United States Patent [19]

Favre

[11] **3,797,224**

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[54] **COMPENSATION OF THE THERMAL FREQUENCY DRIFT OF A MECHANICAL OSCILLATOR FOR TIMEKEEPING**

[75] Inventor: **Robert Favre,** Lausanne, Switzerland

[73] Assignee: **Fabriques Movado,** La Chaux-de Fonds Canton, Neuchatel, Switzerland

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** .... **58/23 TF,** 310/25, 331/156

[51] **Int. Cl.** **G04c 3/00,** H02k 33/00

[58] **Field of Search** .... 58/23 R, 23 AC, 23 TF, 58/23 D, 23 V; 310/25; 331/154, 156, 175; 84/457

[56] **References Cited**

UNITED STATES PATENTS

3,207,900	9/1965	Fitzgerald	331/156
3,310,757	3/1967	Dostal	310/25
3,283,495	11/1966	Hetzel et al.	58/23
3,496,391	2/1970	McShan	84/457

Primary Examiner—Richard B. Wilkinson
Assistant Examiner—Edith C. S. Jackmon
Attorney, Agent, or Firm—Dwight H. Smiley; Imirie & Smiley

[57] **ABSTRACT**

A system for compensation of the thermal frequency drift of a mechanical oscillator for timekeeping, wherein the compensating effect is obtained by interaction of magnets fixed to the oscillator, such magnets having a thermal coefficient of negative character. A secondary compensating effect is obtained by means of magnetic shunts associated with said magnets, such shunts having a Curie-point at a suitable temperature.

6 Claims, 4 Drawing Figures

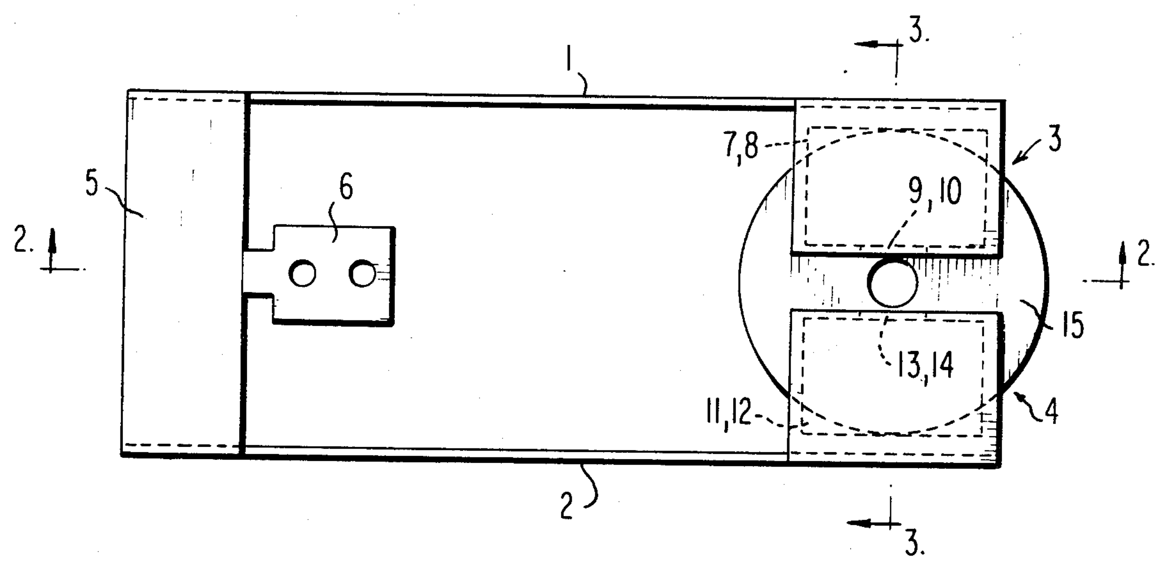


FIG. 1

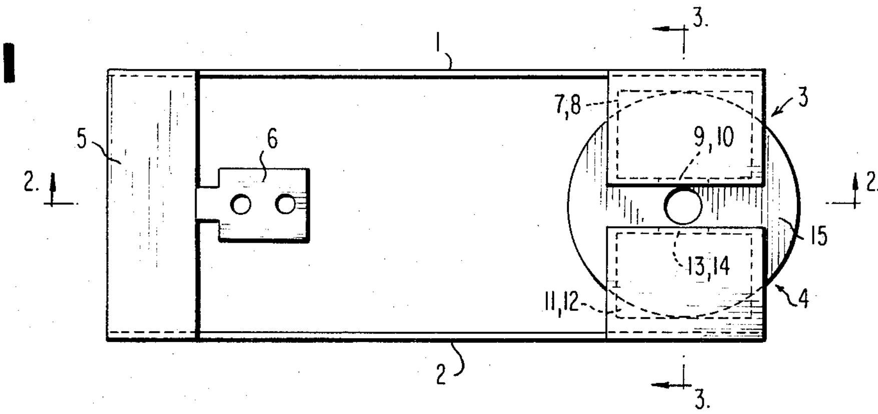


FIG. 2

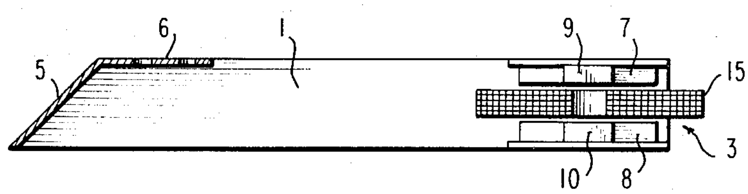


FIG. 3

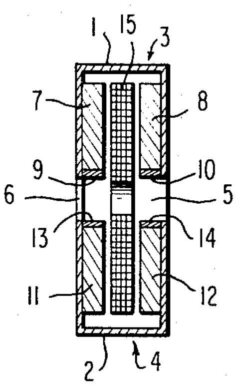
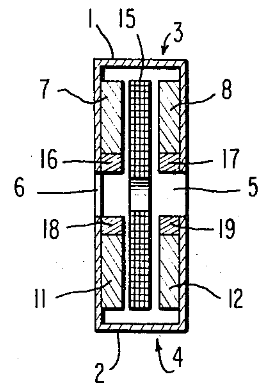


FIG. 4



COMPENSATION OF THE THERMAL FREQUENCY DRIFT OF A MECHANICAL OSCILLATOR FOR TIMEKEEPING

BACKGROUND OF THE INVENTION

In clock and watch practice, it is known to distinguish two thermal drift components affecting the frequency of oscillators used in time-keeping

Let

F be the nominal frequency of an oscillator,

$T1$ and $T2$ two extreme reference temperatures,

To the average temperature of $T1$ and $T2$, that is, $T_2 = T_1 + T_2/2$

Fo, $F1$ and $F2$ the frequency of the oscillator at the respective temperatures To, $T1$ and $T2$.

The average thermal co-efficient of the frequency of the proposed oscillator is defined by the ratio: $F1 - F2/T1 - T2$

The secondary error includes the non-linearity of the thermal effect by the expression:

$$\frac{\dfrac{F1+F2}{2}-Fo}{\dfrac{T1-T2}{2}}$$

Time-keeping oscillators, more particularly those with which the present invention is concerned, are generally associated with a system for displaying the time, and therefore the variations of frequency are often expressed by "seconds per day" and the thermal frequency effect by "seconds per day degree C" (s/d/°C).

The thermal co-efficient of a mechanical oscillator having an elastic (resilient) structure of carbon steel is of the order of − 10 s/d/°C, which value is incompatible with the precision required today in many timepieces. So-called "compensating" alloys, known by various trade names such as DURINVAL, ISOVAL or NIVAROX, make it possible to cancel the thermal effect by simple cold-hammering (hammer-hardening) followed by a suitable heat treatment. In the annealed or hypertempered condition, these compensating alloys have a positive thermal co-efficient (the reverse of that of steel) of the order of 3s/d/°C.

When the elastic structure of an oscillator includes a sharp bend, it is not possible by employing a simple final thermal treatment, to use material already in the hammer-hardened state required for cancelling the thermal co-efficient, the only maleable conditions of the material being the annealed and hypertempered states, which have positive thermal co-efficients. Thus an auxiliary compensating device for the thermal frequency drift is advantageous, and is more particularly applicable when the elastic structure of the oscillator type includes a sharp bend.

SUMMARY OF THE INVENTION

According to the present invention there is provided a device for compensating the thermal frequency drift of a mechanical oscillator for timekeeping, and in particular of an oscillator operating at an audible frequency and comprising at least one oscillating body and an elastic structure arranged as a resonator, wherein the said elastic structure includes a thermal drift co-efficient component of magnetic origin, capable of reducing the resultant overall thermal frequency drift. The oscillator may have a folded (bent) tuning fork structure, with thermal effects compensated by the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a plan view of an oscillator according to the invention;

FIG. **2** is a cross-sectional view taken on line **2—2** of FIG. **1**;

FIG. **3** is a cross-sectional view taken on line **3—3** of FIG. **1**, and

FIG. **4** is a cross-sectional view similar to FIG. **3** and showing a modification.

DETAILED DESCRIPTION OF THE INVENTION

The oscillator comprises a bent tuning fork with two tines **1** and **2**, two transducers **3** and **4** co-acting with a common fixed driving coil **15**, a link **5** obtained by an oblique fold **5**, and an elastically secured small tongue **6**.

FIGS. **2** and **3** show the structure of the transducers in greater detail. Each of them comprises a thin U-shaped magnetic armature carrying pairs of magnets **7,8** and **11, 12** and pairs of magnetic shunts **9, 10** and **13, 14.**

Since the material of the tuning fork shown is sharply bent it is necessary to start from an annealed or hypertempered compensating alloy, for example, of the "DURINVAL" type which may be hardened by simple heat treatment after bending in the hypertempered condition.

The nominal frequency thermal co-efficient is then of the order of 3s/d/°C. The compensating effect consists in providing a magnetic repulsion interaction between the two transducers **3** and **4**, obtained and adjusted by suitably locating the two pairs of magnets, and in selecting these magnets so that they produce a high negative thermal co-efficient, such as is obtained by ferrite magnets. The amount of magnetic inter-action may be adjusted on assembly so as to cancel the average thermal co-efficient of frequency, but the curve of magnetisation against temperature shows a slight secondary error which it is desirable to eliminate in precision time keeping. For this purpose, small magnetic shunts **9, 10, 13** and **14** are disposed on the opposed faces of the magnets, so as to constitute a screen against the increasing efficiency of interaction when the temperature falls, which condition is required for eliminating the secondary error. The Curie point of the magnetic shunts must be approximately 20°C and the radius of the induction graph curvature, near the Curie point, must be as large as possible for maximum cold hammering. The thickness of the shunts may be very small, for example 0.1 mm. The width thereof is usually equal to the thickness of the magnets. The length is then determined so as to exactly compensate the secondary error over a range of useful temperatures which may extend from 0°C to 40°C.

The magnetic shunts are preferably directly cemented on the respective faces of the magnets.

The device of the present invention enables the thermal frequency drift of a mechanical oscillator to be cancelled by an operation applied during assembly, or subsequently thereto.

It is therefore possible to use elastic structures bent at sharp angles, even in high precision oscillators as used in wrist watches.

It is also possible to use magnetic shunts to eliminate the secondary error in an oscillator, the elastic structure of which does not comprise an acute angles bend, the transducers of which are fitted with very cheap ferrite magnets and having excellent magnetic characteristics and whose magnetic interaction it would not otherwise be possible to eliminate.

If the transducers are not directly suitable for the desired magnetic interaction, it is obviously possible to equip the oscillator with auxiliary ferrite magnets **16, 17, 18** and **19,** as shown in FIG. **4.**

The thermal co-efficient and secondary error are easily reduced to less than 0.1 s/d/°C, by a very rapid adjusting operation.

What we claim is:

1. A device for compensating the thermal drift a mechanical oscillator for timekeeping and in particular of an oscillator operating at an audible frequency and comprising at least one oscillating body and a resilient structure arranged as a resonator, said resilient structure including a thermal drift co-efficient component of magnetic origin capable of reducing the resultant overall thermal frequency drift, said component of magnetic origin being obtained by interaction of magnets mounted on said resonator having a negative thermal coefficient, magnetic shunts mounted on the faces of said inter-acting magnets for reducing a secondary error, the shunts having a Curie point near the useful average temperature, the shunts forming a barrier the efficiency of whose inter-action increases with decreasing temperature.

2. A device according to claim **1,** wherein the said component of magnetic origin is produced by the interaction of the magnets of the transducers for maintaining oscillation.

3. A device according to claim **1,** wherein the component of magnetic origin is produced by the inter-action of auxilliary magnets fixed to the resonator of the oscillator.

4. A device according to claim **1,** wherein the resilient structure is a resonator shaped by deformation and includes at least one sharp bend.

5. A device according to claim **1,** in which the resilient structure is in the form of a tuning fork with permanent magnets fixed to the inside of the tines so that the inner surfaces of the magnets are located near to each other.

6. The device according to claim **1,** wherein the resilient structure is a resonator including at least one sharp bend.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,797,224 Dated March 19, 1974

Inventor(s) ROBERT FAVRE

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Claim 1, line 1, after "drift" insert --of--

Signed and sealed this 19th day of November 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents

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