PATENT SPECIFICATION

Application Date: Sept. 30, 1921. No. 25,936/21. **187,814**

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PROVISIONAL SPECIFICATION.

Improvements in the Synchronisation of Clocks.

I, WILLIAM HAMILTON SHORTT, of "Bramcote", Bramcote Road, Putney, S.W., Civil Engineer, of British nationality, do hereby declare the nature of this invention to be as follows:—

This invention relates to an improved method of synchronising one pendulum clock with another in such a manner that the phase difference of their pendulums shall not vary by more than a very small and definite fraction of the period of vibration of the slave pendulum.

In accordance with my invention the control of the synchronised or slave pendulum is effected by employing periodic impulses—such as are now commonly used for impelling systems of electric clock dials—sent out by the controlling or master pendulum to operate an accelerating device associated with the slave pendulum, immediately this pendulum lags in phase beyond a pre-determined amount; the slave pendulum being so rated that at all times it tends to lag relative to the master. The master clock may cause an electric circuit, containing an electro-magnet, to be closed periodically for a fraction of a second, and the magnet may be arranged to render operative or not to render operative an accelerating device for the slave pendulum according to the position in its swing of the slave pendulum at the moment of energization of the magnet.

According to one particular embodiment of this invention the magnet is fixed adjacent to the slave pendulum in such a manner that its armature is horizontal and will, when attracted, just engage with the lower end of a vertical lever, attached to and swinging with this pendulum as the latter passes its mid position, or thereabouts (when swinging in one direction only). This lever is attached to the pendulum by a pivot at its upper end and a spring near its lower end in such a way that when the lower end is engaged by the armature of the electro magnet, the continued movement of the pendulum extends the spring and calls into play a force, which assists gravity and consequently accelerates that particular half swing by a small fraction of the period of vibration. This quickening is arranged to be about twice as great as the amount which the slave normally drops behind during the interval between the impulses. The lower end of the vertical lever is turned at right angles and brought to a sharp point, and the end of the armature is brought to a chisel point, so that the two parts engage with great precision, and when once they have engaged they cannot disengage until the return swing of the pendulum through its central position.

When starting up the slave pendulum its phase relative to the master is advanced so that the vertical lever is not engaged by the operation of the electro-magnet; owing however to its losing rate the phase difference gradually decreases until engagement finally takes place with a consequent advancement of phase corresponding to the quickening action of the spring, as this quickening is twice as great as the amount lost by the slave during the interval it is undisturbed, it follows that at the next impulse the slave will not have dropped back sufficiently to permit engagement by the electro-magnet, and a miss will occur; by the end of the next interval however, the phase difference will be approximately the same as when the initial engagement took place, and consequently a second engagement will ensue with a corresponding quickening. This cycle of operations will obviously continue indefinitely, engagements and misses recurring alternately or approximately so, the phase difference between the master and slave not being allowed to vary by more than plus or minus the advancement produced by one operation of the quickening spring.

It is not necessary to give the slave a larger losing rate compared with the master than will ensure that it always remains a losing rate, and as a pair of pendulums may be expected to maintain their relative rate constant with ± half a second an hour, the losing rate of the slave should not need to exceed half a second per hour, or $^1/_{240}$ second per half minute, so that if the impulses are at half minute intervals the quickening produced by the spring need not exceed $^1/_{120}$ second. It is therefore clear that by the above device the slave can be held in synchronism with the master in such a manner that their phase difference will not vary more than ± $^1/_{100}$ second, or if the slave pendulum is of seconds beat, more than ± $^1/_{200}$ of the period of vibration.

Whereas in the foregoing reference is made to a lagging pendulum and an accelerating device my invention also includes the use of a gaining pendulum and a retarding device.

Dated the 30th day of September, 1921.

W. H. SHORTT.

COMPLETE SPECIFICATION.

Improvements in the Synchronisation of Clocks.

I, WILLIAM HAMILTON SHORTT, of "Bramcote", Bramcote Road, Putney, S.W., Civil Engineer, of British nationality, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to an improved method of synchronising one pendulum clock with another in such a manner that the phase difference of their pendulums shall not vary by more than a very small and definite fraction of the period of vibration of the synchronised or slave pendulum.

In accordance with my invention the control of the synchronised or slave pendulum is effected by employing periodic impulses—such as are now commonly used for impelling systems of electric clock dials—sent out by the controlling or master pendulum to operate an accelerating device associated with the slave pendulum, immediately this pendulum lags in phase beyond a predetermined amount, the slave pendulum being so rated that at all times it tends to lag relative to the master and the accelerating device being arranged to effect a change of phase of the same amount every time it operates and only to operate when the lag of phase of the slave pendulum exceeds the predetermined amount.

The master clock may cause an electric circuit containing an electro magnet to be closed periodically for a fraction of a second, and the magnet may be arranged to render operative or not to render operative an accelerating device for the slave pendulum according to the position in its swing of the slave pendulum at the moment of energisation of the magnet.

An essential feature of my invention is that the action of the accelerating device is such as to produce, as nearly as practical considerations will allow, an alteration of fixed amount in the phase of the slave pendulum on every occasion that it is rendered operative, so that variations in the relative rate of the master and slave pendulum do not cause any alteration in their mean phase difference, but only result in a variation of the frequency of operation of the accelerating device.

This invention distinguishes my invention from other apparatus wherein a master pendulum sends out periodic impulses to energise an electro-magnet for synchronizing a slave pendulum and in which the phase of the slave pendulum is altered by variable amounts on successive occasions by means of an accelerating device in which a leaf spring is flexed by the slave pendulum an amount which varies with the phase relation of the slave and master pendulums, so that variations in their relative rate result in a change in their mean phase difference.

According to one practical form of this invention, illustrated by Fig. 1 of the accompanying drawings the electro magnet "M" is fixed adjacent to the slave pendulum "D" so that its armature "A" is horizontal and will when attracted just engage with the lower end of a vertical lever "L" attached to and swinging with this pendulum, as the latter passes through its mid-position, or thereabouts; the engagement being possible when the pendulum is swinging in one direction only (in the figure from right to left).

This lever is attached to the pendulum by the pivot "P" at its upper end and the spring "S" near its lower end, so that when this lower end is engaged by the armature "A" of the electro magnet "M" the continued movement of the pendulum extends the spring and calls

into play a force which assists gravity and consequently accelerates that particular half swing by a small fraction of the period of vibration. "X" and "Y" are stops against which the vertical lever and armature respectively rest when they are not engaged.

The quickening is arranged to be about twice as great as the amount which the slave normally drops behind during the interval between the impulses.

The lower end of the lever "L" is turned at right angles and brought to a sharp point and the end of the armature is brought to a chisel point as shewn so that the two parts engage with great precision by the sliding of the one over the other, and when once they have engaged they cannot disengage until the return swing of the pendulum through its central position.

Fig. 2 shews an alternative arrangement in which the necessity for a separate spring and a pivot is avoided by making the lever "L" itself springy.

When starting up the slave pendulum its phase relative to the master is advanced so that when swinging from right to left the vertical lever is just not engaged by the operation of the electro magnet; owing however to its losing rate the phase difference gradually decreases until engagement finally takes place with a consequent advancement of phase corresponding to the quickening action of the spring, as this quickening is twice as great as the amount lost by the slave during the interval in which it is undisturbed it follows that at the next impulse the slave will not have dropped back sufficiently to permit engagement by the electro magnet, and a miss will occur; by the end of the next interval however, the phase difference will be approximately the same as when the initial engagement took place, and consequently a second engagement will ensue with a corresponding quickening. This cycle of operations will obviously continue indefinitely, engagements and misses recurring alternately or approximately so, the phase difference between the master and slave not being allowed to vary by more than plus or minus the advancement produced by one operation of the quickening spring.

It is not necessary to give the slave a larger losing rate compared with the master than will ensure that it always remains a losing rate, and as a pair of pendulums may be expected to maintain their relative rate constant within ± half a second an hour, the losing rate of the slave should not need to exceed half a second per hour, or $^1/_{240}$ second per half minute, so that if the impulses are at half minute intervals the quickening produced by the spring need not exceed $^1/_{120}$ second. It is therefore clear that by the above device the slave can be held in synchronism with the master in such a manner that their phase difference will not vary more than $\pm\ ^1/_{100}$ second, or if the slave pendulum is of seconds beat, more than $\pm\ ^1/_{200}$ of the period of vibration.

In the form above described the quickening device only operates in one half period of the slave pendulum's motion, consequently it has to be comparatively powerful in action, my invention however comprises also an arrangement according to which this device shall remain in operation during a number of half periods and its action may then be correspondingly reduced in power.

Fig. 3 shews one method of accomplishing the result. The arrangement is identical with that of Fig. 1 except for the horizontal extension "E" of the armature "A" which engages with the top of the vertical armature "V" of the additional electro magnet "N", and the horizontal extension "F" at the right of lever "L" which prevents "A" moving upwards after "L" has passed to the left of "A". In this construction when "A" moves upwards and engages with "L", "V" passes under the armature "A", moving to the left under the influence of spring "R" against stop "Z", and thereby prevents "A" dropping back clear of "L" when freed by the return swing of the pendulum to the right; consequently "L" and "A" engage on each subsequent half swing of the pendulum to the left with a corresponding quickening of these half swings.

The electro magnet "N" is arranged to be energized by means of a contact made by the slave pendulum when it is making a half swing to the right, one or more half periods before the next energization of magnet "M"—if the slave pendulum is electrically impelled at the same intervals as the master sends out its impulses magnet "N" can conveniently be operated by connecting it in the impelling circuit of the slave pendulum. As a result of the operation of "N", "A" drops back against stop "Y" and is ready to respond to the next impulse given to "M" by the master pendulum.

Whereas in the foregoing description reference is made to a lagging pendulum and an accelerating device my invention also includes the use of a gaining pendulum and a retarding device, and Fig. 4 illustrates one practical form of this arrangement. The arrangement is identical with that of Fig. 1, with the

exception that lever "L" is lengthened so that pivot "P" can be mounted at the top of the pendulum rod and that spring "S" of Fig. 1 is eliminated and replaced by the weight "W" which is attached to "L" so that it comes half way between the bob of the pendulum and its point of suspension. In operation the action is as follows:—The pendulum is started with its phase relative to the master retarded so that the armature "A" has returned to its normal position before lever "L" reaches it, owing however to the gaining rate of the slave pendulum the phase difference gradually decreases until "L" reaches "A" before it has dropped back and engagement occurs with the result that during the ensuing half swing to the left lever "L" is stationary and weight "W" is in effect removed from the pendulum, this results in a slowing of this half period and a consequent retardation of phase. This slowing should be arranged to be about twice as great as the amount which the slave normally gains during the period between the master impulses, in order that engagements and misses may occur alternately or approximately so and the master's control be effective. If the gaining rate of the slave has to be as great as half a second per hour, the weight "W" will probably need to be about one eighth of the weight of the bob of the slave pendulum; it may therefore be preferable to arrange for the retardation to be spread over a number of half periods and the modifications necessary to effect this are shewn by Fig. 5. The arrangement is the same as that of Fig. 4 except for the horizontal extension "E" of the armature and the addition of the supplementary magnet "N" which operates as already described in connection with Fig. 3, to hold armature "A" up when once lifted, and the horizontal extension "F" at the right of lever "L" which prevents "A" rising while "L" is to the left of "A". In all cases the lever attached to the pendulum must have a frequency as a pendulum which is greater than that of the pendulum proper.

To start up the slave the impulse from the master should be arranged to arrive when the slave pendulum is at about the centre of a swing from left to right (instead of from right to left as in all previous cases) and its phase is retarded so that the end of lever "L" is just too late in clearing the end of armature "A" to enable the impulse from the master passing through magnet "M" to raise "A", owing however to the gaining rate of the slave its phase will slowly advance and eventually "L" will clear "A" in time for the master's impulse to lift it, when it is held up by the operation of "V". On the return swing of the pendulum from right to left "L" and "A" engage, "L" becomes stationary and "W" is in effect removed from the pendulum for a half period with a correponding slowing; this action is repeated each half swing to the left until "A" is allowed to drop as a result of the energisation of "N" by the impelling current of the slave pendulum as already explained in connection with Fig. 3. The resulting slowing of the slave makes the lever "L" late in clearing "A" when the next master impulse comes through, and "A" consequently fails to rise, the weight "W" therefore again moves as part of the pendulum and the latter regains its normal quickening rate and a repetition of the above cycle of events is brought about.

With a pendulum of seconds beat "W" should not need to be heavier than $^1/_{100}$ of the weight of the bob of the slave pendulum, since with impulses at half minute intervals, the weight may be kept off during 14 consecutive half swings to the left each time armature "A" rises.

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

1. Any device for synchronising one pendulum clock with another by which periodic electric impulses, sent out by the first or master pendulum, are caused to render an accelerating or retarding device, associated with the second or slave pendulum which alters the phase of this pendulum by a fixed amount each time it operates, operative or non-operative according to the precise position of this second pendulum in its swing at the moment of arrival of the electric impulse, the second pendulum being so rated that it respectively always losses or always gains relative to the first pendulum and the phase alteration produced by the respective accelerating or retarding device being fixed so that it is always greater than the amount by which the second pendulum lags behind or gets ahead of the first during the interval between the impulses sent out by the latter.

2. Any device for synchronising one pendulum clock with another by which periodic electric impulses, sent out by the first or master pendulum, are caused to render an accelerating or

retarding device, associated with the second or slave pendulum which alters the phase of this pendulum by a fixed amount each time it operates, operative for a fixed number of the vibrations made by the slave pendulum during the interval between two consecutive impulses from the master, or non-operative according to the precise position of the slave pendulum in its swing at the moment of arrival of the impulse from the master, the second pendulum being so rated that it respectively always loses or always gains relative to the first pendulum and the phase alteration produced by the respective accelerating or retarding device being fixed so that its total effect for the consecutive vibrations during which it is in operation is always greater than the amount by which the second pendulum lags behind or gets ahead of the first during the interval between the impulses sent out by the latter.

3. In a device for synchronising one pendulum clock with another, a pendulum accelerating or retarding device in which a lever attached to and swinging with the pendulum and the armature of an electro magnet fixed adjacent to the pendulum are so disposed and shaped at the adjoining ends that the momentary energisation of the electro magnet will cause the end of the armature to engage the end of the lever and remain so engaged for a predetermined part of one swing of the pendulum when this momentary energisation finds the pendulum a minute distance away in one prescribed direction from a prescribed position in its swing, and that when this momentary energization finds the pendulum in the prescribed position or a small distance away from it opposite to the prescribed direction no engagement takes place; the engagement of the lever and armature causing a fixed acceleration of the pendulum by the application of an accelerating force or a fixed retardation of the pendulum by the removal of an accelerating force during the continuance of the engagement.

4. In a device for synchronizing one pendulum clock with another a pendulum accelerating or retarding device in which a lever attached to and swinging with the pendulum, the armature of an electro magnet fixed adjacent to the pendulum and the armature of a second adjacent electro magnet are so disposed and shaped at their adjoining ends, that the momentary energization of the first magnet will fall to cause its armature to move into a position for engaging the said lever if at the time of arrival of this energization the pendulum is a minute distance away in one prescribed direction from a prescribed position in its swing, and if at this time of momentary energization the pendulum is in the prescribed position or a small distance away from it in a direction opposite to the prescribed direction the first mentioned armature is moved by its magnet into a position for engaging the said lever and is thereafter held there by the automatic movement of the armature of the second magnet, such movement of the first mentioned magnet armature causing a fixed acceleration of the pendulum by the application of an accelerating force or a fixed retardation by the removal of an accelerating force from the pendulum until the aforesaid armature is released by the energization of the second electro magnet.

5. An improved device for synchronizing one pendulum clock with another substantially as described and as illustrated by Fig. 1 or 4 of the drawings.

6. An improved device for synchronizing one pendulum clock with another substantially as described and as illustrated by Fig. 2 of the drawings.

7. An improved device for synchronizing one pendulum clock with another substantially as described and as illustrated by Figures 3 or 5 of the drawings.

Dated this 28th day of June, 1922.

W. H. SHORTT.

Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.—1922.

Fig 1

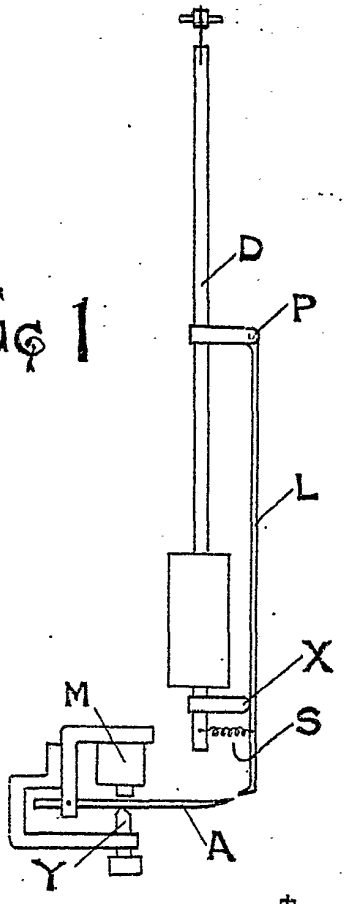
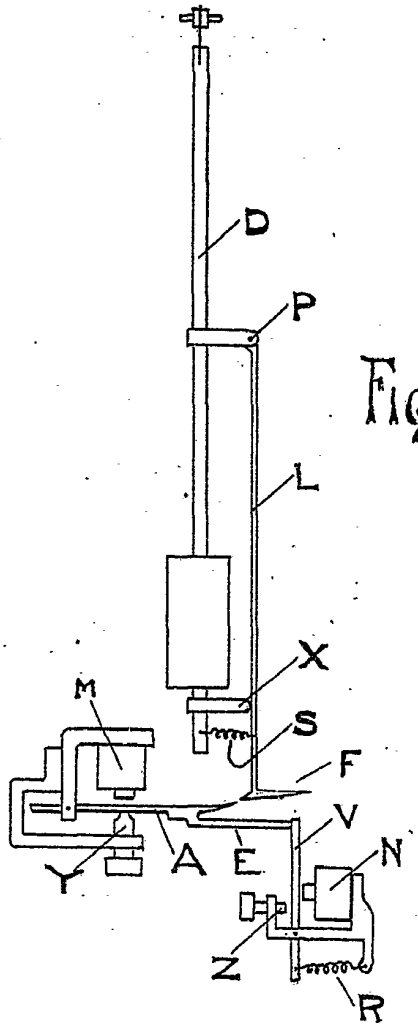


Fig 3



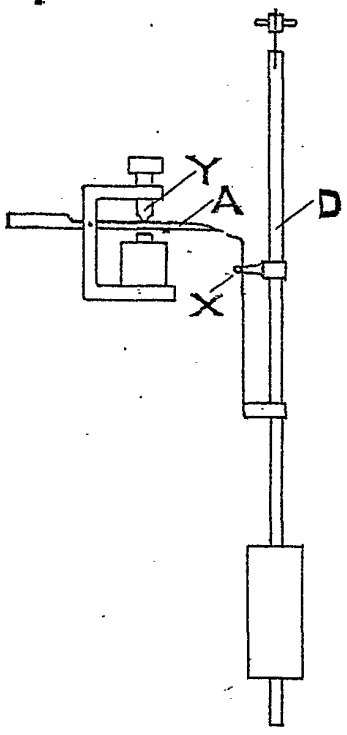


Fig 2

Fig 3

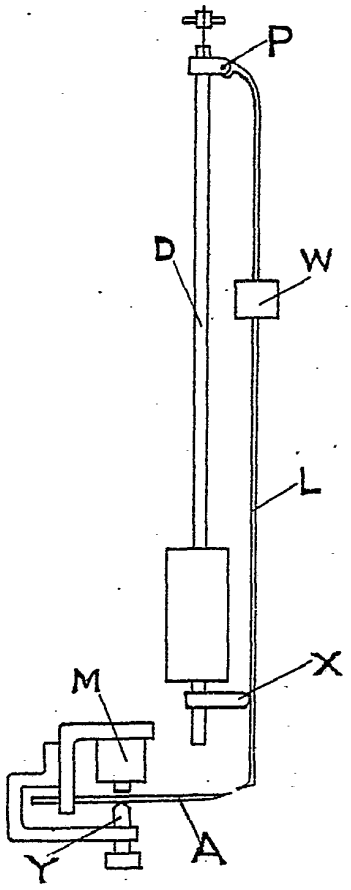


Fig 4

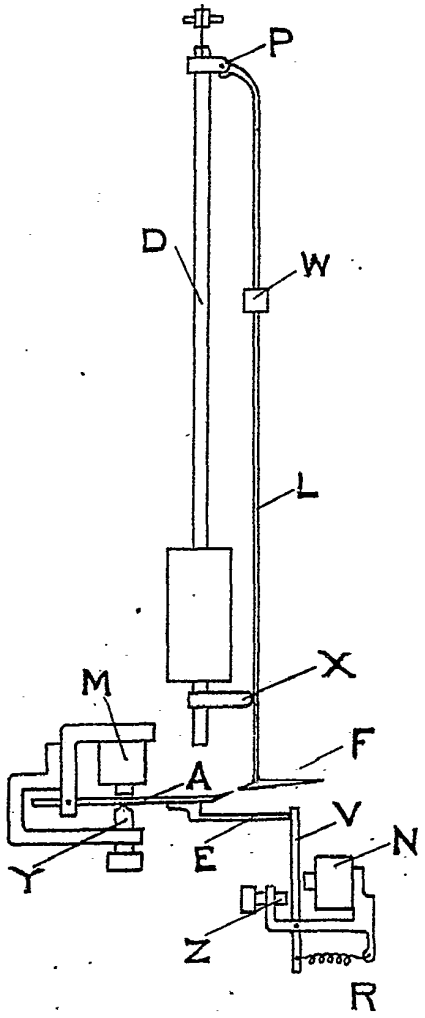


Fig 5

Malby&Sons, Photo-Litho

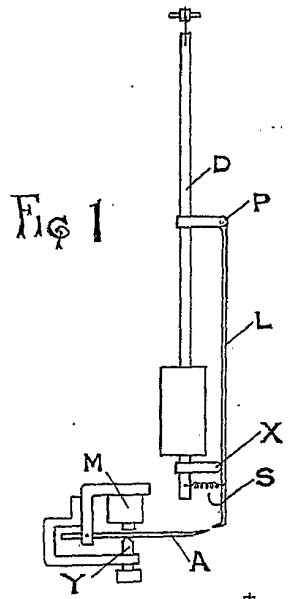


Fig 1

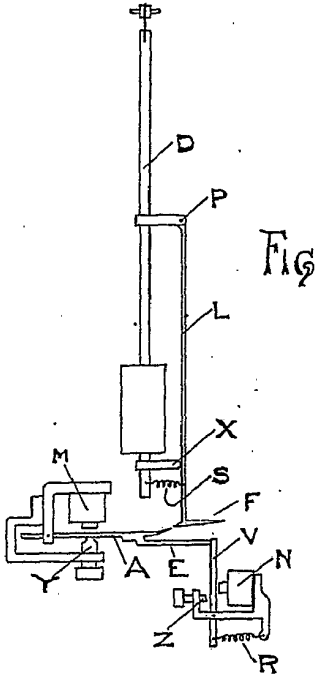


Fig 3

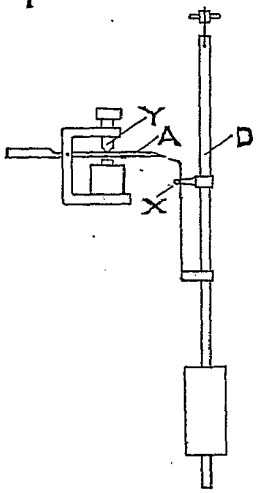


Fig 2

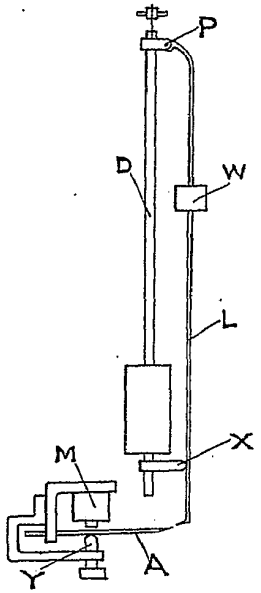


Fig 4

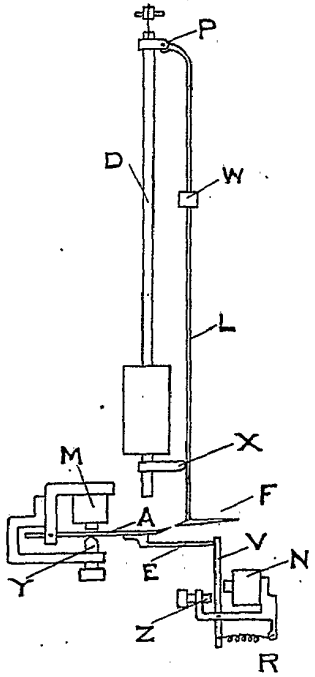


Fig 5

Mauby&Sons, Photo-Litho