A NOTE ON THE EVEN, ODD AND HALF-OVERTONES IN PIEZO-ELECTRIC CRYSTAL PLATES

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1. INTRODUCTION

It is well known that the fundamental and its odd harmonics are the most easily excited frequencies when piezo-electric plates are set into oscillation. Bergmann\(^1\) has recorded that the even harmonics may also be excited by using very strong electric fields when there is want of symmetry in the plate or in the electric field. Working with quartz, he has actually measured a number of these in some cases.\(^2\) Much work does not, however, appear to have been done in the direction of investigating the conditions favourable to the appearance of even harmonics. Even more interesting is the recent observation of Parthasarathy\(^3\) and collaborators\(^4\) that the crystal plates sometimes exhibit a half fundamental and its odd overtones. The authors of this note have, for some time past, been engaged in the study of elastic constants of a number of crystals by piezo-electric methods and had accordingly occasion to study the behaviour of these plates using quartz, tourmaline and sphalerite under various conditions. Some interesting results obtained are reported here.

In this investigation, the resonance frequencies are always detected by the appearance of the Debye-Sears patterns and the measurements which are made with the help of a standard wavemeter are checked against the fringe widths of the diffraction patterns. The crystal plate rests on a horizontal annular brass ring with the lower surface touching the liquid in a glass cell and the upper electrode is a brass plate smaller in diameter than the inner diameter of the lower ring, so that there is always an asymmetric field if the crystal is unsilvered.

2. EVEN AND ODD HARMONICS

It is well known that even overtones cannot be excited in the ideal case of an infinite piezo-electric plate with the electric field constant over the entire area of the plate. In practice, on the other hand, they have been produced under certain conditions of excitation in the longitudinal vibrations of X-cut quartz plates as has been done by Bergmann,\(^5\) Parthasarathy and others.\(^4\) The usual practice in observing the Debye-Sears\(^5\) and
Lucas-Biquard effect in liquids employing a X-cut quartz plate is to silver the two faces of the crystal uniformly with the result that only the odd overtones of the longitudinal vibration come out and with great intensity. We have seen that such a procedure in the case of Z-cut tourmaline plates also gives only the odd overtones of the longitudinal vibration. If, now, the silver is removed from small areas on both sides of the crystal by nitric acid or by rubbing lightly on an abrasive surface such that silvered portions on one side, lie roughly opposite to the unsilvered portions on the other, the even overtones come out in considerable strength, while the intensity of the odd overtones falls slightly. In a 2 mm. tourmaline plate thus treated, we have found the even overtones up to the 6th as fairly strong and could detect the 8th overtone also. A 1 mm. plate with a fundamental at nearly 3.75 Mc. giving only the first and the third overtones strongly when fully silvered, gave two orders in the 2nd overtone after the above treatment. The most interesting feature of this plate is that it is excited by this method, not only in the longitudinal mode but also in a shear mode, as detected again by the appearance of a number of diffraction orders at the overtone values of a different fundamental frequency 2.29 Mc. The second overtone of this shear mode is also present in considerable intensity. The elastic constant $C_{44}$ obtained from this mode as $6.56 \times 10^{11}$ dynes per sq. cm. assuming it to be a thickness shear mode, checks very well with the constants $C_{44}$ (slightly coupled) obtained by us in a separate experiment from both X-cut and Y-cut plates of the same specimen as 6.45 and 6.51 respectively. Even when unsilvered, this 1 mm. Z-cut plate produced diffraction in both the modes and at even overtones also, but with a general loss in intensity of all the overtones of both modes. The shear mode in both the cases is always lower in intensity than the longitudinal mode.

Similarly a 2 mm. X-cut quartz plate with a fundamental at 1.44 Mc. gave the longitudinal even overtones up to the 6th, only when it was badly silvered in the above manner. Again when it was badly silvered or not silvered, a shear mode with a fundamental of 1.29 Mc. in all its overtones including even, up to the 7th overtone appeared. The constant obtained from this mode is very nearly the same as that calculated from the elastic constants of quartz determined by Atanasoff and Hart and corrected by Lawson. It will be noted here that the 5th overtone of the shear mode coincides with 9/2 times that of the longitudinal mode and could easily be mistaken for the latter one. Another 0.198 cm. quartz plate, not strictly X-cut but slightly inclined to the X-axis, has been studied when fully silvered and found to oscillate only in the odd harmonics of two modes, one longitudinal and the other a shear mode similar to that of the above quartz plate, with