$$f = 5733 \text{ c/s} \quad \text{for fundamental}$$
$$= 15749 \text{ c/s} \quad \text{for second harmonics}$$

But experimental values were 5670 and 15180 c/s respectively.

At first, differences about 10 c/s were found between natural frequencies in three directions, so it could scarcely generate three phase oscillation. After taking away this unbalance, approximately symmetrical three phase oscillation was obtained.

Observing the phase angle by Braun tube between the output of any two amplifiers of the oscillator, difference of about 120° was found in any combination.

Another experiment was carried out; namely, adhering a small mirror on the end surface of the reed and magnifying the motion of this portion by means of light lever, it was observed that the locus of light spot drew a circle on the screen.

From these two results, it was proved that three phase vibration can easily be excited by such method.

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4. Study on High Dielectric Constant Ceramics. (XXII)

The Modes of Vibration about Langevin Type $BaTiO_3$ Ceramic Virator. (2)

Kiyoshi ABE, Tetsuro TANAKA and Akira KAWABATA

(Abe Laboratory)

It was reported in part 1 (This Bulletin, **31**, 295 (1953)) that, in resonant condition, the amplitude distribution on the vibrating surface of the cylindrical Langevin type vibrator which has the resonant frequencies at about 50kc and 75kc, was measured by a small piezoelectric type pick-up which has the structure of Langevin type, and modes of vibration were presumed by the result of obtained. Recently, the acoustic directional characteristics of the vibrator were measured in the water and it was shown that these results agree well with our presumption except one for the directional characteristics on the second resonance (75kc). The measured directional characteristics has a minimum at the center and assumes the curve similar to butterfly (Fig. 4). The study were carried out in order to solve this inconsistency, which will be described here.

Method and Result of Measurement.

In Part 1, it was assumed that the vibration of Langevin type vibrator was symmetric on both sides of piezoelectric material and the measurement was carried on upper half of the vibrator. The directional characteristics about the second resonance measured in water suggest that the phase relation between the upper and lower part is opposite to each other. So in this study, phase relations and exact amplitude distribution was measured. The sample and pick-up are the same to those used in the previous study.

(1) The phase relation. It was confirmed that in both resonances the amplitude distribution was symmetric on both sides of ceramic plate, and there was no case that the both sides have opposite phase.

(2) Amplitude distribution and phase relation on curved surface. The measurement was carried on the whole surface, because it is considered that the amplitude distribution on ceramic part has an important role on the directional characteristics of vibrator. As shown in Fig. 1, it was confirmed that the amplitude on the ceramic part had clearly the opposite phase to the other parts.

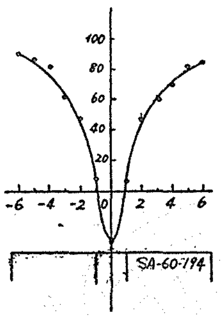

Fig. 1.

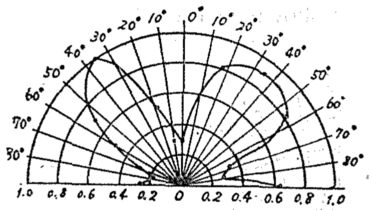

Fig. 4.

Acoustic Directional Characteristics.

The directional coefficient R is defined by the the next equation.

$$R=\frac{1}{2w_m b}\int_{-b}^{+b} w(y)\cos(\kappa y\sin\delta)\,dy \tag{1}$$

where w_m is the average value of the function $w(y)$,

$$w_m=\frac{1}{2b}\int_{-b}^{+b} w(y)\,dy \tag{2}$$

κ is $2\pi/\lambda$ and δ is the angle between the measured direction and the center axis on the searched surface. $w(y)$ is a function which has the characteristics of the curve of Fig. 1 and is approximately given by next formulas.

$$w(y)=\gamma-\frac{\beta}{\sqrt{1+\alpha\frac{y^2}{b^2}}} \tag{3}$$

$$w(y)=\gamma-\beta e^{-\alpha\frac{y^2}{b^2}} \tag{4}$$

$$w(y)=\alpha\frac{y^4}{b^4}+\beta\frac{y^2}{b^2}+\gamma \tag{5}$$

$$w(y)=\beta\frac{y^2}{b^2}+\gamma \tag{6}$$

Eqs. (3) and (4) give the curves very approximate to that of Fig. 1. Eqs. (5) (6) are inferior to eqs. (3) and (4) in the approximation to the measured curve. Eqs. (5) and (6) were used in calculation, though the degree of approximation are inferior to eqs. (3) and (4), because their integration can not be solved when the eq. (3) or (4) is inserted in eq. (1). When eq. (5) was used, we have with $\alpha=-1.5$, $\beta=6.5$ and $\gamma=-1$,

$$R=4.6\frac{\sin u}{u}+8.05\frac{\cos u}{u^2}+5.80\frac{\sin u}{u^3}+41.5\frac{\cos u}{u^4}-43.3\frac{\sin u}{u^5} \qquad (7)$$

When the values of R are calculated for every values of δ, the directional characteristic curve is obtained as shown in Fig. 2. When eq. (6) was used, we have with $\beta=5$ and $\gamma=-1$,

$$R=6\frac{\sin u}{u}+15\frac{\cos u}{u^2}-15\frac{\sin u}{u^3} \qquad (8)$$

This result is shown in Fig. 3.

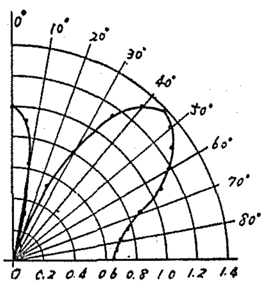

Fig. 2.

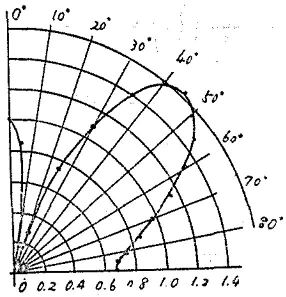

Fig. 3.

It may be said that they coincide qualitatively with the directional characteristics measured realy in water.

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5. Study on High Dielectric Constant Ceramices. (XXIII)

The Modes of Vibration about Langevin Type $BaTiO_3$ Ceramic Vibrator. (3)

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As a cylindrical Langevin type vibrator has simple construction and is manufactured easily, it has already been practically used as an underwater supersonic transducer. Recently, the rectangular Langevin type vibrator is also required from a view point of the directionel characteristics, and so, such vibrator was made and the modes of vibration were inspected.