

INVESTIGATION OF ULTRASONIC VELOCITIES IN LIQUIDS BY A NEW METHOD

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1. INTRODUCTION

SEVERAL authors¹⁻⁴ have investigated the ultrasonic velocities in liquids by employing various methods of which the latest liquid film method⁵⁻⁶ offers many advantages. In a recent communication⁷ from this laboratory we have reported a simple and new method for determining ultrasonic velocities in liquids. In this method ultrasonic waves generated by a piezoelectric plate are communicated into a column of liquid enclosed between the radiating surface of the crystal and a reflector set parallel to it at a distance and the diffraction pattern is observed in the usual Debye-Sears arrangement. The intensity of the diffraction orders is found to change periodically as the frequency of the oscillator is varied from one end of the breadth of resonance to the other. Pronounced maxima in the intensity of the diffraction pattern are observed when a stationary ultrasonic grating is formed in the liquid column, which happens only at those frequencies for which the path length is an integral multiple of half the wavelength of the sound wave. In other words, diffraction maxima are observed when the liquid column is thrown into resonance at one of its higher harmonics. The frequency interval for any two consecutive positions of diffraction maxima gives the fundamental frequency of the liquid column which enables us to calculate the velocity of ultrasonic waves in the liquid under investigation in the usual manner.

2. EXPERIMENTAL DETAILS

A special type of crystal holder shown in Fig. 1 has been designed to suit this method. The crystal holder consists of two brass sheets A of 3" × 3" × 1/5" size the top surfaces of which are ground plane. Four bolts B are fixed to the bottom plate at the four corners and are loaded with steel springs C. Knurled nuts D are provided for the purpose of adjusting the top surfaces of both the plates to be parallel. A quartz plate or wedge rests on a 1 cm.² slot E provided in the centre of the top plate so as to be in direct contact with the liquid under investigation. The crystal is clamped in position by a phosphorbronze strip G insulated from the body of the crystal holder by the amphenol polysterene strip H. The body of the crystal holder

and the phosphorbronze strip serve as the two electrodes for connecting the output from a Hartley shunt fed oscillator. A side hole I is provided to

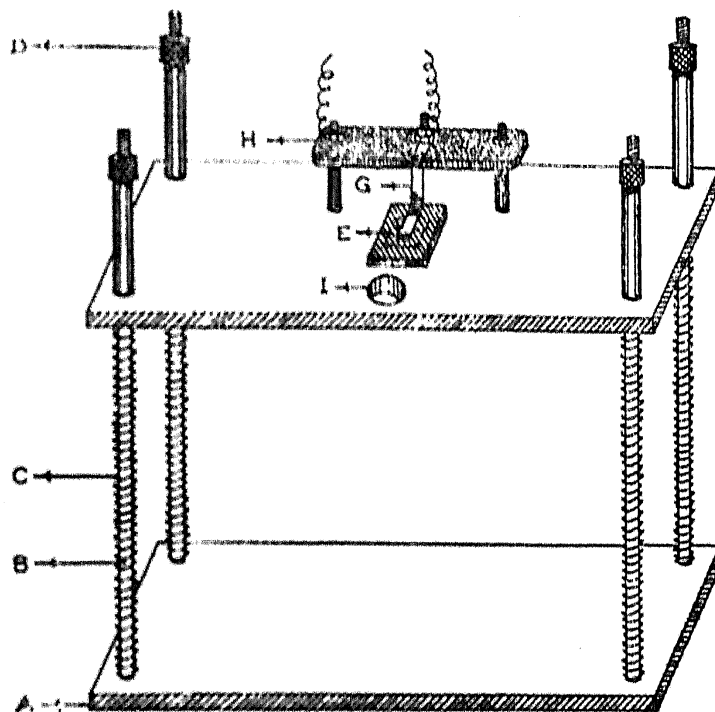


FIG. 1

facilitate addition or removal of liquid from the cell so as to be at the desired level. The complete crystal holder is now inserted snugly into a glass cell containing the liquid under investigation. The usual Debye-Sears diffraction arrangement is set up and observations of the diffraction patterns are made visually.

Before introducing the liquid in the cell, it is placed on a levelling stand and by using a microscope of least count 0.001 cm., the top surfaces of both the plates are adjusted to be parallel to within 2 vernier divisions. The cell is now filled with the liquid under investigation to the desired level taking care to see that there is no air bubble beneath the crystal or wedge. In order to obtain intense diffraction spectra the cell is now tilted by adjusting the three screws of the levelling stand such that the sound wave front is parallel to the incident light beam. Since the fundamental frequency is of the order of 0.01 Mc/sec. for the lengths of 3 to 5 cm. of the liquid column used in the investigation, the diffraction maxima are found to be very closely spaced and it will be very difficult to set the frequency of the oscillator for any diffraction maxima. Hence it is found necessary to attach a slow motion gear having a reduction ratio of 1/50 to the variable condenser of the Hartley

oscillator which enables a fine variation of its frequency. Though a crystal having a reasonably wide breadth of resonance can be used as a source of ultrasonic radiation, it is found advantageous to use an X-cut quartz wedge of 1 to 3.5 Mc/sec. range because it gives a wider frequency range having almost constant output and hence more number of diffraction maxima. In this investigation about 150 to 200 diffraction maxima are observed in the frequency range of the wedge employed. In order to enable rapid determination of velocities, frequencies corresponding to the diffraction maxima at every interval of 50 maxima are measured using a BC-221 frequency meter having an accuracy 0.02 per cent. Thus the error involved in the frequency determination due to visual estimation of diffraction maxima is considerably minimised because of the large number of maxima observed. The average frequency interval Δf for every two consecutive maxima is thus obtained with fairly high accuracy (0.02 per cent.) and the velocity is calculated employing the usual formula

$$V = 2L \times \Delta f,$$

where L is the length of the liquid column which is measured to within 0.05 per cent. accuracy.

3. RESULTS

To illustrate the method of obtaining the fundamental frequency, measurements of the frequencies for diffraction maxima taken at every consecutive interval of ten maxima are presented in Table I.

TABLE I

Liquid — Xylol.

Length of the liquid column $L = 3.585$ cm.

Temperature of the liquid $T = 30^\circ$ C.

Frequencies for intervals of ten diffraction maxima Mc./sec.	Frequency differences for ten diffraction maxima Mc./sec.
1.212	
1.396	0.184
1.578	0.182
1.762	0.184
1.942	0.180
2.128	0.186
2.312	0.184
2.494	0.182
2.678	0.184
2.860	0.182
3.046	0.186
3.230	0.184

Average fundamental frequency $\Delta f = 18.35$ Kc./sec. Taking the fundamental frequency thus obtained the velocity of ultrasonic waves in xylol as calculated comes out as 1316 m./sec.

Thus it can be seen that by taking a large number of maxima, the error introduced in the determination of the fundamental frequency of the liquid column is minimised.

Investigations have been made to see if there is any error introduced in velocity measurements due to size effect. For this the top plate of the crystal holder is set for different heights from the reflector by loading the bolts with suitable lengths of steel springs and the ultrasonic velocity is determined in xylol for different path lengths of the liquid column and it is found that there is no change in velocity with the change of the length of the liquid column in the range of the lengths investigated. Perhaps this may be due to the fact that plane waves are set up in the liquid column since the area of the radiating surface of the crystal (1 cm.²) is much higher when compared to the wavelength of the sound waves employed.

To show the applicability of this method the ultrasonic velocities are determined in about ten commonly available liquids. The experimental results are given in Table II along with comparison values obtained by other methods.

TABLE II

Length of the liquid column $L = 3.718$ cm.
Temperature of the liquid $T = 30^\circ$ C.

Liquid	Average 50 Δf in Mc./sec.	Ultrasonic velocity determined m./sec.	Diffraction method by Willard ⁸ Temp. 23° C.-27° C.	Pulse method ⁴
Water	1.020	1517	1500
Benzene	0.875	1301	1295	1382 (7.5° C.) 1312 (21.8° C.)
Xylol	0.885	1316	1325
Nitro-Benzene	0.975	1450	1490	1518 (7.5° C.) 1462 (23.5° C.)
Chloroform	0.666	990	995
Ethyl-alcohol	0.805	1199	1150	1246 (2° C.)
Acetone	0.798	1187	1170
Carbon tetrachloride	0.620	922	930	924 (23.5° C.)
Toluene	0.870	1294	1300
Ethyl-acetate	0.764	1136	1145	1145 (24.3° C.)

It can be seen that there is good agreement between the velocities determined by this method with those reported by the other methods.

4. DISCUSSION

In view of the high frequencies employed in the investigation and the comparatively large size of the dimensions of the cell no corrections need be applied for the observations thereby making the calculations much simpler. The main advantage of this method is that it combines the simplicity of the diffraction method with the accuracy of the interferometer method. High accuracy in the velocity measurements can be achieved in this method by using a precision wavemeter and by measuring the length of the liquid column accurately. A precision thermostat to control the temperature of the liquid is also necessary for attaining such high accuracy.

Though this method is simple, accurate and rapid, it is limited to transparent liquids. The method is equally applicable for solids upto higher frequencies than in the case of liquids. An improved crystal holder is being developed for extending this method for the study of acid and corrosive liquids.

5. SUMMARY

The principle and the experimental details of the new method of determining ultrasonic velocities in transparent liquids along with a brief description of the crystal holder designed to suit this method are given. Ultrasonic velocities determined for about ten common liquids are tabulated along with those obtained previously by different methods. The main features of this method are briefly discussed.

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