PATENT SPECIFICATION

323,001

Application Date: Sept. 13, 1928. No. 26,279/28.

Complete Left: July 12, 1929.

Complete Accepted: Dec. 13, 1929.

PROVISIONAL SPECIFICATION.

Improvements in Synchronous Propulsion of Pendulums.

I, FRANK HOPE-JONES, M.I.E.E., F.R.A.S., &c., of 32 & 34, Clerkenwell Road, in the County of London, Electrical Engineer, British Subject, do hereby declare the nature of this invention to be as follows:—

This Invention has for its object the synchronising of pendulums and also their synchronous propulsion, and is accomplished by transmitting impulses thereto at regular but comparativly infrequent intervals,—that is to say compared with the frequencies previously employed in similar methods of synchronisation.

I have recently demonstrated in the science of horology that the more a pendulum is free, the greater the accuracy of its time measurement, and that when it is entirely free an extraordinary degree of precision is achieved.

This invention applies the principles of the Free Pendulum, as described in Patent No. 1945 of 1907, and developed in conjunction with Patent No. 187,814 of 1921, to the problem of the synchronisation of any number of pendulums and results in holding them more firmly in synchronisation with the Master pendulum than has hitherto been possible, at the same time, if desired, in dispensing with the necessity of applying separate means of maintenance to them.

In this my invention the synchronising and impelling signal is transmitted by the Master pendulum every half-minute or minute, (or quarter minute in the case of pendulums beating half-seconds), and is received by the subsidiary or slave pendulum on an electro-magnet which synchronises or synchronises and impels the slave pendulum by direct attraction, the armature or magnet being carried by the pendulum or by a crutch associated with it, whilst the magnet or the armature is fixed adjacent thereto, so arranged that they are not precisely opposite each other when the pendulum is at zero.

In one form of this invention, the armature is fixed centrally at the lower extremity of the pendulum and the magnet is fixed a short distance out of centre but adjacent to it. Impulses are transmitted to the magnet every half-minute by the Master pendulum of the type described in my Patent No. 1945 of 1907, or Patent No. 9527 of 1915, or any combination or modification thereof, the essential features of such impulses being (1) the uniformity of their wave-shaped, (2) the wide intervals between them, and (3) the precision of their periodicity.

As it is also an essential feature of this invention that the electro-magnet is placed a little away from zero it is desirable to explain the reason for this.

In a general sense the use of an electro-magnet below the pendulum functions as an addition to the force of Gravity, and by increasing the value of Gravity it causes the clock to gain whether the fixed member is placed exactly at zero or not. This is well-known and is usefully employed in the method of correcting a clock due to Sir George Airey in which a permanent magnet is fixed on the pendulum and by changing the direction of the current flowing through the fixed coil below it, gravity is either augmented or reduced and the clock is thus made to gain or lose according to the E.M.F. and the period for which it is applied.

It is customary to arrange such an electro-magnetic system at zero, i.e. vertically below the centre of suspension of the pendulum when the object is merely correction or setting, and when the current is applied continuously for considerable periods, it is not a matter of importance whether it is placed in this theoretically best position or not.

In this my invention the current is applied in the form of short duration electrical impulses at definite periodic intervals intended to coincide in phase with the Slave pendulum and to bring it into phase if wrong and to keep it in phase when right.

If the electro-magnet is placed vertically under the pendulum and the slave clock is in correct phase with the synchronising signal then the armature on the pendulum will be exactly over the magnet when the signal arrives and the magnet will attract it vertically and will function solely as an addition to Gravity

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for a negligible period and the rate of the clock will not be appreciably affected.

But if the Slave pendulum is not in phase, the synchronising impulse will attract the pendulum horizontally as well as vertically, again acting in the same sign as Gravity whether the pendulum is slow and approaching the magnet or is fast and receding from it. The effect will be to make the pendulum gain in any event and it is to be observed that the arc of the pendulum will be increased if it is slow and diminished if it is fast.

If on the other hand the magnet is placed a little out of the centre, say to the right, then when the pendulum is moving from left to right and is fast, it will have passed beyond zero when the synchronising signal arrives and the magnet will be pulling against Gravity, thereby slowing the pendulum and increasing the arc.

This invention may be used merely to synchronise a pendulum whose vibrations are maintained by other means in which case a very weak electro-magnetic impulse will be found sufficient to maintain indefinitely a high degree of accuracy in phase.

It is of course superior to any method which is based upon the correction of a gaining or a losing rate since the slave pendulum is rated as closely as possible to the rate of the Master to begin with.

As an example only of the many useful applications of this invention, it may also be used for the synchronous propulsion of groups of pendulums such as would appropriately be used in small mantelshelf clocks or domestic or Office dials, particularly where seconds or half-seconds indication is required and silent action is desired. Such clocks might be called Silent Synchronous Seconds Dials. They would have comparatively short pendulums such as $\frac{1}{4}$ or $\frac{1}{2}$ seconds, or partly counter-balanced pendulums or balance wheels, which would be maintained in synchronous vibration by means of half-minute impulses from a Master Clock of the type indicated.

The pendulum would propel the hands and their gear-wheels by any known method such as the lifting of a one-sided gravity arm or crutch, and would be given a comparatively large arc in order that the energy available may not only be sufficient to do this work but completely dominate it and any possible variation in friction in the wheelwork or hands.

The most essential and novel feature of this invention lies in the wide intervals between the synchronising signals and their perfection of wave-shape and periodicity.

Every attempt to synchronise or propel pendulums by direct electro-magnetic attraction since the days of Bain, 1840, and R. L. Jones, 1857, have failed owing to uncertain and too frequent contacts.

I have proved conclusively that where mechanical impulses are imparted to a pendulum by such means for instance as a falling gravity arm, success is achieved only by one comparatively large and robust impulse, say every thirty seconds, and never by thirty smaller ones, one per second, the reason being that when the force to be applied is small it is impractical to maintain its predominance over pivot friction and other varying irregularities to the same extent as you can when the force is large, the latter method having also the great advantage of leaving the pendulum absolutely free for long periods in between the impulses.

This my invention applies the same principles to the synchronising and propulsion of pendulums by electro-magnetism and reaps the same advantages.

Instead of frequent impulses all more or less ragged and uncertain which constantly interfere with the freedom of the pendulum, this invention leaves the pendulum absolutely free except for a period of the order of one part in 500 of the time measured and has been found in practice to be absolutely reliable for this purpose and to hold pendulums in synchronisation even if their natural period of vibration is appreciably different from that of the Master pendulum.

This invention also provides means for starting a slave pendulum in phase with the synchronising signal or sufficiently close to its true phase to enable the signal to bring it into phase rapidly. One method of accomplishing this may be described, only by way of an example, as a loose link device, whereby when it is desired to start the pendulum a light strut is used to hold it a little away from zero. This strut is made of soft iron and is lightly held by friction close above the poles of the magnet so that the first synchronising impulse will unseat it and drop it out of the way.

Another method is provided by the "Accelerating" device of my Patent No. 6066, 1905, or its equivalent. One or any number of synchronous pendulums in circuit with such a transmitting device will start themselves as a result of a short series of signals transmitted in precise phase at every vibration of the Master pendulum instead of at every 30th vibration.

Dated the 13th day of September, 1928.

F. HOPE-JONES.

COMPLETE SPECIFICATION.

Improvements in Synchronous Propulsion of Pendulums.

I, FRANK HOPE-JONES, M.I.E.E., F.R.A.S., &c., of 32 & 34, Clerkenwell Road, in the County of London, Electrical Engineer, British Subject, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This Invention has for its object the simultaneous propulsion and synchronisation of the pendulums of a group of subsidiary or slave clocks by electrical impulses of equal intensity and duration occurring at regular but wide intervals such as 30 seconds or more (as for instance the impulses produced by an electrically operated master pendulum as described in Patents Nos. 1945—1907, and 9527—1915).

I have recently demonstrated in the science of horology that the more a pendulum is free, the greater the accuracy of its time measurement, and that when it is entirely free an extraordinary degree of precision is achieved.

This invention applies the principles of the Free Pendulum, as described in Patent No. 1945 of 1907, and developed in conjunction with Patent No. 187,814 of 1921, to the problem of the synchronisation of any number of pendulums and results in holding them more firmly in synchronisation with the Master pendulum than has hitherto been possible, at the same time, if desired, in dispensing with the necessity of applying separate means of maintenance to them.

In one form of this my invention the synchronising and impelling signal is transmitted by the Master pendulum every half-minute or minute, and is received by the subsidiary or slave pendulums on electro-magnets which synchronise and impel them by direct attraction, the armature being carried by the pendulum or by a crutch associated with it, whilst the magnet is attached to the pendulum support or vice-versa. The magnet and armature are so positioned that they are not opposite each other when the pendulum is at zero.

In the case of a half-seconds slave pendulum the armature may be fixed centrally about half-way down the pendulum rod and the magnet fixed to the pendulum support adjacent to it but displaced to right of the centre line by about 10 mm.

Impulses are transmitted to the magnet every half-minute by the Master pendulum of the type described in my Patent No. 1945 of 1907, or Patent No. 9527 of 1915, or any combination or modification thereof, so long as such impulses are uniform in their wave-shape and precise in their spacing, these intervals being wide, such as thirty seconds or more.

The manner in which these impulses can serve both to impel and synchronise the slave pendulum will best be understood if the conditions obtaining when the slave pendulum is swinging normally under the influence of the master pendulum's half-minute impulses are examined.

The magnet being placed on the right 10 mm. from zero, it will usually be found that the slave has settled down so that the impulse comes through the magnet when the pendulum is approaching its zero position from left to right, and that the relative position of the armature and magnet during the impulse are such that the magnetic attraction between them has considerably less than its maximum value.

Now if from any cause the slave tends to go faster this will immediately result in its being nearer its zero position when the impulse commences and in an increase in the magnetic attraction so that the pendulum is more vigorously propelled and consequently increases its arc, which results in the neutralisation of the quickening tendency by the increase in the slowing effect of circular error.

Owing to the magnetic attraction taking place while the pendulum is approaching its zero position it produces a quickening of that particular semi-vibration, and experiment has proved that this quickening decreases with increasing pendulum arcs and vice-versa so that the change in this effect supplements the effect of the circular error and strengthens the control which the master impulses have over the motion of the slave pendulum.

Obviously any tendency for the slave to go slower will be equally effectively checked by the combination of the same two influences in the opposite sense.

The longer the slave pendulum or the slower its natural rate of vibration at practically zero arc i.e. when the amplitude is practically at zero, the smaller its arc when controlled by the master impulses.

The greater the displacement of the magnet to the right the closer the slave

gets to its zero position before the impulse, comes through and the smaller the quickening effect of the impulse and the less its variation with change of arc and consequently its strengthening of the control.

By sufficiently increasing the displacement of the magnet, say to the right, it is possible to get the slave pendulum moving from left to right away from zero before the impulse comes through, but as the effect of the impulse is then to slow the period of that particular semi-vibration and as this slowing increases with decreasing arc the result is to weaken the control effected by the circular error. When the displacement is such that circular error effect is completely neutralised or more than neutralised, synchronisation or control is impossible.

It will be understood from the foregoing that the slave pendulums are normally adjusted so that their natural rates of vibration at practically zero arc are slower than the rate of the master pendulum.

In practice it is found that the master pendulum is capable of controlling slave pendulums which if unsynchronised would lose as much as three minutes per day on the master pendulum.

The slave pendulums are in consequence usually adjusted so that their natural rates are about one minute per day slower than the rate of the master clock.

This invention may also be used to synchronise pendulums whose vibrations are independently maintained by the application of the magnet and armature already described in the case where propulsion is also required. The normal arc of the slave pendulum will of course be increased which in general will be advantageous rather than otherwise.

As an example only of the many useful applications of this invention, it may also be used for the synchronous propulsion of groups of pendulums such as would appropriately be used in small mantelshelf clocks or domestic or office dials, particularly where seconds or half-seconds indication is required and silent action is desired. Such clocks might be called Silent Synchronous Seconds Dials. They would have comparatively short pendulums such as $\frac{1}{4}$ or $\frac{1}{2}$ seconds, or partly counter-balanced pendulums, which would be maintained in synchronous vibration by means of half-minute impulses from a Master Clock of the type indicated.

The pendulum would propel the hands and their gear-wheels by any known method such as the lifting of a one-sided gravity arm or crutch, and would be given a comparatively large arc in order that the energy available may not only be sufficient to do this work but completely dominate it and any possible variation in friction in the wheelwork or hands.

I have proved conclusively that where mechanical impulses are imparted to a pendulum by such means for instance as a falling gravity arm, success is achieved only by one comparatively large and robust impulse, say every thirty seconds, and never by thirty smaller ones, one per second, the reason being that when the force to be applied is small and frequent it is impracticable to maintain its predominance over pivot friction and other varying irregularities to the same extent as can be done when the force is large and infrequent the latter method has also the great advantage of leaving the pendulum absolutely free for long periods in between the impulses.

This my invention applies the same principles to the synchronising and propulsion of pendulums by electro-magnetism and reaps the same advantages.

Instead of frequent impulses which constantly interfere with the freedom of the pendulum, this invention leaves the pendulum absolutely free except for a period of the order of one part in 500 of the time measured and has been found in practice to be absolutely reliable and as already stated capable of holding pendulums in synchronisation when their natural rates of vibration are slower than that of the Master pendulum by as much as three minutes per day.

This invention also provides means for starting a slave pendulum in phase with the synchronising signal or sufficiently close to its true phase to enable the signal to bring it into phase rapidly. One method of accomplishing this may be described, only by way of an example, as a loose link device, whereby when it is desired to start the pendulum a light strut is used to hold it a little away from zero. This strut is made of soft iron and is lightly held by friction close above the poles of the magnet so that the first synchronising impulse will unseat it and drop it out of the way.

Another method is provided by the "Accelerating" device of my Patent No. 6066, of 1905, or its equivalent. One or any number of synchronous pendulums in circuit with such a transmitting device will start themselves as a result of a short series of signals transmitted in precise phase at every vibration of the Master pendulum instead of at every 30th vibration.

In the annexed drawings illustrative of this my invention, and in which like letters indicate like or equivalent parts,

Figure 1 illustrates a circuit of synchronous seconds slave clocks operated by a master clock which normally transmits impulses thereto at wide intervals such as once every half-minute, but which, in order to start them in correct phase, may be set temporarily to transmit impulses at much more frequent intervals, such as every two seconds.

Figure 2 illustrates by way of example only one method of starting a slave pendulum in approximately correct phase by means of a lever link or strut which holds the pendulum away from the vertical until the first synchronising impulse removes it.

Figure 2A shows a plan of Figure 2.

Figure 3 shows the positioning of the impelling and synchronising electro-magnet and its armature most generally suited to the stable control of a half-seconds pendulum by half-minute impulses transmitted from a master clock of the type described in Patents Nos. 1945—1907, and 9527—1915.

Referring now to Fig. 1, in which S^1, S^2, and S^3 represent synchronous slave pendulums, and A the master clock, the gravity arm G and armature F represent the Switch, as described in my Patent No. 6066, of 1905, or No. 1945 of 1907, or other equivalent automatic time transmitter whose important features are for the purpose of this invention the normal transmission of electrical impulses at wide intervals such as minutes or half-minutes, the short duration of these impulses, and the precision in their spacing.

The circuit comprises a battery B, and any number of electro-magnets M, of a series of slave clocks S, whose pendulums carry armatures N adapted to swing in close proximity to the magnets M, which are placed close to the zero position of the pendulums.

In the illustration the pendulums are furnished with armatures, and their corresponding electro-magnets are invariably fixed in the cases of the clocks. The disposition of these parts may of course be reversed.

It will be understood that these slave clocks are provided with dials whose hands are propelled by the pendulums through the medium of trains of wheels or "motion-work" by means which are well known in the science of Horology, and form no part of this invention.

It will also be understood that the catch K of the electrical time transmitter A shown in Fig. 1 is normally released by the master pendulum through the medium of the hook J, the wheel C and vane D, once every 30 seconds.

In any such system of electrically propelled slave clocks, means must be provided for starting them in synchronisation, and one method of accomplishing this may be described by reference to the Master Clock A in Fig. 1, in which a lever L or its equivalent is provided, whereby the hook J may be temporarily guided into such a position that it will engage the arm K^1 and thereby release the catch K at every complete vibration of the pendulum, thus transmitting synchronising and impelling impulses to the slaves every two seconds, in the case of a seconds pendulum.

By this means the slave pendulums will in a short time be started from rest sufficiently close to their correct phase to enable the less frequent but more accurate impulses to take charge of them.

Various forms of magnets and armatures are shown in various positions on the pendulums, it being immaterial for the purposes of this invention which are employed. But in every instance the magnet is placed away from the vertical or zero of the pendulum.

With reference to Fig. 2, in which M is the synchronising and impelling magnet and N is the armature on the pendulum, O is a strut of soft iron free and unattached, shown in plan in Fig. 2A, which serves as a starting armature. Before starting the pendulum, it is deflected to the right and the strut O is placed between the stop P and the pendulum armature N. The first synchronising impulse dislodges the strut from P and it thus falls out of the way.

Referring to Fig. 3, "M" is the synchronising and impelling magnet, "N" is the armature attached to the pendulum which is assumed to be of half-seconds periodicity. The armature "N" is situated centrally on the pendulum rod "R" and about 85 mm. below the centre of suspension, while the magnet "M" is displaced to the right so that its centre line is about 10 mm. to the right of the line representing the zero position of the pendulum.

"R" and "N" are shown in the position they might be expected to occupy at the commencement of the impulse, while the dotted lines indicated by the letters "R.1" and "N.1" indicate the normal position of pendulum rod and armature at the end of the impulse.

The bracket lines indicated by the letters "S" and "S" indicate the normal extent of the armature's excursion. The line "Z.Z" represents the centre line of the pendulum when in its zero or rest position.

Since in this my invention the control

of the slave pendulums is largely achieved through the circular error by controlling their arcs, it is desirable that the normal arcs shall be large and easily varied, and for that purpose the shorter the pendulums the better, consistent with their ability to maintain their vibrations between the signals.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed; I declare that what I claim is:—

1. Any system of synchronous clocks in which the pendulums of the secondary or slave clocks are propelled and synchronised by the magnetic attraction of armatures mounted on the pendulums or their crutches by solenoids or electro-magnets mounted on the pendulum supports very near to the zero positions of the pendulums, such electro-magnets or solenoids being energised by electrical impulses of equal duration and intensity occurring at regular but wide intervals such as thirty seconds or more (as for instance the impulses produced by an electrically operated Master pendulum as described in Patents Nos. 1945 of 1907 and 9527—1915).

2. Any system of synchronous clocks in which the pendulums of the secondary or slave clocks are propelled and synchronised by the magnetic attraction of electro-magnets or solenoids mounted on the pendulums or their crutches by armatures mounted on the pendulum supports very near to the zero positions of the pendulums, such electro-magnets or solenoids being energised by electrical impulses of equal duration and intensity occurring at regular but wide intervals such as thirty seconds or more (as for instance the impulses produced by an electrically operated master pendulum as described in Patents Nos. 1945 of 1907 and 9527—1915).

3. A system of synchronous clocks, as in Claim 1, in which the magnets or solenoids and their armatures are so disposed in their small relation to one another on each subsidiary pendulum that, when such pendulum is operating normally, the closer it is to its zero position the greater the attraction of the armature, and that the magnetic force tends always to advance the phase of the pendulum in relation to the electrical impulse and so that this phase advance increases with a decrease in the arc of the pendulum, whereby slave pendulums normally having losing rates may be kept under stable control, and vibrating continuously in step with the impulses.

4. A system of synchronous clocks as detailed in Claim 3 and substantially as described with reference to Figs. 1 and 3.

5. In a system of synchronously propelled clocks as described in Claim 3 the starting up of the secondary or slave pendulums from their normal positions of rest, into a state of synchronous vibration in phase with the impulses intended to operate them occurring at regular but wide intervals such as thirty seconds or more, by a succession of similar impulses temporarily made to recur at short intervals, such as two seconds.

6. In a system of synchronously propelled clocks as described in Claims 1 & 2, the starting up of the secondary or slave pendulums from a position of rest, with their normal amplitude and in phase with the impulses intended to operate them, by means of struts dislodged by the first impulse as described with reference to Figs. 2 and 2A.

Dated this 7th day of December, 1929.

F. HOPE-JONES.

Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.—1930.

FIG. 1

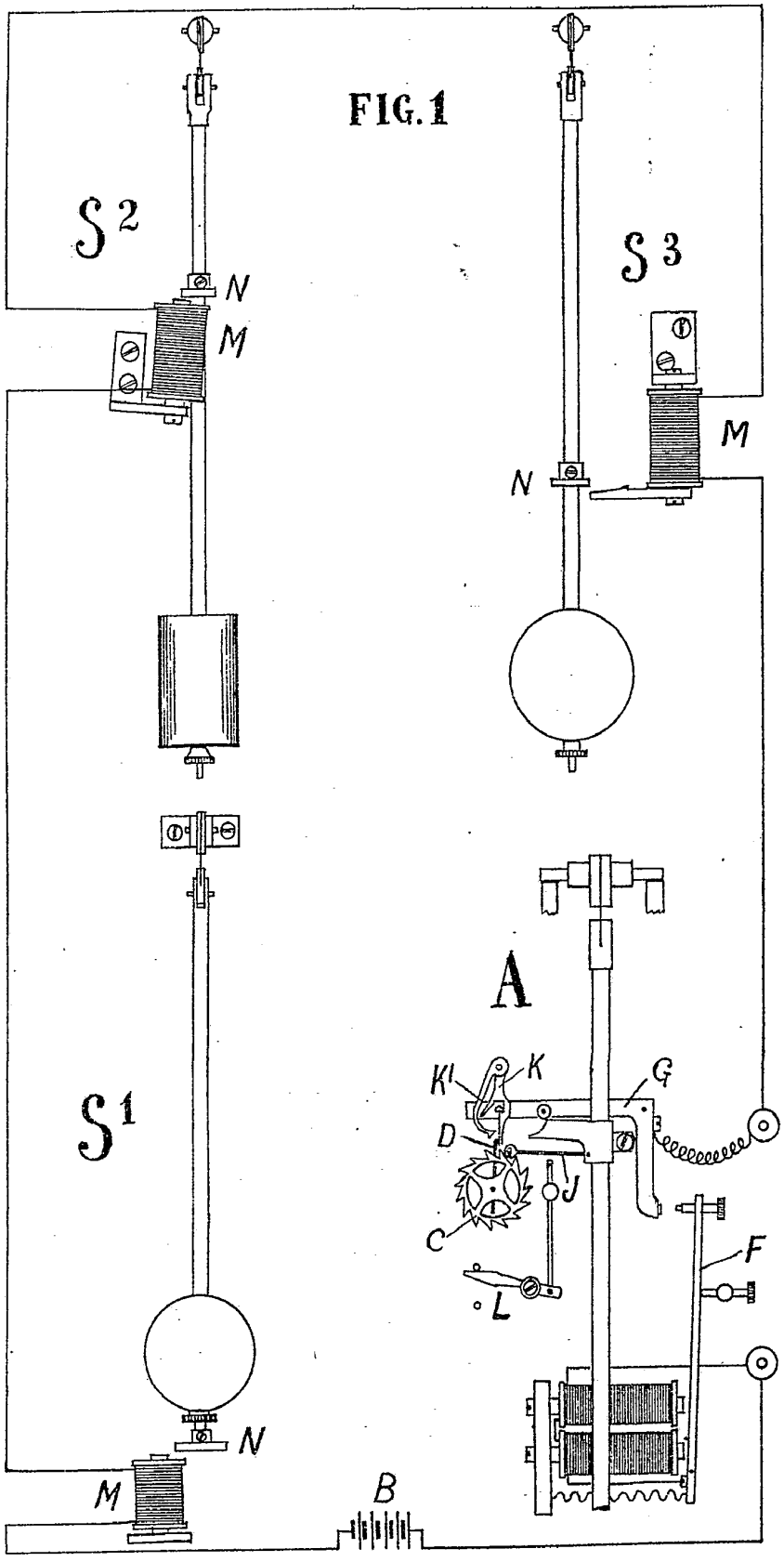


FIG. 2.

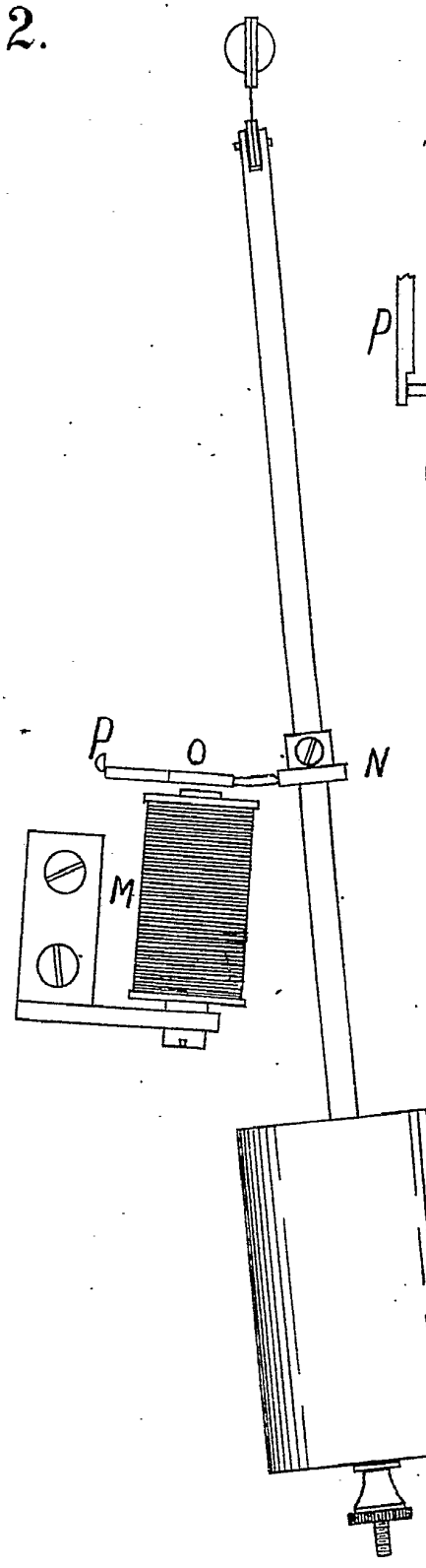
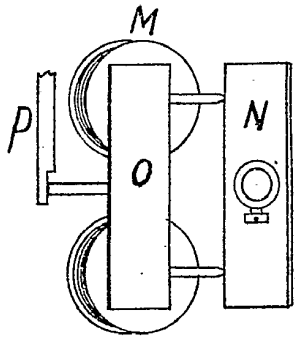


FIG. 2A.



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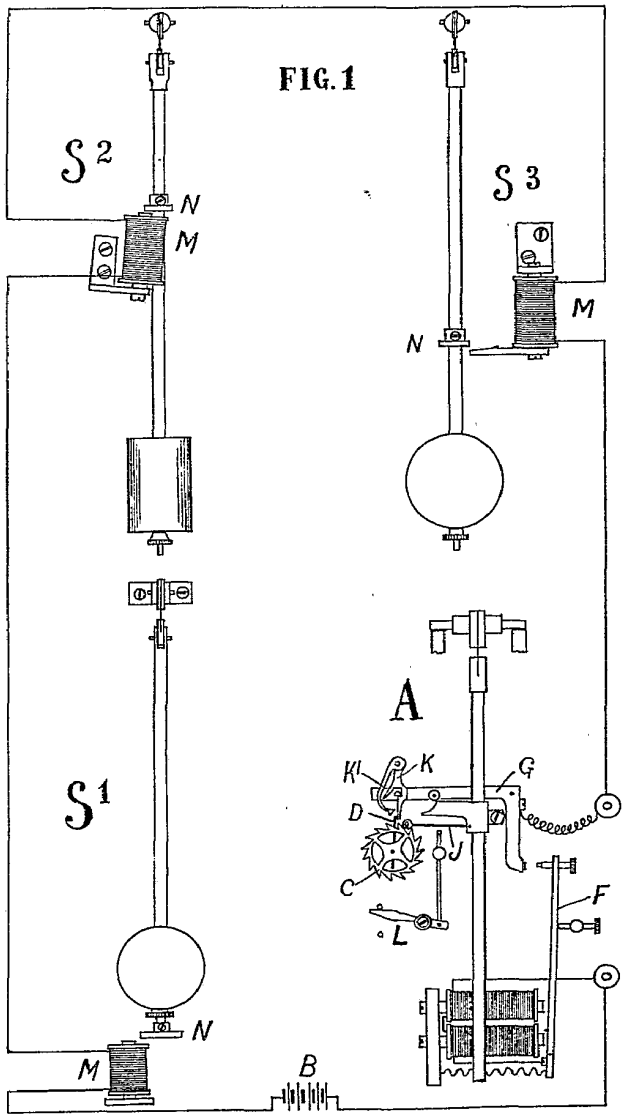
SHEET 1

FIG. 1



[This Drawing is a reproduction of the Original on a reduced scale.]

SHEET 2

FIG. 2.

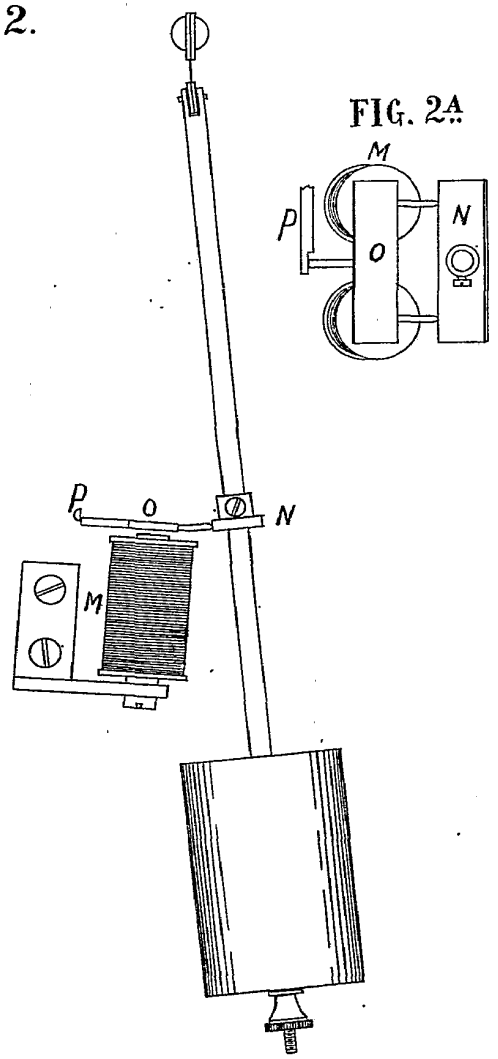


FIG. 2A.

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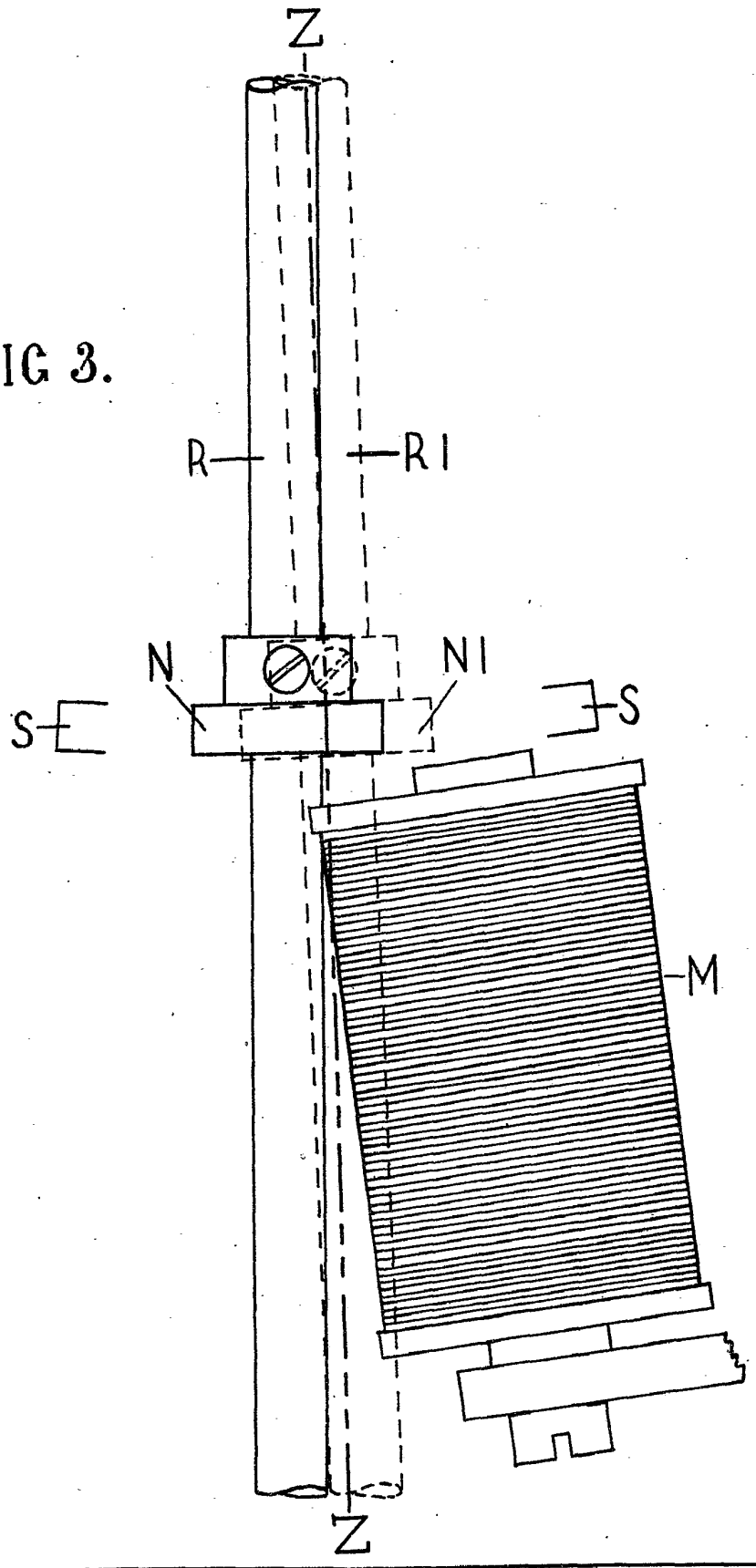
FIG 3.



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