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# A NEW TECHNIQUE FOR DETERMINING ULTRA-SONIC VELOCITIES IN LIQUIDS

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Plate VII

**ABSTRACT.** A method is developed for determining the ultra-sonic velocity in liquids by obtaining simultaneously the diffraction pattern over the entire region of the visible spectrum using white light and a spectrograph. A superposed iron-arc enables the diffracted angles to be computed for a number of standard wave-lengths. The calculation of the angle involves the determination of the focal length of the camera lens for various wavelengths with its attendant errors; but this difficulty has been overcome by obtaining on the same photographic plate the diffracted pattern from a grating, the number of lines per centimetre of which is known. Knowing in addition the ultra-sonic frequency and the ratio of the displacements due to diffraction by the grating and by the liquid a ratio constant at all wavelengths—the velocity of sound in the liquid is calculated.

Various investigators have determined the velocity of propagation of ultra-sonic waves in liquids using the diffraction of monochromatic light by a liquid in which ultra-sonic waves are generated. In all these investigations the diffraction angles are either directly measured or deduced by photographing the diffraction pattern ; in the latter case the focal length of the camera lens for the particular radiation employed should be known precisely. When the experiment is to be repeated for different optical wave-lengths, the choice of suitable filters and fresh determination of focal length become necessary. Two slightly different methods are here developed by means of which ultra-sonic velocities can be determined more precisely by obtaining a diffraction pattern for a number of wave-lengths simultaneously. The first method is to use an incandescent lamp L along with a spectrograph having two slits at right angles ; the light is focussed on to this crossed slit S (*vide* Fig. 1), and the parallel beam from the collimator passes through an optically good parallel-sided vessel V containing the liquid with the oscillating quartz-crystal on top partly immersed in the liquid. The quartz-crystal is set in vibration by connecting it across the split-stator variable condenser of the tank circuit of an oscillator employing two RCA 830 B

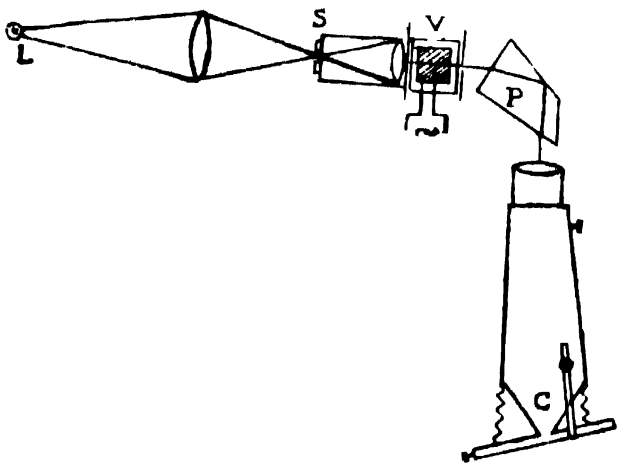


FIGURE 1

valves in push-pull. The frequency of the oscillations is measured by an absorption wave-meter built round a Muirhead Standard variable air-condenser calibrated against a precision wave-meter. The light both direct and diffracted by the liquid passes through the prism P and the spectrum is then focussed on to the photographic plate in the camera C attached to the spectrograph. After the necessary exposure, which is of the order of 1 minute in duration, the crossed slit above the ordinary slit is removed and the iron-arc is exposed for a few seconds. Fig 2 A (see plate VII) gives the result obtained by this method in toluene ; while the optical dispersion is along the length of the figure as indicated by the iron-arc spectrum, the diffraction due to the acoustic waves takes place at right angles and shows at a glance the dependence of the angle of diffraction on the wave-length of light used. A measurement of the first and higher order diffraction angles is possible at various standard wave-lengths on a cross-slide micrometer. Fig. 2 B gives the diffraction spectrum obtained with conductivity water.

A second method which while avoiding the double exposure indicated above has all the advantages of the first method is to use the iron-arc itself in place of the incandescent lamp. Fig. 2 C shows a spectrum of this type obtained with carbon tetrachloride. It must, however, be mentioned that, in consequence of the intensity variations along the length of the spectrum in this method, the diffraction angles as measured by the previous method are comparatively more accurate.

The computation of the velocity of sound from the above photographs requires a knowledge of the focal length of the camera lens at various wave-lengths. A direct determination of these focal lengths, though not difficult, involves errors of the order of 1 per cent ; it is therefore necessary to eliminate this uncertainty in precision measurements of velocity. The method adopted finally is to obtain the diffraction pattern arising from a transmission grating

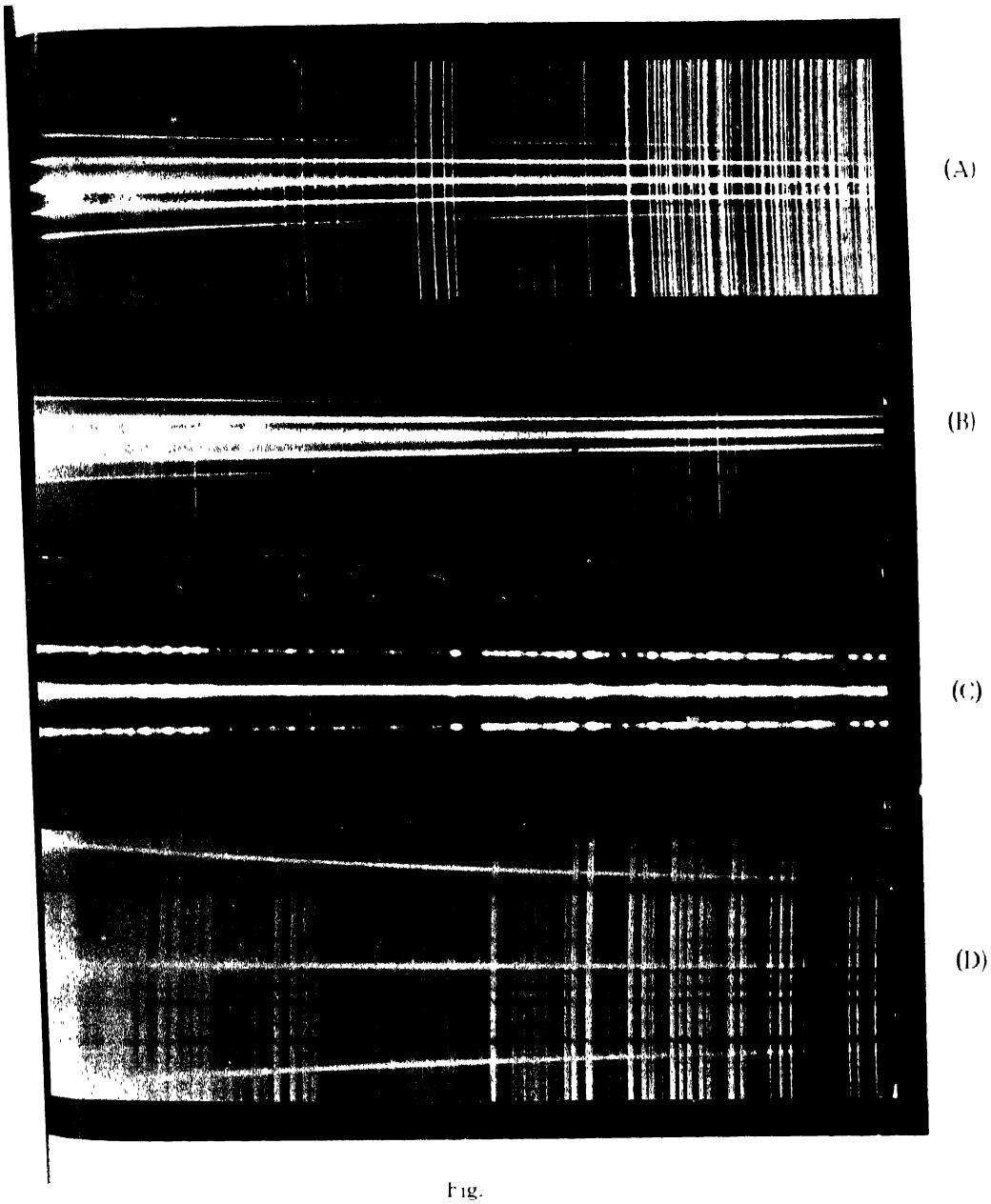


Fig.

Diffraction patterns of continuous spectra produced by ultra-sonic waves in (A) toluene, and (B) conductivity water.

(C) Diffraction pattern of iron arc spectrum by ultra-sonic waves in carbon tetrachloride.

(D) Diffraction pattern of continuous spectrum by a grating. Iron arc lines are superposed on (A), (B) and (D).

of 231·5 lines per centimetre without altering the setting of the spectrograph. The vessel containing the liquid and the quartz oscillator is removed and the grating is placed after the collimator with its lines horizontal. Using white light and a point slit (obtained by use of the crossed slit), a diffraction pattern very similar to that of the liquid is obtained ; the iron-arc spectrum is superposed on it (*vide* Fig. 2 D) If $f_\lambda$ represents the focal length of the camera lens for a wave-length $\lambda$, in the case of the liquid for the first order

$$\text{Sin } \theta = \frac{\lambda}{\Lambda} = \frac{d_l}{f_\lambda} \qquad \ldots \quad (1)$$

where $\Lambda$ is the wave-length of sound in the liquid and $d_l$ the linear shift of the first-order diffraction on the photograph at $\lambda$. At the same wave-length the shift $d_g$ in the case of the first-order diffraction in the grating spectrum is given by

$$\frac{d_g}{f_\lambda} = N\lambda \qquad \ldots \quad (2)$$

where N is the number of lines per centimetre on the grating. It follows from (1) and (2) that

$$\Lambda = \frac{1}{N} \cdot \frac{d_g}{d_l},$$

and if the ultra-sonic frequency is F Hz, the velocity of sound in the liquid

$$v = F\Lambda = \frac{F}{N} \cdot \frac{d_g}{d_l}.$$

Using toluene and an ultra-sonic frequency of $5{\cdot}060 \times 10^6$ Hz, the velocity of sound in toluene has been obtained as 1314 ± 2 metres per second at 20·4 °C.

This method is being used for the determination of ultra-sonic velocities in solutions and liquid mixtures.

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