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TIMING APPARATUS FOR CLOCKS AND WATCHES

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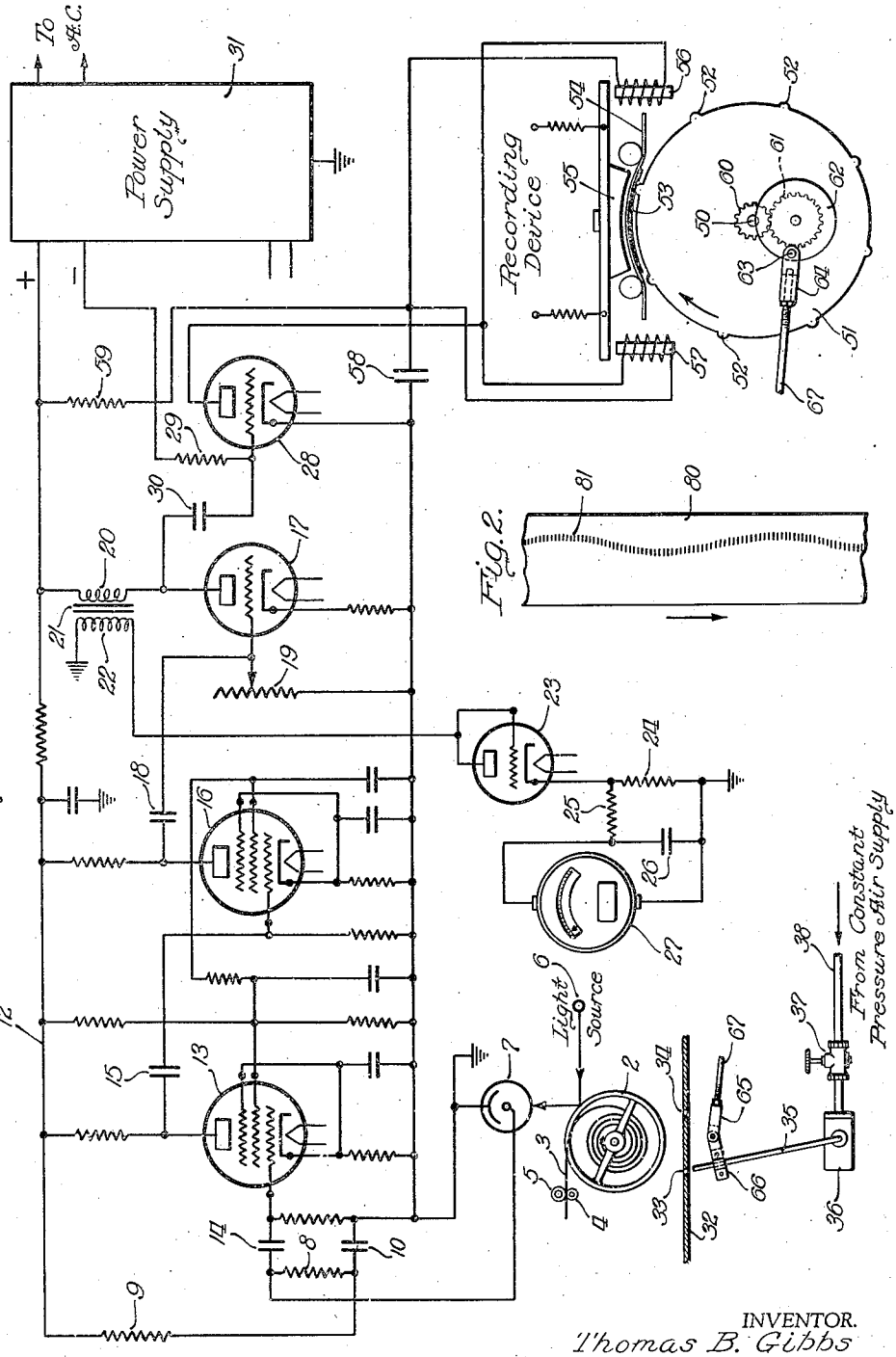


Fig. 1.

Fig. 2.

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TIMING APPARATUS FOR CLOCKS AND WATCHES

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The present invention relates in general to timing apparatus for clocks and watches, and more in particular to an arrangement of apparatus for timing the balance-wheel of a clock or watch before it is assembled with the remainder of the movement. It is the common practice in the art to time balance-wheels by adjusting the length of the associated hairsprings and the operation of timing is therefore commonly referred to as hairspring vibrating. The object of the invention is the production of new and improved apparatus for vibrating hairsprings.

The invention will be described more in detail hereinafter with reference to the accompanying drawing, in which Fig. 1 shows diagrammatically the circuits and apparatus involved, while Fig. 2 shows the character of record that may be obtained on the recording device that forms part of the apparatus.

Referring to Fig. 1, the equipment therein shown will be briefly described. The reference character 2 indicates a balance-wheel having a hairspring 3, which is to be timed or "vibrated" as mentioned in the foregoing. The balance-wheel is supported on a suitable stand (not shown) having pivots for the balance staff so arranged that the balance-wheel can be quickly placed in position and removed. The end of the hairspring 3 is clamped between the two rollers 4 and 5, one of which may be provided with a knob by which it can be rotated to feed the hairspring in and out to adjust the effective length thereof. The details of a suitable stand for the purpose are well known in the art.

The reference character 6 indicates a source of light which is arranged in any suitable manner, as by a reflector or lens system, to throw a beam of light onto the rim of the balance-wheel 2. The reflected beam is intercepted by a photocell 7. The cathode of the photocell is grounded, while the anode is connected to the plus B lead 12 through resistors 8 and 9. A filter condenser is indicated at 10.

The reference character 13 indicates a space discharge tube of the pentode type, arranged to operate as an amplifier. The control grid of this tube is coupled to the photocell circuit through a condenser 14, which may have a capacity of 100 mmf. The circuits of tube 13 are more or less conventional and need not be described in detail.

The plate circuit of tube 13 is coupled by means of a condenser 15 to the control grid of a second space discharge tube 16, which may be the same as tube 13 and also has a conventional amplifier circuit.

A third space discharge tube is indicated at 17. This tube may be of the triode type, and is coupled to the preceding stage through a condenser 18. The grid circuit in the case of tube 17 preferably includes the variable resistance 19 which may be used to regulate the potentials impressed on the grid by the preceding stage. The plate circuit includes the primary winding 20 of the transformer 21.

The reference character 23 indicates a rectifier tube which is connected in series with the secondary winding 22 of transformer 21 and the resistance 24. A direct current voltmeter 27 is arranged to measure the drop across the resistance 24. A condenser 26 is provided to smooth out the current fluctuations so that a steady reading of the voltmeter may be obtained.

The reference character 28 indicates a space discharge tube of the gas filled type, which is normally biased to cut off by a negative potential on the control grid, applied through the resistor 29. The grid is coupled to the plate circuit of the preceding tube by means of condenser 30.

The rectangle 31 represents a suitable power pack for supplying plate voltage to the various tubes, also negative potential for biasing the grid of tube 28. The filament or heater circuits of the tubes are conventional and have been omitted in order to simplify the drawing.

The apparatus includes means for directing spurts or impulses of air against the rim of the balance-wheel in order to start and maintain the periodic oscillations thereof. The air impulses are delivered at a constant rate or frequency which is the current frequency for the wheel. This part of the apparatus will now be described briefly.

When the balance-wheel 2 is positioned on the stand ready to be vibrated or regulated, the rim of the balance-wheel is a short distance above a shield or plate 32, which may form part of the stand, and which is provided with small openings 33 and 34. These openings are in the plane of the balance wheel and are equally spaced on opposite sides of the balance staff. Beneath the plate 32 there is arranged an air pipe 35, the lower end of which has a pivotal connection with the junction box 36. The pipe 35 is in the same vertical plane with the openings 33 and 34. Air is supplied to box 36 and pipe 35 through a valve 37 and pipe 38, the latter being connected to any suitable pump and reservoir system for furnishing compressed air at constant pressure. It will be seen that if the pipe 35 is given the proper reciprocating motion about its pivot the upper

end of the pipe will be moved alternately beneath the openings 33 and 34 so that spurts or blasts of air can be directed first through one opening and then the other.

In order to reciprocate the pipe 35 at the proper rate and also to assist in regulating the balance-wheel, a recording device having a constant speed element is employed. This recording device, sometimes referred to as a "printer," may be of the type shown and described in the patent to Gibbs, No. 2,254,649, granted September 2, 1941. The essential parts of the recording device are shown diagrammatically in the drawing and will be described briefly.

The shaft 50 is driven at constant speed by any suitable means such as a synchronous motor which is supplied with current of constant frequency. On the shaft 50 there is mounted a toothed disc 51, which rotates beneath a strip of paper or other record material 53. Suitable means is provided for feeding the paper strip past the edge of the disc in a direction parallel to its rotation axis and for giving the strip a curved formation where it passes the disc. The feeding means is preferably arranged so that it can be started and stopped independent of rotation of the disc 51. The reference character 54 indicates a printing ribbon which extends transversely across the strip 53 in the plane of disc 51. The ribbon may be fed along in known manner. Above the ribbon is located the printer bar 55, which is arranged to be operated by the electromagnets 56 and 57. When the magnets are energized momentarily the printer bar is pulled down and presses the ribbon and paper strip momentarily against some tooth of the disc 51 which at the moment is passing beneath the strip. This operation prints a short dash or mark on the strip. The energization of the electromagnets 56 and 57 is controlled by the tube 28 in a manner which will be explained shortly.

As previously intimated, the printer is arranged to operate the air pipe 35 and to this end is provided with a gear wheel 60 which is supported on the shaft 50 and rotates with it. Suitably supported on the frame of the printer there is a second gear wheel 61 which is in mesh with gear 60. Gear 61 has an annular flange 62 at one side thereof on which is fixed a pivot stud 63. The latter supports one end of a connecting rod which comprises the members 64 and 65, the threaded rod 67 and the bracket 66 attached to pipe 35. It will be seen that when the gear 61 is rotated the air pipe 35 will be moved back and forth on its pivot. The parts are so adjusted that with gear 61 in the position in which it is shown the pipe 35 will be exactly underneath the opening 33, while if the gear 61 is rotated 180 degrees the pipe will move to a position in which it is exactly underneath the opening 34.

The speed at which the shaft 50 is driven depends on the correct beat frequency of the balance-wheels to be regulated. Preferably the shaft and disc 51 make one complete rotation for each beat, from which it will be seen that if the balance wheel frequency is 272 beats per minute the shaft 50 will be driven at 272 R. P. M.. In any event the ratio between gears 60 and 61 is 1 to 2, so that gear 61 will rotate at half the speed of shaft 50.

The operation of vibrating a hairspring, or regulating the period of the associated balance-wheel, may now be described. For this purpose, it may be assumed that the recording device or printer is in operation, although the feed mechanism for the paper strip 53 may be stopped for the time being. Disc 51 is rotating, likewise gears 60 and 61, and the air pipe 35 is moving to and fro between openings 33 and 34. The air valve 37 should be adjusted properly so that a stream of air of the requisite velocity will be issuing from the end of pipe 35.

A balance-wheel such as 2 may now be placed in position on the stand, with the end of the hairspring clamped between the rollers 4 and 5. Being free to oscillate in its bearings, the balance-wheel will immediately be set in motion by the blasts of air which issue alternately from openings 33 and 34 and impinge on the rim of the wheel first to one side and then to the other. Assuming that the hairspring is clamped at approximately the correct point, as determined by experience, the balance-wheel will rapidly pick up motion and will begin to oscillate with appreciable amplitude.

When the balance-wheel is set in motion as described in the preceding paragraph, certain variations are produced in the current which flows through the photocell. The photocell current is responsive to light reflected from the rim of the wheel and the variations are due to movement of the wheel beneath the impinging light beam. This phenomenon is more fully described in the patent to Gibbs and Brown, No. 2,231,849, granted February 11, 1941. It will be sufficient to state here that the currents generated by the photocell due to movement of the balance-wheel are of various frequencies, including components having a much higher frequency than the frequency of the wheel, and that the volume increases with the amplitude of the wheel, that is, with the speed at which the rim of the wheel moves beneath the impinging light beam. The currents are generated while the wheel is in motion in either direction and cease when the wheel stops to reverse its direction of rotation.

The invention provides two means for determining when the balance-wheel is properly regulated. One of these is the voltmeter 27, which provides for a coarse regulation, sufficient for some purposes. The other is the recording device, by means of which a finer adjustment can be secured if desired. The process of vibrating or regulating by use of the voltmeter will first be explained.

The photo cell currents generated by movement of the balance-wheel are amplified in the tube 13, and are further amplified in tubes 16 and 17, with the result that considerable variations in the plate current at tube 17 take place, whereby alternating voltages are induced in the secondary winding 22 of transformer 21. An intermittent direct current therefore flows in the circuit which includes the secondary winding 22, the rectifier tube 23, and the resistance 24. The value of this current is proportional to the amplitude of the balance-wheel oscillations, and is measured by the voltmeter 27; or rather, the voltmeter 27 measures the drop across the resistance 24, which is proportional to the current flow. The filter arrangement comprising the resistance 25 and condenser 26 enables the voltmeter to show a steady reading.

The method of hairspring vibration or regulation according to the invention depends on the fact that the balance-wheel will attain a maximum amplitude when its natural frequency of oscillation is the same as the frequency of the air blasts by which it is driven. If the frequency

of the wheel is different from the air blast frequency the wheel will oscillate with an amplitude which is less than its maximum and will fall out of step with the air blasts at regular intervals the length of which is inversely proportional to the difference in frequency.

In practice the hairsprings are always made too long, for obvious reasons, and the natural frequency of the balance-wheel 2 will therefore be too low when the vibrating operation is started. The operator is, of course, acquainted with the situation and understands that she has to raise the balance-wheel frequency until it is the same as the air blast frequency. This is done by rotating the roller 5 in the proper direction to feed the hairspring to the left and thus shorten its effective length, the voltmeter 27 being observed at the same time to note the effect on the amplitude of the wheel. As the hairspring is shortened the balance-wheel will run in step with the air blasts for increasingly long periods and its amplitude will increase. The operator will continue to shorten the hairspring until the indication shown by the voltmeter reaches a maximum and begins to fall, thus insuring that the point of maximum amplitude has been passed. The hairspring is then lengthened slowly until the voltmeter again shows the maximum reading, and the operation is completed by marking the hairspring in some suitable manner at a point adjacent the rollers to indicate where it should be clamped when the balance-wheel is assembled. The balance-wheel may then be removed from the stand, and the operation can be repeated with another balance-wheel.

The method of vibrating or regulating just described gives fairly accurate results, which are good enough for certain kinds of clocks and watches. It will be appreciated, however, that there is a small range of frequencies including the correct frequency for which the changes in amplitude are quite small and difficult to detect with the voltmeter. In this range also the balance-wheel runs in step with the air blasts for comparatively long periods. The operator can indeed determine that the balance-wheel is slightly off in frequency and the amount of the departure by noting the rate at which the wheel goes out of step, but this is a tedious and time-consuming process, which is rendered more difficult by the fact that there is nothing to definitely indicate whether the balance wheel is too fast or too slow at any given instant.

For extremely accurate regulation, therefore, recourse is had to the recording device, the operation and utility of which will now be explained. This equipment enables exact adjustments to be made with great facility.

Assuming that the balance-wheel 2 is oscillating in its bearings and that the hairspring has been regulated in the manner explained, the large variations in plate current which take place at tube 17 will result in large variations in plate voltage at this tube. At each oscillation or beat of the balance-wheel, therefore, voltage changes will be transmitted to the grid of tube 28 through the condenser 30 which overcome the normal negative bias on the grid and cause the tube to fire. The condenser 58 is normally charged, being connected between ground and the plus B lead 12 through the resistor 59. When the tube 28 fires, or begins to pass current, the condenser 58 discharges over a path which includes the cathode and plate of tube 28 and the electromagnets 56 and 57. The condenser discharges quickly and the current flow rapidly decreases to a point where the tube 28 is extinguished and ceases to pass current. The condenser 58 then charges up again through the resistor 59. The arrangement thus provides for transmitting short impulses of current to the electromagnets 56 and 57, one impulse for each beat of the balance-wheel.

Each time the electromagnets 56 and 57 are energized the printer bar 55 is operated and a mark will be printed on the paper strip 53. If the paper feed is started now, the marks will be spaced out lengthwise of the strip on a line the direction of which will indicate to the operator whether the balance-wheel is correct or not, and if incorrect, whether it is too fast or too slow. If the balance wheel frequency is correct, the particular tooth of disc 51 which is used in printing will return to exactly the same point for successive printing operations, and the line of marks will be parallel to the edge of the paper strip. If the balance-wheel is too slow, the disc 51 will gain on the balance-wheel and the tooth in use will advance a little farther before each printing operation, with the result that the line of marks will trend to the right. Similarly, if the balance-wheel is too fast, the disc 51 will fall behind and the line of marks will trend to the left.

Fig. 2 shows a fragment of paper strip 80 bearing a printed record 81 of the beats of an oscillating balance-wheel. The record shows that the frequency of the wheel is correct, as the general direction of the line of marks is parallel to the edge of the strip. The waves in the line are due to the slight hunting of the balance-wheel which takes place even when correctly adjusted.

It will be clear from the foregoing that in a very few seconds a long enough record will be made so that the operator can determine the trend of the line and make the necessary further adjustment, if any, which is required to bring it into parallelism with the edge of the paper strip. Frequently the balance-wheel will be found to be correct, due to the preliminary adjustment with the voltmeter, but in any case the departure from the correct frequency will not be great. Thus the final regulation can be made rapidly and to any desired degree of accuracy.

The invention having been described, that which is believed to be new and for which the protection of Letters Patent is desired will be pointed out in the appended claims.

What is claimed is:

1. Apparatus for use in regulating the rate of an oscillating balance-wheel, comprising means for applying driving impulses to the wheel at the frequency to which the same is to be regulated, and means for detecting when the oscillations of the wheel reach the maximum amplitude as the associated hairspring is adjusted, said last means including electrical means for generating voltages having a value which is proportionate to the speed of said wheel.

2. Apparatus for use in regulating the rate of a body having periodic oscillatory motion, comprising means for applying driving impulses to the body at the frequency to which the periodic motion of the body is to be regulated, and means sensitive to the speed at which the body is moving for detecting when the body is oscillating with the maximum amplitude, said last means including apparatus for generating elec-

trical current which is proportionate to the amplitude of oscillation of the body.

3. Apparatus for use in regulating the rate of a body having periodic oscillatory motion, comprising means for applying driving impulses to the body at the frequency to which the periodic motion of the body is to be regulated, means responsive to motion of the body for generating electrical energy having a component which varies in proportion to the amplitude of the oscillations of the body, and means for measuring said component.

4. Apparatus for use in regulating the rate of a body having periodic oscillatory motion, comprising means for setting the body in motion by applying driving impulses thereto at the frequency to which the rate of the body is to be regulated, and means effective while the rate of the body is being regulated for determining when the oscillations of the body reach their maximum amplitude, said last means including electrical generating means responsive to movement of the body and having an output including a component which varies with the amplitude of the oscillations of the body, and an instrument for measuring said component.

5. Apparatus for use in regulating the rate of a body having periodic oscillatory motion, comprising means for setting the body in motion by applying driving impulses thereto at the frequency to which the rate of the body is to be regulated, and means effective while the rate of the body is being regulated for determining when the oscillations of the body reach their maximum amplitude, said last means including a photoelectric device responsive to movement of the body beneath a light beam, means for amplifying the photoelectric currents, the amplifier output including a component which varies with the amplitude of the oscillations of the body, and an instrument for measuring said component.

6. The combination, for use with a balance-wheel and associated hairspring to be regulated, of a pneumatic device for causing the wheel to oscillate, a photoelectric device for producing current variations responsive to movement of the wheel, and a meter controlled by said current variations for indicating the amplitude with which the wheel responds to said pneumatic device.

7. The combination, for use with a balance-wheel and associated hairspring to be regulated, of a pneumatic device for delivering impulses of air to the wheel to cause the same to oscillate, means responsive to movement of the wheel for generating an electrical impulse at each oscillation thereof, a recording device controlled by said impulses, said recording device including a constant speed element, and means whereby said element controls the rate at which the air impulses are delivered to said wheel.

8. The combination, for use with a balance-wheel and associated hairspring to be regulated, of an air nozzle adjacent said wheel, a constant speed element for reciprocating said nozzle to cause the same to drive said wheel, means responsive to oscillations of the wheel for generating impulses, and means controlled by said impulses and cooperating with said element for making a record which indicates whether the rate of the oscillations is fast or slow with respect to the rate of said element.

9. Apparatus for use in regulating the rate of a member having periodic oscillatory motion, comprising means for applying constant frequency driving impulses to said member, means responsive to movement of the member for generating electrical current, means for utilizing the output of said generating means to produce a sustained electrical potential of a value proportionate to the amplitude of oscillation of the member, means for also utilizing the output of said generating means to produce impulses having a frequency bearing a fixed relation to the beat frequency of the member, and separate devices controlled by said potential and impulses, respectively, for indicating the relation between the beat frequency and the frequency of said driving impulses.

10. Apparatus for use in regulating the beat frequency of a balance wheel and hairspring comprising means for applying driving impulses to the wheel at the standard frequency for which the wheel is constructed, said wheel being free to oscillate at its natural frequency, means for continuously giving an indication of the amplitude of oscillation of the wheel while a coarse adjustment is made on the hairspring to enable the wheel to respond to the driving impulses at substantially maximum amplitude, and means effective while the wheel is responding to said driving impulses for comparing the beat frequency of the wheel with said standard frequency while a fine adjustment of the hairspring is made.

11. Apparatus for use in timing a body adapted for periodic oscillatory motion, comprising a constant speed element for applying driving impulses to said body, means responsive to oscillations of said body under the influence of said impulses for generating a train of electrical impulses, and means controlled by said electrical impulses and cooperating with said element for making a record which indicates whether the rate of the oscillations is fast or slow with respect to the rate of said element.

12. Apparatus for use in timing a body adapted for periodic oscillatory motion, comprising means for applying driving impulses to said body tending to oscillate the same at a predetermined constant frequency while permitting the body to oscillate at a different frequency, means for generating electrical energy responsive to oscillations of said body under the influence of said impulses, and means for utilizing said energy to compare the frequency of the oscillations of said body with said constant frequency.

13. Apparatus for use in timing an oscillatable body, comprising means for applying driving impulses to said body tending to oscillate the same at a predetermined constant frequency, means responsive to oscillations of said body at a different frequency under the influence of said impulses for generating electrical energy which varies in inverse proportion to the difference between the frequency of said oscillations and said constant frequency, and an instrument for indicating the difference between said frequencies controlled by said energy.

14. Apparatus for use in timing a body adapted for periodic oscillatory motion, comprising means for applying driving impulses to said body tending to oscillate the same at a predetermined constant frequency, means responsive to oscillations of said body at a different frequency under the influence of said impulses for generating a train of electrical impulses having a frequency bearing a predetermined relation to the frequency of said oscillations, and means for comparing the fre-

quency of said electrical impulses with said constant frequency.

15. Apparatus for use in timing a body adapted for periodic oscillatory motion, comprising means for applying driving impulses to said body tending to oscillate the same at a predetermined constant frequency, means responsive to oscillations of said body at a different frequency under the influence of said impulses for producing current variations having an amplitude which depends on the extent to which the frequency of said oscillations agrees with the said constant frequency, and means operated in accordance with the amplitude of said current variations to indicate whether said frequencies are the same or not.

16. Apparatus for use in timing a body adapted for periodic oscillatory motion, comprising means for producing oscillations of said body at its natural frequency of oscillation by applying thereto driving impulses having a predetermined standard frequency, means responsive to said natural frequency oscillations for producing electrical phenomena having a characteristic which depends on said natural frequency, and means for utilizing said characteristic to compare said natural frequency with said standard frequency.

17. Apparatus for use in regulating the rate of an oscillating balance wheel, comprising means for oscillating said wheel at a frequency which is determined by the characteristics of the wheel and hairspring, including means for applying to said wheel momentary spaced impulses having a frequency which bears a predetermined relation to the correct frequency to which the wheel is to be regulated, the said wheel oscillating freely with an amplitude depending on the extent to which its frequency approximates said correct frequency, and means for detecting when the oscillations of the wheel reach the maximum amplitude as the associated hairspring is adjusted.

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