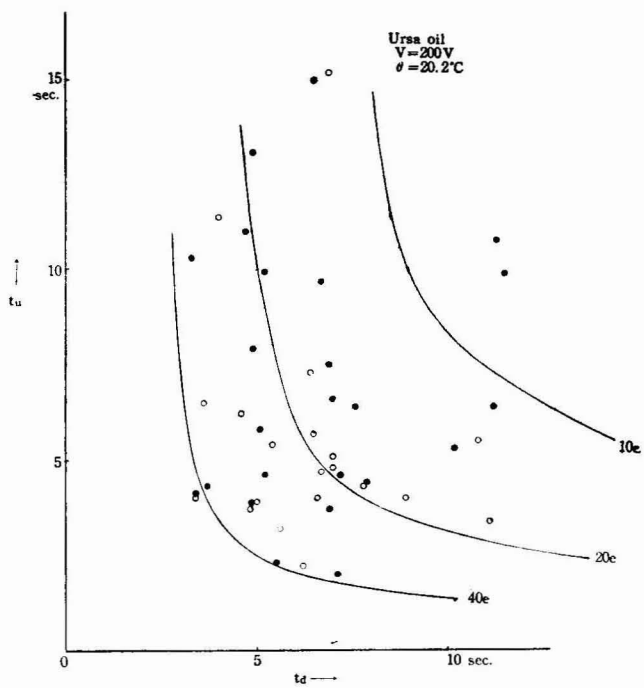


Fig. 7. $t_d$ and $t_u$ of drops of Ursa oil.
○; Positively charged drops.
●; Negatively charged drops.

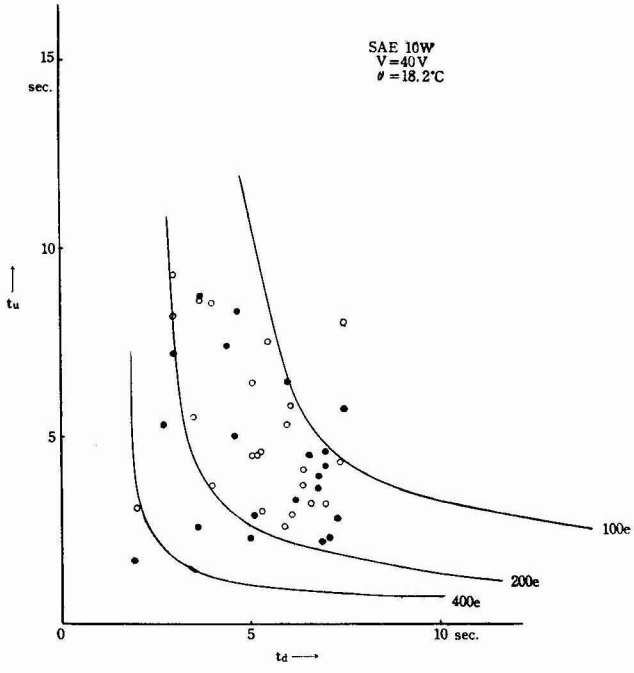


Fig. 8. $t_d$ and $t_u$ of drops of SAE 10 W.
○; Positively charged drops.
●; Negatively charged drops.

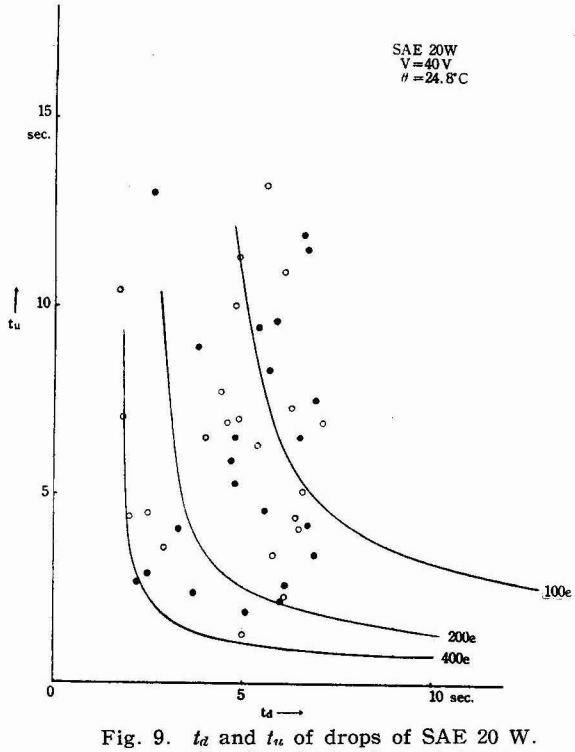


Fig. 9. $t_d$ and $t_u$ of drops of SAE 20 W.
○; Positively charged drops.
●; Negatively charged drops.

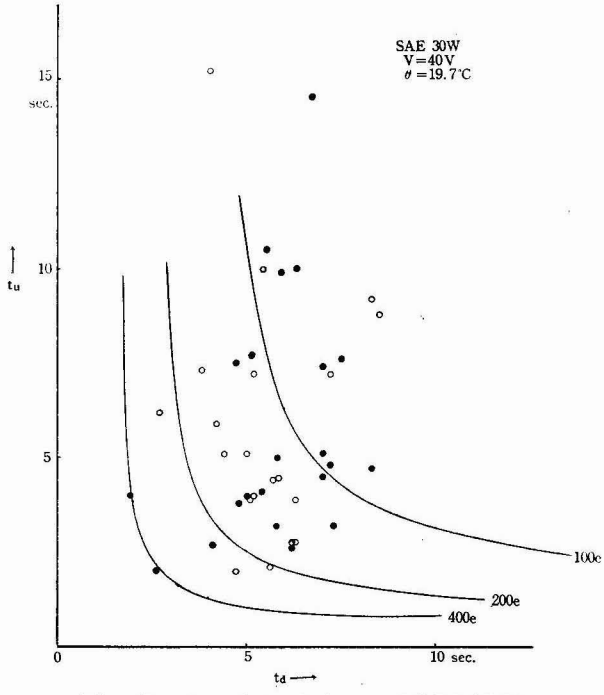


Fig. 10. $t_d$ and $t_u$ of drops of SAE 30 W.
○; Positively charged drops.
●; Negatively charged drops.

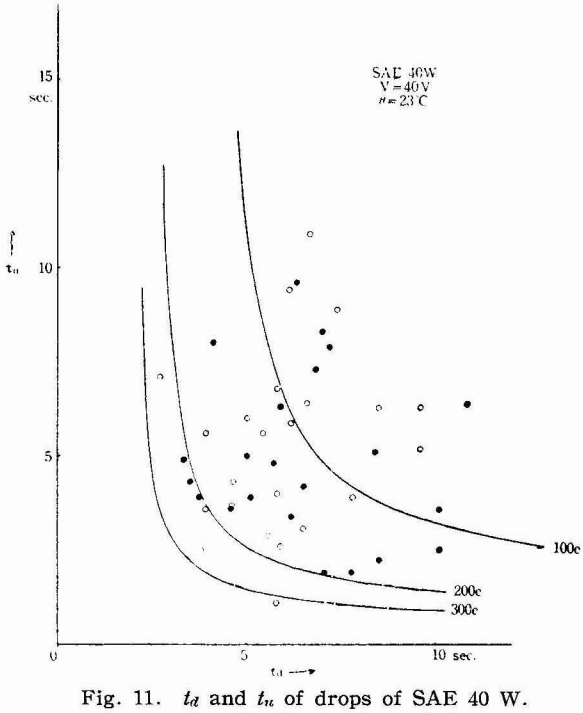


Fig. 11. $t_d$ and $t_u$ of drops of SAE 40 W.
○; Positively charged drops.
●; Negatively charged drops.

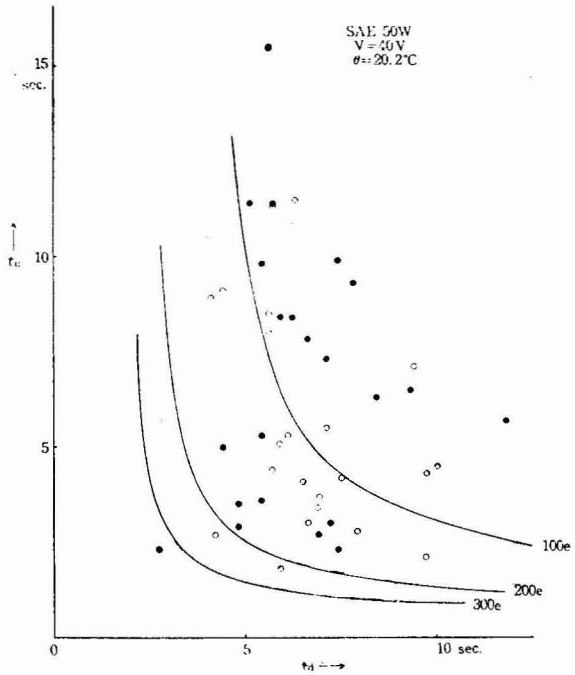


Fig. 12. $t_d$ and $t_u$ of drops of SAE 50 W.
○; Positively charged drops.
●; Negatively charged drops.

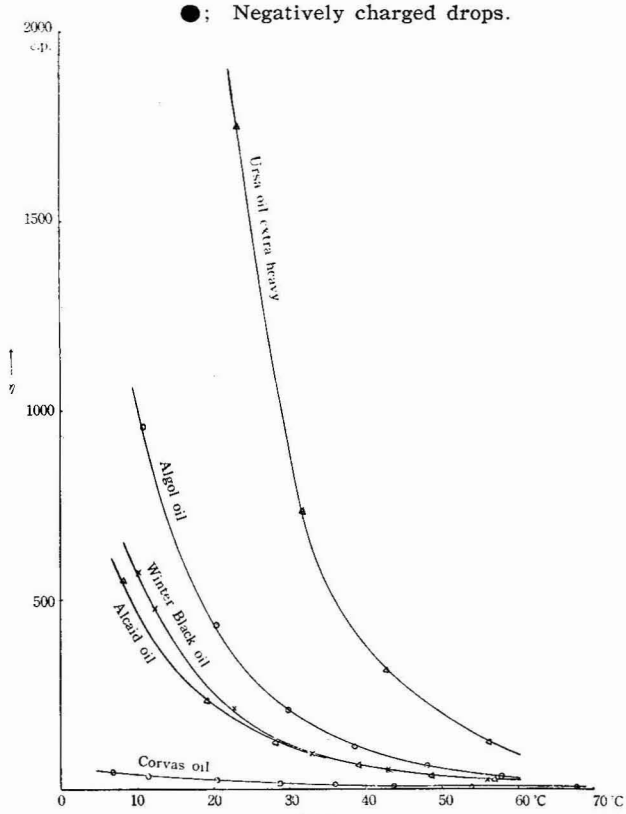


Fig. 13. Coefficient of viscosity of oils of group A vs. temp.

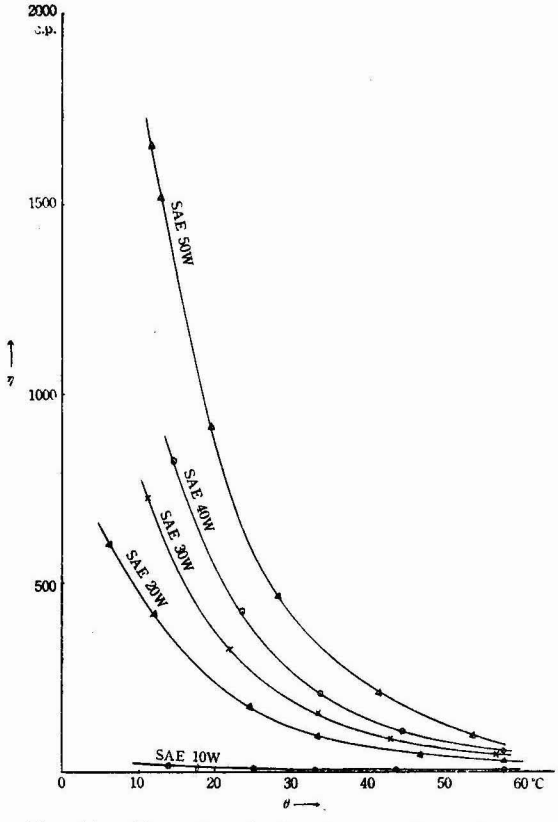


Fig. 14. Viscosity of oils of group B vs. temp.

## 5. Acknowledgement

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## Reference

(1) K. Miyagi: Bull Arts and Sci. Div., Ryukyu Univ. (Math. and Nat. Sci.) 6 (1963) 3.