Reference 7 English Translation

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Piezoelectric Quartz Oscillating Plates with Temperature Coefficients less than 10^{-7}/°C

by

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We reported in Joint Conference (April 1933, see Ref. 6) on the oscillation frequencies and temperature coefficients of thin plates cut in parallel to X-axis. In this report, we pointed out that oscillation frequencies and temperature coefficients changed continuously by varying cutting angle and there existed plus and minus temperature coefficients. From these results we can estimate there are two angles where temperature coefficients are zero. We carried out experiments to determine the specific angle θ corresponding to zero temperature coefficients. The results of the experiments are shown in Table 1 and 2 and Figure 1 and 2. In Tables 1 and 2, α and θ correspond to those of Figure 3. In the experiments, we measured the angle α against r'-face using X-ray spectrometer for deciding precise cutting angles. The angle between X-axis and the plate face was within 0.5'.

Table 1

θ	Thickness	Frequency	Tempareture Coefficient
	mm	kc	$\times 10^{-5}$/°C
27	0.71	2 715	−10.0
32	0.47	3 978	− 9.0
45	0.63	2 709	− 4.8
52	0.62	2 690	− 1.8
64	0.56	2 981	+ 4.8
73	0.57	2 980	7.6
80	0.65	2 691	9.8
90	0.73	2 688	10.0
100	0.71	2 981	8.7
110	0.84	2 689	6.3
123	0.90	2 700	3.2
128	0.92	2 689	2.0
133	0.93	2 696	+ 0.9
138	0.94	2 690	− 0.2
148	0.95	2 690	− 2.4
153	0.95	2 690	− 3.4
158	0.94	2 690	− 4.5
163	0.93	2 693	− 5.5

Plate size : 22mm X 27mm
Narrow side : Parallel with X-axis
Frequency : Measured at 25°C

In order to measure temperature coefficients, we made two identical plates. One was placed in a thermostat chamber and the other was put in a variable temperature oven. By Pierce's circuits was used. We adjusted the frequencies of both oscillators so that the difference of two frequencies was about 1000 Hz of a folk oscillator by changing the gaps between the plates and electrodes of the oscillators. In this setting, we measured the beat frequency between the difference frequency of two oscillators and the frequency of the folk oscillator using a stopwatch.

When we tested the plate of α = 2°58', we changed the temperature of the oven from 35°C to 65°C several times, the change of frequency was only about 0.3 Hz during the test. Oscillation was extremely vigorous. The result shown in Table 1 was measured by comparing the difference frequency of two oscillators with the calibrated frequency of the audio frequency generator. It is not necessary to say that oscillation stopped when the angle θ was reaching to zero.

Table 2

α	θ	Plate size	Freq.	Temp. Coeff.
		mm³	kc	$\times 10^{-7}$/°C
2° 51'	54° 38'	0.615×23.1×28.3	2 688.9	−5.2
56'	43'	0.618×23.2×28.5	2 689.8	−1.4
58'	45'	0.615×23.2×28.5	2 689.3	0.0
3° 02'	49'	0.618×21.2×24.1	2 691.7	+3.0

Narrow side : Parallel with X-axis
Frequency : Measured at 25°C

As shown in Figure 1, it is obvious that we can also realize a plate having zero temperature coefficient in the region of θ = 130°~140° (there is a typo: θ = 40°~50° was written in the original Japanese paper) if we carry out the precise experiment. However, it took about one year from September last year to find the place of θ shown in Table 2 and Figure 2 and it will be not so easy to measure the cutting angle in this case even if we use X-ray spectrometer. So, we postponed this experiment to the later date.

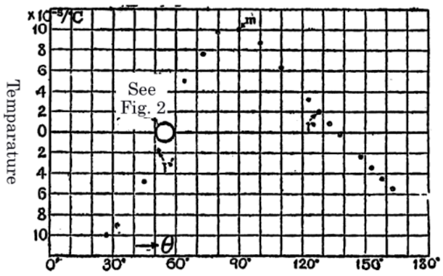

Figure 1

From the result shown in Table 1, we can calculate the temperature coefficients of elastic constants. We will report about this in the next time.

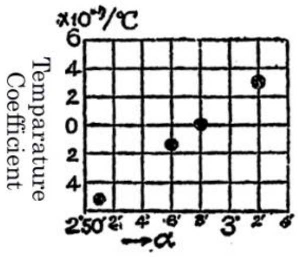

Figure 2

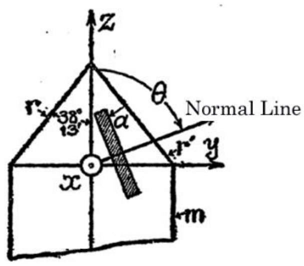

Figure 3

We can conclude as follows. For industrial production of quartz crystal plates having low temperature coefficients, it is cumbersome to use X-ray spectrometer. However, it is not difficult to make plates having temperature coefficient less than ±3 X 10^{-6} without using X-ray spectrometer but using an ordinary protractor having the accuracy of 20'. This value of temperature coefficient is enough to keep the frequency tolerance less than 10^{-4} without using thermostat chambers for ordinary transmitters.

Y-cut plate, which is cut in parallel to X-axis, shows the worst temperature coefficient among various plates which are also cut in parallel to X-axis.

Realization of plates having temperature coefficient less than 10^{-7} /°C may be the first case in the world.

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