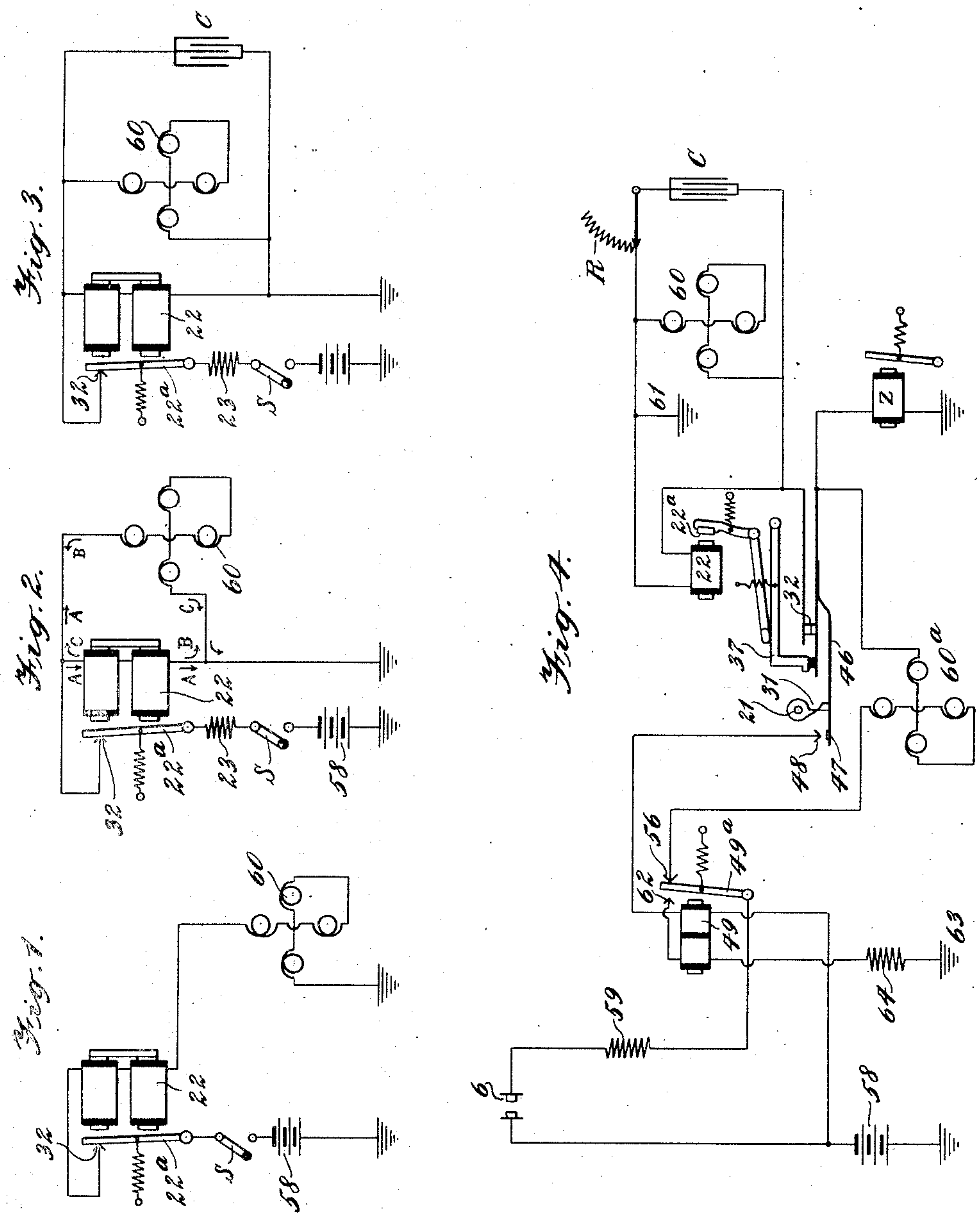
A. D. CARDWELL.

MAGNET CONTROL.

APPLICATION FILED NOV. 16, 1914.

1,279,653. Patented Sept. 24, 1918.

3 SHEETS—SHEET 1.



Witnesses:

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3 SHEETS—SHEET 2.

Fig. 5.

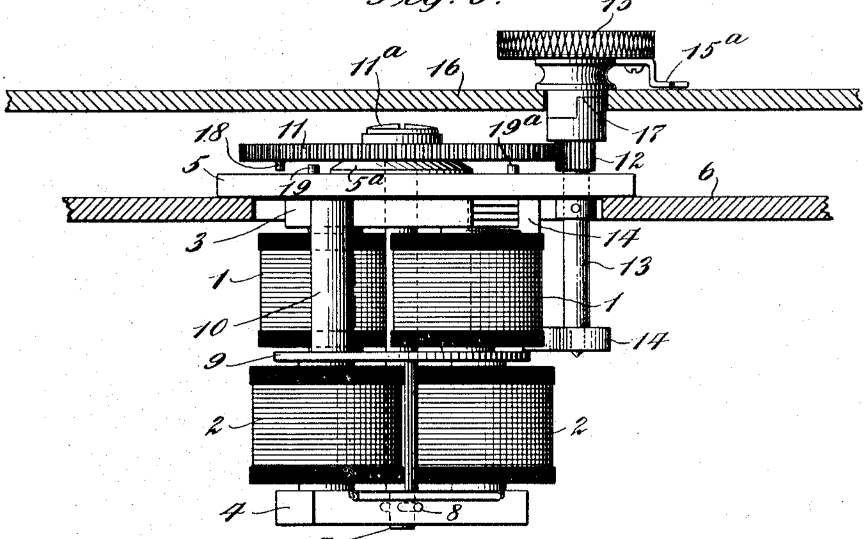
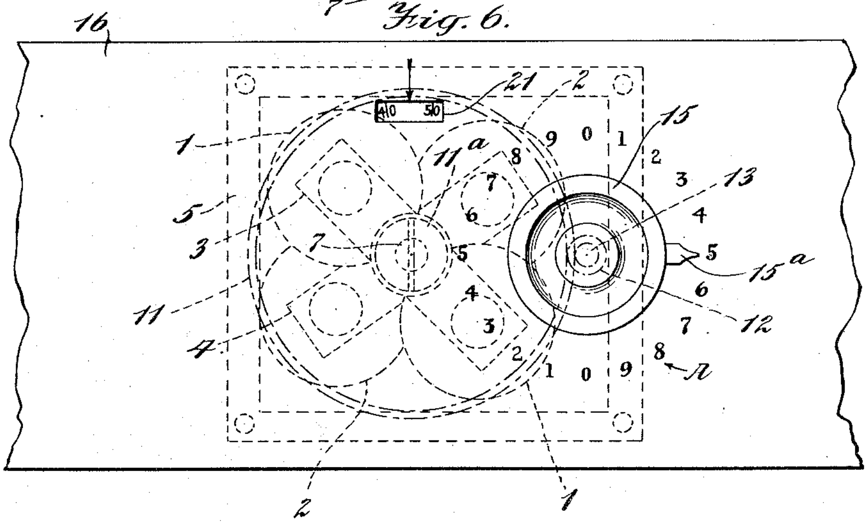


Fig. 6.



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3 SHEETS—SHEET 3.

Fig. 7.

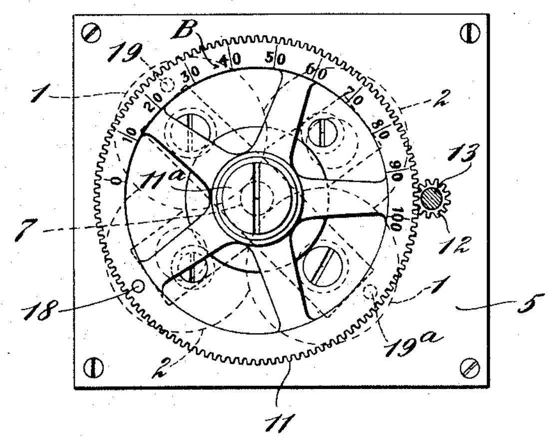
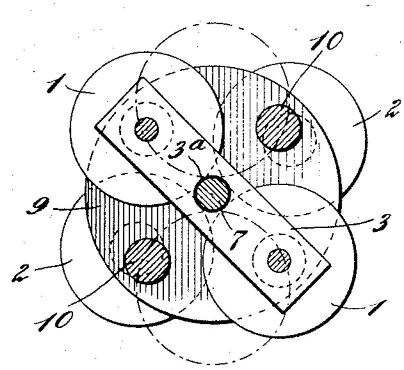


Fig. 8.



Witnesses:
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UNITED STATES PATENT OFFICE.

ALLEN D. CARDWELL, OF NEW YORK, N. Y.

MAGNET CONTROL.

1,279,653. Specification of Letters Patent. Patented Sept. 24, 1918.

Application filed November 16, 1914. Serial No. 872,320.

To all whom it may concern:

Be it known that I, ALLEN D. CARDWELL, a citizen of the United States, and a resident of the city of New York, county of Kings, and State of New York, have invented new and useful Improvements in Magnet Controls, of which the following is a specification.

The general object of my invention is to provide means by which the various operations of an electromagnet may be controlled with respect to the time at which or during which these operations are performed.

More particularly, the objects of my invention contemplate the connection of the electromagnet in circuit with auxiliary apparatus such as inductances, capacities and resistances, to effect the control of the magnet in various ways, for instance, to vary the rate of magnetization of the magnet; to vary its rate of demagnetization, or both its rate of magnetization and demagnetization; to control, vary and maintain the periodicity of the energization of a magnet when the magnet is periodically energized from some source of power; to provide an arrangement whereby, when the magnet is periodically energized, energy may be stored during one period of energization, for use during a subsequent period, to control, vary or maintain the periodicity at that time; when the magnet is periodically energized for a group of cyles of its operation, to control the time of initial energization of the magnet with respect to the time of operation of the energizing means and to thereafter control the periodicity of the subsequent energizations of the group, which two controls may be independent of each other, but capable of being combined in the same apparatus.

Generally speaking, I obtain these controls by the connection of the magnet to be controlled in various circuits, which will be more particularly described hereafter, with inductances, capacities and resistances, or such of these as are necessary to secure the desired results, which inductances, capacities and resistances may be variable or fixed in value, according to the object to be attained.

A further object of my invention is the provision of a convenient form of variable inductance, which is so arranged as to be simple, compact and durable, so that it is possible to obtain therewith minute variations in inductance or impedance by a simple manual adjustment and which, in order to effect these results, takes advantage of the possibility of arranging magnetic fields of force to act in conjunction with, or in opposition to, each other.

My invention is applicable in many connections in which it is desired to control the action of an electromagnet in various ways, and I do not intend to limit it to any specific uses. However, in order to illustrate an operative apparatus in which my invention has found great utility, I have shown it in Figure 4 as being used in connection with a circuit system, such as is described in my application, Serial No. 860,318, for electric controlling systems, filed Sept. 5, 1914, and in order that the relation of the circuits of this application with those shown in my said application, Serial No. 860,318, may be easily traced, I have used, in Fig. 4, reference characters corresponding to those of Fig. 1 of my aforesaid application.

In the drawings, Figs. 1 and 2, and also Fig. 3, are simplified diagrams of connection illustrating some of the controls obtainable by my invention in an elementary way;

Fig. 4 is a a diagram of connections showing my invention applied to a system such as illustrated in my said application, Serial No. 860,318;

Fig. 5 is a side view of my improved variable inductance device;

Fig. 6 is a plan view thereof;

Fig. 7 is a plan view thereof with the cover plate removed; and

Fig. 8 is a sectional plan view of a portion of Fig. 5, illustrating varying positions of its elements.

Similar reference numerals indicate corresponding parts in the several drawings.

Fig. 1 illustrates means by which the rate of magnetization of an electromagnet may be varied, and thus the time within which the magnet shall reach its maximum magnetization. The rapidity with which the magnet attracts its armature may thus be controlled. In Fig. 1, I have shown an electromagnet 22, energized by a battery 58, and connected in series therewith through a switch S, armature 22^a of the electromagnet and contact 32. Connected in series with the electromagnet 22 is the variable inductance 60, which is grounded, as is the battery 58, to complete the circuit. Any other suitable connection, however, may be used instead of the ground. The inductance elements of the variable inductance 60, are preferably wound upon cores of magnetic material, to increase the field set up by the passage of current through the coils.

Contact 32 is normally closed by a spring or equivalent means or armature 22^a. When switch S is closed, a path is established for the current from the battery 58 to the coils of the electromagnet 22, thence through variable inductance 60 to the ground. The magnetizing current does not, of course, reach its maximum value instantaneously and, the rise of this current from zero to maximum will set up in inductance 60 a counter-electromotive force of self-induction, which opposes the flow of current in the circuit.

Upon the breaking of the contact 32, by the movement of armature 22^a, the current in the circuit will again fall to zero, which change of current from maximum to zero will set up in variable inductance 60 an electromotive force due to self-induction, in the same direction as that previously taken by the battery current. This electromotive force so set up, however, produces no current flow in a circuit, except while contact 32 is breaking, such as that illustrated in Fig. 1, since no path is provided for it.

By taking advantage of these phenomena, I am enabled, in an arrangement such as that of Fig. 1, to vary the rate of magnetization of magnet 22, by increasing or decreasing the inductance and, consequently, the impedance of variable inductance 60, which may be conveniently done in the manner pointed out hereafter, thus causing the magnetism in electromagnet 22, to build up more or less rapidly. Furthermore, in such an arrangement I can control the rate of magnetization without at the same time affecting the rate of demagnetization since, while an impedance is offered to the magnetizing current, the decrease of current from maximum to zero remains substantially unaffected.

Fig. 2 illustrates an arrangement in which both the rate of magnetization and of demagnetization may be varied. This arrangement, however, is capable, by slight alteration, of controlling the rate of demagnetization only. Fig. 2 shows a battery 58, connected through switch S, and a resistance 23 to the armature 22^a, which is normally held so as to close contact 32. In this case, the variable inductance 60 is connected in shunt with the magnet 22, instead of in series therewith, as shown in Fig. 1.

Upon the closing of switch S, (contact 32 being closed), the magnetizing current passes through the conductor to electromagnet 22, and also to variable inductance 60. It is for the purpose of effecting this division of current and reduction of potential that resistance 23 is included in circuit, since, were it omitted, the difference of potential across the terminals of the electromagnet would always be the same as that across the battery terminals.

With resistance 23 included in the circuit, however, the current divides as indicated by arrows "A", part of it going through the electromagnet 22, and part of it through the variable inductance 60. By varying the inductance 60, I am thus enabled to impede, to a greater or less extent, the current flowing in the shunt circuit which includes variable inductance 60, while this current is increasing in value, viz.: the time during which the magnetism is being built up in electromagnet 22. As a result of impeding the current in the shunt circuit, which includes variable inductance 60, to a greater or less extent, the current is varied in the circuit passing through the electromagnet 22, while the magnetization is being built up, and the rate of magnetization may thus be controlled.

For varying the rate of demagnetization, which may be accomplished by the arrangement of Fig. 2, as pointed out above, resistance 23 is not necessary, although its inclusion in the circuit does not affect the performance of this function.

Assuming the circuit to be broken at contact 32, by the movement of armature 22^a, a decrease in current will set up, in both the electromagnet 22 and in the variable inductance 60, electromotive forces by reason of their respective self-inductions, which electromotive forces will tend to cause currents to flow in the same direction as that taken by the battery current before the interruption of the circuit. Thus, as the battery current previously flowed in the direction of the arrows A—A, the current set up by the self-induction of the electromagnet 22 will flow in the direction of the arrows B—B, and that set up by the self-induction of the variable inductance 60 will flow in the direction of the arrows marked C—C, a path having been provided for each of these currents of self-induction.

Since these electromotive forces of self-induction oppose one another, a current of greater or less magnitude may be caused to flow in either direction, depending upon the relative values of the self-inductions of the magnet 22 and variable inductance 60.

Thus, if the adjustment is such that the electromagnet 22 has the greater self-induction, a current will be set up in the direction of the arrows B—B, the flow of which will be opposed, to greater or less extent, by the electromotive force of self-induction generated by variable inductance 60. The rate of demagnetization of electromagnet 22 may thus be varied by varying the inductance of variable inductance 60, since its rate of demagnetization depends upon the relative values of the electromotive forces of self-induction generated in electromagnet 22 and in variable inductance 60. Thus, as the electromotive force of self-induction of variable inductance 60 increases, the opposition to the flow of current, (due to self-induction of electromagnet 22) increases and demagnetization of the magnet is more rapidly effected.

If the value of the self-induction of variable inductance 60 is greater than that of electromagnet 22, a current will flow in the direction of the arrows C—C, thus tending to neutralize any magnetizing current which may tend to exist in electro-magnet 22, and to thus still further increase the rate of demagnetization of the magnet.

In the arrangements of Figs. 1 and 2, I have shown means for controlling one cycle of operations of the magnet by controlling constituent operations of that cycle, thus enabling me to vary the time of a cycle of operations of the magnet by varying either the time of magnetization or the time of demagnetization, or both.

In Fig. 3, however, I have illustrated means whereby I am enabled to control not only the time of one cycle of operations by controlling constituent operations of the cycle, but the periodicity of a group of cycles of operation, assuming the magnet to be periodically energized. By the term "cycle of operations of the magnet" I mean to include a magnetizing period and a demagnetizing period.

In Fig. 3, I have shown the battery 58 connected through the switch S and resistance 23 to the armature 22^a, which normally holds contact 32 closed, thus permitting current to flow to the electromganet 22, as in the previous figures. Connected in shunt with electromagnet 22, I connect the variable inductance 60 and a capacity C, which may or may not be variable.

By means of capacity C, variable inductance 60 and electromagnet 22 (which may be considered as an inductance), I establish an oscillatory circuit which includes electromagnet 22. This circuit should have substantially the periodicity of the energizing means, or that of a multiple of this periodicity. The periodicity of the energizing means depends to some extent upon a number of factors, such as the voltage of the battery, the value of the resistance 23, the inertia and momentum of the armature, and the tension of its operating spring. These factors may differ widely, depending upon the particular means used to energize the magnet, and the characteristics of its component elements, or other factors may cause variation.

The rate of magnetization and demagnetization of electromagnet 22 may be varied within limits in the same manner as described within reference to Fig. 2.

A decrease in the average periodicity throughout the group of operations of electromagnet 22 might be caused, for instance, by some mechanical derangement of the energizing means, say a sticking of the contacts, an increase of friction, or other cause, during certain of the cycles of the group, thus causing a lag in the operation of electromagnet 22. On the other hand, an increase in the average periodicity throughout the group might also be produced by some change in condition, say an increase in battery voltage, or other cause, affecting certain cycles of the group.

It is, therefore, apparent that if the average periodicity throughout the group is to be maintained constant, energy must be furnished to the electromagnet 22 to overcome a tendency to decrease the periodicity, and taken from electromagnet 22 to neutralize the cause tending to increase the average periodicity. In an oscillatory circuit, such as that including the magnet 22, variable inductance 60 and the condenser C, there is, as is well known, an interchange of energy between the inductance and the capacity, which interchange takes place at the periodicity of the circuit. Thus, the strength of electromagnet 22 is added to, or subtracted from, at a rate governed by the periodicity of the oscillatory circuit. If, therefore, the periodicity of the energizing means should tend to depart from its original value which, as I have stated, should be substantially equal to the periodicity of the oscillatory circuit, or a factor thereof, energy will be furnished to, or taken from, electromagnet 22, thus tending to restore it to its proper periodicity.

Assuming the energizing means to tend to retard and to cause the energization of the magnet to take place at a later time, the condenser will discharge current into the electromagnet 22, thus momentarily increasing the magnetizing current and the energization of the magnet, and thereby tending to cause the point of maximum energization of the magnet to be reached more rapidly. Conversely, should the energizing means tend to increase in speed, energy will be taken from the electromagnet, thus neutralizing a portion of the energy furnished by the energizing means, and causing the point of maximum magnetization to be reached more slowly.

In an apparatus such as that disclosed in Fig. 3, wherein the system is supplied with energy at each operation of the energizing means, maximum power for controlling purposes will always be available, since it will be understood that if the oscillatory circuit were not supplied with energy, there would be surges of energy between the capacity and inductances which would constantly diminish in force until the energy was entirely dissipated.

The action of my apparatus is, therefore, to some extent, that of a balance wheel, which acts to supply or abstract energy as and when needed, to effect constant periodicity of action.

By varying the value of the inductance of variable inductance 60, I am not only enabled to change the periodicity of the oscillatory circuit to compensate for changes in the factors controlling the periodicity of the energizing means, but the periodicity of the oscillatory circuit may be imposed upon the energizing means to thus modify the periodicity of the latter to a considerable degree.

In Fig. 4, I have shown the apparatus of Figs. 1 and 3, applied to the circuit shown in Fig. 1, of my said application, Serial No. 860,318, wherein the magnet 22 controls the rotation of a shaft, shown at 21.

In Fig. 4, the setting in operation of magnet 22 is effected by closing the contact 6, thus causing the current from battery 58 to flow through contact 6, resistance 59, armature 49^a, contact 56, variable inductance 60^a, contact 32, electromagnet 22 to the ground at 61. This causes the initial energization of magnet 22. This first impulse is controlled with respect to the time of closure of contact 6, by means of variable inductance 60^a, as pointed out with reference to Fig. 1. The time of magnetization and demagnetization of magnet 22 may be controlled, to some extent, by variable inductance 60 and capacity C, during this starting operation.

The magnet 22 having been set into operation, causes the closure of contact 47, under the control of cam 31, thereby establishing a circuit from battery 58, through relay 49, contact 47, contact 32, magnet 22, to ground at 61. The energization of relay 49 causes the starting circuit to be broken at 56, so that the latter no longer has any effect. A holding circuit is at the same time established through armature 49^a, contact 62, relay 49, resistance 64 to ground at 63.

From this time on, throughout the time that magnet 22 is periodically energized, the periodicity of the energization of magnet 22 may be controlled and varied by variable inductance 60 and condenser C, in the manner pointed out in describing Fig. 3. In the oscillatory circuit I have shown, in Fig. 4 I have illustrated a resistance R, for the purpose of limiting the mount of energy available for control. In practice, I find it best to have as large as possible an amount of energy available for this purpose, and preferably an amount of energy which approximates the amount necessary to operate magnet 22.

The variable inductance used in connection with the circuits above described may take any convenient form. A form which I have found to have many advantages in actual practice is that illustrated in Figs. 5, 6, 7 and 8.

Referring to Fig. 5, I have shown my improved variable inductance as consisting of two inductance elements, each comprising a pair of coils of insulated wire wound upon magnetic cores. The cores of inductance element 1, are connected by a yoke 3, and those of inductance element 2 are connected by a yoke 4. The yoke 3 is suitably connected to a plate 5, which may rest upon and be secured to a suitable support 6. A shaft 7 is journaled in and depends from plate 5, passes through an opening 3^a, in yoke 3, between the coils, and is secured to yoke 4, thus supporting inductance element 2, and permitting it to be rotated relatively to inductance element 1. The inductance elements are preferably separated by a non-magnetic plate 9, which is held in place by posts, or other means, 10.

Gear 11 may be secured to shaft 7 by a screw or the like 11^a. At 5^a is a spring washer or retarding device shown located between plate 5 and gear 11 and bearing thereon with sufficient friction or spring action to retain shaft 11 and element 2 in set position, serving also to draw shaft 11 upwardly to retain the cores of element 2 in contact with non-magnetic plate 9, to prevent variation of the air gap between the elements 1 and 2, said plate 9 and spring washer, also serving to steady element 2 and prevent chattering of the same.

Any suitable means may be provided to rotate inductance element 2, and retain it set in position as, for instance, shaft 7, provided with gear wheel 11, of relatively large diameter, which meshes with the pinion 12, carried by shaft 13, and a suitable removable finger piece, as indicated at 15, for rotating shaft 13, by means of the clutch members 17, thereby affording a convenient means of removing finger piece 15 if it is desired to remove cover plate 16. Pin 18 on wheel 11, and spaced pins 19, 19^a on plate 5 limit the rotation of gear wheel 11 in opposite directions.

The arrangement of the apparatus is, therefore, such that the inductance elements may be rotated with respect to one another, so that the direction of the magnetic flux tending to pass through the cores of one element may be the same as, or opposite, that tending to pass through the cores of the other element. The total inductance of the apparatus intermediate these points will be determined by the characteristics of the magnetic field at the point at which the apparatus is set. As shown, for the purpose of indicating to the operator the relative positions of the poles of the magnets, the gear 11 is provided with a scale coöperating with an index point *a*, located on the cover plate 16, and so arranged that when the zero mark is opposite the index point *a* (see Fig. 6) the paths of flux of the inductance elements will be the same, at which time the maximum impedance will be obtained and, when the numeral 100 is opposite the index point *a*, the magnetic fluxes will oppose one another, thus giving the minimum impedance. Additional means for indicating the adjustment of the inductance elements are shown in the numbers A, on cover plate 16, with which a pointer 15^a on finger piece 15 coöperates. These numbers are arranged so that a movement of the pointer 15^a from one of these numbers to the next produces a movement of one unit of gear wheel 11, thus providing means for more exact adjustment. The arrangement illustrated is such that when the zero of numerals B coincides with the index point *a*, the index pointer 15^a will coincide with the upper zero of the numerals A, and when said pointer has moved in a clockwise direction to the lower zero of the numerals A the numeral "10" of the index numerals B will coincide with the index point *a;* when the pointer 15^a is next moved from the lower zero to the upper zero, in a clockwise direction, the numeral "20" of the index numerals B will coincide with the index point *a*, and so on alternately for each ten spaces of the index numerals B. Thus when pointer 15^a is at the lower zero, the 10, 30, 50, 70 and 90 numerals will coincide with index point *a*, and when the pointer 15^a is at the upper zero, the zero 20, 40, 60, 80 and 100 of the index numerals B will coincide with the index point *a*.

It will be noted that the effect of my improved variable inductance is limited to the time during which the current is changing in value in the circuit, and operates to increase the apparent resistance of the circuit, and not its actual resistance (except by reason of such small ohmic resistance as it may have) and, therefore, does not affect the maximum power available on the line. My apparatus, therefore, is of great value for the regulation of telegraphic apparatus, in which the current impulses are necessarily minute.

While I have shown my invention in connection with various circuits, and described it with relation to certain apparatus, I do not intend to be confined to the precise details illustrated and described, as for instance, the particular kind of electro-magnet illustrated, nor to the use of the various controls with apparatus of any particular nature, since many changes may be made in the apparatus without departing from the spirit of my invention, as will be apparent to those skilled in the art.

What I claim is:

1. The method of varying the periodicity of energization of a magnet which consists in causing the magnet to make and break its own circuit and imposing upon the circuit of the magnet the periodicity of an oscillatory circuit.

2. The method of varying the periodicity of energization of a magnet which consists in causing the magnet to make and break its own circuit, varying the periodicity of another circuit, and imposing the periodicity of the last named circuit upon the circuit of the magnet.

3. In an apparatus of the kind described, an electro-magnet; a circuit therefor having a contact controlled by the magnet, and a variable inductance in circuit therewith for controlling the rate of magnetization of said magnet.

4. In an apparatus of the kind described, an electro-magnet; a circuit therefor having a contact controlled by the magnet, and means in circuit therewith for varying the rate of demagnetization of the magnet.

5. In an apparatus of the kind described, an electro-magnet; a circuit therefor having a contact controlled by the magnet, an inductance and means for opposing the electro-motive force of self-induction of the magnet by that of the inductance, so that the resulting current flow controls the rate of demagnetization of the magnet.

6. In an apparatus of the kind described, an electro-magnet; a circuit therefor having a contact controlled by the magnet, and a variable inductance in circuit therewith for controlling the rate of demagnetization of said magnet.

7. In an apparatus of the kind described, an electro-magnet; a circuit therefor having a contact controlled by the magnet, and means in circuit therewith for varying both the rate of magnetization and of demagnetization of said magnet.

8. In an apparatus of the kind described, an electro-magnet; a circuit therefor having a contact controlled by the magnet, a resistance in the circuit, and a variable inductance in circuit therewith for controlling both the rate of magnetization and of demagnetization of said magnet.

9. In an apparatus of the kind described, an electro-magnet; a circuit therefor having a contact controlled by the magnet, and a variable inductance in series therewith for controlling the rate of magnetization of the magnet.

10. In an apparatus of the kind described, an electro-magnet; a circuit therefor having a contact controlled by the magnet, and means connected in parallel therewith for varying the rate of demagnetization of the magnet.

11. In an apparatus of the kind described,

an electro-magnet, a circuit therefor having a contact controlled by the magnet, a resistance in series therewith, and a variable inductance in parallel therewith for controlling the rate of magnetization of the magnet.

12. In an apparatus of the kind described, energizing means including a source of energy, an electromagnet periodically energized thereby, a contact in the magnet circuit controlled thereby, and means for controlling the periodicity of the energization of the magnet, irrespective of the energizing means.

13. In an apparatus of the kind described, energizing means including a source of energy, an electro-magnet periodically energized thereby, a contact in the magnet circuit controlled thereby, and means tending to maintain a given periodicity of energization.

14. In an apparatus of the kind described, energizing means including a source of energy, an electro-magnet periodically energized thereby; a contact in the magnet circuit controlled thereby, means for storing energy during one period of energization for use in said magnet during a subsequent period of energization.

15. In an apparatus of the kind described, an energizing means including a source of energy, an electro-magnet periodically energized thereby; a contact in the magnet circuit controlled thereby, and means for storing energy during each period of energization for use in said magnet during a subsequent period of energization.

16. In an apparatus of the kind described, energizing means including a source of energy and an electro-magnet periodically energized thereby; and an oscillatory circuit including said magnet, having a variable periodicity and adapted to control the periodicity of energization of the magnet.

17. In an apparatus of the kind described, energizing means including a source of energy and an electro-magnet periodically energized thereby; and an oscillatory circuit including said magnet, having a variable periodicity and adapted to control the periodicity of energization of the magnet by storing energy during one period of energization of the magnet for use in the magnet during a subsequent period of energization.

18. In an apparatus of the kind described, energizing means including a source of energy, an electro-magnet periodically energized thereby; and an oscillatory circuit including the magnet and having a periodicity the same as or a multiple of the periodicity of the energizing means.

19. In an apparatus of the kind described, an electro-magnet; means for periodically energizing said magnet, including a source of energy; a contact in the magnet circuit controlled thereby, means for initiating the energization of said magnet; means for controlling the rate of magnetization of said magnet during the initial energization, and means for controlling both the rate of magnetization and of demagnetization of said magnet, during the subsequent energizations.

20. In an apparatus of the kind described, an electro-magnet; means for periodically energizing said magnet, including a source of energy; a contact in the magnet circuit controlled thereby, means for initiating the energization of said magnet; means for controlling the rate of magnetization of said magnet during the initial energization, and means for controlling both the rate of magnetization and of demagnetization of said magnet, during the subsequent energizations, said controlling means being independent of each other.

21. In an apparatus of the kind described, an electromagnet, means for periodically energizing said magnet, including a source of energy; a circuit for said magnet including means for initiating the energization thereof; a variable inductance in said circuit for controlling the rate of magnetization of said magnet during the initial energization; a second circuit for said magnet adapted to effect the subsequent energization thereof, and a variable inductance in said second circuit for controlling the rate of magnetization and of demagnetization of said magnet during such subsequent energization.

22. In an apparatus of the kind described, an electromagnet, means for periodically energizing said magnet, including a source of energy; a circuit for said magnet including means for initiating the energization thereof; a variable inductance in said circuit and in series with said magnet for controlling the rate of magnetization of said magnet during the initial energization; a second circuit for said magnet adapted to effect the subsequent energization thereof, and a variable inductance in said second circuit and in parallel with said magnet, for controlling the rate of magnetization and of demagnetization of said magnet during such subsequent energization.

23. In an apparatus of the kind described, an electro-magnet, means for periodically energizing said magnet, including a source of energy; means for initiating the operation of the energizing means; means for controlling the rate of magnetization of said electromagnet during the initial energization; and means for controlling the periodicity of the subsequent energization of said magnet, independent of the energizing means.

24. In an apparatus of the kind described, an electro-magnet, means for periodically energizing said magnet, including a source of energy; means for initiating

the operation of the energizing means; means for controlling the rate of magnetization of said electro-magnet during the initial energization; and means, including a variable inductance, in circuit with the magnet for controlling the periodicity of the subsequent energization of said magnet, independent of the energizing means.

25. In an apparatus of the kind described, an electro-magnet, means for periodically energizing said magnet, including a source of energy; means for initiating the operation of the energizing means; means for controlling the rate of magnetization of said magnet during the initial energization; and means, including a variable inductance and a capacity, in circuit with the magnet, for controlling the periodicity of the subsequent energization of said magnet, independent of the energizing means.

26. In an apparatus of the kind described, an electro-magnet, means for periodically energizing said magnet, including a source of energy; means for initiating the operation of the energizing means; means for controlling the rate of magnetization of said electro-magnet during the initial energization; and means for controlling the periodicity of the subsequent energization of said magnet, independent of the energizing means, by storing energy during one period of energization of the magnet for use in the magnet during a subsequent period of energization.

27. In an apparatus of the kind described, an electro-magnet, means for periodically energizing said magnet, including a source of energy; means for initiating the operation of the energizing means; means for controlling the rate of magnetization of said electro-magnet during the initial energization; and means for controlling the periodicity of the the subsequent energization of said magnet, independent of the energizing means, comprising an oscillatory circuit including said magnet and having a variable periodicity.

28. In an apparatus of the kind described, an electro-magnet, means for periodically energizing said magnet, including a source of energy; means for initiating the operation of the energizing means; means for controlling the rate of magnetization of said electro-magnet during the initial energization; and means for controlling the periodicity of the subsequent energization of said magnet, independent of the energizing means, comprising an oscillatory circuit including the magnet and having a periodicity the same as, or a multiple of the periodicity of the energizing means.

In witness whereof I have hereunto signed my name, in the presence of two witnesses, this 14th day of Nov., 1914.

ALLEN D. CARDWELL.

Witnesses:

T. F. BOURNE,

MARIE F. WAINRIGHT.