Letters to the Editor.

[The Editor does not hold himself responsible for opinions expressed by his correspondents. Neither can he undertake to return, nor to correspond with the writers of, rejected manuscripts intended for this or any other part of NATURE. *No notice is taken of anonymous communications.]*

Oscillation in Ultrasonic Generators and Velocity of Longitudinal Vibrations in Solids at High Frequencies.

THE increasing use of piezo-electric quartz for the stabilisation of radio frequencies has promoted many investigations of the vibration of the quartz. In the last few years a mass of information has been accumulated disclosing the complexities of vibratory modes and types which may exist simultaneously in one and the same crystal plate or rod. Along with the longitudinal, flectural and torsional oscillations may exist, as well as overtones of any or of all. In this connexion mention may be made of the experiments of Cady, Tawil, Dawson, Harrison, Hund, Giebe and Schiebe, Meisener, Ny Tzi Ze, Crossley, Dye, and others.

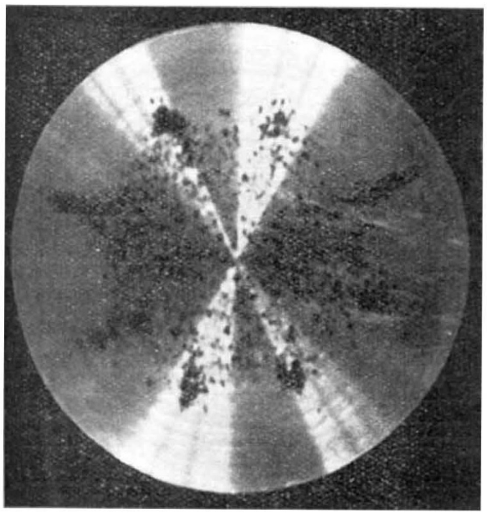

FIG. 1.

It is obvious that if the quartz is cemented to metallic plates or rods, as in ultrasonic generators, when vibrating it can transmit its motions to these bodies, and at very high frequencies, in the plates or rods themselves additional complicated oscillations may arise. A result is that often irregularities of distribution of amplitude, energy, and phase exist at the face of any ultrasonic radiator. Experimentally this was shown by the writer and assistants (*Trans. Roy. Soc. Can.*, **19**, p. 187; 1925) by surveying the energy distribution near the face of an ultrasonic generator operating in water, frequencies around 140,000 cycles per second.

A study carried out in this laboratory last year by Mr. Sproule on the behaviour of dust particles on the ends of vibrating metal rods, held vertically, and set into high frequency vibration by active quartz, revealed interesting examples of very complicated vibratory types. At certain resonant frequencies the dust arranged itself in patterns similar to some of Chladni's figures; four-, six-, eight-, and twelve-pointed stars could be obtained. At certain frequencies the particles were observed to move continuously in a circle about the centre of the section, sometimes those near the outer edge moving in a clockwise direction and those nearer the centre moving anti-clockwise. At times little whirls of dust were formed off centre. Evidently torsional vibrations and radial vibrations of other types could be set up in the rod. The photograph (Fig. 1) shows an example of an 8-pointed star so obtained. Here the rod was of duraluminum 5·1 cm. in diameter and 48·1 cm. long; frequencies of experiment ranging from 84,000 to 140,000 cycles per second.

Such work shows that very cautious judgment must be exercised when determining a resonant frequency, particularly the overtones, of any vibratory type; and mathematical computations of energy output, based on theoretical data alone, or on measurements taken near the radiator, or in any confined space in which the radiatory operates, may easily be misleading.

However, in the case of longitudinal vibrations of a rod of solid material set into high frequency oscillation by a piezo-electric plate, this method may be used, with due caution, to determine the velocity of sound in, and Young's modulus of, the rod at the frequencies of the fundamental note and lower overtones. Pierce, by setting rods of metallic alloys into longitudinal vibration by magnetostrictive action, has recently carried out very precise determinations of the same kind (*Proc. Amer. Acad. Arts and Sciences*, vol. **63**, No. 1; April 1928).

For the natural modes of vibration of a free rod, the length of the rod is equal to an integral number of half wave-lengths ($l = k\,\lambda/2$); and the velocity $V = \sqrt{E/d}$ when the rod is thin (r/l small, for a circular section). But possible corrections may have to be applied in case of varying frequency and changing ratio r/l on account of the lateral inertia of the rod. For example, Rayleigh's correction ("Theory of Sound," vol. 1, p. 252; ed. 1894) makes the velocity a function of the mode of vibration, Poisson's ratio, and (rk/l). The work last year on the velocity of ultrasound in metallic rods of different proportions, using the method of high frequency piezo-electric excitation, indicated where the correction for lateral inertia should be applied (*Science Progress*, **89**, p. 92; July 1928). For example, with duraluminum, for $(rk/l)^2 < 0{\cdot}07$, the effect of lateral inertia is inappreciable and the velocity may be computed from $V = \sqrt{E/d}$. In the range $0{\cdot}07 > (rk/l)^2 < 0{\cdot}3$, Rayleigh's expression gave the velocity approximately enough for most purposes; but for $(rk/l)^2 > 0{\cdot}3$ the types of vibration could not be distinguished, the frequency of successive modes of any type followed no apparent law, and no known formula for velocity could correctly be applied.

Frequencies of 8000 to 200,000 cycles per second here were used with duraluminum rods of length varying from 4·1 to 61 cm. and radii of section from 0·63 to 2·55 cm.

Incidentally, the method was applied to determine Young's modulus of ice, for use in association with other problems. This physical constant is most uncertain in quoted values by other methods, but by the present method of high frequency longitudinal vibration it can be easily and quickly determined. The velocity of sound in ice just below 0° C. was found to be $3{\cdot}2 \times 10^5$ cm. per second and does not vary much with changing temperature or direction in the crystal. This velocity gives a value for Young's modulus of $9{\cdot}36 \times 10^{10}$ dynes per sq. cm.

R. W. BOYLE.
D. O. SPROULE.

University of Alberta,
Nov. 17.