

[54] **METHOD OF ADJUSTING FREQUENCY OF TUNING FORK TYPE VIBRATOR**

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[22] Filed: **May 18, 1972**

[21] Appl. No.: **254,599**

[52] U.S. Cl. **29/169.5**, 29/177, 58/23 TF, 84/409, 84/457

[51] Int. Cl. **B29d 17/00**

[58] Field of Search. 29/169.5, 177, 178, 29/407; 58/23 TF; 84/409, 457

[56] **References Cited**

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[57] **ABSTRACT**

A tuning fork type vibrator is formed with a root portion not more than three times as thick as the region of the tines adjacent said root portion. Frequency balance is achieved by cutting off portions of the root portion in the region adjacent the tine having the higher frequency. The frequency of the vibrator as a whole is adjusted by cutting off symmetrical portions of said root portion.

3 Claims, 12 Drawing Figures

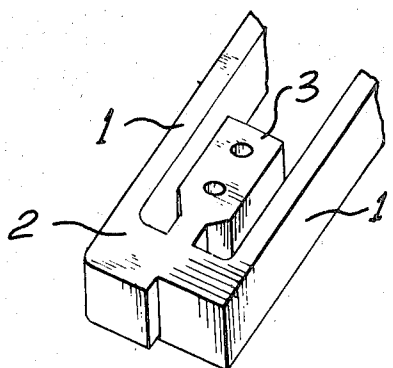


FIG. 1

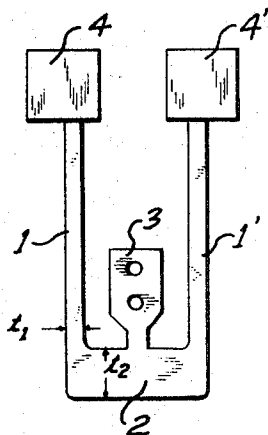


FIG. 2

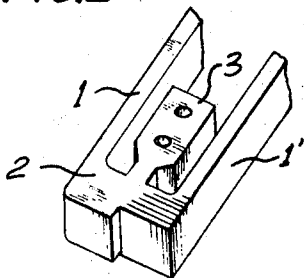


FIG. 3

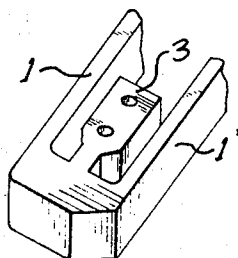


FIG. 4

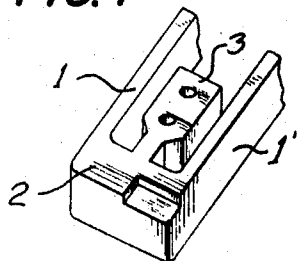


FIG. 5

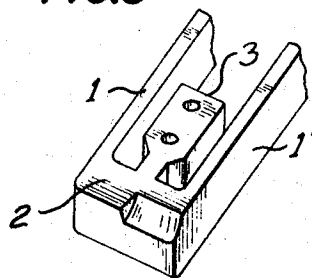


FIG. 6

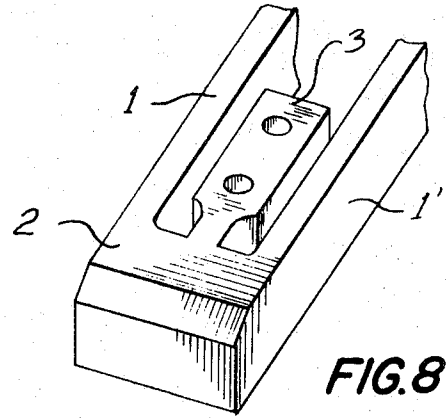
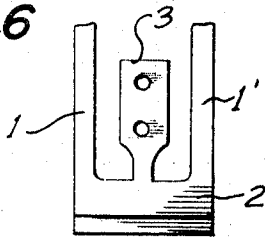


FIG. 8

FIG. 7

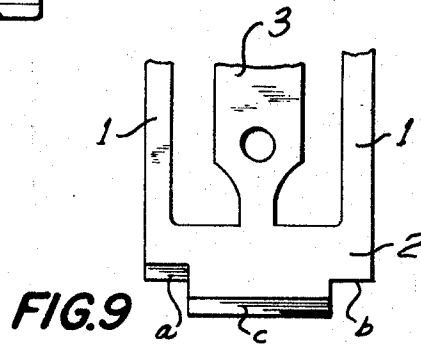
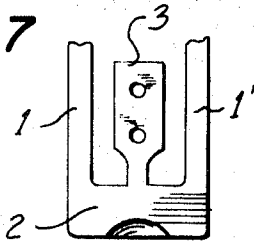


FIG. 9

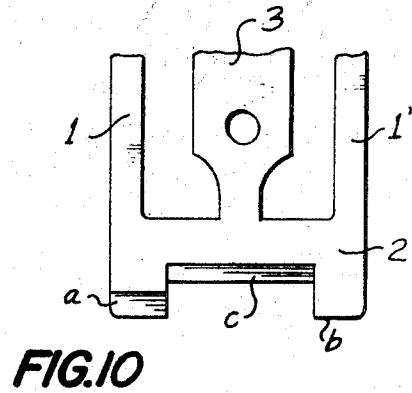


FIG. 10

FIG. 11

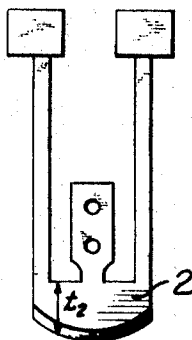
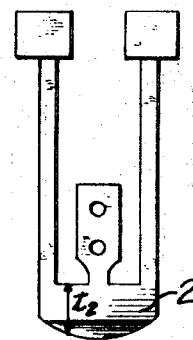


FIG. 12



METHOD OF ADJUSTING FREQUENCY OF TUNING FORK TYPE VIBRATOR

BACKGROUND OF THE INVENTION

This invention relates to a method of adjusting the frequency of a tuning fork type vibrator which may be used as the time standard vibrator of an electric time-piece or the like.

Such tuning fork type vibrators must be precisely set at a predetermined frequency. It is also necessary that the frequency of the two tines of the vibrator coincide. However, it has proved difficult to initially manufacture tuning fork type vibrators which are both balanced and are set at the predetermined frequency.

Accordingly, balance and frequency adjustment of prior art tuning fork type vibrators was achieved by slightly cutting the mass carried by the free end of the completed tuning fork or cutting the two tines of the tuning fork. If said mass is used in a magnetic circuit and the tuning fork type vibrator is driven, the cutting of said mass presents substantial drawbacks in that the amount that may be cut is limited and the range of frequency adjustment is narrow. It is difficult to perform precise adjustment by cutting the tines of a tuning fork type vibrator since the frequency varies substantially in response to a very small amount of cutting. For this reason, it is technically difficult to cut both tines uniformly to achieve frequency adjustment. Further, the cutting of the tines produces an inner strain within the tines and reduces the Q-value of the vibrator.

SUMMARY OF THE INVENTION

Generally speaking, in accordance with the invention, a method for fine adjustment of a tuning fork wherein a tuning fork is formed with a root portion of a thickness no greater than the thickness of the tines in the region adjacent said root portion. The tuning fork type vibrator is initially formed so as to have a frequency higher than the desired predetermined frequency. The frequency is adjusted by cutting away portions of the root portion symmetrical relative to the axis of symmetry of the tuning fork. The tuning fork is balanced by cutting away portions of the root portion on the same side of the axis of symmetry as the tine having the higher frequency.

Accordingly, an object of the invention is to provide a method for readily balancing and adjusting a tuning fork type vibrator without lowering the Q-value thereof.

Still other objects and advantages of the invention will in part be obvious and will in part be apparent from the specification and drawings.

The invention accordingly comprises the several steps and the relation of one or more of such steps with respect to each of the others thereof, which will be exemplified in the method hereinafter disclosed, and the scope of the invention will be indicated in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the invention, reference is had to the following description taken in connection with the accompanying drawings, in which:

FIG. 1 is a top plan view of a tuning fork type vibrator suitable for use as a time standard for an electric time-piece and the like;

FIGS. 2-5 are perspective fragmentary views of the tuning fork vibrator of FIG. 1 illustrating the method

for balancing such vibrators in accordance with the invention;

FIGS. 6 and 7 are fragmentary top plan views illustrating the method of adjusting the frequency of the tuning fork type vibrator in accordance with the invention;

FIG. 8 is a perspective fragmentary view of the vibrator of FIG. 6;

FIGS. 9 and 10 are top plan views illustrating the adjustment of both balance and frequency of a tuning fork type vibrator in accordance with the invention; and

FIGS. 11 and 12 are top plan views illustrating the frequency adjusting method in accordance with the invention as applied to vibrators having non-uniform root portions.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to FIG. 1, the tuning fork type vibrator depicted has a pair of tines 1 and 1' connected by a root portion 2. A supporting portion 3 projects from said root portion between said tines from the center of said root portion and is substantially aligned with the axis of symmetry of the tuning fork type vibrator. Said vibrator may be fixed to a base plate by means of said supporting portion. Masses 4 and 4' are respectively carried by the free ends of tines 1 and 1'. As shown in FIG. 1, the region of the tines adjacent root portion 2 is of a thickness t_1 , while said root portion is of a thickness t_2 .

Generally, in tuning fork type vibrators of the type depicted in FIG. 1, it is necessary to adjust the frequency of the two tines so as to be substantially equal. The respective frequencies f_1 and f'_1 of tines 1 and 1' are shown by the following equations:

$$f_1 = 1/2\pi \sqrt{K_1/M_1} \quad f'_1 = 1/2\pi \sqrt{K'_1/M'_1}$$

where M_1 and M'_1 = the equivalent masses of the respective tines and K_1 , K'_1 = the spring constants of the respective tines.

Accordingly, if $K_1 = K'_1$ and $M_1 = M'_1$, f_1 equals f'_1 and no adjustment is required. However, as noted above, it is impossible to manufacture a vibrator with such precision. However, even if $K_1 \neq K'_1$ and $M_1 \neq M'_1$, if $f_1 = f'_1$, the tuning fork type vibrator vibrates normally.

The prior art methods for frequency adjustment required either the cutting off of the mass carried by the free end of the tine having the lower frequency so as to change the mass M , or the cutting off of the whole or one portion of the tine having the higher frequency so as to change the spring constant K . In this manner, f_1 was made equal to f'_1 and both tines were balanced.

The frequency f of the tuning fork type vibrator is given by:

$$f = 1/2\pi \sqrt{K/M}$$

where, M equals the equivalent mass of the vibrator and K equals the spring constant of the vibrator itself.

Frequency adjustment was heretofore achieved by changing M by uniformly cutting off portions of the masses 4 and 4' carried by the free ends of tines 1 and 1' or by uniformly cutting off the whole or one portion of both tines 1 and 1' so as to change the spring constant K . However, as discussed above, such adjustment method offers substantial disadvantages. Each of the spring constants K_1 and K'_1 referred to above represent

the combination of the spring constant of the respective tines 1 and 1' determined by the respective sectional geometry of said tines and the spring constant of the root portion 2 determined by the sectional geometry of said root portion. The tuning fork body, excluding the masses 4 and 4', is generally formed from a plate of uniform thickness. Similarly, the thickness t_1 of each tine in the region adjacent the root portion is substantially equal. When the thickness of the root portion t_2 is substantially larger than the thickness of the tines t_1 , the spring constant K_1 (or K'_1) is substantially determined by t_1 . When t_2 is smaller than t_1 , the spring constant K_1 (or K'_1) is determined by t_2 . However, if t_2 is no more than two or three times larger than t_1 , the spring constant K_1 (or K'_1) is determined by t_1 and t_2 , but the influence of t_2 is less than the influence of t_1 .

Where the tuning fork type vibrator is formed in accordance with the latter proportions, correction of small fluctuations in frequency may be readily achieved. Thus, where f_1 is less than f'_1 , such correction may be achieved by cutting off a slight portion of the root portion 2 in the region of said root portion on the same side of the axis of symmetry as tine 1'. This serves to decrease the portion of the spring constant of the root portion contributing to the value of K'_1 . Although the effect on K_1 is slight, f_1 can be made equal to f'_1 . Several methods of cutting root portion 2 are illustrated in FIGS. 2-5. In FIGS. 2 and 3, the cuts are through the entire thickness of the tine portion, with the cut extending obliquely in FIG. 3 and substantially normal to the axis of symmetry in FIG. 2. Similarly, in FIGS. 4 and 5, the cuts are in the surface of the root portion, the cut in FIG. 4 lying in a plane which includes the axis of symmetry, the cut in FIG. 5 being oblique to said axis.

The same principle may be adapted for adjusting the frequency of a tuning fork type vibrator to a predetermined value. This adjustment technique requires the formation of the vibrator with a frequency higher than the predetermined value. The root portion 2 of the vibrator is then cut an amount sufficient to reduce the frequency to the desired value. Such a cut is made symmetrically relative to the axis of symmetry of the vibrator as illustrated in FIGS. 6-8. In the embodiments of FIGS. 6-8, an oblique cut is made in the root portion 2. In FIGS. 6 and 8, the cut is uniform across the entire width of the root portion, while in FIG. 7, an arcuate oblique cut is formed in the central region of the root portion.

The balance adjustment and the frequency adjustment in accordance with the invention can be carried out in the same tuning fork type vibrator. Thus, the balance of a vibrator may be adjusted in accordance with the method illustrated in FIG. 2 while the frequency is adjusted by the method of FIG. 8. Similarly, the balance adjustment of FIG. 3 may be performed in conjunction with the frequency adjustment of FIG. 7; the balance adjustment of FIG. 4 can be made in conjunction with the frequency adjustment of FIGS. 6-8; and the balance adjustment of FIG. 5 may be made in conjunction with the frequency adjustment of FIGS. 6-8.

If the root portion 2 is formed as shown in FIGS. 9 and 10, the balance adjustment can be performed by cutting portions a or b while the frequency adjustment can be made by cutting the portion c.

As illustrated in FIGS. 11 and 12, where the thickness t_2 of the root portion of the vibrator is not uniform,

frequency adjustment can still be achieved by the symmetrical cutting away of portions of the root portion. The essential feature of this frequency adjustment in accordance with the invention is the cutting away of portions of root portion 2 so as to decrease the flexural rigidity (spring constant) of said root portion.

The method in accordance with the invention offers substantial advantages over the prior art. Thus, in the case of a vibrator having a frequency of 500 Hz, the size of vibrators incorporated in wrist watches, a frequency adjustment of 2-3 Hz may be achieved by cutting away about 0.05-0.1 mm. of the thickness t_2 of root portion 2. By application of precision cutting techniques, the frequency of the vibrator can be shifted to the predetermined frequency. The range of adjustment permitted by the method in accordance with the invention is broad as compared with the prior art method of cutting the masses carried by the free end of the tines. Similarly, more precise adjustment of frequency can be achieved by the method in accordance with the invention as compared with the method of cutting the tines, the method in accordance with the invention not requiring uniform cuts of the tines, and having a minimum effect on the Q-value of the vibrator.

The method in accordance with the invention can also be applied to other vibrators using the tuning fork vibrator as a base, such as the tuning ring vibrator, a special tuning fork vibrator, or a trifurcated tuning fork type vibrator.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in carrying out the above method without departing from the spirit and scope of the invention, it is intended that all matter contained in the above description shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

What is claimed is:

1. A method of adjusting the frequency of a tuning fork type vibrator comprising the steps of forming a tuning fork type vibrator having a root portion of a thickness not more than three times the thickness of the region of the tines adjacent said root portion, said vibrator being formed with a frequency higher than the desired predetermined frequency; and cutting away symmetrical portions of said root portion relative to the axis of symmetry of said vibrator until the actual frequency of said vibrator is substantially equal to said predetermined frequency.

2. The method of claim 1, including the further step of balancing said vibrator by cutting away portions of said root portion on the same side of said axis of symmetry as the tine having the higher frequency until the frequencies of the two tines are substantially equal.

3. The method of balancing the frequency of a tuning fork type vibrator comprising the step of cutting away portions of the root portion of the vibrator on the same side of the axis of symmetry of said vibrator as the tine having the higher frequency until the frequencies of said tines are substantially equal.

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