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PATENT SPECIFICATION

DRAWINGS ATTACHED

L.196.579

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Date of Application and filing Complete Specification: 14 March, 1969.

No. 13635/69.

Application made in United States of America (No. 725275) on 30 April, 1968

Complete Specification Published: 1 July, 1970.

Index at acceptance: —G3 T(A5B1, A6A)

International Classification: —G 04 b 17/06

COMPLETE SPECIFICATION

Horological Hairspring

5 We, THE UNITED STATES TIME CORPORATION, a Corporation organised under the laws of the State of Connecticut, United States of America, of Waterbury, Connecticut, United States of America, do hereby declare the invention, for which we pray that a Patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

10 The present invention relates to hairsprings for horological instruments, more particularly watches.

15 A horological instrument requires some device to provide a regular beat. In a standing clock the beat may be provided by a swinging pendulum. Watches for many years have used a circular balance wheel for that function. The balance wheel is fixed to a staff which is free to pivot in bearings or jewels. 20 The balance wheel is oscillated by means of a spiral hairspring and an impulsing means. The hairspring is usually wound in a number of turns and formed from spring steel having a rectangular cross-section. Mechanical 25 watches use a single hairspring. Electrical watches also use a single hairspring which, when a coil is carried by the balance, carries electrical current to the coil.

30 A hairspring in a watch is critical to its timekeeping. If the spring force of the hairspring changes, for example, with temperature variations, the passage of time and the influence of magnetism, the accuracy of the watch may suffer.

35 The usual watch hairspring, as a result of research efforts over many years, is often constructed of the high quality and expensive steel alloys. The cleaning and heat treatment of the hairspring is carefully controlled. 40 The hairspring is, in practice, exactly wound so that its pitch, i.e., degree of curvature, is constant, following an Archimedes spiral formula. This type of hairspring winding pre-

sents a problem in that the outer turns may be close enough together to clash against each other during the movement of the balance wheel which winds up the hairspring. Such clashing causes a loss of accuracy.

50 The height of the hairspring, i.e. its dimension parallel to the axis of the balance wheel staff, may present a problem. The height of the hairspring adds to the thickness of the watch, particularly if the watch is an electronic watch which uses two hair springs. 55

In accordance with the present invention, a hairspring and a balance and hairspring assembly is provided for a watch. The hairspring is wound to a non-uniform pitch and is round in cross-section. 60

The hairspring is preferably wound to a formula which results in the turns toward the centre being more tightly wound than in its outer turns, which avoids clashing of the outer turns. The round cross-section of the hairspring requires less vertical space, i.e., parallel to the axis of the balance wheel staff. The saving in vertical space may be of particular importance in electronic watches using two hairsprings arranged in different parallel planes. A hairspring which is round in cross-section, compared to one having a rectangular section of the same force and length, would weigh less. The lighter spring, of round cross-section, will sag less when the watch is in its normal position, i.e., normal relative to the balance wheel axis. This will result in improved time-keeping, due to less position error, as there will be less harmful effect on timekeeping in the vertical position. 75 80

The sagging which may occur in the horizontal position of the watch will not affect the timekeeping of the watch. In addition, the hairspring having a round cross-section may be comparatively less affected by stray magnetic flux and by air pressure changes. The round hairspring may be formed from relatively inexpensive and round drawn wire, 85

[Price 5s. 0d. (25p)]

The hairspring having a round cross-section, if wound with the conventional constant pitch, would require a larger outside diameter than is attainable by using a non-constant pitch.

A preferred embodiment of the invention will now be described in detail, by way of example, reference being made to the accompanying drawings, in which:—

Fig. 1A is a top plan view of a prior art watch hairspring;

Fig. 1B is a cross-section along lines A—A of the hairspring of Fig. 1A;

Fig. 2A is a top plan view of a hairspring according to the present invention;

Fig. 2B is a cross-section along line B—B of the hairspring of Fig. 2A; and

Fig. 3 is a perspective view showing the hairspring of Figs. 2A and 2B connected in a balance assembly in an electronic watch.

The conventional prior art watch hairspring of Figs. 1A and 1B consists of a strip of spring steel whose cross-section is rectangular and uniform along its length. The height of the spring is the long part of the rectangular cross-section parallel to the axis of the balance wheel staff (not shown) with which it is connected in use. The conventional spring, having a constant pitch, is wound according to the following formula:

$$\rho = A + K\theta$$

where

ρ =coordinate of a point of the hairspring;

A =a constant giving the inside radius of the hairspring;

K =a constant providing the pitch, i.e., degree of curvature, of the hairspring;

θ =the angular coordinate

If a balance wheelstaff has a hub requiring that the spring have a certain radius A , the above formula then becomes simply $\rho = K\theta$, which is an Archimedes curve.

The Archimedes curve has a long history, particularly in the later Middle Ages, as possessing almost magical properties. On a more practical basis, the Archimedes curve has been considered relatively simple to measure to a selected tolerance and relatively simple to manufacture.

The rectangular cross-section has been utilized as it presented a stiffness against the drooping of the hairspring, i.e., deflection parallel to the axis of the balance wheel staff. However, the rectangular cross-section, when compared to a hairspring of round section, requires a larger cross-section to obtain the same spring force. In other words, in a given space, more force may be obtained from a spring of round cross-section than a spring of rectangular cross-section. With a spring of rectangular cross-section, the moment of elasticity (return torque) M_r is

$$M_r = \frac{E h w^3 \cdot \alpha}{12 l}$$

where E is the modulus (coefficient) of elasticity, w is the width and h the height of the cross-section. A spring of round cross-section has its moment of elasticity

$$M_d = \frac{E \pi r^4 \cdot \alpha}{4 l}$$

where E is the modulus of elasticity, and r is the radius of the cross-section. One may compare a spring having a round cross-section with one having a rectangular cross-section; and, using the following assumptions, it is found that a rectangular spring, delivering the same force as a round spring, has a cross-sectional area A_r which is more than twice as large as the cross-sectional area A_d of a round spring, i.e., $A_r:A_d=1.00:0.46$. The assumptions made are (1) the same material is used, so that E is the same in both types of springs; (2) both springs are wound with the same pitch; (3) the inside radius A of both springs is the same; (4) the lengths l of both springs are equal; (5) the moments of elasticity of both springs are equal, i.e., $M_d=M_r$; (6) the ratio, in the spring having a rectangular cross-section, of its width w to its height h is 1 to 5, a conventional ratio for such springs.

As a specific example leading to the relationship $A_r:A_d=1.00:0.46$, typical dimensions of a rectangular shaped spring as, for instance, in a wrist watch, having the conventional ratio, width w to height h , of 1 to 5, are width of 0.03 mm and height of 0.15 mm. The assumption is made that $M_d=M_r$, therefore:

$$(1) \quad \frac{E h w^3 \alpha}{12 l} = \frac{E \pi r^4 \alpha}{4 l}$$

Since modulus of elasticity E , angular constant α and length l are assumed to be equal for both the rectangular spring and the round spring, expression (1) above becomes:

$$(2) \quad \frac{h w^3}{12} = \frac{\pi r^4}{4}$$

Using $w=.03$ mm, $h=.15$ mm in expression (2) above, then:

$$(3) \quad \frac{\pi r^4}{4} = 33.8 \times 10^{-8}$$

Solving expression (3) for r :

$$r^4 = \frac{4(33.8 \times 10^{-8})}{\pi} = 43 \times 10^{-8}$$

$$r = 2.56 \times 10^{-2} = 0.0256 \text{ mm}$$

Cross-sectional area rectangular spring:

$$A_r = wh = 0.03(0.15) = 0.0045 = 45 \times 10^{-4} \text{ mm}^2$$

5 Cross-sectional area round spring:

$$A_d = \pi r^2 = \pi(0.0256)^2 = 20.6 \times 10^{-4} \text{ mm}^2$$

Relationship of A_r to A_d :

$$A_r : A_d = 45 \times 10^{-4} : 20.6 \times 10^{-4}$$

Therefore, $A_r : A_d = 1.00 : 0.46$

10 The regular (Archimedes) curve, i.e., a constant pitch, has been utilized in conventional hairsprings as it was widely thought to provide an even spring power and because it is relatively easy to wind. However, a spring
15 may be wound according to a preselected curvature, i.e. a variable pitch, according to the following formula:—

$$\rho = A + K\theta[F(\theta, b, c \dots)] +$$

$$K\theta[G(i, k \dots)]$$

20 where:

ρ = coordinate of a point of the hairspring

A = a constant giving the inside radius of the hairspring

25 K = the pitch of the hairspring

θ = the angular coordinate

F = function

$b, c \dots$ = constants

30 The function $F(\theta, b, c \dots)$ is selected to obtain one or more of the requirements of the hairspring, such requirements including the pitch determined by the theoretical equations of chronometry, the result of experimental testing, the characteristics of the spring
35 material, the heat treatment to be carried out in the spring and on the wire from which the spring is formed, the mechanical working of the wire, and other processing steps.

40 The function $G[\theta, i, k \dots]$ provides the pitch for the outside coil turn of the hairspring coil. The outside turn is selected to match the regulator so that the rate may be set.

45 Preferably the interior convolutions (windings) of a hairspring 10 according to the present invention, as shown in Fig. 2, are at a relatively lesser pitch than the outer windings. The clashing of the outer windings is avoided by spacing them further apart.

As an example of the hairspring according to the present invention, a hairspring having twelve coils (complete turns) is wound with a pitch of two thicknesses of the hairspring starting at the first coil, to a final pitch of 3 or 4 or 5, the pitch continuously
55 growing from 2 to 3 or 4 to 5. This type of hairspring may, compared to hairsprings having a constant pitch, be of greater length within a given volume or, alternatively, a given length of hairspring would have a
60 smaller outside diameter.

The hairspring of the present invention, having a non-regular pitch and a round cross-section, finds particular application in an electronic watch. In the electronic watch
65 shown in Fig. 3 a balance 20 is mounted on a balance staff 21. The staff rotates freely in jewels or other bearings in a frame plate 22 and a bridge 23. The balance carries a round coil 24 having two terminal wires 26
70 and 26a. The coil 24 interacts with a series of three North-South-North permanent magnets 25 fixed to the shunt plate 25a. A circuit 27 having terminal wires 30
75 and 31 is connected to a battery (not shown). The circuit 27 pulses the coil 24 with current during its passage through the magnetic fields of magnets 25. A suitable details circuit and magnet structure is explained in United States
80 Patent No. 3,046,460.

The coil terminal wires 26 and 26a are connected to respective circuit wires 30 and 31 through hairsprings 32 and 33. The hairsprings are round in cross-section and are wound with a non-regular pitch. One hairspring 32 is connected to wire 26 of the coil and is on one side of the balance, and the other hairspring 33 is connected to wire 26a on the other side of the balance. The hairspring
85 outer ends are fixed in insulated posts 34, 35 in the frame and bridge through which the wires 30, 31 make connection with the hairsprings. Their inner ends are fixed in hairspring hubs on the balance staff.

A drive 36 fixed to the balance interacts with the arms of a fork lever 37 to oscillate the lever 37. The lever 37 is pivoted on staff 38 and has banking pins (not shown) which limit its movement. A pin 39 on the opposite
90 end of the lever engages in the teeth of a ratchet (index) wheel 40 and indexes the wheel. The movement of wheel 40 is transmitted by a conventional gear train (not shown) to the hands of the watch.

The hairspring of the present invention is also adapted for use in a mechanical watch,
105 which is powered by a mainspring. Such a mainspring is normally housed in a barrel having exterior gear teeth and is wound by a crown, through one or more gears. The
110 barrel meshes with a set of gears to drive the time indicating hands. The release of the mainspring power is controlled by an escapement which includes a lever and balance wheel

assembly, the lever being pivoted and providing an impulse to the balance wheel. The balance wheel assembly pivots between the movement frame and a bridge. A hairspring, in accordance with the invention of round cross-section and non-uniform in its winding pitch, is connected between the bridge and a hub on the balance wheel staff.

WHAT WE CLAIM IS:—

- 10 1. A hairspring for connection to a balance assembly for a horological instrument, wherein said hairspring is round in cross-section and is wound to a non-uniform pitch.
- 15 2. A balance assembly for a horological instrument, and a hairspring connected at its inner end to the balance assembly wherein the hairspring is round in cross-section and non-uniform in its winding pitch.
- 20 3. An electronic watch including a frame, a bridge connected to the frame, a balance assembly rotatably positioned between said frame and said bridge, an electronic circuit including means to be connected to a battery, a coil being carried on the balance means
- 25 to create at least one magnetic field positioned to interact with the coil, a first hairspring connected between the frame and the balance assembly, and a second hairspring connected between the bridge and the balance assembly,
- 30 wherein the first and second hairsprings each serve to make electrical connections between the circuit and the coil and at least one of the hairsprings is a hairspring which is round

in cross-section and non-uniform in winding pitch.

4. An electronic watch as claimed in claim 3, wherein both hairsprings are round in cross-section and non-uniform in winding pitch.

5. A watch movement including a frame, a bridge connected to the frame, a balance assembly rotatably positioned between said frame and said bridge, a lever rotatably positioned on said frame to impulse said balance, a mainspring in a mainspring barrel rotatably positioned on said frame to drive the movement, and a hairspring round in cross-section and non-uniform in its winding pitch connected between said bridge and said balance assembly.

6. A hairspring for connection to a balance assembly for a horological instrument, substantially as hereinbefore described with reference to Figs. 2A and 2B of the accompanying drawings.

7. A balance assembly substantially as hereinbefore described with reference to Fig. 3 of the accompanying drawings.

8. A watch incorporating the hairspring or balance assembly as claimed in any one of claims 1, 2, 6 or 7.

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assembly, the lever being pivoted and providing an impulse to the balance wheel. The balance wheel assembly pivots between the movement frame and a bridge. A hairspring, in accordance with the invention of round cross-section and non-uniform in its winding pitch, is connected between the bridge and a hub on the balance wheel staff.

WHAT WE CLAIM IS:—

10 1. A hairspring for connection to a balance assembly for a horological instrument, wherein said hairspring is round in cross-section and is wound to a non-uniform pitch.

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20 3. An electronic watch including a frame, a bridge connected to the frame, a balance assembly rotatably positioned between said frame and said bridge, an electronic circuit including means to be connected to a battery, a coil being carried on the balance means to create at least one magnetic field positioned to interact with the coil, a first hairspring connected between the frame and the balance assembly, and a second hairspring connected between the bridge and the balance assembly, wherein the first and second hairsprings each serve to make electrical connections between the circuit and the coil and at least one of the hairsprings is a hairspring which is round

in cross-section and non-uniform in winding pitch.

4. An electronic watch as claimed in claim 3, wherein both hairsprings are round in cross-section and non-uniform in winding pitch.

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6. A hairspring for connection to a balance assembly for a horological instrument, substantially as hereinbefore described with reference to Figs. 2A and 2B of the accompanying drawings.

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Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1970.
Published by The Patent Office, 25 Southampton Buildings London WC2A 1AY. from which copies may be obtained.

