Electric Conductivity of Flowing Water And A Mothod of Measuring Instantaneous Water Discharge And Velocity

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0. Electric current at a constant voltage between a pair of electrodes fixed in water varies as the water and the electrodes are in a relative motion.

A new method of measuring discharge or velocity has been developed and has proved excellent sensitivity, quick indication and applicability to very wide range of discharge as well as of velocity of water or of electrodes relative to each other. The influences of water temperature and ion concentration are cancelled on diagrams prepared for the geometrical condition of each set consisting of a guide pipe, a pair of electrodes and a thermometer.

By some properties of the phenomenon, the writers are convinced that it can be interpreted by the movement of ions in water and carried out some calculations to obtain characteristic curves which proved a very close similarity to what had been observed in their experiments. As a result of calculation, the conduc-tivity variation was understood to be caused by conductivity difference between the water itself and the water domain thru which ions from electrodes' surfaces move, which suggests us a view of so called transportation number.

1. Apparatus and Measurement.

Fig. 1. shows general conceptien of apparatus used. Water runs thru AB and its temperature is read on the thermometer T. V and mA are a voltmeter and a milliammeter, respectively. Beside the wiring shown in Fig. 1. I, some other circuits were connected to a. c., supply and to an elctrolysis vessel as a standard with both d. c. and a. c.

The electrodes were made of every available kind of wire into various shapes with their surfaces coated with glass for insulation but small parts at the ends for conduction. Pt, Nichrom and other metals prove excellent properties as electrodes letting bubbles appearing on the surfaces slip off easily before they grow large, while Cu, Fe and others are apt to keep bubbles on their surfaces and cause fluctuations on milliammeter when water flows slowly. Moreover, as d. c. prefered to attain a good sensitivity, the latter may not be used for a long time making green or yellow dirty stuff around the electrodes as a result of electrolysis.

A Glass pipe with a pair ef elctrodes was connected to water supply with rubber tube about 3 cm in diameter and about 3 meters in length. The water discharge was measured with some messcylinders and a stop-watch. Because of the small capacity of our water supply equipment, dischare Q was found over 100cc/sec only when the pipes over 8mm in diameter were used.

The water temperature was measured at A with a thermometer with marks at every 0. 1 deg. C on it and was observed thru a microscope eyepiece for magnify-ing and a telescope for elliminating parallax, which enabled us to read water temperature up to 0.01 deg. C easily.

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Another thermometer was used for calibration of temperature difference between A and B. In practical applications, a thermometer may be fixed just behind the electrodes. After every series of measurements followed a comparison of water temperatures at A and B under exactiy idential condition in order to elliminate water temperature change. The water was heated or cooled directly or indirectiy with gas flame or ice in order to find out the influence of water temperature. As this method, however, proved little effect for great discharge, graduai temperature variation of supplied water caused by temperature difference under ground and in the room was made use of by suddenly opening and closing the stop cock and those for leakage. (Fig.1.2.)

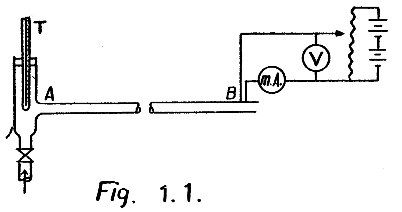


Fig. 1.1.

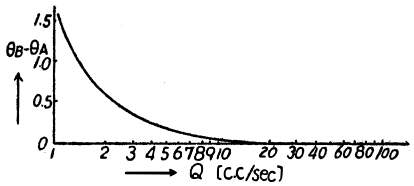


Fig 1.2.

2. How to Draw Reffering Curves.

The electric current j at a constant voltage applied to the electrodes and the voltage V to maintain a constant electric current thru water show some irregularities as they are measured. The irregularities were found to have been caused by irregular temperature variation as well as by ion concentration variation which occurs rather seldom in practical cases.

Influence of Water Temperature.

About 1.8%/deg. C of conductivty change is observed with supplied water. Water temperature varies from time to time if discharge Q be kept constant and, moreover, discharge variation causes' another temperature variation even if the reservoir be set in the same room. Since both j at constant V and V at constant j are affected by water tempersture, proper considerations should be paid in case of paractical application.

Fig. 2.1 shows procedures of drawing j and V versus log Q for a certain constant temperature. All the data are plotted on (a) after they are obtained in such a way that Q be kept constant and checked every time j or V and Q are measured at several temperatures during its gradual change within the range likely to take place in practical application, and then approximate curves at constant temperatures are drawn to let $\delta j / \delta \log Q$ or $\delta V / \delta \log Q$ be estimated. The effect of small discharge fluctuations ΔQ caused by the difficulty to keep Q strictly constant is reduced on (b) making use of $\delta j / \delta \log Q$ or $\delta V / \delta \log Q$ to give interpolation curves for the water temperature θ at constant Q, which in turn give the desired curves on (a′). Curves (a′) thus obatained are accurate enough for application with their points all falling within the breadth of curves.

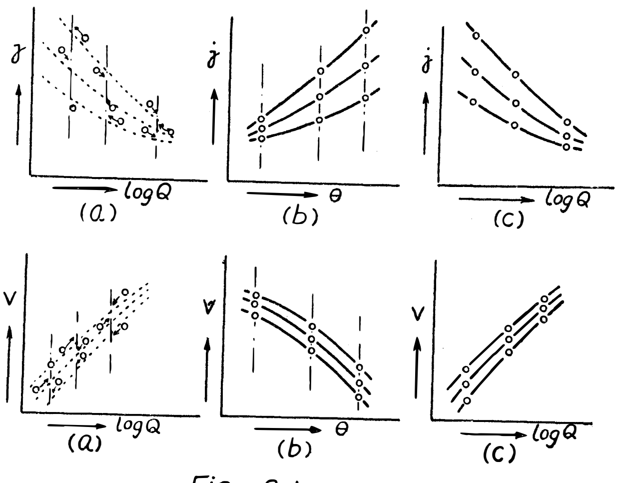
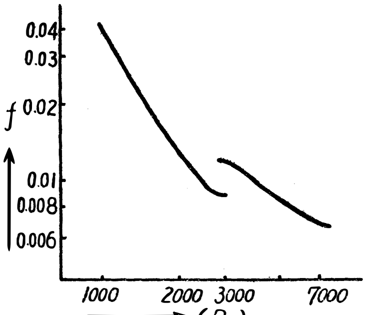


Fig. 2.1

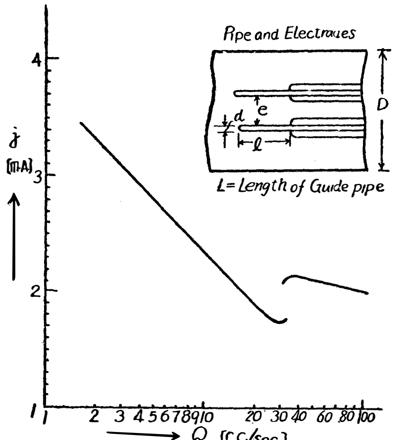
3. Characteristic Curves.

The figures 3.1, 3.2 and 3.3 show how j at constant V, V at constant j and the Fanning's friction factor f depend upon the water discharge when measured in a glass pipe. Both characteristic curves of j and V are the final results drawn after the procedures described above. The points of discontinuity on the curves j and V are the transitional points of laminer and turbulent flows whose critical Reynolds' numbers coincide exactly that of f. In fact, vibrations are felt on the pipes when Q is over the critical value. They are created at the connecting point of the glass pipe and reach the other end of the pipe when Q is great and diminishes within a certain distance from the point of connection when Q is below the critical value. The milliammeter as well as the water flowing out of the pipe fluctuate when Q is just a little below the critical value and the identity of their fluctuation periodes suggests that the fluctuations are due to so called plugging effect of turblulent blocks in the water pipe. Below and above the critical points, the milliammeter stays strictly steadsy and works as a discharge meter of almost constant relative sensitivity as high as to let 2% of discharge varia-tion be detected thruout the measurable discharge range but a small part of critical Reynolds' number.



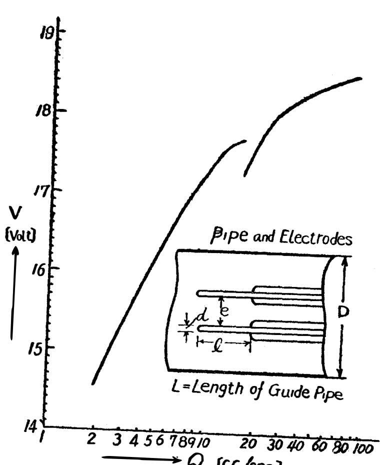
D = 7m.m. L = 1500m.m. Glass Tube
θ = 18°C

Fig. 3.3.



V=30[Volt] D=7m.m. L=1155m.m. d=0.41m.m.
ℓ=4.6m.m e=0.73m.m. θ=17°C
Glass pipe. Pt. Electrodes.

Fig. 3.1.



γ=3 (m.A.) D=7m.m L=1500m.m d=0.7m.m.
ℓ=4.0m.m. e=0.7m.m. θ=18°C
Glass pipe Pt. Electrodes

Fig. 3.2