Feb. 11, 1941. T. B. GIBBS ET AL 2,231,849

TIMING APPARATUS FOR CLOCKS AND WATCHES

Filed Aug. 16, 1937 2 Sheets-Sheet 1

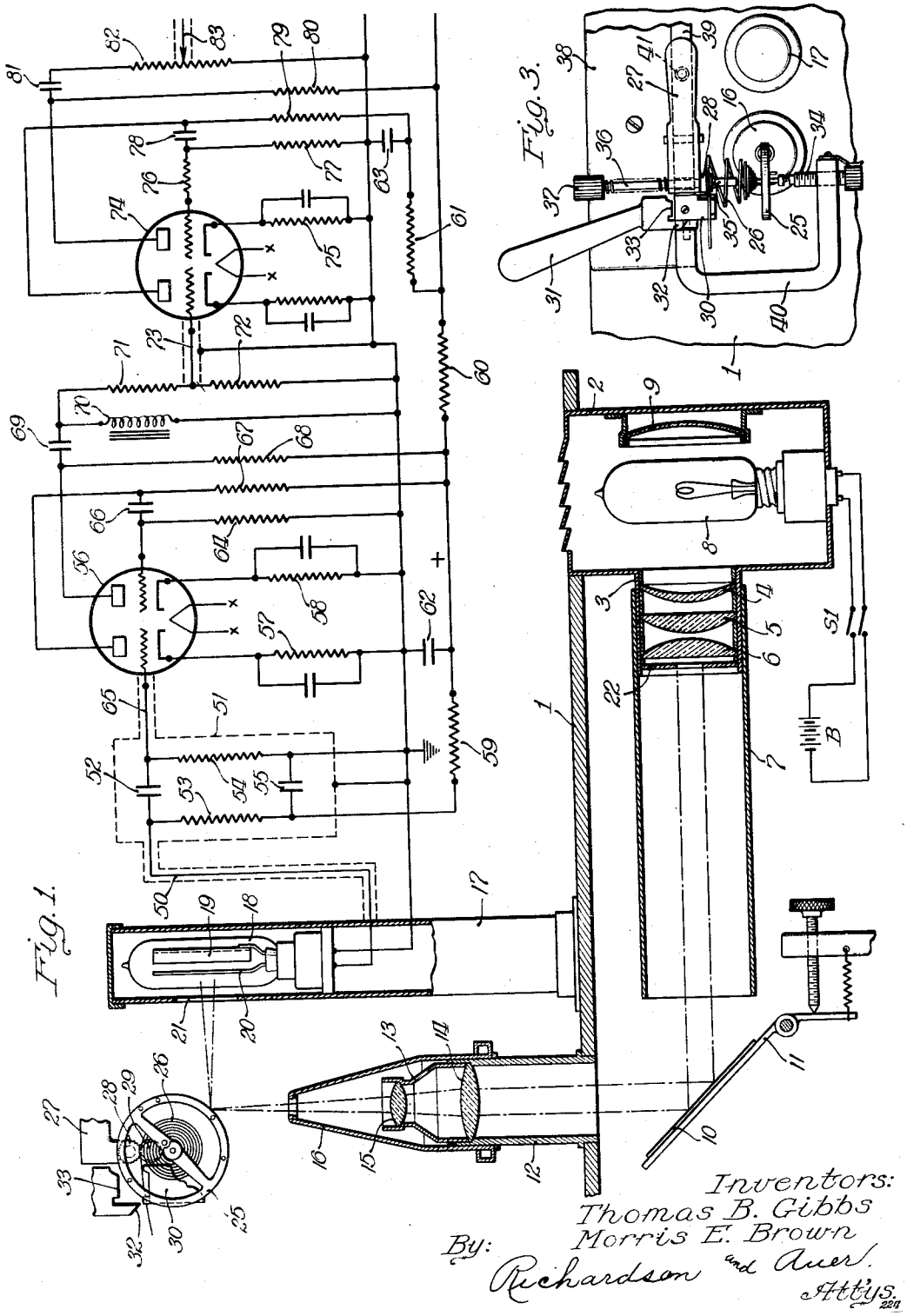


Fig. 1.

Fig. 3.

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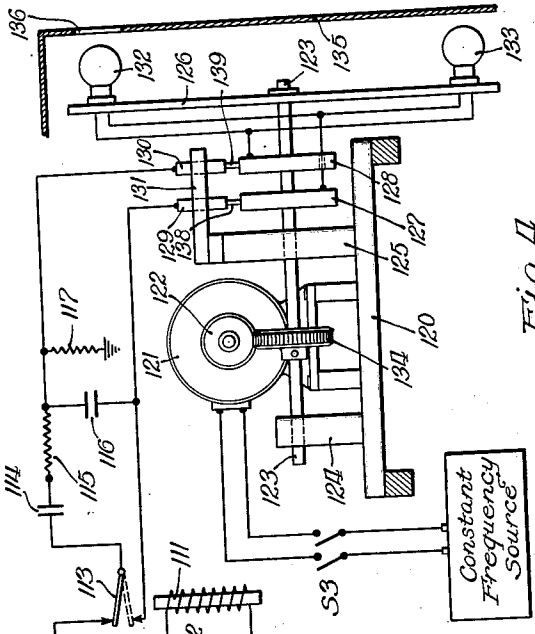
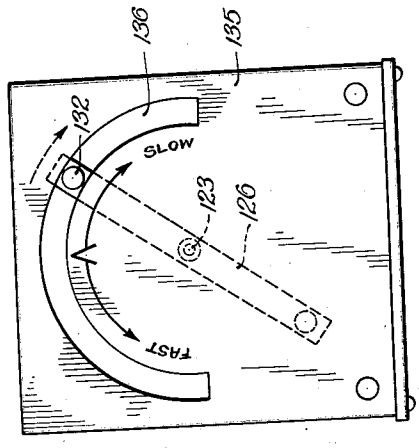


Fig. 4.



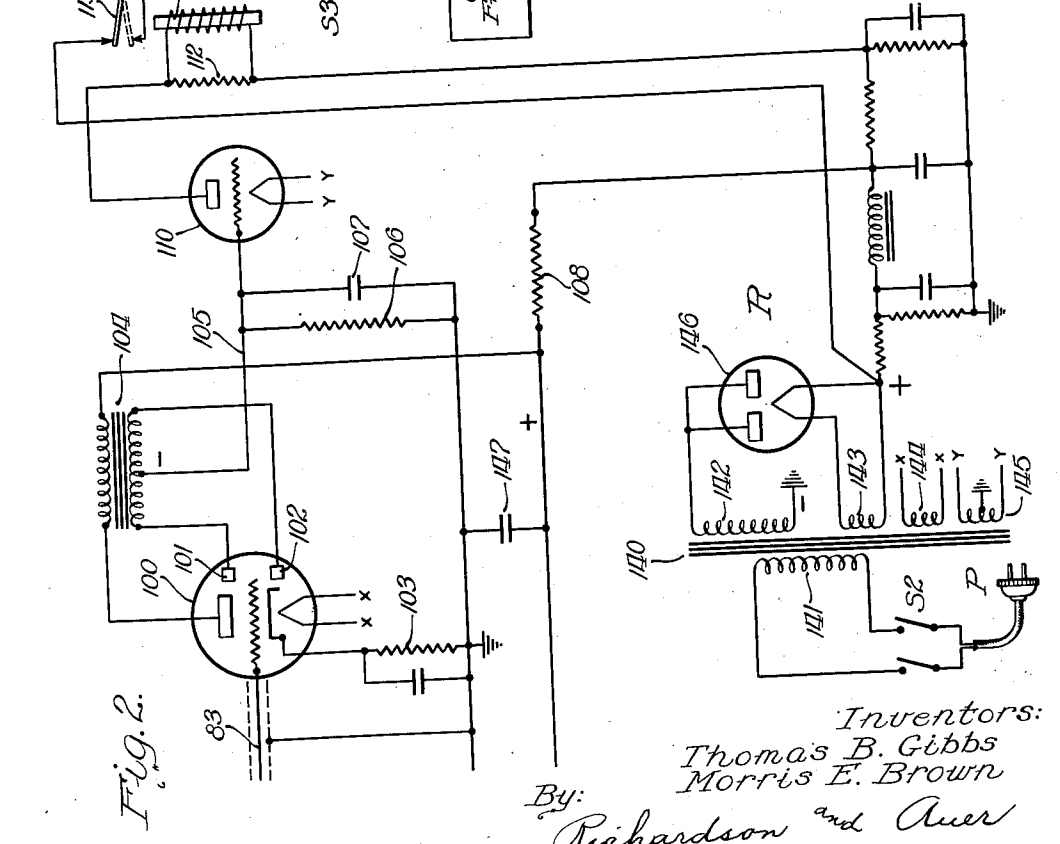


Fig. 2.

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UNITED STATES PATENT OFFICE

2,231,849

TIMING APPARATUS FOR CLOCKS AND WATCHES

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Application August 16, 1937, Serial No. 159,302

37 Claims. (Cl. 73—51)

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. The object of the invention is to produce a new and improved apparatus of this character.

In the manufacture of clocks and watches, the balance wheels with their associated hair springs have to be given a preliminary adjustment before assembly to insure that the complete clock or watch movements will run at a rate which is well within the limits of adjustment provided for. The rate at which a balance wheel vibrates depends on the weight of the balance wheel and on the length and stiffness of the hair spring. For some watch movements the proper rate of vibration is secured by adjusting the weight of the balance wheel. The more common practice, however, is to make the balance wheels of a predetermined size and weight as uniformly as possible and to secure the desired rate of vibration by adjusting the length of the hair springs, which of course are made of a uniform stiffness so far as possible. The operation of adjusting the length of the hair spring is known in the art as "vibrating" the hair spring, and the apparatus used for this purpose is known as a hair spring vibrator.

This apparatus as commonly used comprises a stand on which there is mounted a standard balance wheel and hair spring which have the proper rate of vibration. The stand also comprises means including a fixed and a movable bearing for temporarily mounting a balance wheel to be tested alongside the standard balance wheel, and in addition includes means for clamping the free end of the hair spring. One jaw of the clamping device is a knurled or toothed wheel which can be rotated to feed the hair spring forward and back to adjust its length.

When a balance wheel to be tested has been placed in position, the operator seizes the end of the hair spring with a pair of tweezers and inserts it in the clamp. Both balance wheels are then started vibrating simultaneously by means of an attachment which is provided for this purpose, and the operator then observes the expansion and contraction of the coils of the two hair springs to determine if they remain in phase or not. If the balance wheel on test is too fast or too slow the hair spring is lengthened or shortened accordingly, by turning the rotatable part of the clamping means, and the two balance wheels are again set in motion in order to determine the effect of the adjustment. These operations are repeated as many times as are necessary to secure synchronous operation. The operator then actuates a lever which gives the hair spring a slight kink at a point adjacent to where it was clamped in the final test and cuts off the excess length. The balance wheel and vibrated hair spring are then removed. The kink in the hair spring is a mark which indicates where the free end of the hair spring is to be clamped when it is assembled later on in the complete clock or watch movement.

It will be evident from the foregoing brief description that the vibration of hair springs with the known apparatus is slow and tedious. It demands great concentration on the part of the operators, who frequently suffer from nervous break down, unless relieved from duty at regular intervals. Furthermore the results secured are not what they should be, as they depend too much on the individual judgment of the operators, and many completed movements have to be rejected on test. On the whole, therefore, the known apparatus for hair spring vibrating is not satisfactory.

In accordance with the present invention a new and improved apparatus is provided, operating on entirely new principles, by means of which the majority of the troubles incident to use of the old apparatus are avoided and vastly improved results are secured. The invention is characterized by the abandonment of the idea of comparing the balance wheel and hair spring undergoing vibration with a standard balance wheel and by the use in place thereof of an arrangement which is controlled by the balance wheel being vibrated and by means of which the operator is enabled to directly compare the beat frequency of the balance wheel with a time standard.

In carrying out the invention, in its preferred form, a constant frequency source is employed to drive a motor which in turn drives a shaft at a speed which is equal to or an exact multiple of the beat frequency of the balance wheels to be tested. This shaft rotates a pair of neon lamps, which are flashed each time the balance wheel under test stops to change its rotational direction. The flashing arrangement includes means for forming a spot of light on the rim of the balance wheel, a photocell to which the light is reflected, and apparatus controlled thereby for periodically charging a condenser and discharging it through the lamps. One of the lamps is always visible

to the operator, who is able to tell at once by the apparent stationary position of the lamp or its drift to the right or left whether the balance wheel is in time or too fast or slow.

The invention and various specific features thereof will be described more in detail hereinafter, reference being had to the accompanying drawings, in which—

Figs. 1 and 2 are diagrammatic circuit drawings, including also certain mechanical details, of a complete hair spring vibrating equipment;

Fig. 3 is a view from the top of a part of the stand on which a balance wheel and hair spring are temporarily mounted for vibrating; and

Fig. 4 is a front view of the stroboscopic indicator.

Referring to Fig. 1 of the drawings, the reference character 1 indicates a portion of a heavy metal plate, which may be set into the top of the work bench where the hair spring vibrating operations are carried out. The plate 1 may be the top member of a suitable casing (not shown) which is provided as a housing for the parts located beneath the plate. This casing is located in a cutout space in the bench and is secured in position in such manner that the plate 1 is flush with the surface of the bench. These details will facilitate an understanding of the invention, but should not be regarded as essential.

Beneath the plate 1 there is mounted a projector 2, which has a tube 3 extending from the left side thereof, in which are mounted the lenses 4, 5, and 6. Inside the body of the projector is a lamp 8 and a reflector 9. Current is supplied to the lamp from a battery B, through a switch S1. There is also a tube 7, preferably blackened on the inside which is fitted over the tube 3. At the end of the tube 3 there is a shield 22 having an opening in the center. The shield limits the size of the light beam which is projected through the tube 7 by the reflector 9 and the lens system 4—6.

Near the end of tube 7 there is located a mirror 10 which intercepts the light beam and reflects it upward. The mirror is mounted on an adjustable holder or frame 11.

Just above the mirror 10 there is an opening in the plate 1, in which there is mounted the tube 12 which supports the lens 14. At the upper end of tube 12 there is inserted a tapered tubular member 13 as shown, which supports the lens 15. A conical cap 16 fits over the outside of the tube 12. This cap has a small opening at the top large enough to pass the light beam and is provided to shield the eyes of the operator. The function of the lenses 14 and 15 is to project the light beam reflected from the mirror 10 on to the rim of a balance wheel such as 25, where it is focused in a small spot.

From the balance wheel 25 the light is reflected through a window 21 in the tube 17, which is mounted vertically on the plate 1. Inside the tube 17 is located the photoelectric cell 18 in the proper position to be acted on by the light received through the window 21.

The balance wheel 25 is mounted in a stand, which is conveniently represented in Fig. 3 as including a horizontal base 38 and a vertical plate 39 on which the various parts are mounted. In the drawings the essential parts are shown in their proper relation, but the drawings are otherwise diagrammatic. The stand rests on the plate 1 to which it is secured in such a position that the rim of a balance wheel placed in the stand will be at the focus point of the light beam, as shown in Fig. 1.

The stand will be described only insofar as is necessary to an understanding of the invention. The reference character 35 indicates the rear bearing for the balance staff and is carried on the vertical frame plate 39 of the stand. Directly opposite the rear bearing 35 is the front bearing screw 34, which is threaded in the end of the bracket 40. The rear bearing 35 may be fixed, in which case a balance wheel such as 25 is placed in position by first backing off the screw 34 a few turns, but in practice the rear bearing is preferably made longitudinally slidable in the frame plate 39 and is held in its forward position by means of a spring. This facilitates the quick insertion and removal of balance wheels during the hair spring vibrating operations.

The clamping means for holding the end of the hair spring includes a grooved roller 29, seen in Fig. 1, and a roller 28, Figs. 1 and 3, which has an enlarged toothed portion which enters the groove in the roller 29. The lower grooved roller 29 is rotatably mounted on a stud which projects forward from the frame plate 39. The upper roller 28 is rigidly mounted on a shaft 36, Fig. 3, which lies in a slot cut in the plate 39 and is rotatable in bearings in the finger lever 27. This latter is pivoted on the frame plate 39 as shown in Fig. 3, and the right hand end of the lever is normally pressed upward by means of a small compression coil spring 41. Thus the roller 28 is at all times pressed firmly down against the lower roller 29, except of course when the end of the finger lever 27 is depressed. The end of the shaft 36 carries a knurled knob or head 37 by means of which the shaft 36 can be rotated.

The arrangement for cutting off the excess length of hair spring and for putting a kink in the hair spring near the end comprises a pivoted lever 31 having a cutting knife 32 and a die face 33. Fig. 3 shows this lever in its normal position. Co-operating with the lever 31 is a member 30, set into the upper edge of the frame plate 39, and having its upper surface recessed in conformity with the shape of the die face 33. The member 30 also has a square edge at the left adapted to co-operate with the cutting knife 32. The contour of the upper face of the member 30 is seen clearly in Fig. 1, which also shows the cutting knife 32 about to descend and sever the hair spring 26.

The foregoing will suffice to explain the construction of a stand which is suitable for use in carrying out the invention. Other forms may of course be used, especially with different types of balance wheels, and it may be remarked here that certain modifications are in fact required for the very small balance wheels which are used in watches. The type of stand herein described is well suited for use with the relatively large balance wheels which are used in clocks.

Proceeding now with a description of the remainder of the apparatus which is shown in Fig. 1, this comprises the double triode tubes 56 and 74 with the circuit connections as shown. These tubes may be of the type known as 6C8–G, although other types of tubes could be used. For instance, each of these tubes could be replaced by two ordinary triodes.

Explaining the circuit connections briefly, the cathode 19 of the photocell 18 is grounded and the anode 20 is connected by way of conductor 50 and the resistor 53 to the plus B lead. The re-

sister 53 may have a value of 10 megohms. The conductor 50 is coupled to the grid of the left triode of tube 56 by means of the condenser 52 and the grid lead 65. The reference character 54 indicates a grid leak which may have a value of 6 megohms. The condenser 52 may have a capacity of 70 mmf. The reference character 55 indicates a by-pass condenser. The resistors 53 and 54, the condensers 52 and 55, and the leads 50 and 65 should be shielded and for this purpose the resistors and condensers may be enclosed in a metal can indicated by the dotted rectangle 51. The conductors 50 and 65 may be enclosed in flexible metal sheathing as is common practice in the manufacture of radio sets, which is of course soldered to the metal can 51. The can should be grounded as shown.

The cathode of the left hand triode of tube 56 is connected to ground through a resistor 57. A similar resistance 58 is included in the cathode circuit of the right hand triode of tube 56. These resistors are shunted by condensers and constitute the usual means for placing a negative bias on the grids of the tubes when they are passing current. The plate of the left hand triode of tube 56 is connected to the plus B lead through a resistor 67, and is coupled to the grid of the right hand triode by means of a condenser 66. This grid is connected to ground through a grid leak 64.

The plate circuit of the right triode of tube 56 is coupled to the grid of the left hand triode of tube 75 by an arrangement which comprises a condenser 69 and resistors 71 and 72, these resistors being connected in series and being shunted by the impedance coil 70. The condenser 69 may have a capacity of 5000 mmf., resistor 71 may have a value of 150,000 ohms and resistor 72 may have a value of 100,000 ohms. The impedance 70 has a relatively low ohmic resistance but has an iron core and offers high impedance to alternating currents having a frequency of about 300 cycles per second and upwards. It may be mentioned at this point that the arrangement just described constitutes a filter for blocking alternating currents having a frequency of about 100 cycles per second and for passing on to the grid of the left hand triode of tube 74 only those components which have a considerably higher frequency. This will be explained more fully in discussing the operation. The grid lead 73 should be shielded as indicated in the drawings.

Both triodes of the double triode tube 56 just described function as amplifiers. The next tube, the double triode 74, is a combined amplifier and voltage regulator. That is, the left hand triode functions as an amplifier, while the right hand triode functions as a voltage regulator. The cathode of the left hand triode has the usual arrangement for placing a negative bias on the grid. The plate is connected to the plus B lead through a resistor 79, and is coupled to the grid of the right hand triode by means of a condenser 78 and a resistor 76. The condenser 78 may have a capacity of .1 mf., while the value of the resistor 76 should be high, preferably about 5 megohms. Between the condenser 78 and the resistor 76 there is connected a grid leak 77. This grid leak may have a value of about 250,000 ohms. The cathode of the right hand triode is connected to ground through resistor 75 to provide for a negative bias on the grid of a predetermined value as will be explained more fully hereinafter. The plate is connected to the plus B lead through a resistor 80.

The plate circuit of the right triode of tube 74 is coupled to the grid of tube 100, Fig. 2, by means of condenser 81 and a potentiometer 82, which also functions as a grid leak. The grid lead 83 should be shielded as shown in the drawings. The tube 100 may be of the type known as a 6R7 tube, and comprises a triode section and two diode sections. The cathode, which is common to the triode and diode plates, is connected to ground through the resistor 103, which is shunted by a condenser. The triode plate is connected to the plus B lead through the primary winding of a transformer 104. The two diode plates are connected to the opposite terminals of the secondary winding, and the midpoint of the secondary winding is connected to ground through the load resistor 106. This resistor is shunted by a condenser 107. It will be seen that the arrangement just described constitutes a full wave rectifier, to which power is supplied by the triode plate circuit and in which the two diodes perform the rectifying function. The mid-point of the secondary winding, to which conductor 105 is connected, constitutes the negative terminal of the rectifier and is directly connected to the grid of tube 110.

The tube 110 may be a type 2A3 tube. The plate of this tube is connected to plus B through a relay 111 which is shunted by the resistance 112. Relay 111 may be an ordinary quick acting telephone type relay having a resistance of 3300 ohms, while the resistor 112 may have a value of 5000 ohms. Relay 111 is provided with a movable contact spring 113 represented in the drawings as an armature, and has front and back contacts. The circuits controlled by these contacts will be described shortly.

The indicator which is shown at the right of Fig. 2 and in Fig. 4 will now be briefly described. This indicator comprises a suitable casing in which the parts are enclosed, a cross arm 126 on which are mounted the neon lamps 132 and 133, a shaft 123 on which the cross arm 126 is mounted, and a motor 121 for rotating the shaft. The casing is only partly shown in Fig. 2, from which it may be seen, however, that it includes a vertical front panel portion 135 having a window 136. The entire front of the indicator is shown in full in Fig. 4, from which it can be seen that the window 136 is semi-circular in shape and has an angular length which is slightly over 180°.

The indicator is preferably located at the rear of the bench on which the photoelectric equipment shown in Fig. 1 is mounted, and in line with the vibrating stand as view by the operator. The distance from the stand to the indicator may be about five or six feet, and the indicator is of relatively large size, which enables it to be read accurately and without eyestrain on the part of the operator. The arm 126 may be, for example, long enough so that the neon lamps 132 and 133 rotate in a circle about 18 inches in diamter. This arm therefore should be considerably longer in proportion to the other parts than it is shown in the drawings, which as already stated are diagrammatic in part and not working drawings.

Describing the mechanical parts of the indicator somewhat more in detail, the motor 121 may be a synchronous A. C. motor having a speed of 1800 R. P. M. when operated on 60 cycle current. Power may be supplied to the

motor through a switch S3 from any suitable source of alternating current which has a constant frequency. As such constant frequency sources are known, no details have been shown, and the source used is merely indicated herein by an appropriately labeled rectangle. The motor 121 is mounted on a shelf 120 on the inside of the indicator casing, and drives the shaft 123 by means of a worm wheel 122 mounted on the motor shaft and a gear 134 mounted on the shaft 123. Assuming that the balance wheels which are to be vibrated are 5 beat wheels, then the rato of speed reduction in the worm drive may be such that the shaft 123 rotates 5 times per second. The shaft 123 has bearings in the two supports 124 and 125. On the latter is mounted an insulating member 131 which supports the two brush holders 129 and 130. The associated brushes 138 and 139 provide for a circuit to the neon lamps and are in engagement with the two slip rings 127 and 128, respectively, which are mounted on the shaft 123. Slip ring 128 is connected to one side of both lamps as shown while the slip ring 127 is connected to the other side of both lamps. In other words, the two neon lamps 132 and 133 are connected to the slip rings in parallel.

When the relay 111 is in de-energized condition, the left hand terminal of the condenser 114, which may have a capacity of .2 mf., is connected to the positive pole of the rectifier R, and the condenser is charged through a resistor 115 and a resistor 117. The former may have a value of 200 ohms while the latter may have a value of 50,000 ohms. When relay 111 is energized the condenser 114 is discharged over a circuit which includes the two brushes 138 and 139, the two slip rings 127 and 128 and the lamps 132 and 133 in parallel. The condenser 116 may have a capacity of .02 mf., and functions as a spark condenser, to protect the front contacts of relay 111.

A rectifier for supplying plus B potentials to the various plate circuits in Figs. 1 and 2 is indicated by the reference character R and comprises the transformer 140 and the rectifying tube 146. The primary winding 141 may be connected through a switch S2 to a plug P which in turn may be inserted in an outlet connected to a source of commercial alternating current. The winding 142 of the transformer 140 has one terminal connected to the two plates of the rectifier tube 146 and the other terminal is grounded. This grounded terminal constitutes the negative pole of the rectifier. A winding 143 of the transformer 140 provides current for heating the cathode of the rectifier tube 146. One side of the cathode constitutes the positive pole of the rectifier. The transformer 140 has two other windings, windings 144 and 145, which provide current for the heater circuits of the tubes shown in Figs. 1 and 2. These circuits are not drawn out in full but it will be understood that the heater circuits labeled X—X in the drawings are connected to winding 144, while the heater circuit of tube 110, labeled Y—Y, is connected to winding 145. The rectifier R is a conventional form of half wave rectifier, but the output should be exceptionally well filtered in view of the high degree of amplification which is employed. The filter circuits are shown in the drawings and will need no detailed explanation. It may be mentioned also that large capacity by-pass condensers should be used where the plate circuits and the anode circuit of the photocell connect to the plus B lead at points beyond the bleeder resistances 59, 60, 61 and 108. These by-pass condensers are indicated by the reference numerals 55, 62, 63 and 147, and may have a capacity of 8 mf. each.

The tubes 56, 74, 100 and 110 with their associated circuit elements, condensers, resistors, etc., may be housed in a separate casing or cabinet if desired, along with the rectifier R, or these parts may be located in the indicator casing beneath the shelf 120. The constant frequency source for running the motor 121 and the battery B may be located at any convenient point. The switches S1, S2 and S3 are preferably located at the front of the bench, where they are convenient to the operator. The necessary wiring, shown in the drawings in schematic form, will of course conform to the location of the parts and will follow standard practices.

The apparatus having been described, its operation in vibrating hair springs will be explained. On starting up the apparatus the plug P is inserted in a convenient receptacle and the switch S2 is closed. This supplies power to the rectifier R and the various tubes and the photoelectric cell 18 are rendered active. The grid of tube 110 is normally at the same potential as the cathode and the tube accordingly passes current, energizing relay 111.

The constant frequency source having been started up, the switch S3 may be closed and alternating current of constant frequency is supplied to the motor 121. The motor accordingly starts up and rotates the shaft 123 at five revolutions per second. The neon lamps 132 and 133 are thus rotated successively past the window 136 in the front of the indicator casing. The direction of rotation may be clockwise as seen from the front, as indicated by the arrow in Fig. 4. For the time being the lamps are not flashed.

The switch S1 may now be closed, connecting the battery B to the lamp 8 in the projector 2. The lamp 8 lights up and as a result a beam of light is projected on to the mirror 10, as indicated in the drawings, where it is projected upward and through the lens system comprising lenses 14 and 15.

The apparatus is now ready for the insertion of a balance wheel in the stand for the purpose of vibrating the hair spring. The balance wheel such as 25 is presented to the stand with the hair spring 26 to the rear and the balance staff is positioned in the bearings 34 and 35. This takes only an instant especially if the rear bearing is movable in the manner previously explained. The front bearing should of course be adjusted so that the balance wheel will turn freely, but after this adjustment is made it will seldom need to be changed. The operator now grasps the end of the hair spring with a pair of tweezers, depresses the lever 27, and inserts the hair spring in the groove in the roller 29. The lever 27 is now released, allowing roller 28 to descend, with the result that the hair spring is clamped between the bottom of the groove in roller 29 and the enlarged toothed portion of roller 28. Fig. 3 shows the balance wheel 25 in position with the hair spring 26 properly clamped between the rollers.

The operator now sets the balance wheel in motion with a flick of the finger. When properly started in this way the balance wheel will rotate first in one direction and then in the opposite direction, simulating its motion when later on it is assembled in a clock. The motion will continue for fifteen or twenty seconds. The amplitude of the to and fro movements gradually de-

creases, but the rate, or beat frequency, remains constant until the motion has nearly stopped. It will be assumed that the balance wheel is for use in a five beat clock and accordingly it reverses its direction of movement five times per second.

As shown in the drawings and as previously explained, the light beam reflected upward by mirror 10 is brought to a focus in a small spot on the rim of the balance wheel by the lenses 14 and 15. From the rim of the balance wheel the light is reflected through the window 21 onto the photoelectric cell 18, causing the cell to pass current in a circuit which extends from the grounded cathode 19 to the anode 20 and thence by way of resistor 53 to the plus B lead, or to the positive pole of the rectifier. The negative pole of the rectifier being grounded, the circuit is complete.

So long as the balance wheel is stationary the output of the photoelectric cell remains constant, but when the wheel is set in motion as described in the preceding paragraph certain variations are produced in the photocell current. The varying current continues while the balance wheel is moving in either direction, but the variation ceases when the wheel stops to reverse its direction of rotation. As will be explained presently, the resumption of constant current flow through the photocell, or the cessation of the varying current, is made use of to flash the rotating neon lamps in the indicator each time the balance wheel stops to reverse its direction.

The current variations that are produced are of a very complex character. Their exact nature and cause is not wholly understood, although the motion of the balance wheel evidently alters the amount of light which reaches the photocell in some way. So far as can be determined there are two principal components. One of these is a low frequency component, whose frequency varies in proportion to the amplitude of the wheel, or to the speed at which the rim of the wheel passes under the light spot, and has a maximum value of about 100 cycles per second. This component has by far the most power, and is thought to be due to visible and manifest irregularities and imperfections in the reflecting surface of the wheel rim. It is present in the photocell output in large volume when balance wheels having poising and adjusting screws in the rim are being vibrated, but is also produced by balance wheels with smooth rims. This component is highly variable and unreliable and is not used. The other component has a higher frequency, and although produced in small volume, is entirely reliable. It is not a pure wave of a single frequency, but appears to be made up of a number of different frequencies, all within the audible range, with a lower limit of about 300 cycles per second and an upper limit of about 1200 or 1500 cycles per second. In tests that have been made so far a comparatively large component having a frequency of about 700 cycles per second has been noticed. These frequencies do not appear to vary with the amplitude of the wheel; but the strength or volume of the whole high frequency output varies with the amplitude of the wheel. That is, the high frequency component has its highest volume or amplitude when the balance wheel is first set in motion and the amplitude diminishes to zero as the wheel slows down and stops.

Continuing with the explanation, the current variations in the photocell circuit produce potential variations at the upper terminal of the resistor 53 and the condenser 52 charges and discharges, producing voltage changes on the grid of the left hand triode of tube 56. These voltage variations result in amplified current variations in the plate circuit, producing potential variations at the upper terminal of resister 67, which are transmitted to the grid of the right hand triode of tube 56 by the condenser 66. The voltage variations impressed on the right triode grid are further amplified and appear as current variations in the plate circuit of the right triode. The foregoing briefly describes the ordinary amplification which takes place in the tube.

All the components of the photocell output appear in amplified form in the plate circuit of the right triode of tube 56. The condenser 69, however, by means of which the plate circuit is coupled to the grid of the left triode of tube 74, is of low enough capacity to block most of the low frequency component, and only a very small part of what gets through is impressed on the circuit through resistances 71 and 72, because of the shunting effect of the impedance 70, which offers little resistance to currents of a frequency of 100 cycles per second, but offers high resistance to currents having substantially higher frequency. The arrangement at this point therefore functions as a high pass filter, eliminating the low frequency component and passing on to the grid of the left triode of tube 74 only the high frequency component.

The left hand triode of tube 74 functions as an amplifier. The high frequency voltage variations which are impressed on the grid cause the plate current to fluctuate and as a result the voltage on the plate rises and falls. This causes the condenser 78 to charge and discharge in series with the resistor 77 and alternating voltages are produced at the junction of the condenser and resister which are applied to the grid of the right triode of tube 74 through the resistor 76. These voltages vary in amplitude, depending on the amplitude of the to and fro movements of the balance wheel, and it is the function of the right triode to limit the effect of both the positive and negative half waves and maintain a substantially uniform output independent of the strength of the impressed voltages.

The effect of the negative potentials is limited by proper adjustment of the grid bias of the right hand triode, that is, by assigning the proper value to the resistor 75. This grid bias is so adjusted that with a negative half wave of the minimum strength some current will still flow in the plate circuit, but with a stronger signal, producing voltage changes of higher amplitude, the negative half waves will bias the tube to cut-off, and no current will flow during the peak values of such negative half waves.

The positive half waves are limited as to their effect by means of the resistor 76, which is in series with the grid. This resistance has no effect during the negative half waves, as the grid is drawing no current, but when the grid swings positive it draws current in a circuit including resistor 76. This resistor is quite high, being about 5 megohms in value, and consequently the fall in potential across the resistor is so great that the potential on the grid can rise only a very small amount. The result is that no matter what amplitude the positive half wave voltages have, the grid can never become more than a fraction of a volt positive, and the current in the plate circuit is definitely limited to what can flow with this grid potential.

The current fluctuations in the plate circuit of

the right hand triode produce voltage changes at the upper terminal of resistor 80, or on the plate, and since the current fluctuations are limited in the manner just described, the voltage changes are likewise limited. The right hand triode of tube 74 therefore functions as a voltage regulator to prevent the plate voltage fluctuations from rising in amplitude above a predetermined value. This value is selected by proper adjustment of the circuit elements so that it is approximately equal to what is produced when the balance wheel has lost most of its amplitude and is about ready to stop. It will be seen, therefore, that the voltage regulating function of the right triode of tube 74 comes into play when the balance wheel is first set in motion, when it vibrates with the greatest amplitude. At this time the high frequency component in the output of photocell 18 has its greatest strength or amplitude, and this component, amplified at tube 56 and at the left triode of tube 74, produces voltage changes at the plate of the left triode of tube 74 of high amplitude. By the action of the right triode of tube 74, however, the resulting voltage changes on the plate of the right triode are held to a certain maximum value in the manner explained. As the balance wheel loses amplitude the amplitude of the high frequency component decreases and approaches its minimum value, so that the voltage regulator has to reduce the amplitude by a continually decreasing amount. Eventually the vibrations of the balance wheel, and the high frequency component, reach the minimum amplitude for which the voltage regulator is adjusted, when it ceases to function. Shortly after this, when the balance wheel is nearly ready to stop, the high frequency component practically disappears and the apparatus ceases to operate. In the meantime, however, the operator has had ample time to do the work required, as will presently appear.

From all the foregoing it will be seen that throughout nearly the entire time the balance wheel is vibrating responsive to the starting impulse, high frequency voltage changes of substantially constant amplitude are produced at the plate of the right triode of tube 74. The voltage changes take place of course only while the balance wheel is actually moving and cease entirely at times when the balance wheel stops to reverse its direction of motion. These voltage changes are transmitted to the grid of the tube 100, Fig. 2, by the coupling means comprising the condenser 81 and the potentiometer 82. The latter affords means for impressing any desired part of the output of tube 74 on the grid of tube 100.

The triode section of tube 100 functions as an amplifier and the high frequency voltages impressed on the grid produce fluctuating currents in the plate circuit, which includes the primary winding of the transformer 104. Power is thus intermittently supplied to the rectifier comprising the secondary winding of the transformer and the two diode plates of tube 100. That is, power is supplied while the balance wheel is in motion in either direction, but the supply ceases when the balance wheel stops to reverse its direction. While power is being supplied, the rectifier produces a flow of direct current in a circuit which may be traced from the cathode of tube 100 by way of diode plate 101, the left hand half of the secondary winding, conductor 105, load resistor 106, and thence back to the cathode. This is the circuit in effect when the left hand terminal of the secondary winding is positive with respect to the mid point. When the right hand terminal of the secondary winding becomes positive the circuit is the same, except that it includes the diode plate 102 and the right hand half of the secondary winding. Current flow in conductor 105 and resistor 106 is always in the same direction and the conductor 105 is maintained at a negative potential during the periods that power is being supplied. Conductor 105 is connected directly to the grid of tube 110.

The tube 110 normally passes current in its plate circuit and relay 111 is energized. When the balance wheel is set in motion, however, the high frequency photocell currents which result cause power to be supplied to the rectifier in the manner explained, and a negative bias is applied to the grid of tube 110, sufficient to bias it to the cut-off point. The flow of current in the plate circuit accordingly ceases and relay 111 deenergizes. On deenergizing relay 111 connects the left hand terminal of the condenser 114 to the positive pole of the rectifier R and the condenser charges over an obvious circuit including resistance 115 and the resistor 117. The latter is high enough to avoid too sudden a load on the rectifier, which might affect the operation of the amplifier tubes. Relay 111 remains deenergized while the balance wheel is moving to its extreme position in the direction in which it is started. When the balance wheel stops momentarily to reverse its direction of rotation, the generation of high frequency currents by the photocell 18 ceases, the supply of power to transformer 104 is cut off, and the negative potential on the grid of tube 110 disappears. The tube 110 therefore again becomes conducting and relay 111 is energized.

On energizing, relay 111 closes an obvious circuit for discharging the condenser 114 through the two neon lamps 132 and 133 in parallel, thus flashing the lamps. The flash is of very short duration, or about $\frac{1}{1000}$ of a second. Relay 111 is only momentarily energized, for the balance wheel immediately takes up its rotary motion in the other direction, the output of high frequency current is resumed, and the negative bias is again applied to the grid of tube 110.

It will be clear now that relay 111 is deenergized during the times that the balance wheel is actually moving and that the relay energizes momentarily each time the balance wheel stops to reverse its direction. Relay 111 therefore operates in synchronism with the balance wheel. Each time the relay deenergizes the condenser 114 is charged and each time it energizes the condenser is discharged through the neon lamps. The lamps, therefore, flash in synchronism with the vibrations of the balance wheel, or once per beat. As the balance wheel in question has a beat frequency of five, the lamps flash five times per second, or at about that rate, depending on how near the balance wheel is correct. This regular flashing of the lamps continues until the amplitude of the high frequency component of the photocell output has fallen below the minimum working value mentioned in the discussion of the voltage regulator and the output from tube 74 has become so weak that sufficient negative bias can no longer be maintained on the grid of tube 110. This tube therefore passes current continuously and relay 111 remains energized until another balance wheel is put in place and started in motion.

The hair spring vibrating operation may now be explained from the standpoint of the operator. When the operator sets the balance wheel

in motion as described hereinbefore, she watches the indicator, Fig. 4, and observes the flashing of the neon lamp such as 132 through the window 136. Both lamps flash at the same time but only one of them will be visible, unless the flashes happen to begin at a time when the cross arm 126 is exactly horizontal. The cross arm may be in any position when the flashes start. Now the lamp 132 is rotated at a constant speed of exactly five revolutions per second and since the balance wheel has a beat frequency of five beats per second the lamp will be able to make exactly one revolution between the successive flashes which take place responsive to successive beats. It follows therefore that if the balance wheel is vibrating at exactly the correct beat frequency the lamp will be flashed in the same position each time and will appear to stand still. This indicates to the operator that the balance wheel is correct and that the hair spring requires no adjustment as to length.

Assuming now that the balance wheel is vibrating too fast, if the lamp 132 flashes the first time in the position where it is shown in Fig. 4, the next flash will occur slightly less than one-fifth of a second later and the lamp will not have had time to return to its former position. The next flash will therefore take place when the lamp is slightly to the left of the position where it is shown in Fig. 4, and the succeeding flashes will occur at positions still further to the left. The lamp will therefore appear to drift to the left, indicating to the operator that the beat frequency of the balance wheel is too fast. This fact will become evident almost at once or as soon as a few flashes have occurred, and the operator will make the necessary adjustment by rotating the knob 37 so as to feed the hair spring backward through the rollers 28 and 29 and increase its effective length. This will reduce the beat frequency, and the effect will at once become apparent at the indicator. As soon as the lamp appears to stand still the operator knows that the beat frequency is correct and discontinues the adjustment.

If the balance wheel should vibrate too slowly the lamp such as 132 will appear to drift to the right, making it necessary to shorten the hair spring. This is done by turning the knob 37 in the opposite direction, thus feeding the hair spring forward between the rollers and shortening its effective length. As before, the lamp will appear to stand still as soon as the correct adjustment is attained.

It may be pointed out here that the proper adjustment is secured in a very short time. As soon as a slight drift in the lamp appears the operator at once compensates for it by changing the hair spring length, observing the lamp to note the effect of the change, and making such further changes as are necessary. In a few seconds the lamp is brought to a stationary position and the adjustment is complete. In practice the hair springs are always made too long, and as the length is always the same, an operator will learn by experience about how far from the end the hair spring should be clamped between the rollers 28 and 29. This facilitates the work somewhat, but of course some adjustment is still necessary in the majority of cases.

When the vibrating operation is complete, that is, when the hair spring is correctly adjusted as to length, the operator pulls the lever 31 forward, which cuts off the excess length of hair spring by means of knife 32. At the same time the die 33 produces a slight kink in the hair spring at a point adjacent to where it is clamped between the rollers, for a purpose already explained. The lever 31 is then returned to its former position, the end of the hair spring is released from the clamping rollers by depressing the lever 27, and the balance wheel with the attached hair spring is removed from the stand.

It will be obvious from the preceding explanation that the invention has great advantages over previously known methods and apparatus for doing this work. As an example of the gain in speed that is attained it may be stated that whereas with the old apparatus an operator was able to vibrate only about 300 hair springs per day, with the new equipment the output of an operator is increased to upwards of 1000 hair springs per day. There are other advantages, including relief of the operator from the intense concentration required with the old apparatus and greater accuracy in the vibrating operations, resulting in less frequent rejections of finished clock movements.

While the indicator shown and described herein has been especially designed for use in vibrating hair springs it may also be used in timing watches. When used for this purpose, the neon lamps may be flashed from a watch under test by means of a microphone and amplifier equipment such as is disclosed in the patent to Young, No. 2,092,039. For watch timing, the window 136 is preferably provided with a calibrated scale and a pointer to register the initial position of the lamp. These parts are not required in hair spring vibrating.

It will be clear also that the invention is not necessarily restricted to vibrating hair springs or timing watches, and that the principles involved in the invention may be applied to other uses, suitable modifications being made if necessary to adapt the apparatus to the purpose in view. We do not, therefore, desire to be limited to the exact form of the invention as disclosed herein but desire to include and have protected by Letters Patent all forms and modifications thereof that come within the scope of the appended claims.

We claim:

1. The combination, for use with a member adapted to be vibrated, of a photocell, means for projecting a light beam on said member whence it is continuously reflected to said photocell regardless of the changes in the position of said member while vibrating, and a circuit in which sustained signal currents are produced by said photocell responsive to movement of said member beneath the impinging light beam.

2. Apparatus for timing a balance wheel adapted to vibrate, comprising a photocell, a light source, means for projecting a beam of light from said source on said balance wheel whence it is reflected to said photocell, a circuit including said cell in which signal currents of both low and high frequency are produced by movement of said balance wheel, means for filtering out the low frequency currents, and an indicator controlled by the high frequency currents.

3. The combination, for use with a balance wheel and hair spring to be adjusted as to rate of vibration, of a lamp, means for flashing said lamp each time said balance wheel slows down below a predetermined speed preparatory to reversing its direction while vibrating, and means for rotating said lamp at a constant speed bearing a predetermined relation to the proper rate of vibration of said balance wheel.

4. The combination, for use with a balance

wheel and hair spring to be adjusted as to rate of vibration, of means including a photocell operated by light reflected from the wheel while vibrating for determining when the wheel is moving and when it stops to reverse its direction, including means for manifesting such determination in terms of electrical impulses, a frequency standard, and means for comparing the rate at which the impulses occur with the rate of said frequency standard.

5. In combination, a plurality of lamps, means for supporting said lamps in spaced relation on the circumference of a circle, shielding means provided with an opening through which at least one of said lamps can be viewed, means for flashing said lamps in synchronism with a vibrating part whose rate is to be tested, and means for rotating said supporting means to cause said lamps to pass said opening successively at a constant speed which bears a predetermined relation to the proper rate of vibration of said part.

6. In an apparatus for timing a part having a periodic oscillatory motion, a space discharge device, means responsive to motion of said part for maintaining a negative potential on the control grid of said device to maintain said device in non-conducting condition, said device discharging each time said potential is removed due to cessation of motion of said part, a time standard, and means for comparing the rate of discharge of said device with said time standard.

7. In an apparatus for timing a balance wheel, means including a photocell responsive to oscillatory movement of said wheel for producing an alternating current, means for rectifying said current, a space discharge device having a control grid on which a negative bias is produced by the rectified current, and means controlled by said discharge device each time the negative bias disappears due to cessation of movement of the wheel between beats for comparing the beat frequency with a time standard.

8. The combination, for use with a balance wheel to be vibrated, of means for projecting a beam of light on said wheel, means including a photocell for producing current variations responsive to changes in the light reflected from a moving surface of said wheel, said current variations including a component whose amplitude is proportionate to the speed of the moving surface of the wheel from which the light is reflected, and means for regulating the amplitude of said component to a value which corresponds to a predetermined minimum speed of the moving surface of the wheel from which the light is reflected.

9. The combination, for use with a part subject to intermittent motion, of said part having a light reflecting surface, means including a photocell for picking up light continuously reflected from said surface and for producing sustained current variations responsive to light changes due to movement of the reflecting surface, and means for utilizing the cessation of said current variations to determine when said part stops moving.

10. Apparatus for testing the beat frequency of a balance wheel, said apparatus comprising means responsive to movement of the wheel for generating high frequency currents bearing no relation to the beat frequency of the wheel, means controlled by said high frequency currents for generating impulses having the same frequency as the beat frequency of the wheel, and means for comparing the impulse frequency with a time standard.

11. The combination, for use with a balance wheel and hair spring to be adjusted as to rate of vibration, of a time standard, a device for comparing the rate of vibration of said wheel with said time standard, and means subject to continuous control by movement of said wheel above a predetermined speed for controlling said device.

12. The combination, for use with a movable member having a smooth light reflecting surface, of a light source, means for focusing light from said source to a spot on said surface, a photocell to which a stationary light beam is continuously reflected from some area of said surface, a circuit, and means including said photocell for producing a continuously varying current in said circuit responsive to movement of said surface beneath said light spot.

13. In an apparatus for timing a balance wheel, means including a photocell responsive to light reflected from a moving surface of the wheel for generating alternating current having a frequency higher than and substantially independent of the beat frequency of said wheel, said current dying down and ceasing altogether as the wheel stops to reverse its direction, a frequency standard, and means for comparing the rate at which the cessations occur with said frequency standard.

14. Hairspring vibrating apparatus, comprising means including bearings for supporting a balance wheel outside of a watch or clock movement where it is free to vibrate out of contact with any other part except the said bearings, means for clamping the hairspring associated with said wheel at a point near the end leaving the entire spring between such point and the point where it is attached to the wheel free to vibrate out of contact with any other part, means responsive to movement of said wheel during each beat thereof for generating an electrical current which is sustained from the beginning to the end of the beat, a frequency standard, and means controlled by said currents for comparing the rate of said balance wheel with the rate of said frequency standard.

15. Hairspring vibrating apparatus, comprising means including bearings for supporting a balance wheel outside of a watch or clock movement where it is free to vibrate out of contact with any other part except the said bearings, means for clamping the hairspring associated with said wheel at a point near the end leaving the entire spring between such point and the point where it is attached to the wheel free to vibrate out of contact with any other part, and means selectively responsive to movement of said wheel and to the cessation of movement thereof for detecting the end of each beat.

16. In an apparatus for timing the frequency of a vibrating member, a stroboscopic device including a lamp, and means responsive to the cessation of movement of said member each time it reverses its direction of movement for flashing said lamp, said means comprising a photocell controlled by a light beam reflected from said member, and impulse generating means controlled by said photocell.

17. In combination, a plurality of lamps, means for flashing said lamps simultaneously and in synchronism with a vibrating balance wheel, means for individually observing said lamps, and means for moving said lamps successively into

and out of operative relation with said observing means at a predetermined constant speed.

18. In a timing apparatus, means for generating spaced pulses of alternating current, means for rectifying said alternating current pulses, a space discharge device, connections over which the rectified currents produce a negative bias on the control grid of said device, a relay connected in the output circuit of said device and energized due to removal of said bias between adjacent pulses, and means controlled by said relay for comparing the frequency of said pulses with a frequency standard.

19. Apparatus for vibrating hairsprings, comprising a stand for supporting a balance wheel and for securing the end of the hairspring, a light source, means for producing a beam of light from said source in the same plane with said wheel, means for directing said beam to cause the same to impinge on the outer rim of the wheel at an angle, whereby it is reflected to one side, and a photocell adjacent said stand adapted to intercept the deflected beam.

20. Apparatus for vibrating hairsprings, comprising a work bench, means for mounting a balance wheel above the top of said bench, a light source mounted beneath the bench, means for directing a light beam from said source upward through an opening in the bench and for focusing the beam on the rim of said wheel, and a photocell supported above the bench adjacent said wheel for intercepting the light beam as it is reflected from the rim of said wheel.

21. Apparatus for testing the beat frequency of a member having periodic oscillatory motion, said apparatus comprising means responsive to movement of the said member for generating high frequency currents of a frequency which is higher than the beat frequency of the member, said means including a device for throwing a beam of light on said member and a photocell to which the light is reflected, means controlled by said high frequency currents for generating impulses having the same frequency as the beat frequency of said member, and means for comparing the impulse frequency with a time standard.

22. The combination, for use with the oscillating part of an escapement type timing device and its associated hairspring to be adjusted as to rate of vibration, of a time standard, a device for comparing the rate of vibration of said part with said time standard, and means subject to continuous control by movement of said part above a predetermined speed for controlling said device, said means including a photocell sensitive to light reflected from the surface of said part.

23. In an apparatus for timing a body having periodic oscillatory motion, a stroboscopic device including a lamp, means for projecting a beam of light onto a reflecting surface of said body, a photocell adapted to intercept the reflected beam in all positions of said body, means for flashing said lamp, and means including said photocell for controlling said flashing means.

24. In an apparatus for timing a part having oscillatory motion, means controlled by light reflected from said part for detecting the instants during the motion of said part when it reverses its direction of motion, said means including a light responsive device for producing electrical phenomena in timed relation with the reversals, and means for determining the frequency of such phenomena with reference to a standard frequency.

25. The combination, for use with a body having periodic oscillatory motion, of means for projecting a beam of light on said body, said beam being reflected from the body in a direction which makes a substantially constant angle with the direction of the incident beam in all positions of said body, a photocell in the path of the reflected beam, and means controlled by said photocell for producing electrical voltages having a frequency bearing a predetermined relation to the oscillatory frequency of said body.

26. The combination, for use with a body having periodic motion, of a photocell, means for causing said body to reflect a beam of radiant energy to said photocell in various positions which said body assumes while in motion and at rest, and means including said photocell for varying a characteristic of an electrical circuit in accordance with the frequency of said periodic motion.

27. The combination, for use with a body having periodic motion, of a photocell, means for subjecting said photocell to the continuous action of radiant energy reflected from said body while the same is undergoing said periodic motion, said photocell having a selective response to the reflected energy depending on whether the energy is being reflected from a stationary or moving surface of the body, and means including said photocell for varying the current in an electrical circuit in accordance with the frequency of said periodic motion.

28. The combination, for use with a body having periodic oscillatory motion, of means for giving said body an independent rotary motion while the same is oscillating, means for projecting a beam of light onto a reflecting surface of said body, a photocell intercepting the reflected beam, and means including said photocell selectively responsive to the oscillatory motion of said body for producing periodic voltages having a frequency bearing a predetermined relation to the oscillating frequency of said body.

29. The combination, for use with a body having periodic motion in a definite plane, of means for projecting a beam of light on said body, the direction of said beam and the plane in which said body moves being so related that a substantially stationary beam is reflected from the body, a photocell acted on by the reflected beam, means including said photocell for producing periodic voltages having a frequency bearing a predetermined relation to the frequency of said periodic motion, and means for comparing the voltage frequency with a standard frequency.

30. Apparatus for timing a body having periodic motion, comprising means for causing said body while in motion to emit a substantially stationary beam of reflected light, a photocell positioned to intercept said beam, means including said photocell for generating a periodic voltage having the same frequency as said periodic motion, and means for continuously indicating whether said voltage frequency is fast or slow with reference to a standard frequency.

31. The combination, for use with a body having periodic oscillatory motion, of a photocell, a light source, means for projecting a beam of light from said source to said body whence a part of the beam is reflected to said photocell, a circuit including said photocell in which signal currents of different frequency are produced by movement of said body, means for filtering out all of said currents except those having a particular frequency, and an indicator controlled by said currents of particular frequency.

32. Apparatus for testing the frequency of a body having periodic oscillatory motion, comprising means for projecting a beam of light toward said body, a photocell arranged to intercept the light reflected from said body at all times while the body is impinged upon by said beam, the motion of the body and the incident beam being so related that the position of the reflected beam relative to said photocell is substantially constant, means including said photocell for generating periodic voltages of different frequencies responsive to motion of said body, apparatus for comparing periodic voltages with a frequency standard, and means for selecting voltages of a particular frequency from said generated voltages to control said apparatus.

33. Apparatus for timing a body having oscillatory motion and an independent rotary motion in the same plane, comprising means for projecting a beam of radiant energy on to said body, a photocell to which a part of said beam is reflected from said body, means including said photocell for generating periodic voltages of different frequency under the action of the reflected beam, including a component having a frequency bearing a fixed relation to the frequency of said periodic motion and independent of said rotary motion, means including a filter for segregating said component, and means for comparing the frequency of said component with a standard frequency.

34. Apparatus for timing a body having periodic motion, said apparatus including a photocell, a source of light, an optical system comprising a plurality of lenses and a reflecting surface of said body for transmitting light from said source to said photocell, the direction of the reflected light being independent of the motion of said body, means including said photocell for generating a periodic voltage responsive to motion of said body, a standard frequency source, and a visual indicator including means for causing said periodic voltage to cooperate with said frequency source to indicate whether said periodic voltage is fast or slow relative to said standard frequency source.

35. The combination, for use with a body having periodic motion, of a source of light, a photocell, means for projecting light from said source to said body whence it is reflected to said photocell, means including said photocell for generating successive trains of high frequency voltages responsive to movement of said body beneath said light, means including a rectifier for converting said trains into periodic voltages having a frequency bearing a fixed relation to the frequency of said periodic motion, and means for comparing the frequency of said periodic voltages with a frequency standard.

36. The combination, for use with a body having periodic oscillatory motion, of means for giving said body an independent rotary motion while the same is oscillating, means for forming a beam of light which is intercepted by said body at a substantially constant angle while the body is undergoing both rotary and oscillatory motion, a photocell in the path of the light transmitted from said source by said body, and means including said photocell for generating periodic voltages having a frequency bearing a predetermined relation to the oscillatory frequency of said body.

37. Apparatus for timing a body having periodic oscillatory motion, comprising a source of light, a photocell, an optical system in which said body functions as a mirror to reflect light from said source to said photocell, the motion of said body being such that the direction of the reflected light is constant, means including said photocell for generating a periodic voltage the frequency of which bears a fixed relation to the frequency of said motion, and means for comparing the frequency of said voltage with a frequency standard.

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