



FIG. 2. Calibration curve of viscometer for 10° angle of tilt.

Hersey<sup>1, 3</sup> and his method was followed in computing the absolute viscosities in poises. Since the roll times as measured are only relative, the viscometer must be calibrated by observing the roll times with liquids of known viscosity. This involves plotting a function  $ST$  against the function  $U/S$ .  $T$  is the roll time,  $U$  the kinematic viscosity, and  $S$  is a function of density equal to  $(\rho_0/\rho - 1)^{1/2}$  when  $\rho_0$  is the density of the steel of the ball and  $\rho$  is the density of the oils in grams per cubic centimeter. Fig. 2 shows the calibration curve for the viscometer, when the angle of tilt is about 10°.

Writing the relation  $ST = f(U/S)$  (1)

the Eq. (1) becomes  $ST = 118(U/S)$  (2)

for long roll times. Solving (2) for the viscosity ( $\mu = \rho U$ )

$$\mu = ((7.36 - \rho)/118)T \quad (3)$$

on setting  $T_1 = 118/(7.36 - \rho)$  where  $T_1$  represents the roll time in seconds for a viscosity of one poise

$$\mu = T/T_1 \quad (4)$$

Thus the computation of viscosity is done in one of two ways: if the roll time is short (region where the calibration curve departs from linearity)  $U$  of Eq. (1) is solved for by referring directly to the curve; if the roll time is long (region where  $ST$  varies linearly with  $U/S$ ), Eq. (3) can be used directly to give  $\mu$ . The values of  $\rho$  were obtained by interpolating the pressure-volume-temperature data of Dow;<sup>9</sup> since the change of volume of oils with pressure is not a strong function of composition, it is sufficiently accurate to use the  $P$ - $V$ - $T$  data of Pennsylvania oil interpolated for 100°, 130°, and 210.2°F.

There are, however, various corrections to be made in applying the formulae. These have been discussed by Hersey. In the present case they reduce to two, namely the change in length of path due to pressure, and the initial acceleration of the ball. The first correction involves the change of length of the viscometer, change of diameter of the ball, and the change of position of the electrical contacts. The first two are negligible in these experiments but the effect of change of position of the contacts is appreciable. The correction was made by observing the change of length of the external stem of one of the end plugs of the viscometer for a certain pressure change. It was observed that at a pressure of 13,500 lb./in.<sup>2</sup> the stem was displaced 0.025

TABLE I. Data for calibration of viscometer; the functions  $ST$  and  $U/S$ .

LIQUID	$ST$	$U/S$
Kerosene	4.69	0.0055
Merusol	20.8	.173
Oil, S.A.E. 10	17.5	.143
" " 20	34.6	.293
" " 30	46.8	.390
" " 40	62.5	.467

inch, which amounts to a correction of 0.05 inch for both contacts. This negative correction was assumed to be linear with pressure. The second correction, that for the initial acceleration, was computed from Hersey's formula

$$\Delta T/T_0 = 0.21 \{1 - (1 - 8/KT_0^2)^{1/2}\}.$$

$T_0$  is the roll time and  $K$  is a constant equal to 8.3. This correction is also negative, amounting to 16.8 percent when the roll time is 1 sec. but vanishing if the roll time exceeds 10 seconds.

Table I calibration mineral oil viscosity S No. 40, re liquids. The these liqu by Mr. C. Laboratory carefully ch viscometers the ball and were determ weighing in Table II derived by graphically computed v smooth cur then readir correspondi of pressure. data are in and the roll former am latter, exp viscosity, n roll time is of estimati nations is computed v T

PRESSURE (lb./

14.2  
1000  
2000  
3000  
4000  
5000  
6000  
7000  
8000  
9000  
10 × 10<sup>5</sup>  
12  
14  
16  
18  
20  
22