

J. L. WOODBRIDGE.
 MEANS FOR RECTIFYING ALTERNATING CURRENTS.
 APPLICATION FILED NOV. 29, 1909.

1,051,941.

Patented Feb. 4, 1913.

2 SHEETS—SHEET 1.

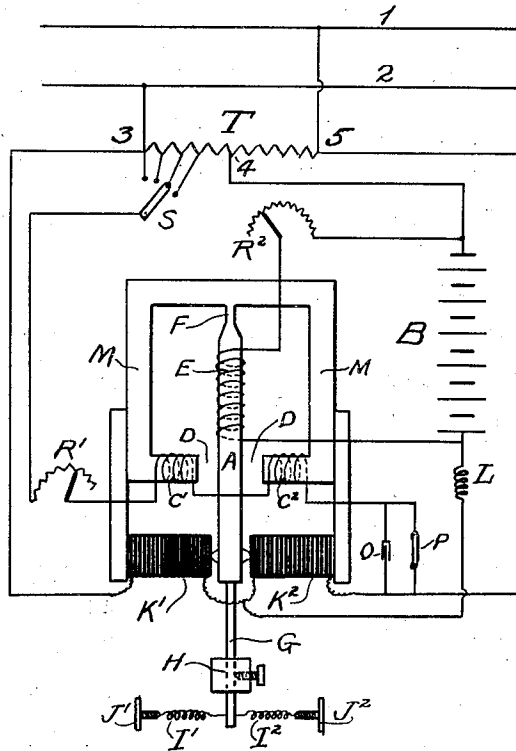


Fig. 1.

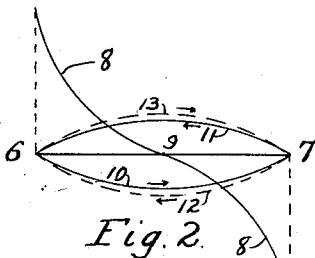


Fig. 2.

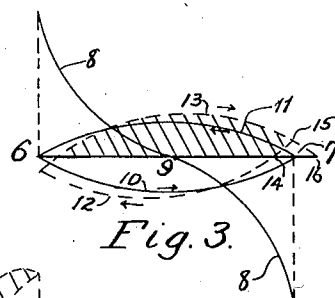


Fig. 3.

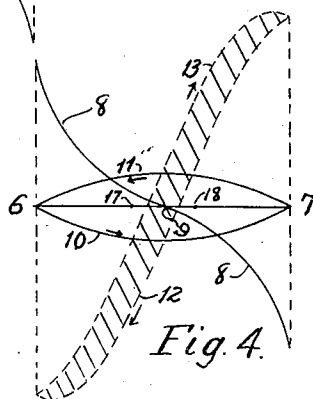


Fig. 4.

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Fig. 5.

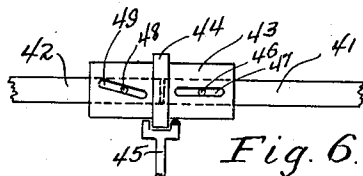
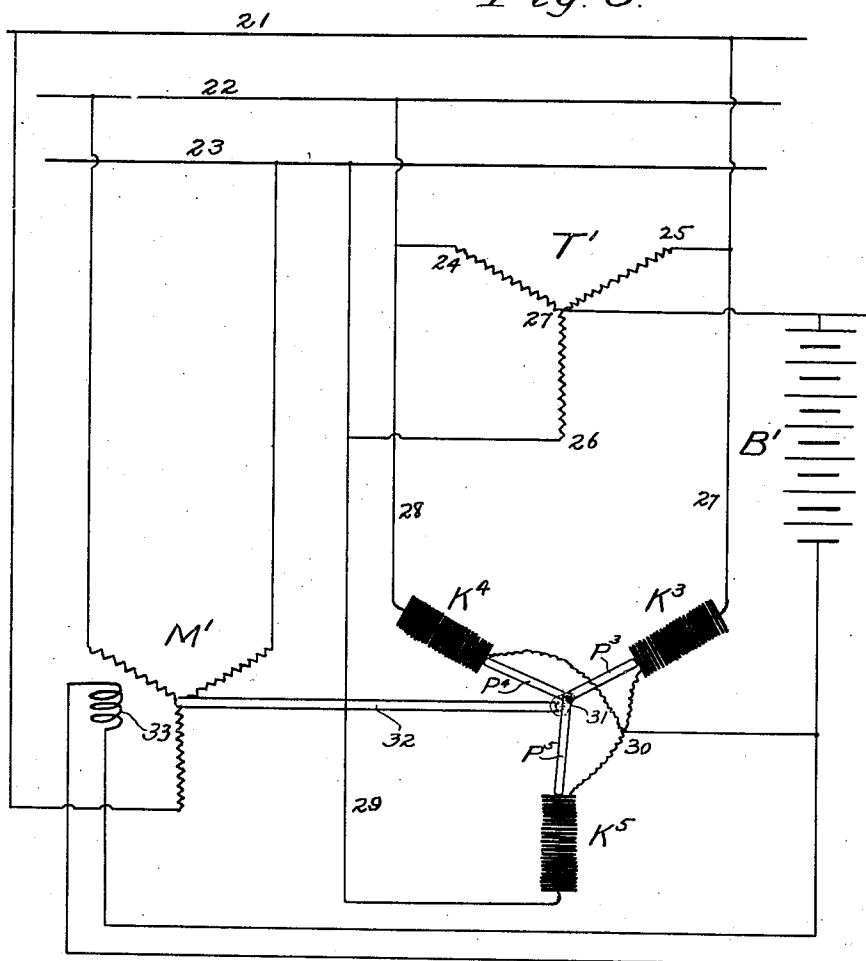


Fig. 6.

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MEANS FOR RECTIFYING ALTERNATING CURRENTS.

1,051,941.

Specification of Letters Patent.

Patented Feb. 4, 1913.

Application filed November 29, 1909. Serial No. 530,368.

To all whom it may concern:

Be it known that I, JOSEPH L. WOODBRIDGE, a citizen of the United States, and a resident of Philadelphia, in the county of Philadelphia and State of Pennsylvania, have invented certain new and useful Means for Rectifying Alternating Currents, of which the following is a specification.

The rectifying apparatus which has heretofore been proposed has involved commutating devices or means for opening the circuit of the alternating current and reversing the connections at or near the instant when the current is passing through zero. Such apparatus is liable to produce troublesome or destructive sparking with slight variations in the phase relation of the current. In the apparatus described below the circuit is at no time broken but resistances are employed whose resistance varies with pressure and means are provided for producing variation of pressure in synchronism with the current alternations.

The invention will be more clearly understood by reference to the following description taken in connection with the accompanying drawings, in which—

Figure 1, shows one embodiment of the invention applied to a single phase alternating current circuit. Figs. 2, 3, and 4, are diagrams illustrating the combination of forces operating in the apparatus of Fig. 1 under different adjustments. Fig. 5, shows another embodiment of the invention applied to a three phase circuit, and Fig. 6, illustrates one means of providing for the adjustment of phase relation in the apparatus shown in Fig. 5.

Referring to Fig. 1, K^1 and K^2 are piles of carbon disks or other material whose electrical resistance varies with pressure, these piles being connected in series across the outer terminals of the auto-transformer T. A storage battery B is shown connected at one end to the middle point 4 of the transformer and at the other end to a point in the circuit between the two carbon piles. Between the two piles is shown a tongue A of magnetic material arranged to vibrate in the air gap D of a magnetic circuit M. When this tongue is in its mean position the

pressure on the two piles of carbon disks is equal and their resistance is equal and it may be comparatively high so that only a small flow of current will take place through them from the alternating current circuit and a small flow of direct current from the battery in the discharge direction. This latter will divide through the two carbon piles and passing through the winding of the transformer T from opposite ends will unite again at the middle point returning from there to the battery. If, however, the tongue A is vibrated in synchronism with and in the proper phase relation to the alternating electro-motive-force on the circuit 1—2 the resistance of the pile K^1 will be reduced at the instant when the alternating current electro-motive-force between the points 3 and 4 is in the proper direction to charge the battery and owing to this reduction in the resistance of the pile K^2 a considerable charging current will flow into the battery during this half cycle. During the following half cycle the other carbon pile K^2 will be under compression and its resistance reduced, and at the same time the electro-motive-force between the points 4 and 5 will be in the right direction to charge the battery so that a considerable charging current will flow into the battery during this half cycle also. The battery will therefore receive a uni-directional current under these conditions. A reactance coil is shown at L which will tend to smooth out the pulsations of this current.

In order to produce synchronous vibration of the tongue A and the proper phase adjustment of this vibration the following construction is shown: The tongue is attached to the magnetic frame M by a flexible suspension at F. A steel spring may be used having considerable resilience or an ordinary hinge joint. At the other end of the tongue A is an extension G carrying an adjustable weight H, which may slide along the bar G and be clamped at any point by a set screw. Two opposing springs I^1 and I^2 whose tension may be adjusted by screws J^1 and J^2 are also shown. The relative tension of these springs will determine the mean position of the tongue A. By ad-

justing their absolute tension as well as the position of the weight H, the natural period of vibration of the tongue A may be varied and adjusted to the frequency of the circuit 1—2. The bar G may be made more or less elastic, permitting the weight H to over-swing to some extent at each end of its travel and prolong the maximum pressure on the carbon piles during each vibration.

In Fig. 2, is shown diagrammatically the variation of force acting on the tongue A during its vibration. The horizontal line between the points 6—7 represents the travel of the tongue, greatly magnified, while the curved line 8 represents the force acting upon the tongue including the elasticity of the spring F and of the springs I¹ and I², and the resisting force of the carbon piles K¹ and K² when under compression. While the tongue is traveling from one extreme corresponding to the point 6 to the middle point 9, these forces tend to accelerate its motion, and are therefore represented as positive corresponding with the ordinates of the curve 8 above the line 6—7. Between the point 9 and the point 7 the forces acting on the tongue will oppose its motion and are represented as negative, the curve 8 being below the horizontal line between these points. These forces will bring the tongue to rest when it reaches the extreme point of its travel and then accelerate it in the opposite direction. If these forces were the only ones acting on the tongue it is evident that the vibration would continue indefinitely after once being set in motion. There are, however, other forces such as friction and air resistance as well as the lack of perfect elasticity in the spring and carbon piles, which will oppose the motion of the tongue in each direction. These forces may be represented by the curve 10 when the tongue is moving to the right and by the curve 11 when the tongue is moving to the left. These resisting forces will soon bring the tongue to rest unless counteracted by others which in the aggregate are equal and opposite to them. These latter forces are supplied in the device shown in Fig. 1 by the magnetic attraction and repulsion produced by the coils C¹ and C² wound on the magnetic frame M and by the coil E surrounding the tongue A. Coil E is connected across the terminals of the battery B, and its effect may be controlled by the rheostat R². The coils C¹ and C² are connected in series across a portion of the transformer T, the number of coils of the transformer T across which these windings C¹ and C² are connected being adjustable by means of the multiple point switch S. A rheostat R¹ is also included in this circuit. The coils C¹ and C² are so wound that when one is producing north polarity at the pole face the other is pro-

ducing south polarity. Thus when the tongue A is attracted by one pole of the magnet M it will be repelled by the other. These attractions and repulsions will alternate at a frequency corresponding with that of the circuit 1—2, and will tend to produce vibrations of the tongue A of the same frequency.

It remains to show how the apparatus may be adjusted so that the tongue A will vibrate in the proper phase relation to produce the compression on the piles K¹ and K² at the times when the alternating current electromotive-force is in the right direction to charge the battery, and further that any departure from this phase relation will introduce forces tending to restore it. There are two different adjustments of the apparatus shown in Fig. 1, either of which will accomplish this result. For the first adjustment the resistance in the rheostat R¹ will be entirely cut out. The resistance of the coils C¹ and C² being comparatively low the counter electro-motive-force developed in its coils will be largely due to the variation of magnetic flux, and since this counter electro-motive-force must be equal to that applied to the terminals of the coils, the magnetic flux must, in accordance with the well known law, reach its maximum value in one direction or the other when the potential applied to the coils C¹ and C² is passing through zero. The value of this flux will be determined by the potential applied to the terminals C¹ and C² as adjusted by the switch S, and the force exerted on the tongue A by this flux may be adjusted by varying the position of the switch S as well as by varying the current in the coil E by means of the rheostat R². Referring to Fig. 2, let us assume that these forces of attraction and repulsion are represented at some particular adjustment by the dotted curves 12 and 13, the curve 12 corresponding with motion of the tongue A from right to left, and the curve 13 corresponding with motion in the opposite direction. It will be seen that these curves more than counter-balance the curves 10 and 11 representing the retarding forces of friction, etc. Under these conditions the vibration of the tongue A would tend to increase, first in amplitude, and therefore in frequency since the force represented by the line 8 increases rapidly at each extreme of the travel with any increase in the amplitude. This momentary increase in frequency of vibration will change the phase relations shown in Fig. 2, so that the magnetic force represented by the dotted lines 12 and 13 will become retarded with reference to the other forces. This new condition is illustrated in Fig. 3, the full lines remaining the same as in Fig. 2, while the dotted lines reach their maximum values a little later. It will be seen that the aggregate effect of

the magnetic force represented by the dotted lines in Fig. 3 is less than it was in Fig. 2, this aggregate being represented by the shaded area which is less than the area included between the line 13 and the horizontal line 6—7 in Fig. 2 by the small area 14, 15, 16. As soon as the shift in phase relation between the vibrations of the tongue and the electro-motive-force applied to the coils C^1 and C^2 is sufficient to reduce the shaded area in Fig. 3 to an equality with the area between the curve 10 and the horizontal line 6—7 no further phase displacement will take place and the tongue will continue to vibrate in this phase relation. A careful adjustment of the switch S and the rheostat R^2 will produce this condition of stability with only a very slight phase displacement, and the tongue A will be in its mean position when the magnetic flux in the magnet M is substantially at its maximum, and therefore when the electro-motive-force across the circuit 1—2 is at or near zero. This adjustment will therefore produce the desired rectification of the alternating current.

The second adjustment will be produced by including a very considerable resistance in series with the coils C^1 and C^2 by means of the rheostat R^1 . Under these conditions the larger part of the counter electro-motive-force in the circuit containing the coils C^1 and C^2 will be that due to the ohmic drop in the rheostat R^1 . The current in this circuit will then be substantially in phase with the applied electro-motive-force producing a magnetic flux in the magnet M and across the air gap D, which will reach its maximum value at the instant of maximum potential across the circuit 1—2. The magnetic forces of attraction and repulsion produced by this adjustment will then be as shown in Fig. 4. In this figure the full lines are the same as in Figs. 2 and 3, and have the same significance. The dotted lines 12 and 13 represent as before the forces due to the magnetic flux, but since this flux is now nearly in phase with the electro-motive-force the adjustment must be such that the lines 12 and 13 will pass through zero when the tongue A is near its mean position and the adjustment must be such that the line 13 will cross the horizontal line 6—7 a little to the left of the middle point 9 but as near thereto as possible, while the line 12 crosses a little to the right of this point. The shaded area between these two lines will then represent the aggregate force tending to counterbalance the friction, air resistance, etc. It will be seen that if the frequency of vibration of the tongue A tends to slow down slightly, giving an increased lead to the alternating current electro-motive-force and the corresponding magnetic flux, the line 13 will cross the line 6—7 a little earlier, that is, nearer to the point 6, and the line 12 will cross the

line 6—7, a little earlier on the return travel, that is, a little nearer to the point 7, which will increase the area included between the lines 12 and 13 thus increasing the force tending to maintain the proper frequency and phase relation.

The lines 12 and 13 in Fig. 4 which represent the variation of magnetic flux will also represent the magnetizing current in the coils C^1 and C^2 which produces this flux, and as this current will be displaced somewhat in the lagging direction from the applied electro-motive-force, this applied electro-motive-force will pass through its zero value a little earlier than the current and flux, for example at the points 17 and 18 in the travel of the tongue as shown in Fig. 4. It is desirable to have these points of zero electro-motive-force as near as possible to the middle point 9, but in order to accomplish this it will be seen that the current and magnetic flux would have to be leading instead of lagging. To produce this result a condenser O is shown on Fig. 1 in series with the coils C^1 and C^2 , which would be short-circuited by the switch P for the first adjustment described above, but can be open circuited by opening the switch P for the second adjustment. The capacity of this condenser may be chosen to give a leading phase position to the current and the magnetic flux so as to bring the points 17 and 18 to coincide with the point 9 or nearly so.

The second adjustment has certain advantages over the first. It will be noted from Fig. 4 that the force exerted by the magnet on the tongue A reaches its maximum near the extreme limits of the travel thus assisting to increase the pressure on the carbon piles, whereas in the first adjustment this force is passing through zero at its extreme limits. Furthermore, since the area included between the curves 12 and 13 is fixed by the retarding forces of friction, air resistances, etc., which must be counteracted, these two curves will approach nearer to each other the greater their maximum height. When the magnetizing force is comparatively small these curves must be farther apart which will throw the vibration of the tongue A somewhat out of phase with the electro-motive-force, and thus reduce the charging current into the battery. As the magnetizing force is increased the curves 12 and 13 will come closer together bringing the vibration of the tongue A more closely into phase with the electro-motive-force and increasing the charging current. The increase in the magnetizing force will also increase the maximum pressure on the carbon piles and still further increase the charging current. With this adjustment therefore, the amount of charging current can be readily varied over a wide range by manipulating the rheostats R^1 and

R^2 or the switch S. With the first adjustment, however, this cannot be so readily accomplished. The curves 12 and 13 in Fig. 2 must have a slightly greater maximum
 5 than the curves 10 and 11, in order to insure stability with any slight changes in the opposing forces of friction, air resistances, etc. Any increase in the magnetizing force will throw the vibration of the tongue
 10 A farther out of phase, while having only a slight effect on the maximum pressure on the carbon piles.

In Fig. 5 a three phase alternating current circuit 21—22—23 is shown, to which
 15 is connected a three phase auto-transformer T^1 . Three piles of carbon disks K^3 , K^4 and K^5 are shown, one terminal of each being connected to the corresponding terminal of the transformer T^1 . The other three terminals of the carbon piles are connected to a
 20 common junction point 30 and a storage battery B^1 is connected between the common junction point 27 of the transformer T^1 and the junction point 30. The three carbon
 25 piles are intermittently compressed in sequence by the three rods P^3 , P^4 and P^5 respectively. These rods are given a reciprocating motion by means of the pin 31, which is mounted eccentrically upon and rotated by the shaft 32. This shaft is driven
 30 by the synchronous motor M^1 connected to the circuit 21—22—23— its field 33 being excited from the battery. It will be seen that each of the carbon piles is connected in
 35 series between one phase of the three phase circuit and the battery. The adjustment of the apparatus is such that the maximum compression on each carbon pile is produced when the potential between the corresponding
 40 conductor of the three phase circuit and the neutral point 27 is a maximum in the direction to charge the battery. This permits the maximum current to flow into the battery in the charging direction through
 45 each carbon pile in succession, the pressure on each being released when the polarity reverses to prevent any appreciable flow of current in the opposite direction.

The phase relation between the electro-
 50 motive-force on the circuit 21—22—23 and the rotation of the pin 31 may be adjusted in many well known ways. Fig. 6 illustrates one of these methods. The shaft 32 shown in Fig. 5 is divided in Fig. 6 into
 55 two parts 41—42, which abut and are surrounded by a sleeve 43. Mounted on the two parts of the shaft are pins 46 and 48, which engage in slots 47 and 49 in the sleeve. Slot 47 is parallel with the axis of
 60 the shaft while the slot 49 is inclined thereto, so that by sliding the sleeve in one direction or the other, the angular relation of the two parts of the shaft may be adjusted. The position of the sleeve may be shifted
 65 by means of the collar 44 and the fork 45.

It will be obvious that many modifications may be made in the details of the invention without departing from the spirit thereof.

What I claim as new and desire to secure by Letters Patent is— 70

1. In a device for rectifying alternating currents, a body of material whose electrical resistance varies with pressure and having both alternating and direct current connections, and means for applying to said body pressures varying in synchronism with the alternations of electro-motive force. 75

2. In combination an alternating current circuit, a direct current circuit, a body of material whose electrical resistance varies with pressure connected between said circuits and means for applying to said body pressures varying in synchronism with the alternations of electro-motive-force in the alternating current circuit. 85

3. In combination an alternating current circuit having a plurality of conductors, a direct current circuit, a body of material whose electrical resistance varies with pressure connected between each conductor of the alternating current circuit and the direct current circuit, and means for applying to said bodies pressures varying in synchronism with the alternations of electro-motive-force on the alternating current circuit. 90 95

4. In combination an alternating current circuit having a plurality of conductors, a direct current circuit, a body of material whose electrical resistance varies with pressure connected between each conductor of the alternating current circuit, and one side of the direct current circuit, and means for applying to each of said bodies pressures varying in synchronism with the alternations of electro-motive-force on the alternating current circuit. 100 105

5. In combination, an alternating current circuit, a direct current circuit, a body of material whose electrical resistance varies with pressure connected between said circuits, means for applying to said body pressures varying in synchronism with the alternations of electro-motive-force on the alternating current circuit, and means for adjusting the phase relation between said pressures and the alternations of electro-motive-force. 110 115

6. In combination an alternating current circuit, a direct current circuit, a body of material whose electrical resistance varies with pressure connected between them, an electro-magnet, a magnetic member arranged in the magnetic field of said electro-magnet and adapted to apply varying pressures to said body, and means for applying to the electro-magnet an alternating excitation in synchronism with the alternating current electro-motive-force. 120 125

7. In combination, an alternating current circuit, a direct current circuit, a closed con- 130

ducting circuit of variable resistance connecting the two, and means for varying the resistance of the conducting circuit in synchronism with the alternations of electro-motive-force on the alternating current circuit without opening said conducting circuit.

8. In combination, an alternating current circuit, a direct current circuit, a body of material whose electrical resistance varies with pressure connected between said circuits and electromagnetic means including windings connected respectively to the alternating current, and to the direct current circuit for applying to said body pressures varying in synchronism with the alternations of electro-motive-force on the alternating current circuit.

9. In combination an alternating current circuit, a direct current circuit, a body of material whose electrical resistance varies with pressure connected between them, electro-magnetic means including windings connected respectively to the alternating current and the direct current circuits for applying synchronously varying pressures to said body, and means for adjusting the phase relation between the variations of pressure and the alternating electro-motive-force of the alternating current circuit.

10. In combination an alternating current circuit, a direct current circuit, a body of material whose electrical resistance varies with pressure connected between them, an electro-magnet, a magnetic member arranged in the magnetic field of said electro-magnet and adapted to apply varying pressures to said body, means for applying direct current excitation to said member, means for applying alternating current excitation to the electro-magnet, and means for adjusting the phase relation of said alternating current excitation.

11. In combination an alternating current circuit, a direct current circuit, a body of material whose electrical resistance varies with pressure connected between them, an electro-magnetic device including a stationary member and a movable member whereof the latter is adapted to apply varying pressures to said body, an exciting coil for each of said members, means for transmitting direct current through one of said coils, means for transmitting alternating current through the other coil, and means for adjusting the phase relation of said alternating current.

12. In combination an alternating current circuit, a direct current circuit, a body of material whose electrical resistance varies with pressure connected between them, an electro-magnetic device including a stationary member and a movable member whereof the latter is adapted to apply varying pressures to said body, an exciting coil on one

of said members connected to the alternating current circuit, and an electrical condenser connected in series with the coil.

13. In combination an alternating current circuit, a direct current circuit, a body of material whose electrical resistance varies with pressure connected between them, a vibrating piece adapted to apply varying pressures to said body, means for adjusting the natural period of vibration of said vibrating piece, and means for applying to said piece magnetic forces to maintain its vibration in synchronism with the electro-motive-force of the alternating current circuit.

14. In combination an alternating current circuit comprising two conductors, means for maintaining a neutral point of intermediate potential with respect to said circuit, a storage battery, connection from one terminal of said battery to said neutral point, two circuit connections from the other battery terminal one to each of the two conductors of the alternating current circuit, two bodies of material whose electrical resistance varies with pressure, one connected into each of the two circuit connections last named, a vibrating piece arranged to apply pressure alternately to the two bodies, and an electro-magnetic device for maintaining the vibration of said piece in synchronism with the electro-motive-force of the alternating current circuit.

15. In combination on alternating current circuit comprising two conductors, means for maintaining a neutral point of intermediate potential with respect to said circuit, a storage battery, connection from one terminal of said battery to said neutral point, two circuit connections from the other battery terminal, one to each of the two conductors of the alternating current circuit, two bodies of material whose electrical resistance varies with pressure, one connected into each of the two circuit connections last named, a vibrating piece arranged to apply pressure alternately to the two bodies, an electro-magnetic device for maintaining the vibration of said piece, a coil connected to the alternating current circuit for exciting said device, and a condenser in series with said coil.

16. In combination an alternating current circuit, a direct current circuit, a body of material whose electrical resistance varies with pressure connected between said circuits, an electro-magnetic device for applying varying pressures to said body, an exciting coil for said device, and means for transmitting through said coil alternating currents in synchronism with the electromotive force on the alternating current circuit and substantially in phase therewith.

17. In combination an alternating current circuit, a direct current circuit, a body of

material whose electrical resistance varies
with pressure connected between said cir-
cuits, an electro-magnetic device for apply-
ing varying pressures to said body, an ex-
5 citing coil for said device, and means for
varying the current strength in said coil to
control the maximum pressure on said body.

In testimony whereof I have hereunto
signed my name.

JOSEPH L. WOODBRIDGE.

Witnesses:

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