# ON THE EXPERIMENTAL STUDY OF THE EFFECT OF TRANSVERSE h.f. ELECTRIC FIELD ON THE VISCOSITY OF LIQUIDS*

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**ABSTRACT.** The paper contains the description of an apparatus designed by the present authors to study the effect of high-frequency transverse electric field on the rate of flow of liquids through narrow channels. The apparatus is suitable for liquids having fairly low conductivity (of the order of 10 mho or less) and for such liquids h.f. fields of the order of several kilovolts/cm. can be applied. The frequency of the h.f. field may be kept at any suitable value. The authors have used fields of the order of $10^6$ cycles/sec. Incidentally the authors have found that in case of xylene (a mixture of ortho-, para- and meta-) no change in the rate of flow is recorded for fields up to 5 kilovolts/cm and even more. In case of samples of amyl alcohol and ethyl acetate used by authors fields up to 1 kilovolt/cm. could be applied and for this field no change in their rate of flow was noted.

During past few years a large number of experimental investigations have been made to study the effect of electric field on the viscosity of liquids. Such investigations have been made with electric fields whose direction is either perpendicular or parallel to that of the flow of liquids. Though the results obtained by various workers appear to be rather conflicting with each other there are a few points on which more or less a general agreement may be observed. In the case of non-polar liquids there is no appreciable effect of either the longitudinal or transverse electric field. The longitudinal electric field does not appear to produce any effect even on polar liquids. The main controversy, therefore, centres round the different results obtained when the direction of the applied electric field is perpendicular to that of the flow of liquids. The recent experimental results of Menz (1939), Andrade (1940), and Prasad *etal*, (1941), however, reveal that even in this last case the effect is either negative or if positive appears to be influenced by the conductivity of the experimental liquids. But according to the results of Andrade conductivity as such is not the determining factor, because liquids like benzene conduct without showing any effect. Andrade further suggests that in case of some polar liquids there is a formation of space charges at the electrodes and hence an abnormal anode and kathode fall. If this be the case, the field in the body of the liquid is much less than the

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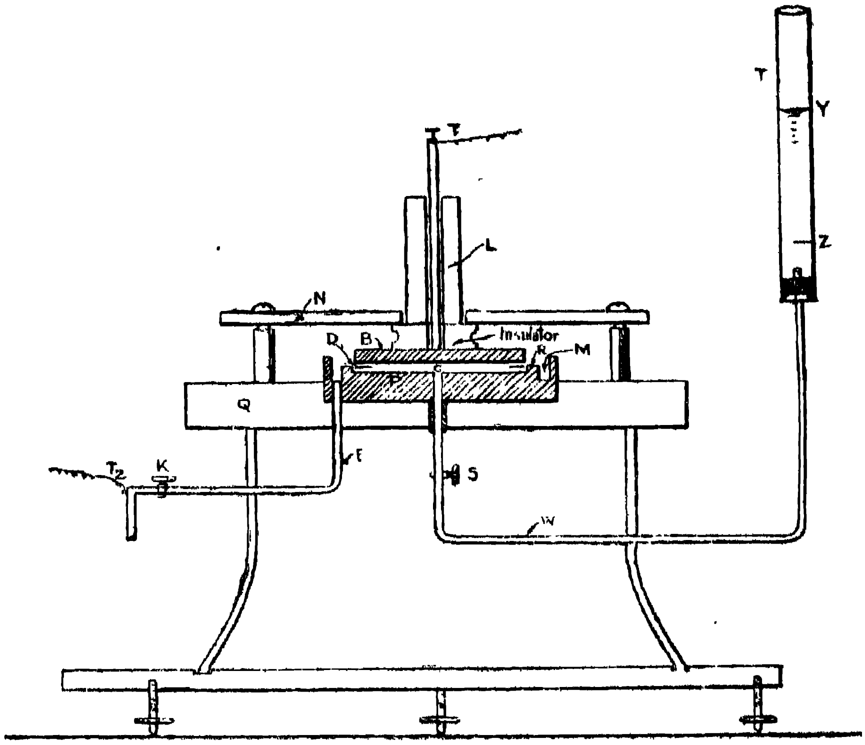


FIG. 1a

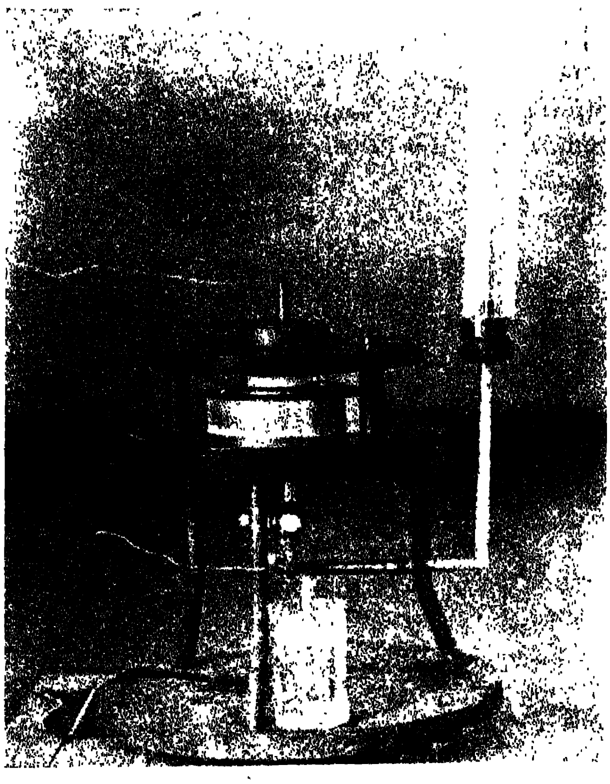

FIG. 1b

"apparent field", namely the applied difference of potential divided by difference between the two electrodes. In view of these possible disturbances the true viscosity effect should be sought with alternating frequency sufficiently high to prevent space charges at the electrodes and sufficiently low to avoid effects due to relaxation time. In the present paper an apparatus designed by the present authors has been described which is suitable for the experimental study of the effect of h.f. transverse electric field on the rate of flow of liquids having fairly low conductivity.

The main body of the apparatus is made of fine steel slab with a central circular platform P (shown in fig. 1*a*) on its upper surface, which is silvered and finely polished. There is a central hole C in the platform which is connected to the glass tube T through a brass U-tube fitted with a liquid-tight stopper S. Three small thin pieces of mica DD (thickness of the order of .003 cm.) are kept over the polished platform. The inside of the central hole and that of the U-tube is also silvered. A circular brass plate B of thickness 6 mm., polished and silvered at its lower surface, is kept over the strips DD. In order to keep the strips well pressed, a heavy ring of lead L is kept over the plate and made tight from above by three screws fitted in an upper circular plate N made of ebonite. The upper plate B is also provided with a handle A and terminal $T_1$. The central circular platform has got a rim RR about 1 mm. high and an annular space M surrounding it. The inner diameter of the circular platform is 4.3 cm. and that of the upper plate is 3.7 cm. Thus when the latter is placed over the former, between the perimeters of the two there is a fair margin of about 3 mm. When the glass tube T is filled with a liquid, the latter forces up through the hole C, passes slowly through the narrow space between the platform and the other plate B, then trickles over the rim of the platform to the annular space and finally escapes through the opening E, which is also fitted with a liquid-tight stopper K. The steel body of the apparatus is provided with another terminal $T_2$ and rests over a thick circular ebonite plate Q. The latter is supported by three firm rigid legs which are permanently fixed to a wooden base fitted with three levelling screws. The upper and lower ebonite plates are rigidly held together with three rods screwed to them. The glass tube T at its lower end is fitted with a rubber stopper over which a layer of mercury is kept to prevent the liquid from coming into contact with the stopper. The electric field is applied between the two terminals $T_1$ and $T_2$ of the apparatus by connecting it in parallel with the oscillating condenser of a radio-frequency oscillator, the range of oscillations in the present case being $10^5$ cycles per sec. to $10^7$ cycles per sec. (The connections are shown in fig. 2). The h.f. voltage impressed between the two plates of the apparatus is measured by a Moullin voltmeter. When the experimental liquid is poured into the glass tube (stopper K being closed), it flows through the U-tube and the central hole comes slowly through the narrow space between the plate and the platform and finally passes over the rim to the annular space. The level of liquid in the glass tube gradually comes down. The time required for the level of liquid to come from a particular mark say Y to another say Z may be noted with the help of a travelling telescope and a stop watch. It will be seen from the experimental

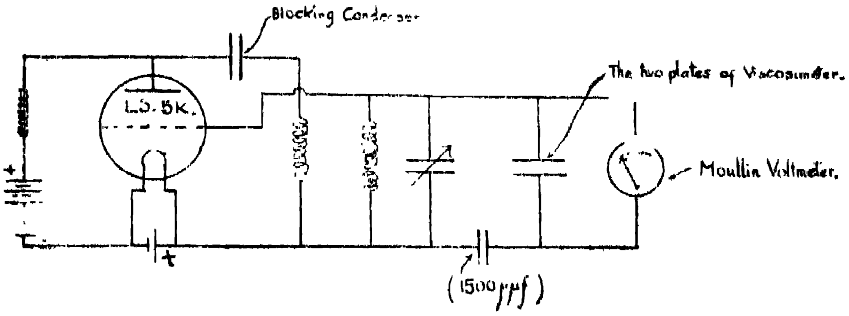


FIG. 2

data given in table 1, that the time of flow of liquid remains fairly constant, the maximum variations being not more than 3 seconds even when the time of flow exceeds 15 minutes. Provided the experimental liquid is pure, throughout the flow over such long periods, the h.f. voltage as measured by Moullin voltmeter remains practically constant. The capacity of the condenser formed by the plate B and the platform P is of the order of a few hundreds of $\mu\mu F$ and hence suitable for introduction into h.f. oscillators of such frequencies which satisfy the condition of being sufficiently high to prevent space charges at the electrodes and sufficiently low to avoid effects due to relaxation time. In view of small separation between the plates, the effective value of the electric field acting on the liquid passing through the channel may be made considerable without the necessity of applying a field of a high order between the plates. Fig. 1*b* gives a general view of the apparatus.

## EXPERIMENTAL RESULTS AND CONCLUSION

In table 1 are given the experimental data for liquids xylene (a mixture of ortho-, para- and meta-), amyl alcohol and ethyl acetate. The experimental values for the conductivity of the same samples of liquids as used for flow are also given in the last column.

The experimental data given in the above table clearly show that in the present apparatus the time of flow of the given liquid remains constant within three or four seconds even if the total time of flow extends up to 15 minutes or more. If the effect of the h.f. electric field is, therefore, to alter the rate of flow of a liquid even to a small extent it can be easily detected in the present arrangement. The only drawback in this design is that liquids not having a fairly low conductivity cannot be used. But this defect will be perhaps inevitable in every design. The fact that in the case of liquids having conductivity of the order of $10^{7}$ mho fields up to 5 kv./cm. or even more can be obtained, shows that if after repeated distillations samples of liquids having a conductivity of a much less order be used, a much higher field may be applied and conclusive results obtained.

From the results already obtained by the present authors it may be seen that the effect of the h.f. field on the viscosity of xylene (a mixture of ortho-, para- and meta-) is negative for the fields up to the order mentioned above. In this case fields of a much higher value were actually applied but could not be

TABLE I

| Liquid | Applied field volts/cm. | Frequency in cycles per sec. | Time of flow without field | Time of flow with field | Conductivity in (mho) |
|---|---|---|---|---|---|
| Xylene | 5000 | $1.11 \times 10^8$ | 617 sec. | 618 sec. | $6.7 \times 10^{-8}$ |
| | ,, | ,, | 618 ,, | 619 ,, | |
| | ,, | ,, | 619 ,, | 620 ,, | |
| | 2000 | ,, | 616 ,, | 618 ,, | |
| | ,, | ,, | 618 ,, | 617 ,, | |
| | ,, | ,, | 617 ,, | 619 ,, | |
| | 5000 | $8.1 \times 10^6$ | 385 ,, | 386 ,, | |
| | ,, | ,, | 386 ,, | 387 ,, | |
| | ,, | ,, | 387 ,, | 388 ,, | |
| | 3000 | ,, | 385 ,, | 386 ,, | |
| | ,, | ,, | 387 ,, | 386 ,, | |
| | ,, | ,, | 388 ,, | 387 ,, | |
| | 5000 | $2.70 \times 10^6$ | 356 ,, | 356 ,, | |
| | ,, | ,, | 357 ,, | 357 ,, | |
| | ,, | ,, | 358 ,, | 359 ,, | |
| | 3000 | ,, | 356 ,, | 355 ,, | |
| | ,, | ,, | 357 ,, | 358 ,, | |
| | ,, | ,, | 358 ,, | 358 ,, | |
| Amyl alcohol | 1000 | $1.11 \times 10^6$ | 1680 ,, | 1681 ,, | $3.16 \times 10^{-6}$ |
| | ,, | ,, | 1681 ,, | 1682 ,, | |
| | ,, | ,, | 1683 ,, | 1681 ,, | |
| Ethyl acetate | 1000 | ,, | 936 ,, | 936 ,, | $2.45 \times 10^{-6}$ |
| | ,, | ,, | 937 ,, | 938 ,, | |
| | ,, | ,, | 938 ,, | 938 ,, | |

measured due to the absence of a voltmeter of suitable range. For the samples of amyl alcohol and ethyl acetate used by the authors h.f. fields only up to 1 Kv./cm. could be applied. It may be added that the voltage of the high frequency can be increased also by using a more powerful oscillating circuit.

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