March 11, 1924.

R. E. HALL

1,486,136

INDICATOR

Filed Jan. 8, 1920

2 Sheets-Sheet 1

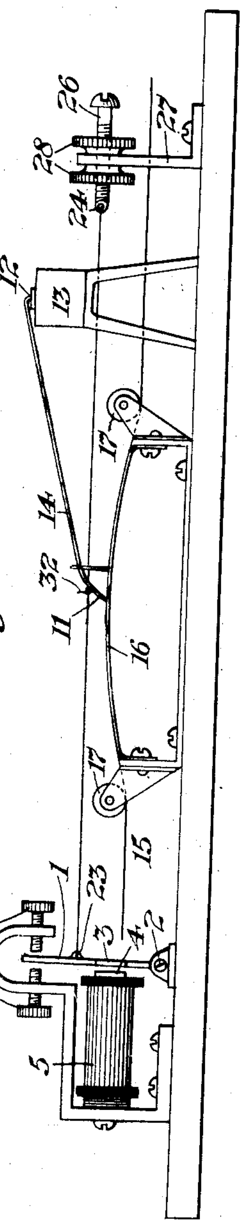

Fig.1

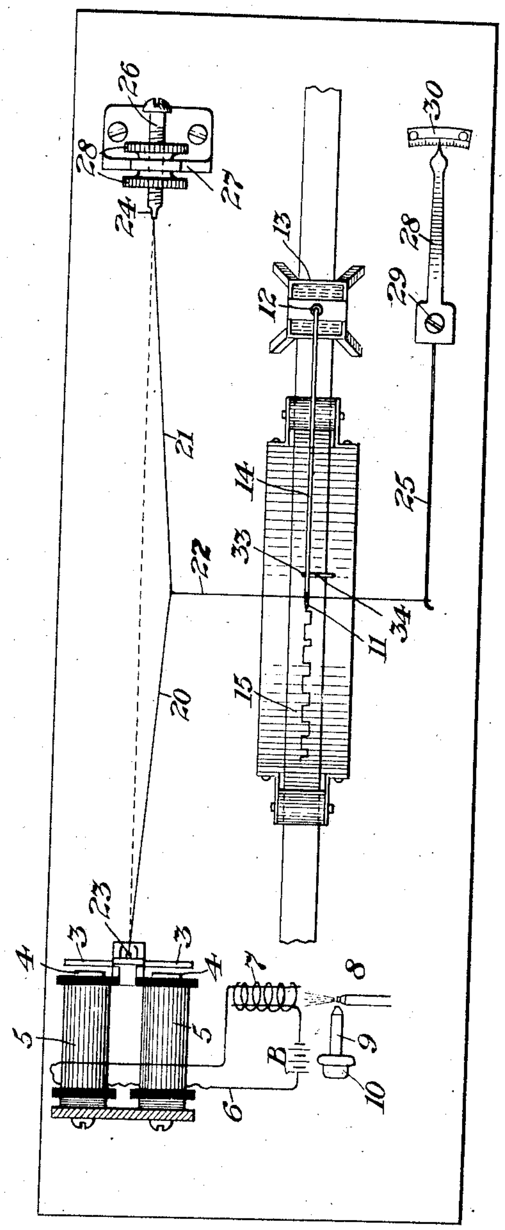

Fig.2

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March 11, 1924. R. E. HALL 1,486,136

INDICATOR

Filed Jan. 8, 1920 2 Sheets-Sheet 2

Fig. 3

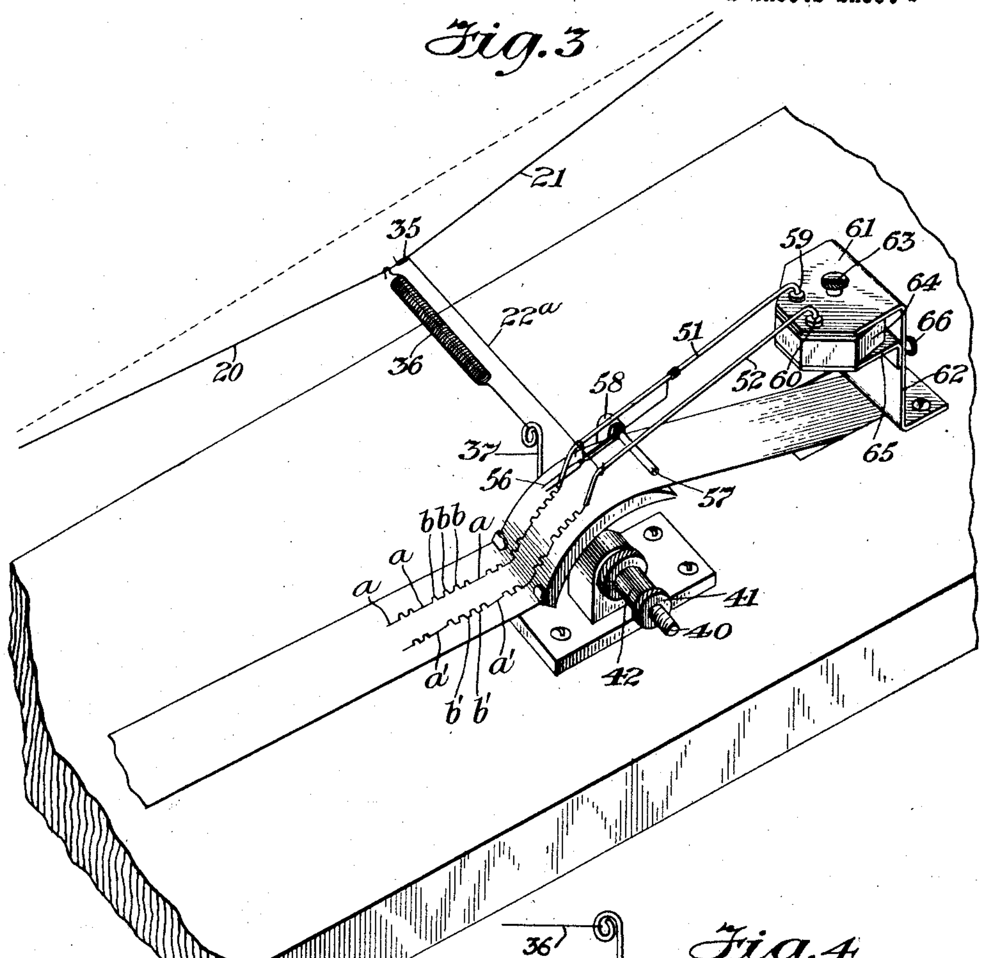


Fig. 4

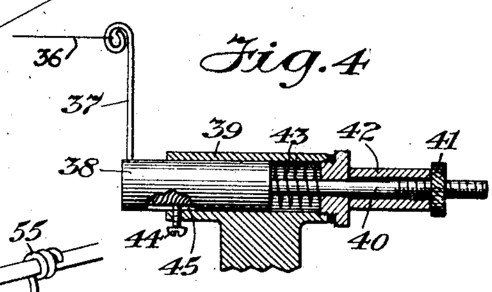
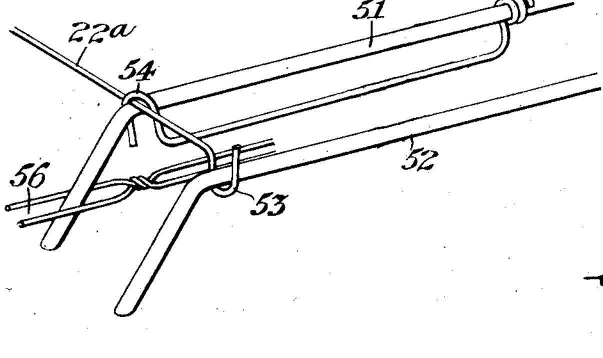


Fig. 5



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Patented Mar. 11, 1924. **1,486,136**

UNITED STATES PATENT OFFICE.

RAY EDWIN HALL, OF CHICAGO, ILLINOIS.

INDICATOR.

Application filed January 8, 1920. Serial No. 350,162.

To all whom it may concern:

Be it known that I, RAY EDWIN HALL, a citizen of the United States, and resident of Chicago, in the county of Cook and State of Illinois, have invented certain new and useful Improvements in Indicators, of which the following is a specification.

My present invention relates to indicators of the type wherein relatively minute physical movements are to be mechanically transmitted and reproduced as corresponding but enlarged or magnified physical movements of an indicating, recording or analogous instrumentality.

One special purpose I have had in view is mechanically enlarging the minute movements of the armature of a relay, actuated by electric current variations such as are available in the indicator circuit of a wireless telegraph or a submarine cable receiving system. In such relays sensitiveness and efficiency require that the movements of the armature be limited to a narrow range close to the poles of the electro-magnet; that the latter be normally, continuously energized and that the normally continuous magnetic pull on the poles of the armature be very delicately yet effectively balanced, usually by spring tension. In relays thus organized and adjusted, as well as in many other relations, there is need for a mechanically acting but practically massless means for magnifying and transmitting such minute and often feeble or irregular movements.

Various arrangements of levers, reflected light beams and similar expedients have been proposed and utilized in such connection, but my present invention has for its object the attainment of such results through the use of tension members which can be made almost microscopically fine and therefore practically massless and free from inertia effects.

One desirable way in which the principle of this invention may be embodied, involves stretching an extremely fine and easily flexible wire, filament, fiber or thread operating as a tension member to restrain and limit movements of the armature toward the electro-magnet poles and laterally deflecting an intermediate portion of said wire, preferably at or near the center, by a delicately adjustable spring.

As regards the action of a spring operating on the armature in this way, it will be noted that for small movements and small angles of deflection of the wire, the spring tension may be very small and yet have extremely wide range of effective values according to how little or how great is the angle at which the stretched wire or filament is deflected from a straight line. This will be evident from the fact that any finite force applied laterally at the center of a straight-stretched string is theoretically of infinite effect in deflecting it, as against any tension that can be applied at the ends of the string.

Another and more important point is that the movement at the center of a wire thus deflected may be many times the distance of endwise stretching and relaxing movements applied by the armature at the end of the wire to produce such lateral movement at the center. Moreover, the ratio of the multiplication varies quite widely for the smaller angles of lateral deflection, thus rendering available almost any distance multiplying ratio that can be desired in view of the inevitable and corelative power-reducing effect.

Some notion of these ratio values may be had from considering the fact that for a 45° deflection of the wire, the distance ratio and the power ratio of the transmission is 1 to 1 neither power nor distance of the movement being multiplied. For angles greater than 45° the effect is power-multiplying and distance decreasing. For angles less than 45° the effect is distance-multiplying, power decreasing. At 30° the distance multiplying ratio is about 3 to 2; at 22° about 3 to 1; at 10° over 4 to 1; at 5° more than 10 to 1; and for angles less than 5° the ratios increase more and more rapidly as the angles are smaller. The ratios of power change are of course the inverse of the above ratios of distance change.

The above described lateral movements at the center of the string when endwise tensioned and relaxed by the armature movement, may be applied to the indicator or recorder through a tension member as in the first embodiment of my invention hereinafter described, but in actual practice, I have found that the advantages available from the stretched string principle of operation are so great that a thrust member may be employed to transmit to the index or stylus the small amount of power required for its movement. Such a thrust member being free from lateral stresses except for its own weight, may, in practice, be made of extremely fine wire.

I have found that fine steel wire now available in the market, as for instance, No. 34 Brown and Sharpe gage (approximately .0063 inch in diameter) will be found flexible enough and light enough for a tension member and at the same time stiff enough for the thrust member, where a light siphon stylus is the recorder to be actuated thereby.

The tension member or thrust member through which the deflection movements of the stretched wire are applied may be connected to the operating stylus without lost motion so as directly and accurately to reproduce all of the armature movements in magnified form. It is also well adapted for operating the stylus through frictional engagement permitting of slip and lost motion. In such case supplying limiting stops for the stylus will cause only regular, equal-amplitude, square-topped deflections to appear on the recording tape, thus giving clear, easily readable indications of the durations and directions of deflections, regardless of the extreme fluctuations of power or distance of the armature movements. Such a regular effect produced from variations which are quantitatively irregular is known as a "jockey" effect, and the frictional engagement of my transverse actuating wire with the stylus is a simple, effective and easily applied expedient for producing it.

The frictional or jockey connection whereby only the regular accurately aligned indications are traced, may be combined with the non-slip connection whereby are traced in magnified but otherwise unchanged form, all of the irregularities and fluctuations of movement just as they occur in the armature. This may be accomplished by having the transverse power applying member simultaneously operating two siphon stylus recorders arranged side by side and tracing their separate records on a single tape. One stylus is positively connected and has no limiting stops to check extreme movements while the other is frictionally connected and has such limiting stops. Such duplex arrangement is of no particular use when transmission is good but in times of electrical disturbances the expert will often be able to piece out portions of the jockeyed record that are unreadable, by minute examination of the faithfully reproduced irregularities of the unjocked record.

The above described relay and recorder affords an outfit capable of translating and recording directly on ticker tape, in most satisfactory manner, the feeble energy variations available in wireless telegraph and submarine cable work, particularly when used in combination with the jet relay described in my prior application Serial No. 301,010, others of the features shown in my said application being also employed if desired. It will be evident, however, that the herein described recorder may be employed in connection with other receiving apparatus and that various of the basic features herein disclosed may be embodied or employed in connection with various elements or combinations different from those which for purposes of illustration are disclosed herein.

The above and other features of my invention may be more fully understood from the following description in connection with the accompanying drawings, in which—

Figures 1 and 2 are respectively side elevation and top plan views illustrating one form of my invention and indicating diagrammatically a source of electrical variations to be indicated or recorded;

Figure 3 is a perspective view showing a modified form of my invention, and

Figures 4 and 5 are detail views of parts shown in Figure 3.

Referring first to Figures 1 and 2, the element of which the vibratory movements are to be translated and recorded, is the armature lever 1, pivoted at 2, and formed with an armature portion 3 closely confronting the electromagnet poles 4, 4. These poles are variably energized by coils 5, 5, which are connected through circuit 6 with any desired source of electrical variations.

The source of variations is diagrammatically indicated as the primary battery B in circuit with a sensitive resistance 7. Changes of resistances in 7 produce the variations of current which variably energize coils 5 and thereby causing corresponding variations of magnetism of pole pieces 4 thereby variably attracting the armature and causing movement thereof in opposition to a spring tension applied by means described below.

The means for varying the resistance of 7 is diagrammatically indicated as the sensitive jet 8 which varies the temperature of the resistance 7 by change of shape of the jet which are precipitated by sound vibrations applied through resonator 9 from a telephone receiver 10 which may be the receiving telephone of a wireless telegraph system.

The element which is to be actuated for magnified movement by and in accordance with the vibratory movements of armature lever 1, is shown as a siphon recording stylus 11.

The siphon recording apparatus may be of any known or desired construction. Preferably the stylus is a fine-drawn glass tube having an upright portion 12 journalled in inkwell 13 and a radially, preferably downwardly extending portion 14, terminating in the tracing point or stylus 11. The tube is of course hollow from end to end and, as its name indicates, siphons ink from the well 13 to the open end which bears on the tape 15. The tube being very fine the ink is retained by capillary attraction, except such as is wiped off on the recording tape to constitute the record of the to and fro movements of the stylus.

The tape 15 may be ordinary ticker tape and in operation is drawn continuously under the stylus over a suitable support 16 by clock work or other mechanism not shown. The support is preferably convex and guide rollers 17 are employed to maintain the tape in smooth contact therewith.

The vibratory movements of the armature are transmitted and applied as magnified transverse movements of the stylus, through a three-limb tension system comprising lengths of wire, filament or thread, 20, 21 and 22. The portions 20 and 21 may consist of a continuous length of the above described fine wire secured at one end to the armature as at 23, and at the other end, to the fixed support 24 in approximate alignment with the to and fro movements of the armature. Normally the tension elements 20, 21 tend to assume the straight line position indicated by the dotted line on Figure 2, but they are held laterally deflected from said position by the transverse wire 22 which is maintained under suitable tension by spring 25 fastened to the other end thereof. It will be obvious that this system, though comprised of tension members transmits the power with the same power and distance changing ratios as would a toggle composed of rigid thrust members yet being tension members, they may be made so as to have no practically observable inertia. The relaxing and tensioning movements of the armature applied at 23 will give a greatly magnified, to-and-fro, endwise movement of wire 22 connected to the center thereof. The smaller the angle of deflection of wire 21 from the dotted line position, the greater will be the distance of movement of wire 22 for a given movement of the armature lever 1. Conversely the greater will be the disadvantage at which the power of the armature operates in producing such movement. For most purposes, it will be found that a satisfactory ratio may be obtained where the wire 21 is laterally deflected from the straight dotted line position through an angle of less than 10°. The deflection indicated in figure 2, which is about 5°, will give endwise movements of wire 22 approximately 10 times the to and fro movement at the point 23 on the armature and even smaller angles may be employed.

The variations of the ratios for angles from 10° to 5° are considerable and from 5° down to zero angle (the dotted line position) they have infinity as their theoretical limit. The desired angle for best working must therefore be predetermined with reference to the strength of the signal variations actuating the armature and with reference to the amount of spring tension required to counterbalance the normal continuous pull of the magnets on the armature as is required if the armature is to be left free for delicate response to the variations of magnetism. As these factors are all interdependent in the system of Figures 1 and 2, I have provided various adjustments. They include means for adjusting the initial length of wires 20 and 21, as by having the fixed anchorage 24 on the end of a screw 26 held firmly in adjusted position by thumb nuts 28 on standard 27. These two nuts provide means for adjusting the screw endwise without turning the screw, thus making it possible to effect the endwise movement of the screw to lengthen or shorten the wire without imparting twist and kinking tendency to the latter.

If the tension member is a wire which is substantially unstretchable under the slight strains imposed upon it, the amount of angular deflection will be exactly predetermined by the amount of slack allowed. On the other hand, if a fiber or filament of slightly stretchable material is employed, the deflection will be determined by the initial tension imposed by screw 26 in combination with the transverse tension imposed by spring 25 through wire 22. In either case, it is desirable to employ means for adjusting the tension of spring 25 as by attaching the same to lever arm 28, pivoted at 29. Lever 28 may be held in adjusted position by its spring pressure on the support or on an index 30 which may be employed to measure the degree of predetermined deflection and stress imposed upon spring 25.

Although the tensions taking effect on armature lever 1 may be very delicately predetermined and adjusted by the above means, it is desirable to employ set screws 31, for limiting the maximum possible to-and-fro movement of said lever, so that under all conditions of practical operation, it will be prevented from approaching the poles close enough to stick, and from receding from them far enough to become too insensitive to their magnetic pull.

In the preferred arrangement, however, the set screws 31 need not and preferably do not function as stops during normal operation, the armature being preferably poised in a position of stable but extremely delicate equilibrium. This position of delicate poise can easily be approximated in practice by making the tension wire perfectly straight and adjusting its length so that the armature cannot quite touch the poles of the magnet and then adjustably applying a slight lateral tension deflecting the wire through a small angle.

At the straight line position the effective pull of the spring is theoretically infinite, but for very slight deflections this effectiveness falls off at an enormous rate. Hence by delicate adjustments of the endwise and lateral tensions a position is soon reached where, for small movements, the rates of change of magnet effectiveness and spring effectiveness are quite nearly the same. From such position any movement of the armature toward the poles increases the effectiveness of the spring pull slightly more rapidly than it increases the effectiveness of the magnet pull. On the other hand, movement of the armature away from the magnet decreases the effectiveness of the spring pull slightly more rapidly than it decreases the effectiveness of the magnet pull. Hence the armature is poised in stable equilibrium and the angle selected being one where the rates of change of effectiveness of the opposing forces approach the crossing point very gradually, the poise is extremely delicate. A stable but delicate poise being attained in this way, it is of course possible to adjust the back stop 31 so that it will touch the poised armature but this is not necessary or desirable.

The magnified movement applied to wire 22 by the tensioning and relaxing movements of armature 23 may be applied to the stylus 11 in any desired way, the preferred way being by frictional contact of said wire 22 with said stylus. In such case a projection 32 may be formed on the stylus for retaining the wire and stabilizing the point of application of the friction. The frictional actuation of the stylus permits "jockeying" the record by arranging parallel spaced apart stops 33, 34, adapted to engage the stylus and confine all its transverse movements to the same fixed limit, regardless of how much greater may be the endwise movements of the actuating wire 22.

A slightly modified arrangement is shown in Figures 3, 4 and 5. In these figures, the tension members 20, 21 are indicated as fine wires and the transverse wire 22ª for transmitting the movement of said tension members to the stylus, is indicated as a similar fine wire twisted around the tension wires as at 35 and arranged to actuate the recording stylus by thrust in one direction and tension in the other direction. The spring tension for deflecting wires 21, 22 is applied by a coil spring 36 which may be formed from steel wire of the same size (No. 34 Brown & Sharpe gage). This spring is made very long so that its tension will be very delicate and very uniform, said tension being capable of delicate adjustment by having one end of the spring secured to a standard 37 carried by plunger 38 slidably held in guide 39. 38 is provided with a rearwardly extending screw-threaded rod 40 adapted to be adjusted by nut 41 bearing on bushing 42 which serves as a guide for rod 40. Lost motion is taken up by spring 43 and the plunger 38 is prevented from rotation by screw 44 engaging slot 45.

The wire 22ª is connected to actuate two siphon tubes 51, 52 which may be each similar to the siphon tube above described in connection with Figures 1 and 2. To one of these siphons as 52 the wire 22ª is positively connected, as by a hook 53 formed at the end of the wire. This imparts to siphon tube 52 all of the movements of wire 22ª without any lost motion and hence in accordance with all of the irregularities as well as the regularities of the vibrating armature. The hook form permits ready removal of siphon tube 52. The other siphon tube 51 is actuated by frictional contact with an intermediate portion of wire 22ª. A very uniform and unchanging friction is afforded by clamping the wire 22ª to the tube 51 by a spring hook 54 mounted upon and anchored to the tube by twisting the wire around the latter as at 55. The frictional contact being between the steel wires and the glass surface and the pressure being delicately regulated by the constant pressure of spring hook 54, the friction desired for actuating the stylus is easily predetermined and not likely to change. The hook form of the clamp permits easy unhooking and removal of tube 51 when required.

The jockey stops are provided in the form of a bifurcated wire 56 straddling the stylus and secured in adjustable relation thereto by a frictional mounting on the transverse stud bar 57 which projects laterally from the support 58.

The siphon tubes are mounted for movement on their vertical axes in bearings 59, 60, formed in the top of horizontal plate 61 supported by standard 62. A screw plug 63 is provided which may be removed for replenishing ink in the reservoir. The reservoir 64 is supported on shelf 65 secured to upright 62 by screw studs 66. Whenever desired, the shelf may be unscrewed and removed and the reservoir 64 moved downward and laterally for cleaning or replenishing.

In Figure 3 an attempt has been made, very feeble and inaccurate in execution, to give some indication of the nature of the difference between the jockeyed and the unjockeyed record. In the jockeyed record all of the tracings lengthwise of the paper are in the same straight line. This means that all lines *a*, *a*, *a*, are in the same straight line and all lines *b*, *b*, *b*, are approximately parallel with and equidistant from said first mentioned line. In the unjockeyed records, the corresponding portions *a'*, *a'*, and also the series of short lines *b'*, *b'*, tend to run up-hill. These, however, are the least important of the non-uniformities that may occur and may make the unjockeyed record give indications not decipherable on the jockeyed record.

I claim:

1. A receiving apparatus including a polarized electromagnet, an armature continuously attracted thereby; and means for varying the attraction of said electromagnet in accordance with the received signals, in combination with a flexible tension member stretched between the armature and a fixed abutment to restrain and limit movement of the armature toward the electromagnet poles; and a delicately adjustable spring element laterally applied to deflect an intermediate portion of the said tension member through a small angle and a nonresilient indicating element actuated by the magnified motion of the deflected portion of the tension member.

2. A receiving apparatus including a polarized electromagnet, an armature continuously attracted thereby; and means for varying the attraction of said electromagnet in accordance with the received signals, in combination with a flexible tension member stretched between the armature and a fixed abutment to restrain and limit movement of the armature toward the electromagnet poles; and a delicately adjustable spring element laterally applied to deflect an intermediate portion of the said tension member through a small angle and an untensed indicating element actuated by the magnified motion of the deflected portion of the tension member.

3. A receiving apparatus including a polarized electromagnet, an armature continuously attracted thereby; and means for varying the attraction of said electromagnet in accordance with the received signals, in combination with a flexible tension member stretched between the armature and a fixed abutment to restrain and limit movement of the armature toward the electromagnet poles; and a delicately adjustable spring element laterally applied to deflect an intermediate portion of the said tension member through a small angle and an untensed indicating element non-positively actuated by the magnified motion of the deflected portion of the tension member.

4. A recorder comprising a receiving electro-magnet and armature, a recording stylus and means for reciprocating said stylus by and in accordance with the to-and-fro movements of the armature, said means including a member movable endwise by said armature, in combination with a non-positive driving connection between said endwise movable member and said stylus, and means for positively limiting the to-and-fro movements of the stylus to a predetermined range substantially less than the endwise to-and-fro movement of said driving member.

5. In the combination specified by claim 4, the further feature of another stylus having positive non-slip connection with said endwise moving member.

6. In the combination specified by claim 5, the further feature of siphon tubes for the recording styluses.

7. In the combination specified by claim 6, the further feature of having the siphon tubes approximately parallel, with their recording ends close together and operating on the same record surface.

8. A signal indicator including an indicating element, an electro-magnet therefor having normally magnetized poles and means for causing fluctuation of said magnetism by and in accordance with current fluctuations representing the received signal, and an armature bodily movable to and from the poles and said electro-magnet, in combination with means for transmitting, multiplying and applying to the indicating element the signal responsive movements of the armature, said means including a tension member adapted to be tensioned and relaxed by the armature movement and having an intermediate portion of its length resiliently deflected from a straight line through a small angle and operatively related to said indicating element to impart to it amplified movements corresponding to the movements of the armature, the length, lateral tension and the resulting angle of deflection of the tension member being co-related to predetermine a normal position of delicate, stable poise of the armature.

9. In the combination specified by claim 8, the further feature of means for adjusting the length, lateral tension and the resulting angle of lateral deflection of the tension member to establish a condition of delicate, stable poise of the armature coordinated with a suitable movement-multiplying, power-reducing ratio for the transmission of the armature movement to the indicating element.

10. In the combination specified by claim 8, the further feature of a fine wire as the tension member.

11. A signal indicator including an indicating element, an electro-magnet therefor having normally magnetized poles and means for causing fluctuation of said magnetism by and in accordance with current fluctuations representing the received signal and an armature bodily movable to and from the poles and said electro-magnet, in combination with means for transmitting, multiplying and applying to the indicating element the signal responsive movements of the armature, said means including a tension member adapted to be tensioned and

relaxed by the armature movement and having an intermediate portion of its length resiliently deflected from a straight line through a small angle and operatively related to said indicating element to impart to it amplified movements corresponding to the movements of the armature, the length of the tension member being sufficient to permit close approach of the armature to the poles of the magnet but insufficient to permit contact therewith when the tension member is free from lateral tension.

Signed at Mechanicsville in the county of Cedar and State of Iowa this 31 day of December, A. D. 1919.

RAY EDWIN HALL.