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C. E. GUILLAUME.

COMPENSATION DEVICE FOR TORSIONAL PENDULUMS.

APPLICATION FILED NOV. 1, 1905.

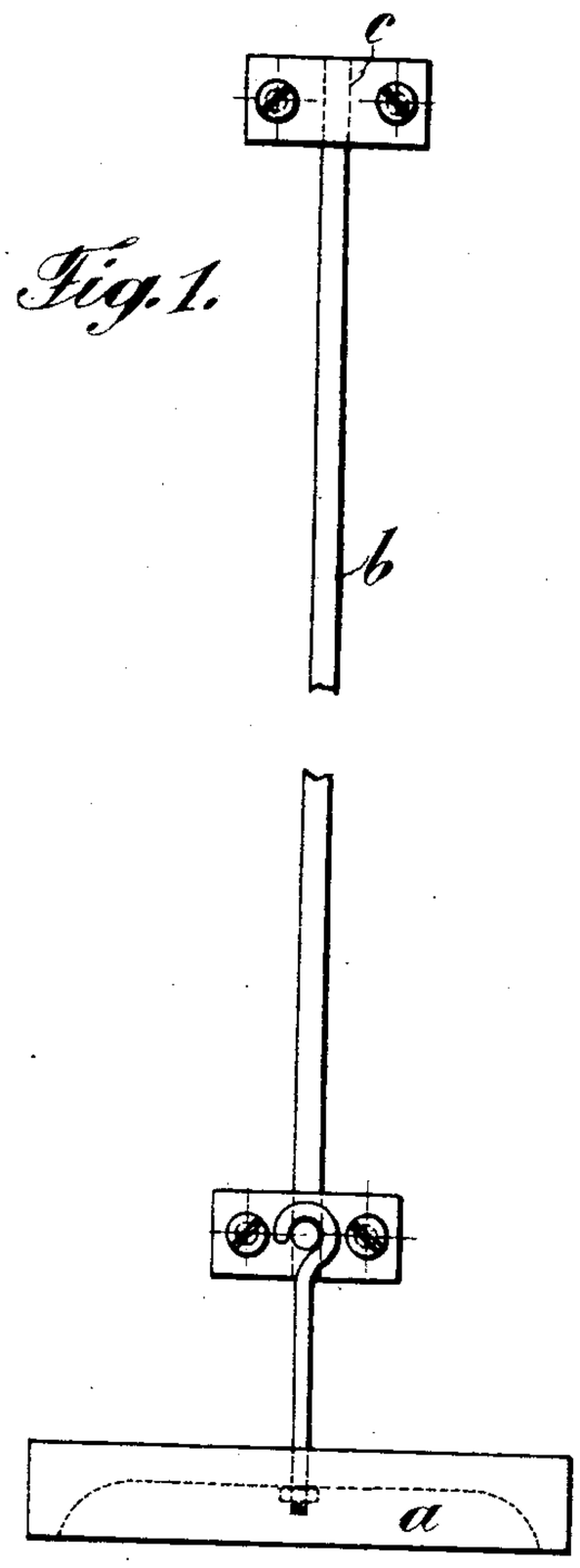

Fig. 1.

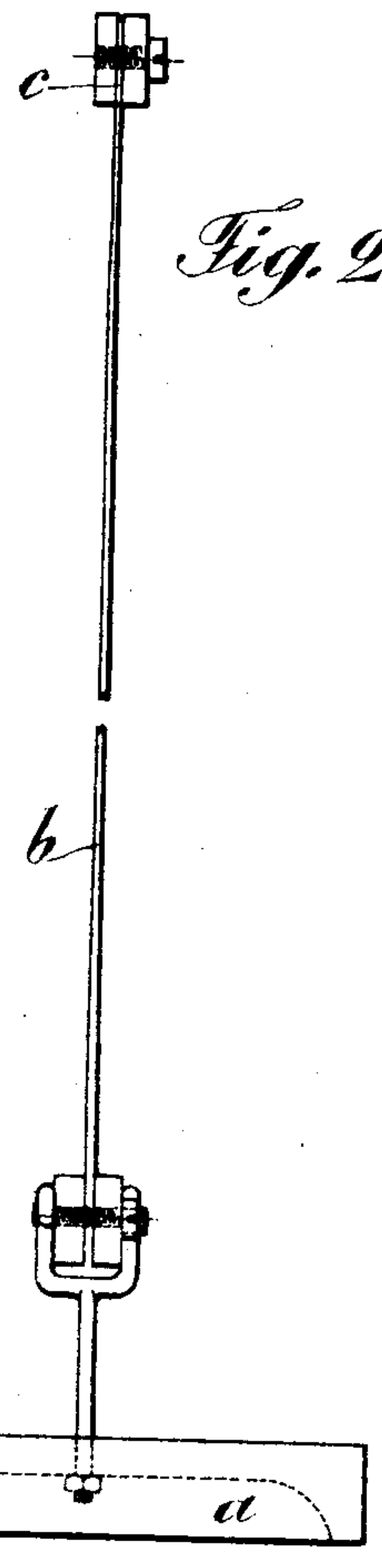

Fig. 2.

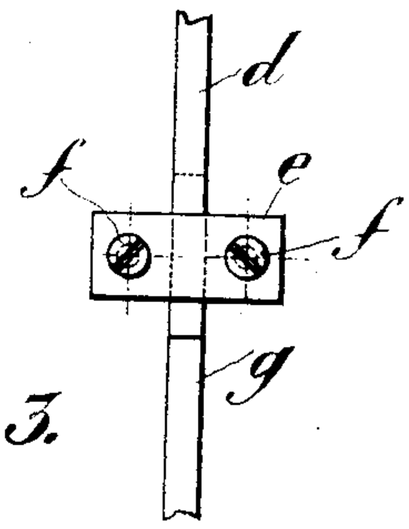

Fig. 3.

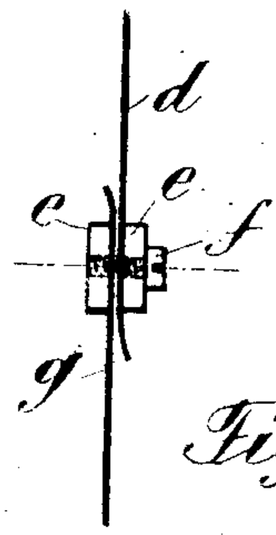

Fig. 4.

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COMPENSATION DEVICE FOR TORSIONAL PENDULUMS.

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To all whom it may concern:

Be it known that I, CHARLES EDOUARD GUILLAUME, a citizen of the Republic of Switzerland, residing at Sèvres, Department of Seine-et-Oise, France, have invented Improvements in or Relating to Compensation Devices for Torsion-Pendulums, of which the following is a full, clear, and exact description.

This invention relates to compensation devices for torsion pendulums.

Clockwork mechanisms in which, as heretofore, the regulator or balance consists of an oscillating mass, moving to and fro in a horizontal plane, suspended from the end of a suspension thread, band or strip and returned by this latter to the position of equilibrium, are exceedingly sensitive to the action of the temperature, and experience, under the influence of heat, considerable variations in the periods of oscillation owing to the actions set up by variations in the modulus of torsion of the said suspension thread and owing to the expansion of the oscillating mass. The expansion of the suspension thread on strips produces an inverse effect, the value of which, however, is small as compared with the sum of the actions previously referred to.

Experiments in connection with the alterations of the modulus of torsion under the influence of the temperature in the case of certain alloys, which contain chiefly iron and nickel, have demonstrated that, contrary to what is the case with the metals or alloys ordinarily employed hitherto, the modulus of torsion increases with the temperature, when these alloys contain a certain percentage of nickel (30 to 46% parts by weight), as will be said more precisely further on.

The present invention is based upon this peculiar phenomenon. Broadly it consists in forming the suspension thread, band or band-like strip of an appropriate alloy of iron and nickel, this alloy being such as to render possible a compensation of the alterations in the period of oscillation of the pendulum mass caused by the action of the temperature.

By reason of the effect of the expansion of the band or strip and that of the oscillating mass, referred to above, this compensation is obtained by forming the suspension thread, band or strip not of an alloy whose modulus of torsion remains absolutely constant at varying temperature, but of an alloy whose modulus of torsion exhibits slight positive or negative variations, and selected in such manner that the sum of the three effects enumerated approximates as closely as possible to zero. This condition is attained by forming the thread, band or strip of an alloy which does not contain exactly 30% or 46% of nickel, but percentages varying slightly therefrom. Obviously with similar alloys the going of the clock will be considerably improved with varying temperatures, as compared with the suspension devices ordinarily employed; absolute compensation will not be attained closer than certain limits.

In the accompanying drawing forming a part of this application, Figure 1 is a front elevation of one form of my improved pendulum. Fig. 2 is a side elevation of the same. Fig. 3 is a front elevation of a portion of the pendulums illustrating a modified form, and Fig. 4 is a side elevation thereof.

Referring to Figs. 1 and 2, the body or weight *a* is suspended to the lower extremity of a metal rod *b* which forms the pendulum, said band fastened at its upper end at *c*, and made of a suitable alloy of iron and nickel in accordance with the invention set forth, the modulus of torsion of said pendulum *b* when suitably formed, being adapted to increase, to compensate for the relative expansion of the said pendulum and the body or weight *a*.

As shown in Figs. 3 and 4, the upper portion *d* of the pendulum consists of a rod of nickel-steel, the modulus of torsion of which increases in proportion as above described. At the end of said first part *d* is fastened the second part *g* of the pendulum by means of the clamping plates *e*, *e* and screws *f*, *f*, said second part being made of a metal or alloy, the modulus of torsion of which decreases when the temperature rises, the said parts *d* and *g* effecting in combination a changing modulus of torsion compensating for the expansion of the same and the weight hung at the lower end thereof. The portions *d* and *g* are, by the connecting means shown, capable of relative adjustment, and therefore may be reset, if, after observations of the clock it is found that compensation has not been perfectly obtained in the first instance.

Experience has demonstrated that in accordance with the present invention compensation is attainable in all cases that can arise in practice, if the oscillating mass is formed of any ordinary metal or any ordinary alloy, and the suspension thread, band or band-like strip of an alloy of iron with an addition of nickel varying between the limits of 29 and 32% on the one hand and 45 and 48% on the other hand, of the weight of the alloy. It is not necessary that these alloys should be produced in a laboratory, that is to say they need not be chemically pure; on the contrary they may be ordinary commercial alloys containing small quantities of the case in the metals as extracted. An admixture therewith of chromium increases the torsional resistance of the suspension devices, that is to say the thread, band or band-like strip. If such an addition be made, the percentage of iron and nickel should be reduced carbon, manganese, silicon and the like, as is usually somewhat, in such manner that with the first group of alloys the percentage of nickel is increased, and in the seeond group it is decreased. In the present case, however, it is only a question of slight difference in the percentages, as any considerable admixture of chromium would render the alloys difficult to work.

When one of the alloys above referred to is employed,

the process and means constituting the present invention permit of obtaining absolute compensation.

The table given below shows the dependence of the modulus of torsion upon the temperature and upon the alloy:—

Alloys. Percentage of nickel.	Variation of the torsion modulus for 1 degree centigrade.
26	−0.00030
28	−0.00018
30	0.00000
32	+0.00026
34	+0.00050
36	+0.00056
38	+0.00040
40	+0.00020
42	+0.00010
44	+0.00004
46	−0.00001
48	−0.00008
50	−0.00012

These figures relate to ordinary temperatures. As, however, in the case of all alloys with a high percentage of nickel, the alteration with the temperature is practically constant, these figures are also applicable to temperatures differing within reasonable limits from the normal. In the case of alloys containing a low percentage, on the other hand, the co-efficient changes somewhat rapidly, tending, with a rising temperature, towards a more negative value.

An addition of chromium imparts to the co-efficients a more constant value and therefore maintains the compensation within wider limits.

In order to allow for any defect in the property of the thread, it is advisable to form the suspension thread, band or strip of two parts, one only of which consists of nickel steel, whose modulus of torsion increases with rising temperature in accordance with what has been stated above. By suitably selecting the lengths and cross section of the two parts of the suspension strip, it is possible to obtain compensation for the alterations in the conditions of the one by the alterations in the other, in combination with the alterations in the moment of inertia of the oscillating mass caused by the temperature.

The two parts of the suspension means are either soldered or riveted together or connected one with the other in any other appropriate manner. A very suitable means is to attach the two parts one to the other by means of an ordinary clip or clamp permitting of alterations in the length of the thread, band or strip. In the first it is advantageous to adjust the two parts of the suspension means to a considerable length, which is reduced towards one side or the other if observations of the clockwork show that the compensation has not been attained on the first step. This adjusting or regulating means is in some instance similar to that employed in watches for the purpose of varying the effect of the bimetallic bands of the balance.

Owing to its extreme simplicity, the first device is preferably employed in the case of works of medium quality; it permits of slight alterations in the period of oscillation of the moving parts at different temperatures. The second device is more exact in its operation and is the preferred form for use in precision clocks in which it fully compensates for variations of the temperature.

The suspension means may likewise consist of more than two parts; the dimensions of this means and its various parts may vary as desired.

Having now particularly described my invention, I claim as new and wish to secure by Letters Patent:—

1. A torsion pendulum comprising a weight and means for supporting said weight, a portion of said supporting means having a modulus of torsion the value of which increases corresponding to the temperature to compensate for the expansion of said entire supporting means and said weight, substantially as described.

2. A torsion pendulum comprising a weight and means for supporting said weight, a portion of said supporting means being constructed of an alloy of iron and nickel and having a modulus of torsion the value of which increases corresponding to the temperature to compensate for the expansion of said entire supporting means and said weight, substantially as described.

3. In a torsion pendulum, a pendulum rod, comprising two relatively adjustable rods fastened one to the other, and a weight carried by the end of the lower rod, one of said rods having a modulus of torsion the value of which increases corresponding to the temperature to compensate for the expansion of said weight and both of said rods, substantially as described.

4. A torsion pendulum comprising a weight and means for supporting said weight, a portion of said supporting means having a modulus of torsion the value of which increases corresponding to the temperature to compensate for the expansion of said entire supporting means and said weight, and being constructed of an alloy of 72 to 64 parts of iron, 28 to 31 parts of nickel, and 5 parts of a rare earth, substantially as described.

5. A torsion pendulum comprising a weight and means for supporting said weight, a portion of said supporting means having a modulus of torsion the value of which increases corresponding to the temperature to compensate for the expansion of said entire supporting means and said weight, and being constructed of an alloy of 72 to 69 parts of iron and 28 to 31 parts of nickel, substantially as described.

6. In a torsion pendulum, a pendulum rod consisting of two bands fastened one to the other, and one of which has a modulus of torsion, the value of which increases corresponding to the temperature.

7. In a torsion pendulum, a pendulum rod consisting of two bands fastened one to the other, and one of which has a modulus of torsion, the value of which increases corresponding to the temperature, said rod being made of an alloy containing 72 to 50 parts of iron, 28 to 50 parts of nickel and 5 parts of a rare earth.

8. In a torsion pendulum, a pendulum rod consisting of two relatively adjustable bands fastened one to the other, and one of which has a modulus of torsion, the value of which increases corresponding to the temperature.

In testimony whereof I affix my signature in presence of two witnesses.

CHARLES EDOUARD GUILLAUME.

Witnesses:
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PIERRE GIRIN.