No. 644,278.

Patented Feb. 27, 1900.

W. H. COOLEY.

MEANS FOR REGULATING ELECTRIC MACHINES.

(Application filed Mar. 9, 1899.)

(No Model.)

6 Sheets—Sheet 1.

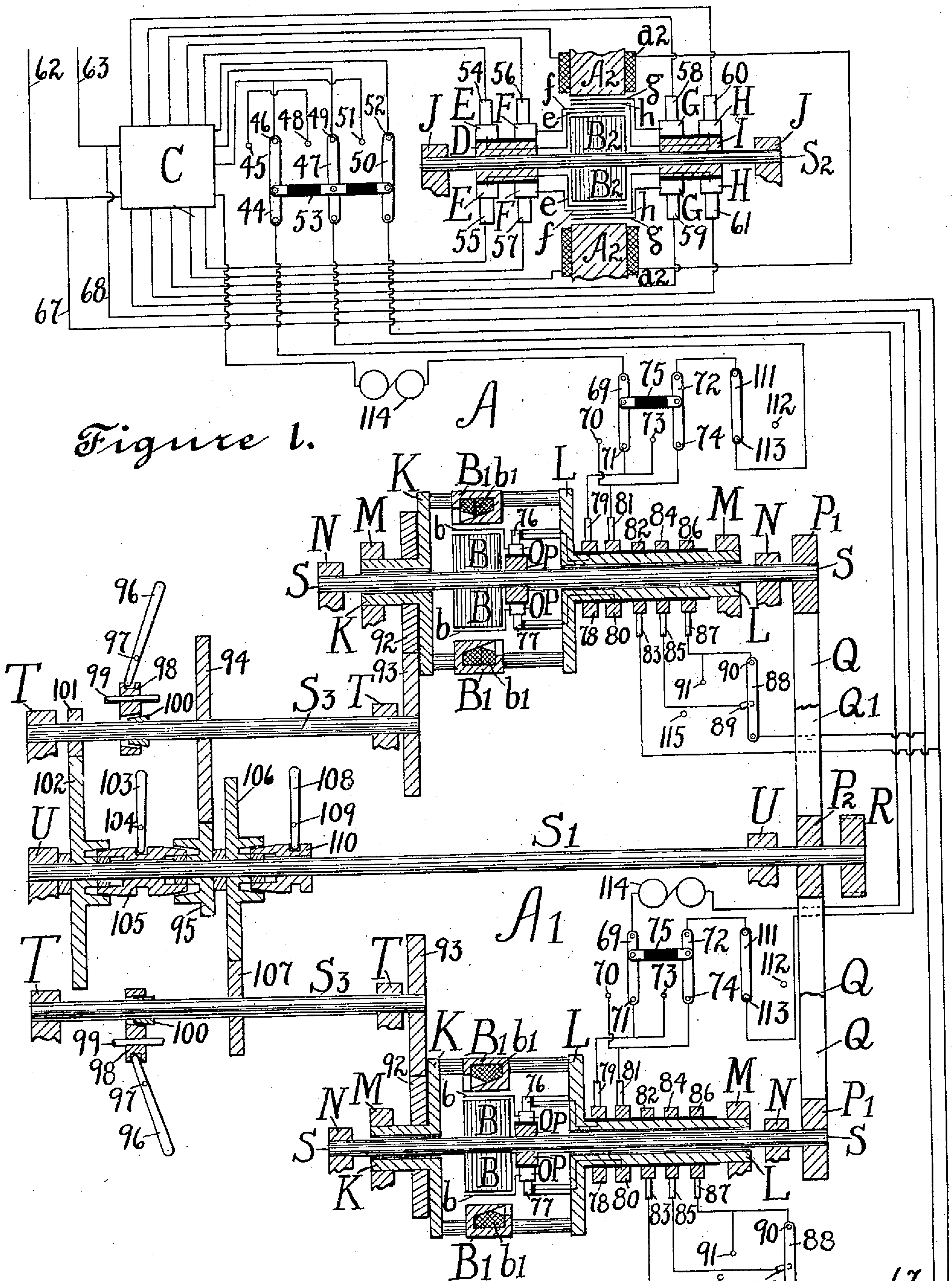

Figure 1.

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Etha M. Smith

Inventor
Wm. H. Cooley.

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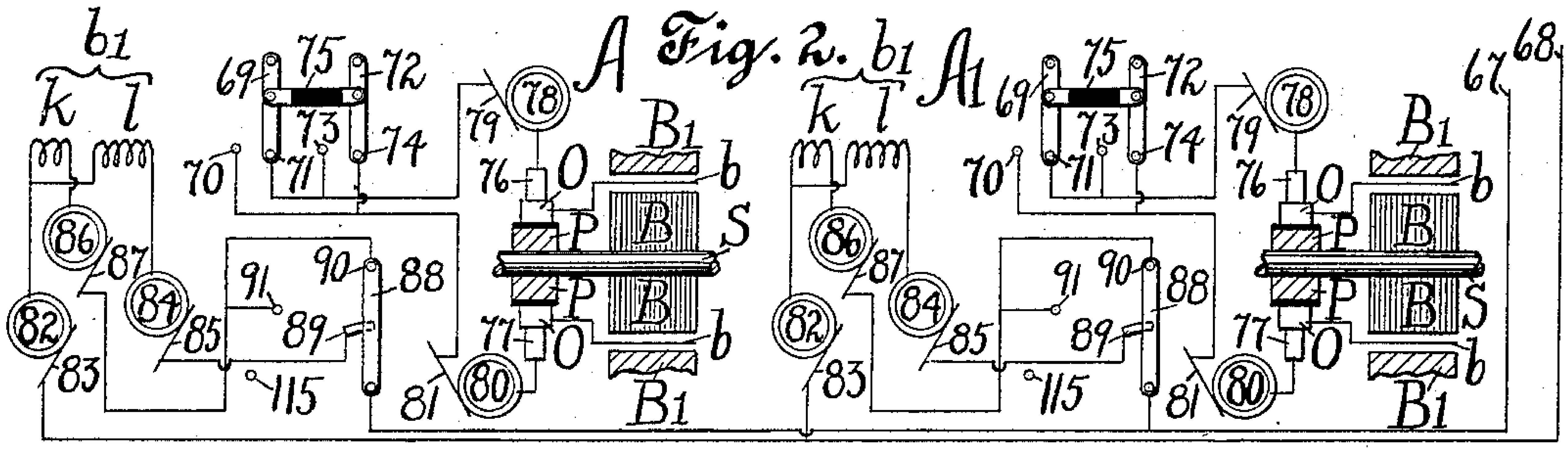


Fig. 2.

Fig. 3a.

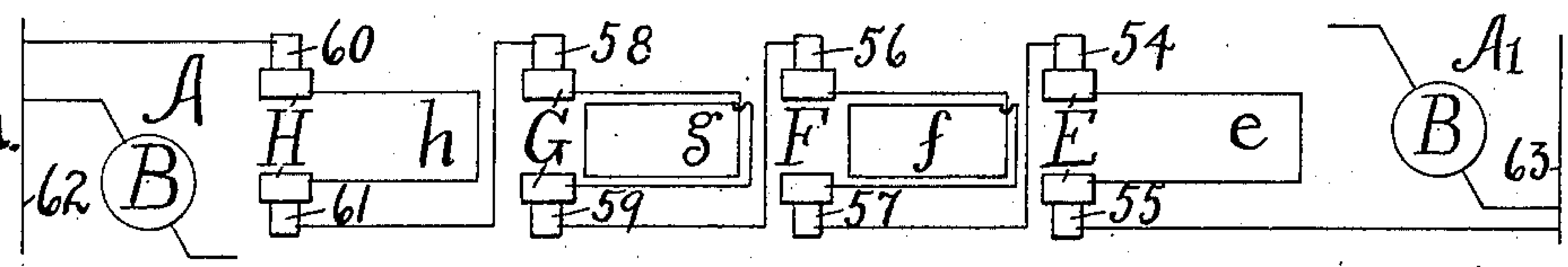


Fig. 3b.

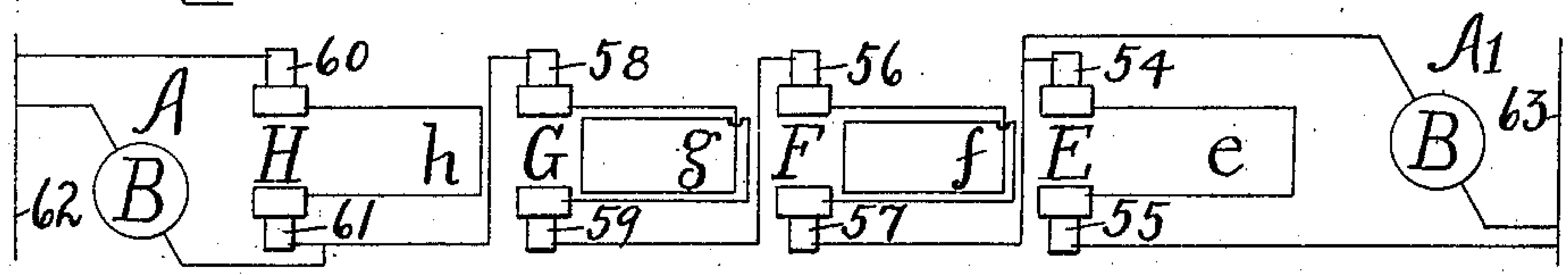


Fig. 3c.

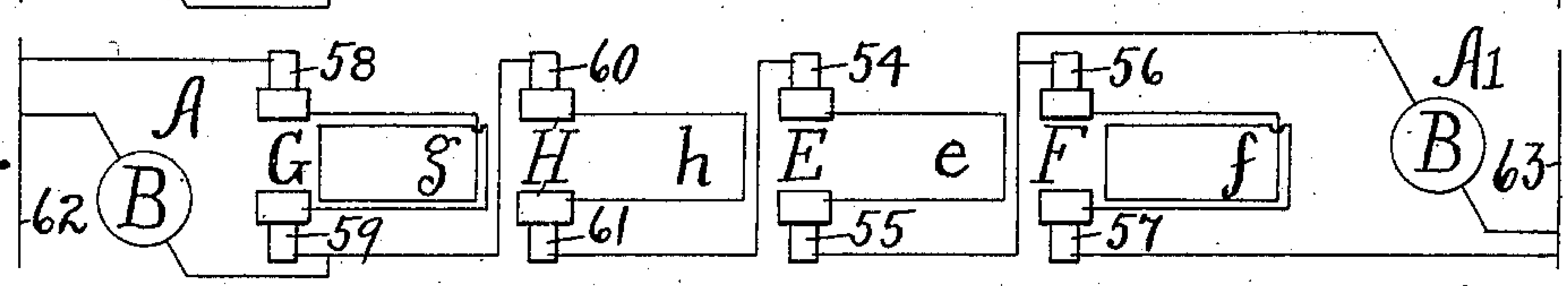


Fig. 3d.

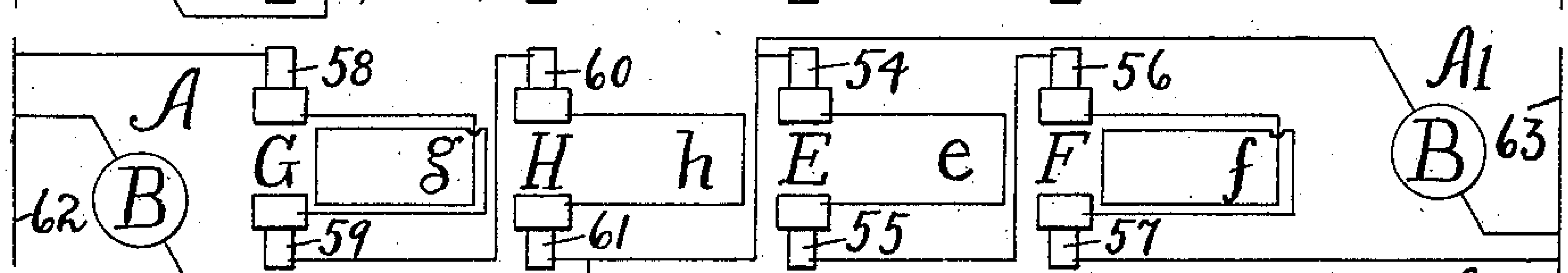


Fig. 3e.

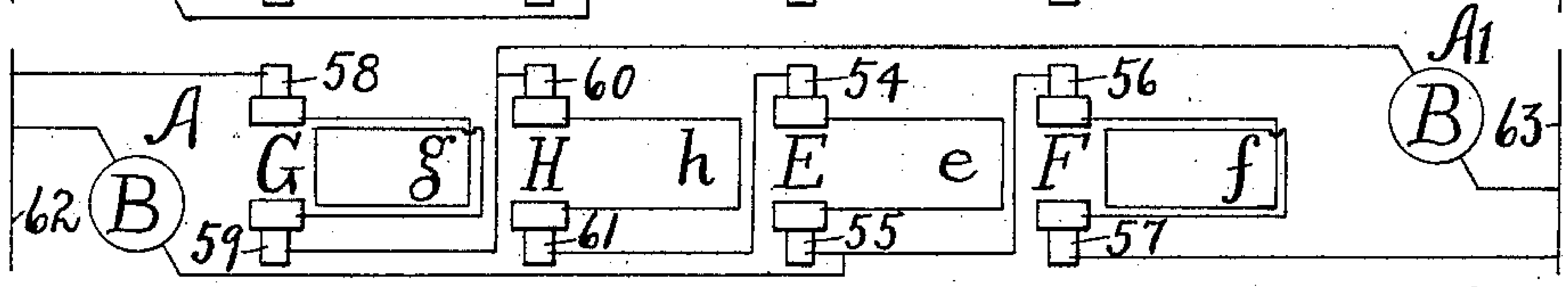


Fig. 3f.

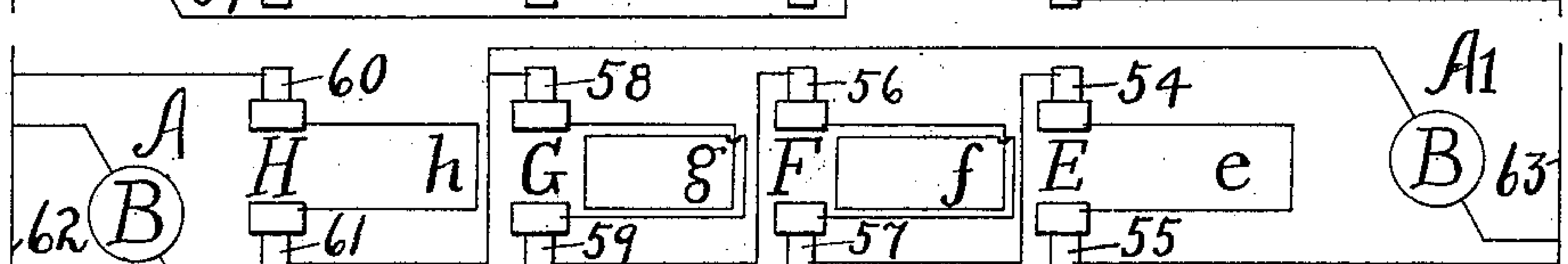
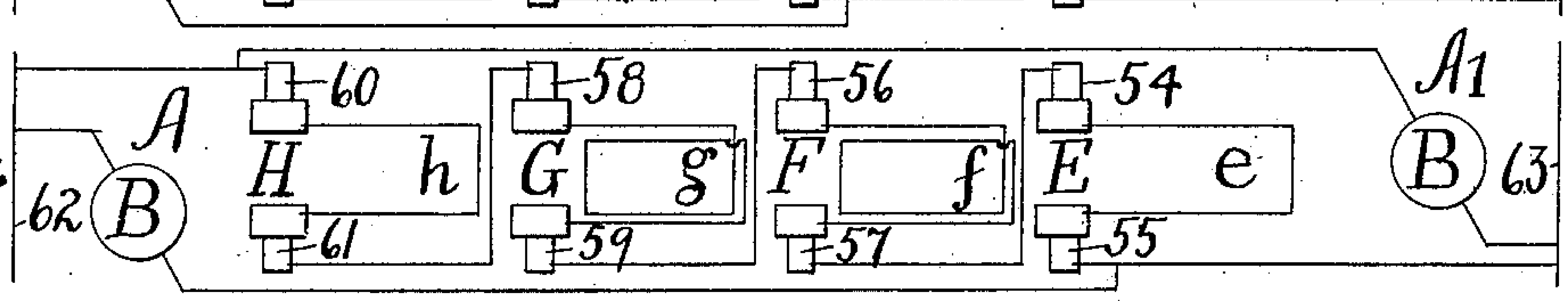


Fig. 3g.



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6 Sheets—Sheet 3.

Fig. 3.

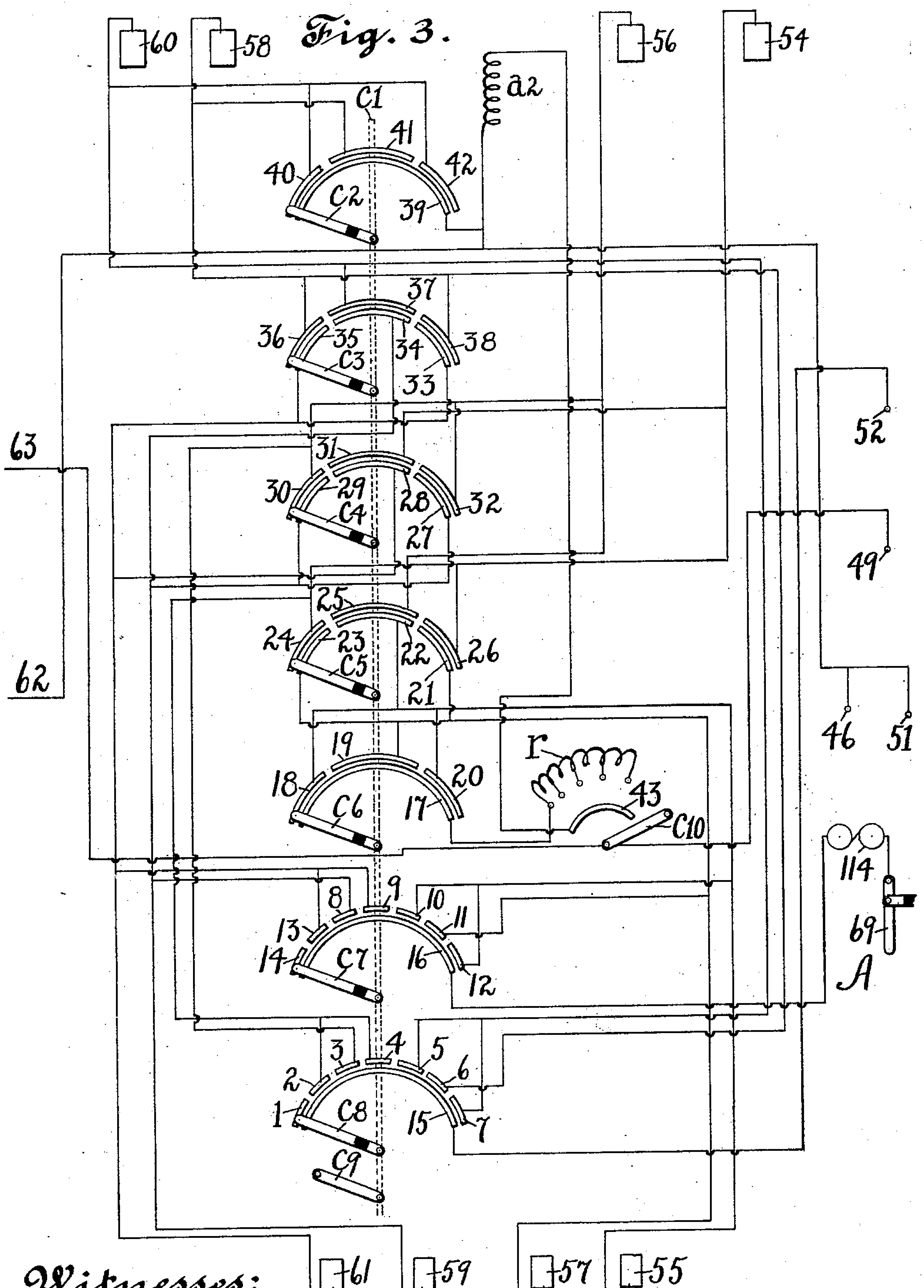

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Fig. 3h.

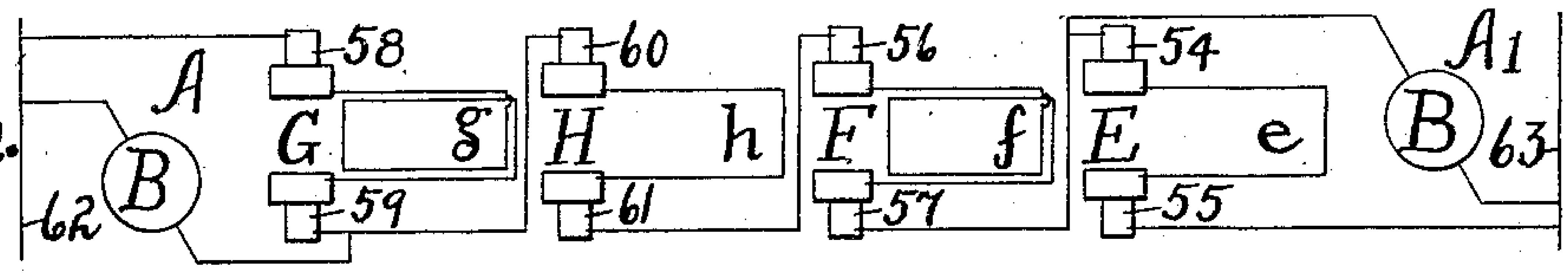


Fig. 3i.

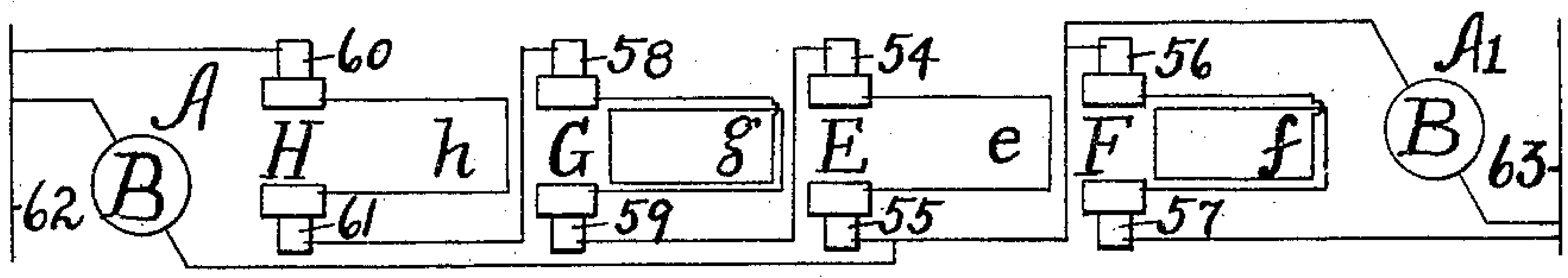


Fig. 3j.

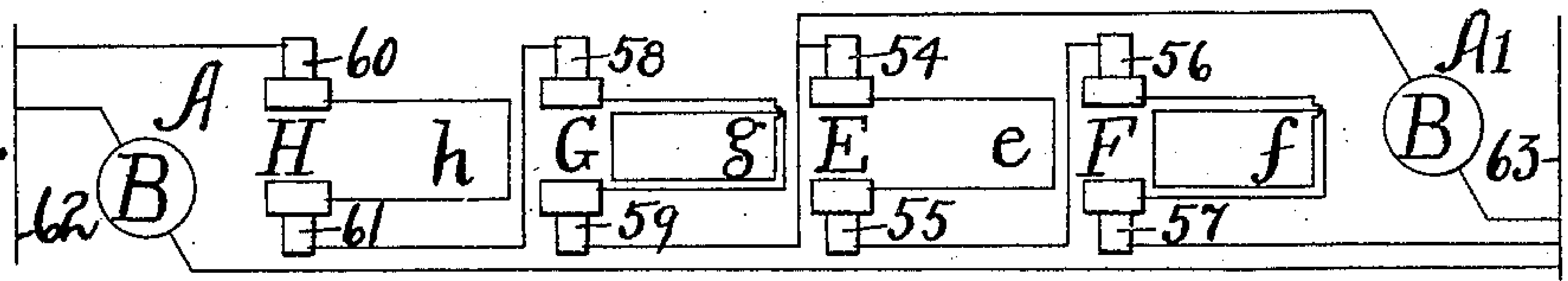


Fig. 3k.

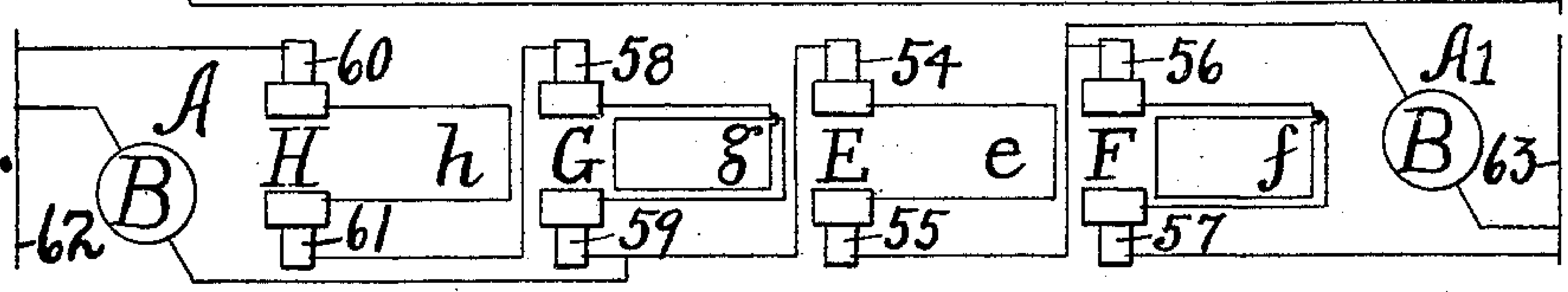


Fig. 3l.

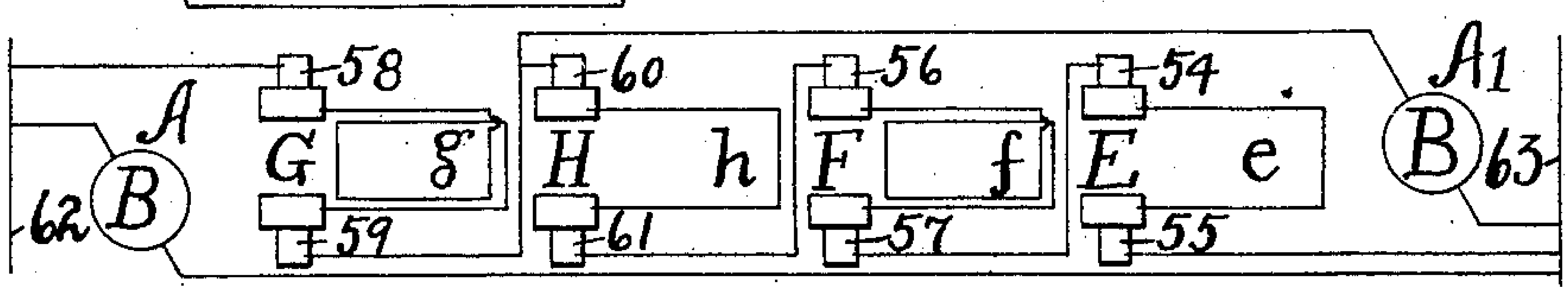


Fig. 3m.

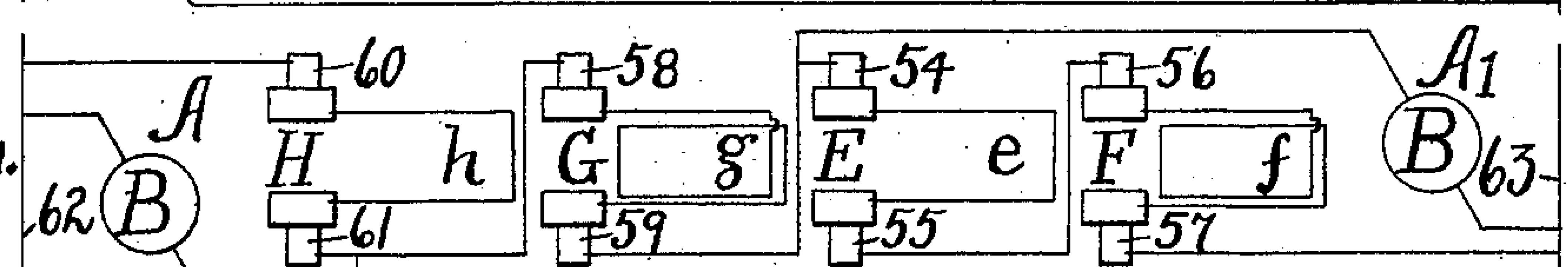


Fig. 3n.

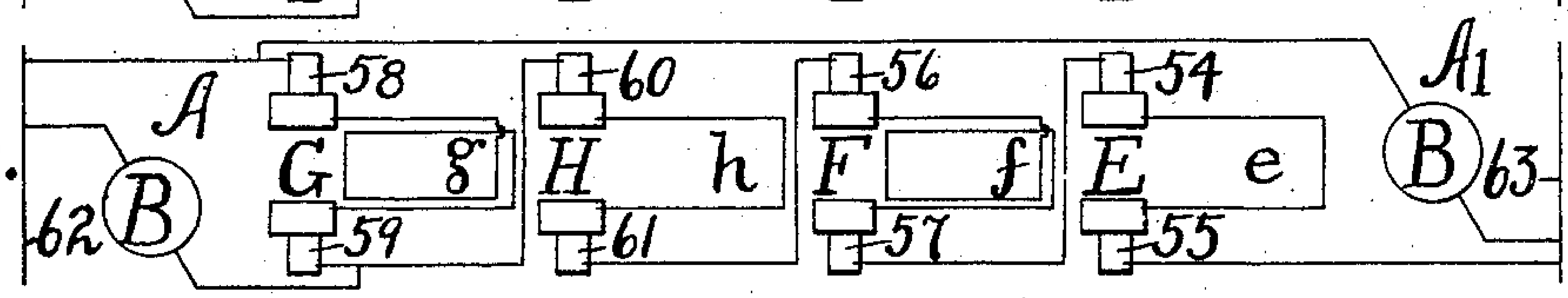
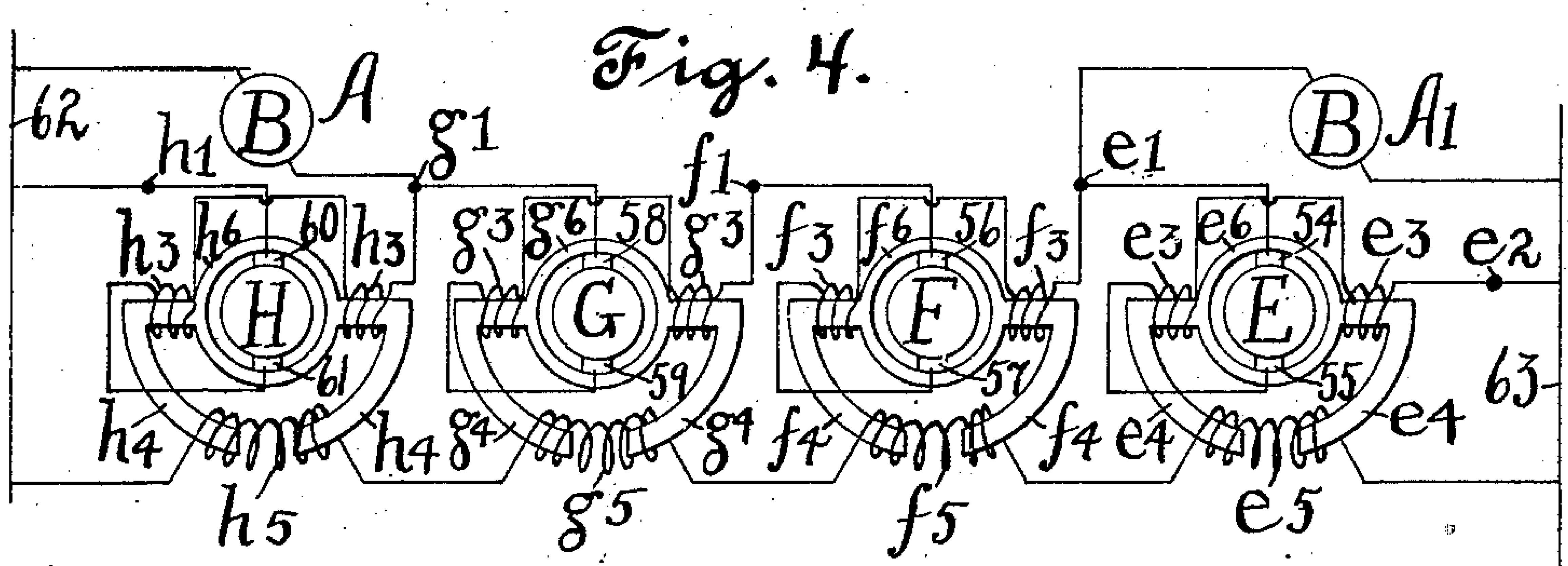


Fig. 4.



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6 Sheets—Sheet 5.

Fig. 5.

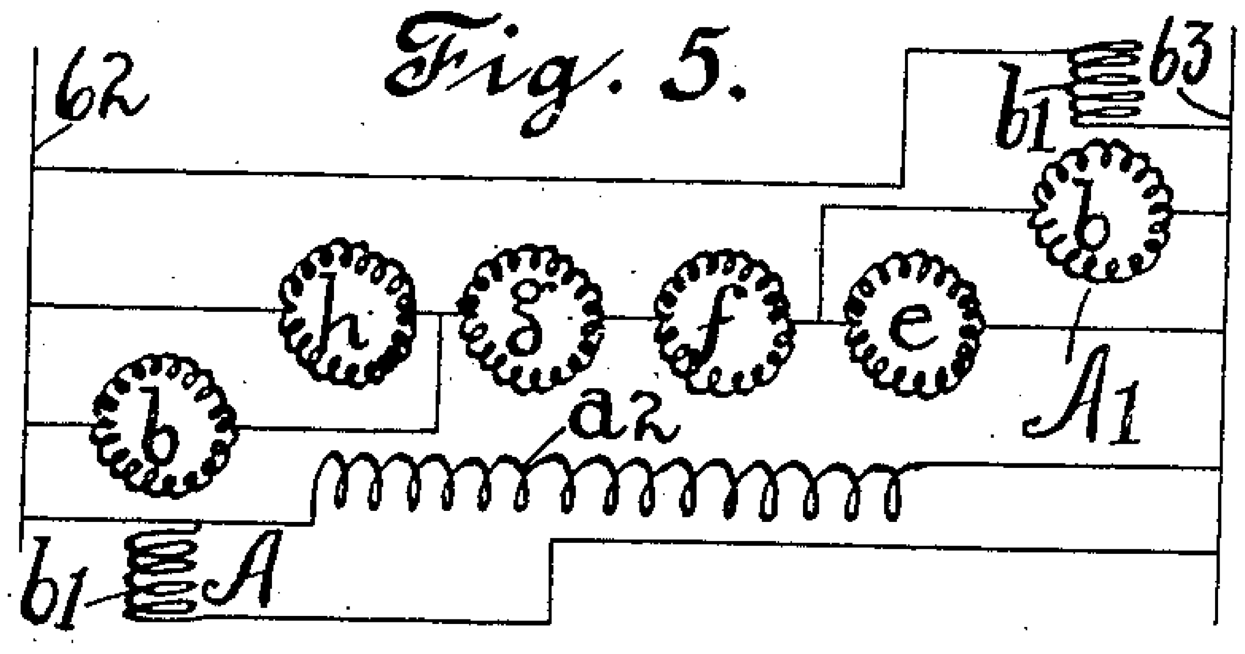


Fig. 6.

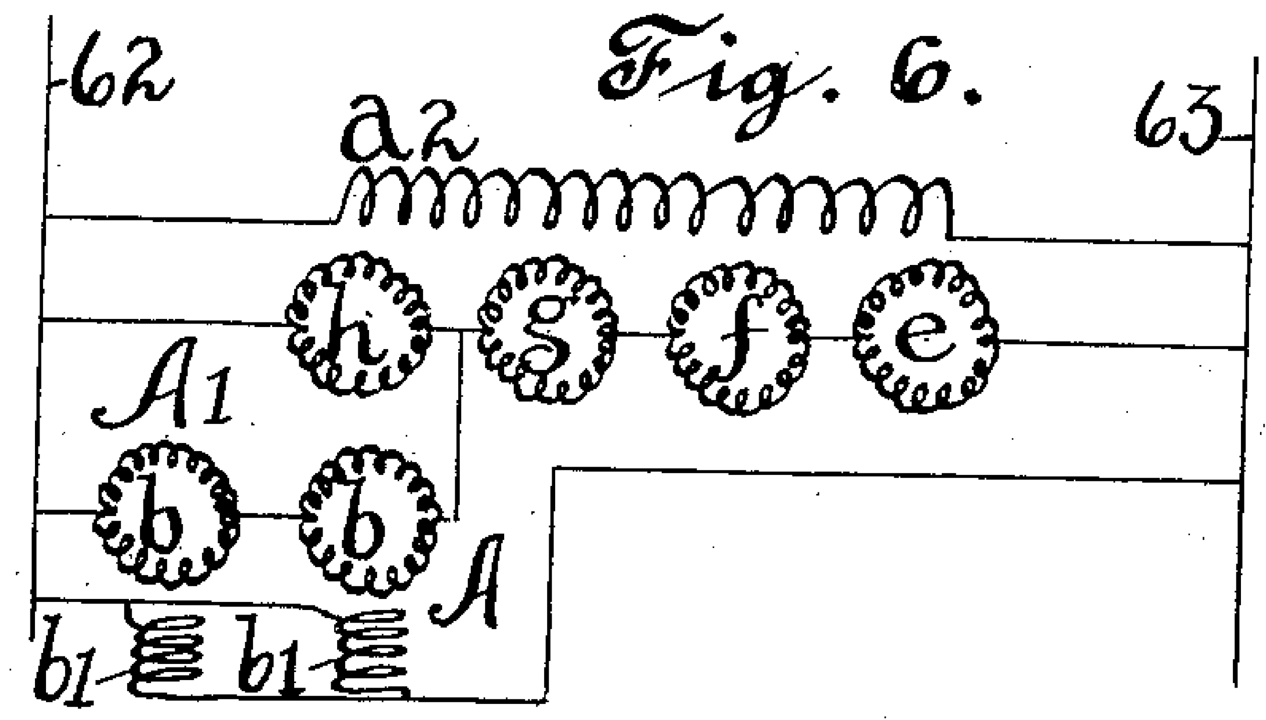


Fig. 7.

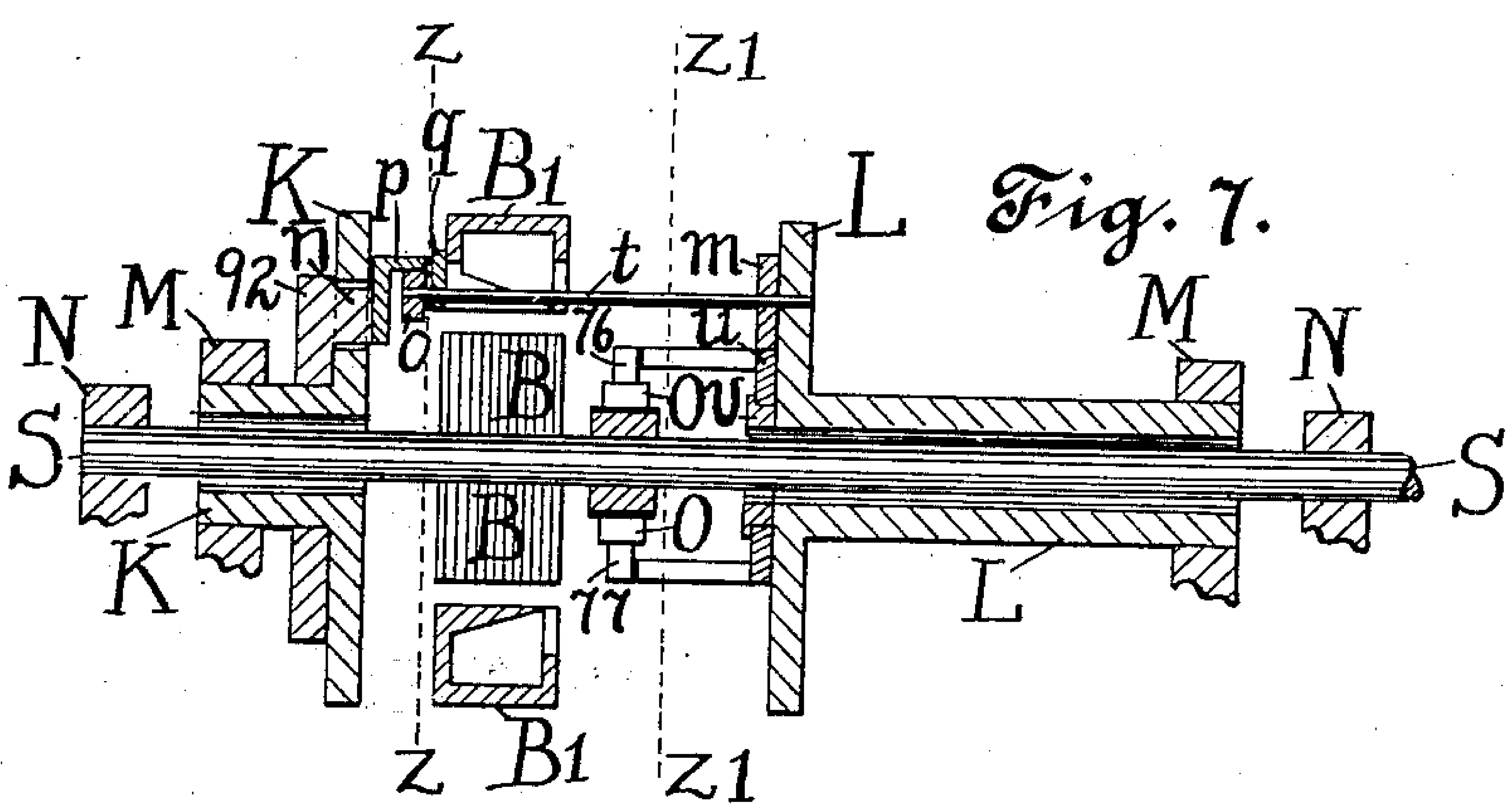


Fig. 7a.

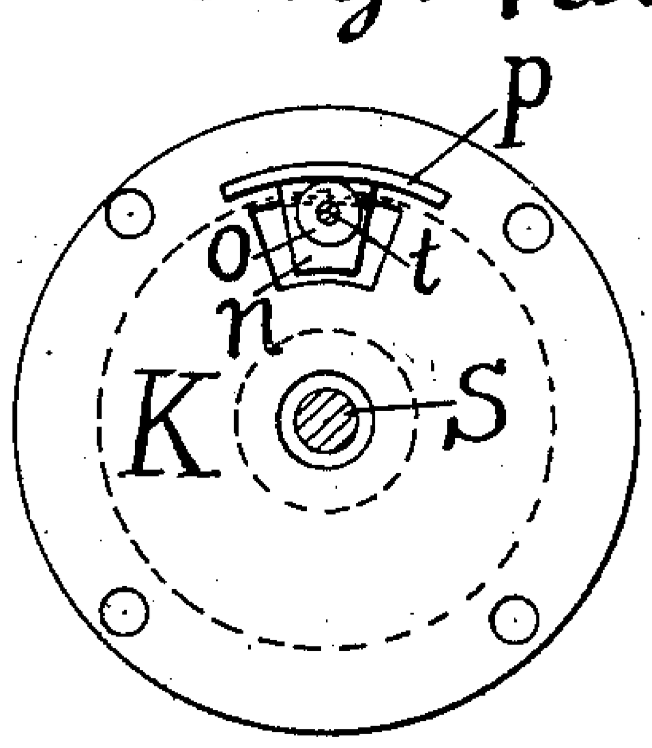


Fig. 7b.

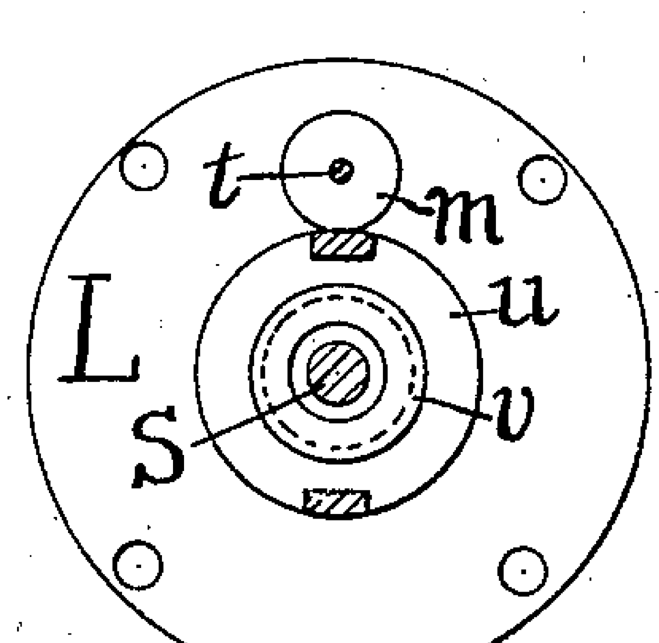
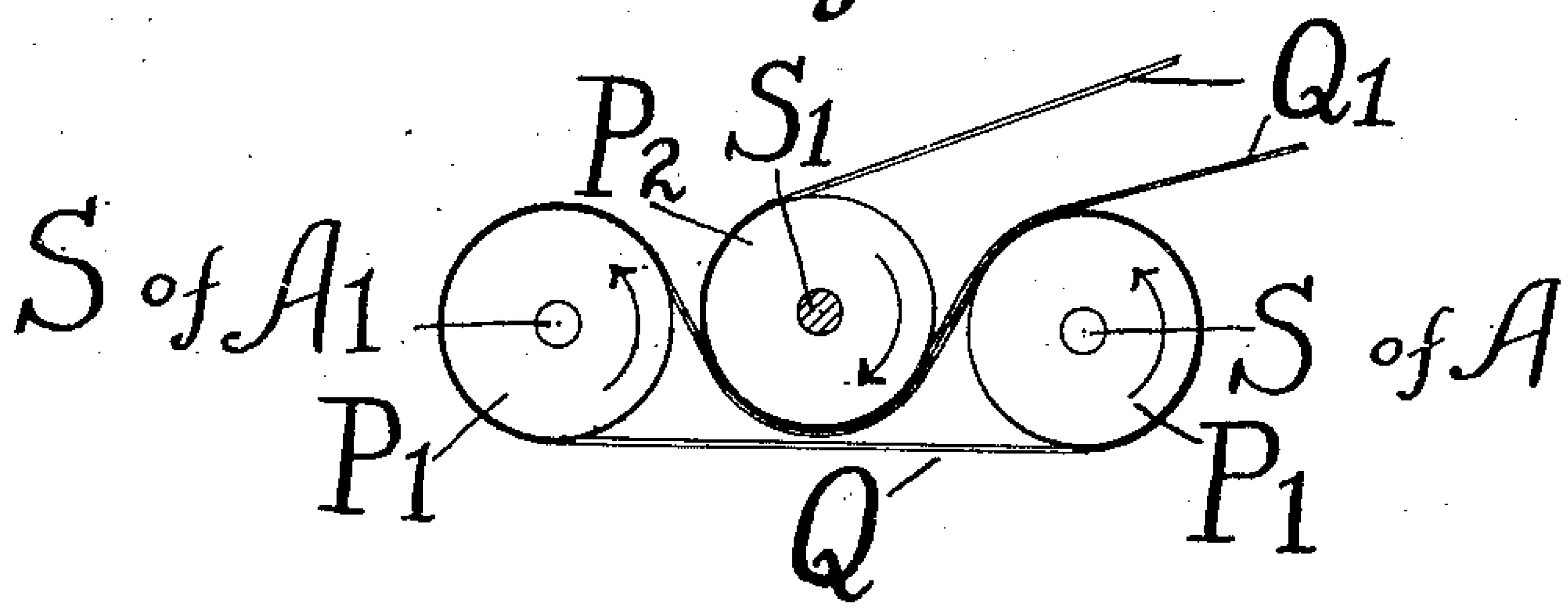


Fig. 8.



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(No Model.) 6 Sheets—Sheet 6.

Fig. 9.

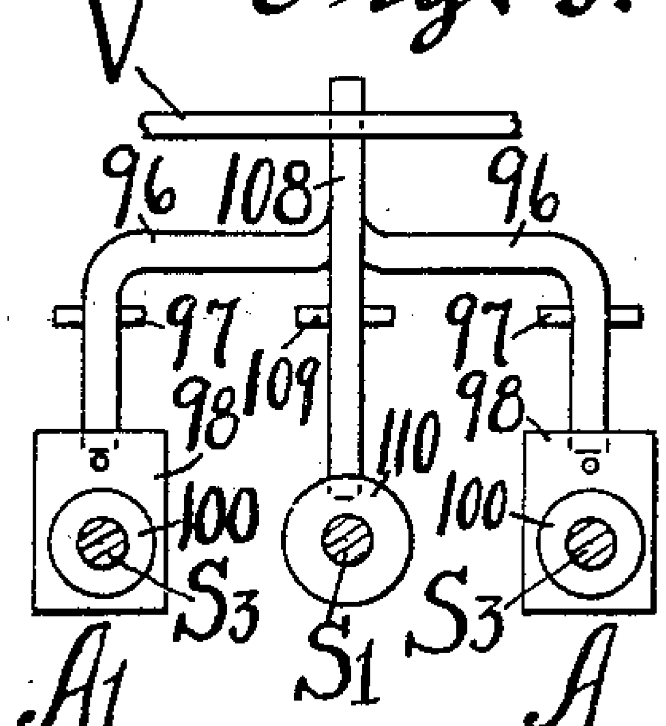


Fig. 10.

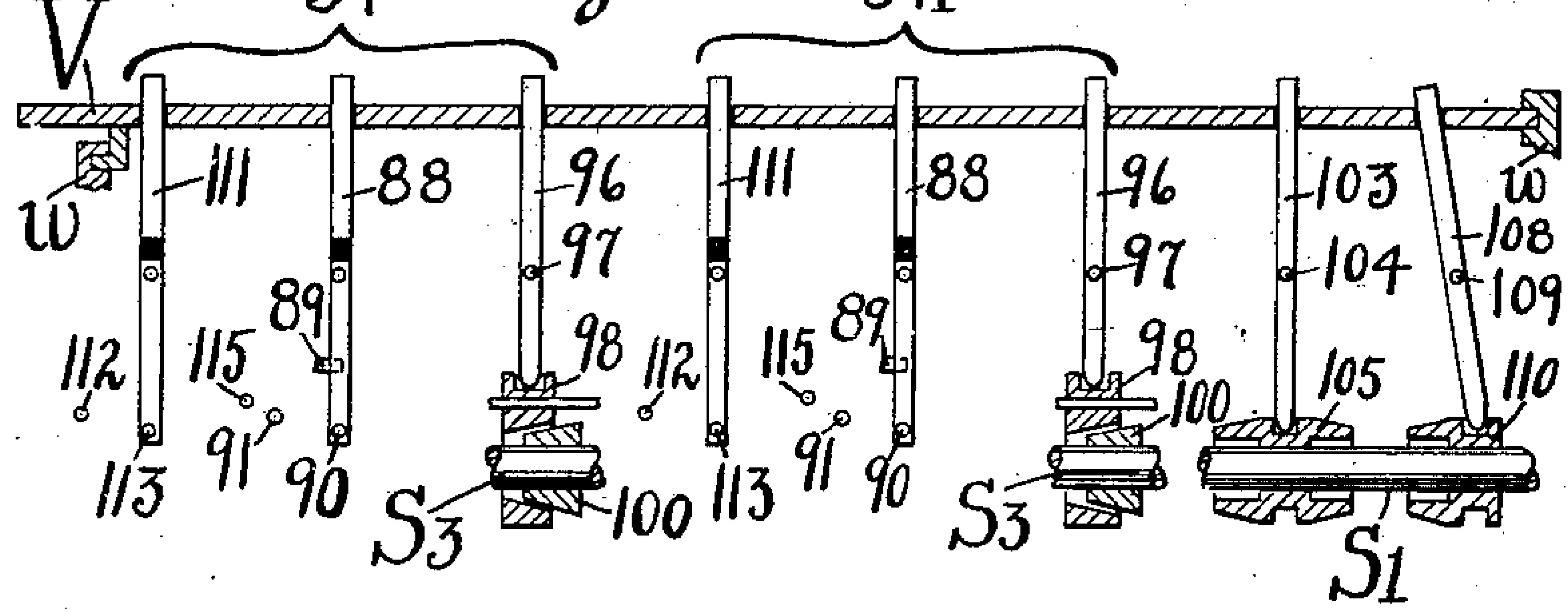
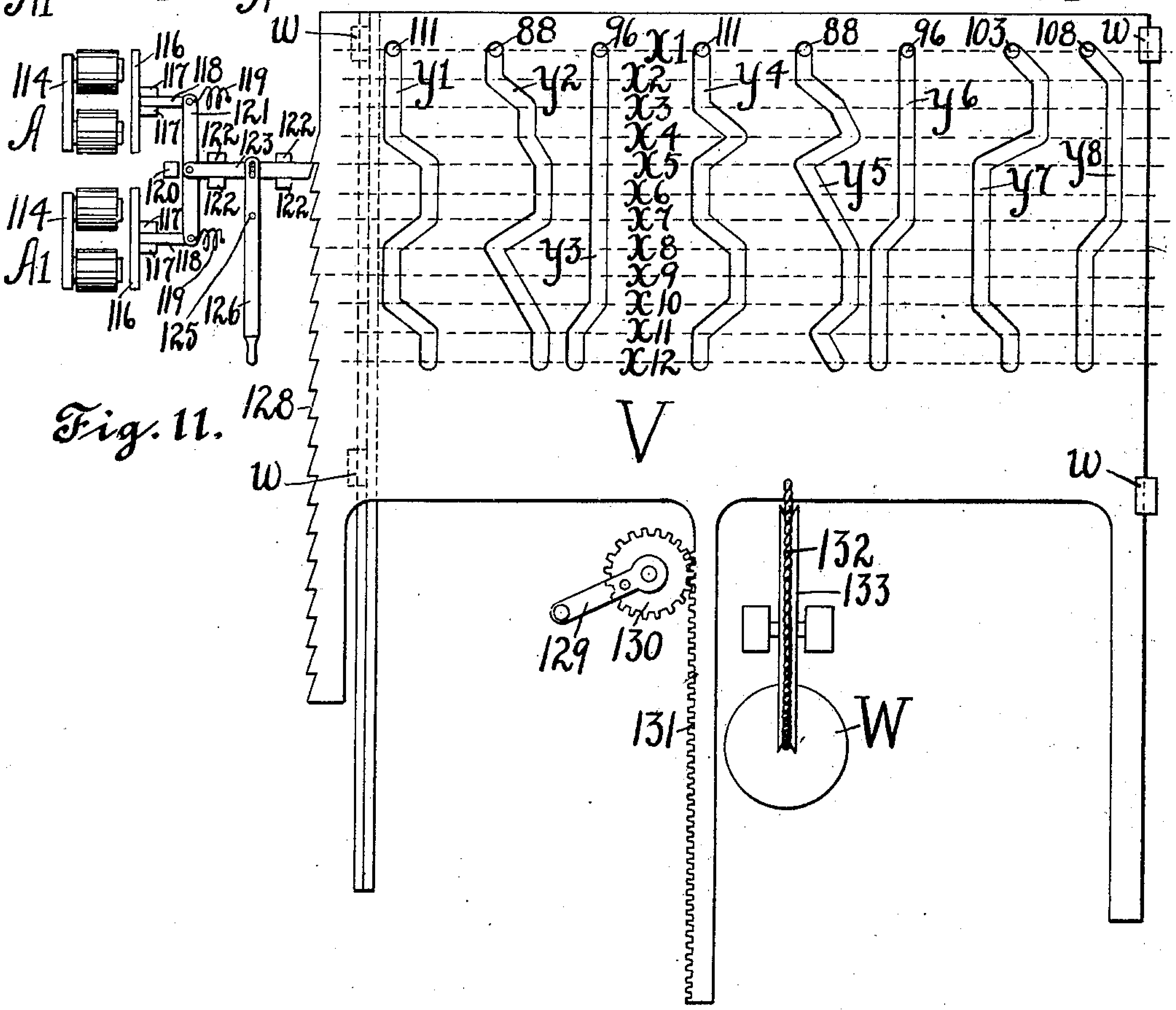


Fig. 11.



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UNITED STATES PATENT OFFICE.

WILLIAM H. COOLEY, OF BROCKPORT, NEW YORK.

MEANS FOR REGULATING ELECTRIC MACHINES.

SPECIFICATION forming part of Letters Patent No. 644,278, dated February 27, 1900.

Application filed March 9, 1899. Serial No. 708,338. (No model.)

To all whom it may concern:

Be it known that I, WILLIAM H. COOLEY, a citizen of the United States, residing at Brockport, in the county of Monroe and State of New York, have invented a new and Improved Means for Regulating Electric Machines, of which the following is a specification.

My invention refers particularly to a system of motor regulation and construction by means of which the speed and torque may be varied inversely over a considerable portion of the range of speed regulation of the load and by means of which also there may be imparted several different rotary efforts to the load at the same speed, with the amount of energy used proportionate to the amount of work done.

Still further features of my invention consist in means whereby the motor to be regulated may at any point over the entire speed range thereof be converted by a negative load into a generator returning energy to the main supply-circuit proportionate in amount to the amount of such negative load and also in means whereby the current required at the time of starting a heavy load may be materially reduced.

My invention is intended also to overcome the difficulty which is experienced when it is attempted to regulate the speed of a varying load by means of a rheostat.

Within moderate limits a very satisfactory speed regulation may be secured by varying the air-gap density. While this method varies the speed only within a narrow range, the rotary effort is over this range varied inversely with the speed.

In carrying out my invention I prefer to make use of two pairs of elements, with both elements of each pair revoluble and with one of the elements of each pair permanently connected to the load, while the other element of each pair is also at times connected to the load, each one of them through a train of mechanism consisting, preferably, in one or more pairs of coöperating gears for each of such elements. In starting the load I prefer to connect the armatures of both of these pairs of elements in series and with the elements which are to be connected to the load at different speed ratios arranged to transmit to the load the greatest effort at the lowest speed. Then by cutting down the air-gap density of either one or each pair of elements or by increasing the potential impressed upon the terminals of the armature of either one or each pair of elements the speed of the load may be raised until one pair of elements may be cut out of circuit and the other pair of elements still connected to the load. Then again, either by field regulation or by varying the potential impressed upon the armature of this last-named pair of elements, a rate of speed of the load may be reached where such load may be shifted again to the first pair of elements and driven at still higher speeds. In this way by shifting the load from one pair of elements to the other and varying the speed ratio of the variable element of each pair I am enabled to accelerate the speed of the load at almost any desired rate, and the rotary effort exerted upon the load is gradually decreased as the speed of the load increases.

When two similar motors are each arranged to transmit power to a common load, such motors must be arranged to run at the same speed, provided they transmit at the same rate relative to the speed of the load to be driven, or the potential impressed upon such motors must vary or their relative air-gap densities must vary. Regulation of the relative air-gap densities can be effected only within a small range economically, and, owing to the objections already above enumerated, the regulation of the potential impressed upon the terminals of the motors by means of a rheostat is impracticable. Hence I make use of a system of regulation consisting, broadly, in an electromotive force opposing or absorbing medium of practically-constant value connected across the terminals of the supply-circuit with different electromotive-force values thereof in series with the motors to be regulated, and so coöperating with clutching and gear mechanism that the system is equally applicable to series or parallel regulation of such motors whether requiring that equal or unequal potentials be impressed thereon. As an example I have shown a single winding or series of windings subjected to inductive action and capable of carrying the current for only one of such motors, which is used to regulate the potential impressed upon the terminals of either one alone or both of them in series or in parallel, while the potential impressed upon one of such machines when in parallel may vary to a considerable extent from that impressed upon the other. By means of this clutching and gear mechanism and by varying the potential impressed upon the terminals of the armatures, in the manner already indicated, by the electromotive-force regulator I am enabled to secure the increase in rotary effort above referred to at very many of the steps in speed regulation which may be secured by my system of construction and regulation—that is, suppose, first, the normal rate of relative rotation between the elements of each pair to be two thousand revolutions per minute with minimum field excitation and with one of such elements fixed; second, that with full-line potential impressed upon the motor the clutching and gearing mechanism admits of a minimum speed of one hundred and thirty-three revolutions per minute of the load with a proportionate increase in rotary effort, and, third, that the electromotive-force regulator has, say, six equal steps, then I may bring the speed of the load up to twenty-two revolutions per minute by using such electromotive-force regulator to impress one-sixth of the full-line potential upon the motors, with the clutching and gearing mechanism so arranged as to secure the minimum speed of the load. It will be understood that at this time the rotary effort imparted to the load is much greater than that represented by the armature-currents flowing in the magnetic fields obtaining in the motors. By changing the relations between the variable elements of the motors the speed may be increased by small increments until the load is brought up to three hundred and thirty-three revolutions per minute. As the speed increases below this point the rotary effort exerted upon the load for the same conditions of field strength and armature-currents decreases. The speed of the load may be further increased by suitable increments from three hundred and thirty-three revolutions per minute by means of the electromotive-force regulator up to two thousand revolutions per minute. In securing the regulation at the lower speeds by changing the relations of the variable elements, all undue shock to the load or to any parts of the motor is relieved on account of the low speed at which such changes are made and the slight differences in speed secured by the changes.

When it is desired, the speed regulation secured by the electromotive-force regulator may be used at any step in the operation of the gearing and clutching mechanism.

Attention is called to the fact that for any speed of the load according to my system, no matter by what means produced, all of the power taken from the line is impressed directly upon the load except that small part required to meet the losses common to dynamo-electric machines.

The electromotive-force regulator may be constructed with as many steps as desired and the regulation secured, by the gearing and clutching mechanism in combination therewith, may be designed to suit any required conditions.

A great advantage to be secured by this system is noticed when it is desired to start a very heavy overload—as, for instance, in starting and carrying a car or train of cars up a steep grade. By means of my system also I am enabled to make use of motors having less capacity because of this increase in rotary effort which may be secured and maintained for any desired length of time in carrying such an overload. Again, by my system it is not necessary, as heretofore, to make use of a motor so large that the maximum safe current will secure the necessary effort at starting or in climbing a steep grade, which current is but partly used under normal conditions. Again, in starting the heaviest load less current is taken from the feeders than is required to carry even a much lighter load at full speed.

The accompanying drawings, illustrating my invention, are as follows:

Figure 1 shows in central horizontal section a motor and regulator in accordance with my invention. In Fig. 1 there is shown in diagram, so far as possible, the circuit connections in my machine and system. Fig. 2 shows the parts of the machine, in a similar sectional view, needed to give a complete diagrammatic representation of all the circuits throughout the motors proper, as well as such circuits. Fig. 3 shows diagrammatically the construction and all of the circuit connections of the controller C. Figs. 3^a to 3^n show in outline diagram different ways of connecting the motor-armatures to the regulator for purposes to be explained. Fig. 4 shows diagrammatically the means used for automatically adjusting the lead of any pair of brushes on the regulator by the direction of the current in the winding connected therewith. Fig. 5 shows in outline diagram the connections of all the windings of the motor and regulator with the motors in parallel on one-sixth of the full potential, while Fig. 6 shows in outline diagram the connections of all the windings of the motor and regulator with the motors in series on one-sixth of the full potential between the main feeders. Fig. 7 is a vertical section of the parts of the motor necessary to show the means used to secure an automatic adjustment of the brushes of such motor according to the direction of the torque. Fig. 7^a is an inside end view of the disk and sleeve K and parts shown in Fig. 7 resulting from taking a vertical section through the shaft *t* just inside of the gear *o* and along the line *z z*. Fig. 7^b is an inside end view of the disk and sleeve L and parts shown in Fig. 7 resulting from taking a vertical section through the shaft *t* just inside of the gear *m* and along line *z' z'*.

Fig. 8 shows the means I prefer to make use of for connecting the shafts S and shaft S′ to the load. Figs. 9, 10, and 11 are end, side, and top views, respectively, of a mechanism used by which all of the speed conditions desired for a given regulator condition may be obtained consecutively by a continuous motion of an actuating-handle and also means for automatically establishing a higher counter-electromotive-force value for any particular speed of the load when the current becomes excessive for that speed.

Similar letters and figures refer to similar parts.

Referring to Figs. 1 and 2, in carrying out my invention I make use of two motors A and A′, which I prefer shall be exactly alike. They are so shown in the drawings. The letters of reference being the same for each of such motors and for most of the circuit connections, it will be necessary to describe only one of them, A. This motor A consists of a cylindrical field-magnet B′, containing the field-coil b' and supported upon suitable bolts between and carried by the sleeves and disks K and L, revolving in bearings M. This field B′ is of the well-known cylindrical type in which an annular field-coil surrounds the pole-pieces. Polarity is given to the different pole-pieces by reason of the direction which the lines of force take between the same and the armature B. On the disk and sleeve L and insulated therefrom are seen the contact-rings 78 80 82 84 86, on which bear, respectively, the springs 79 81 83 85 87. The ring 78 is connected with brush 76, bearing upon one side of the commutator O, while the ring 80 is connected with brush 77, bearing upon the other side of this commutator O. Contact-ring 82 is connected with one terminal of each of the sections k and l of the field-coil b', while the other terminals of these sections k and l of such field-coil are connected, respectively, with contact-rings 86 and 84. Spring 83 is connected by wire 68 to main feeder 63. Spring 85 is connected to contact 89 of switch 88. Spring 87 is connected with contacts 90 and 91 of switch 88. These contacts 89, 90, and 91 are so arranged that when switch 88 is in the position shown in the drawings both the coils k and l are connected through switch 88 and wire 67 with main feeder 62, as indicated in Figs. 1 and 2. For this position of the switch 88, then, we have the field-coils k and l connected up in parallel between the feeders 62 and 63. Moving the switch 88 to the left midway between contacts 90 and 91 cuts out, as will at once be seen, the coil k, while the coil l is still retained in circuit between the feeders 62 and 63. By moving the switch 88 farther over to the left the coil l is cut out of and the coil k again cut into circuit between the feeders 62 and 63. By moving switch 88 still farther, to contact 115, the field-circuit is broken. These coils k and l are so proportioned as to their magnetomotive force relative to the magnetic circuit constituted by the field-magnet B′ and the armature B that their use, each one alone and both together, shall result in air-gap densities between the field and armature whose value shall for the different positions of the switch 88 bear to each other the ratio of six, eight, and ten.

The armature B is secured upon the shaft S, revolving in bearings N. This armature B is wound with insulated wire b, connected to the sections of the commutator O.

The spring 79 is connected with contact-points 71 and 73 of the switches 69 and 72, respectively, and spring 81 is connected with contact-points 70 and 74 of switches 69 and 72, respectively, which switches are connected by the insulating-link 75 and constitute a reversing-switch for the motor A.

The member 69 of the reversing-switch of motor A is connected with the controller C through the electromagnet 114, and the member 72 of this same reversing-switch is connected through switches 111 and 44 with another wire leading to the controller C. The members 69 and 72 of the reversing-switch of motor A′ are connected to the controller C through electromagnet 114 and switch 47 and switches 111 and 50, respectively. These switches 44, 47, and 50 are connected by the insulating-bar 53. Switches 111 have working contacts 113 and open contacts 112. The internal circuit connections of this controller C will be explained with reference to Fig. 3. It is sufficient to state now, however, that the current is supplied to the motor-armatures B through the switches 69 and 72 in a uniform direction up to such switches; but its direction through the armatures is determined by the positions of such switches. The armature-shaft S carries at its right-hand end a pulley P′. The combined disk and sleeve K carries a gear 92, engaging a similar gear 93 on the right-hand end of the shaft S^3, supported and revoluble in the bearings T. On this shaft S^3 of motor A are located spur-gear 94 and 101, engaging similar spur-gear 95 and 102 on the shaft S′, supported and revolving in bearings U and carrying a pulley P^2 and a gear R at its right-hand end. The spur-gear 94 and 101 are rigidly secured to the shaft S^3. There is also rigidly secured to this shaft S^3 one member 100 of a friction-brake, the other member of which, 98, slides upon the fixed rod 99, supported in any suitable manner, (not shown,) and is operated by means of the lever 96, pivoted at 97. By the movement of this lever 96 to the left the rotation of the field B′ of the motor A may be retarded until such field B′ is brought to a standstill.

On the shaft S^3 of the motor A′ there is secured one of the members 100 of a friction-brake, the other member 98 of which, sliding upon the fixed rod 99, is operated by means of the lever 96, pivoted at 97, and by means of which the rotation of the field B′ of the motor A′ may be retarded and reduced to zero when desired.

The spur-gear 102 and 95 on the shaft S′ are arranged to revolve freely thereon. Each of such gear carries one of the members of a friction-clutch, the other of which, 105, is double and common to both of such gear 102 and 95 and is operated by the lever 103, pivoted at 104. With the lever 103 in the position shown in the drawings neither of the spur-gear 102 or 95 are caused to carry the shaft S′ with them. This member 105 is keyed or splined upon the shaft S′. By the movement of the lever 103 to the right the rotation of the shaft S^3 of the motor A is imparted to the shaft S′ at a reduced rate through the gear 102, which at this time is clutched to the shaft S′. By moving this lever 103 to the left in a similar way the rotation of this shaft S^3 is imparted to the shaft S′ at a different rate of rotation of such shaft S′ relative to that of such shaft S^3 by the clutching of the gear 95 to this shaft S′. A second shaft S^3 is similarly operated by a similar gear 93 from the field B′ of the motor A′ and carries a spur-gear 107, which meshes with a similar spur-gear 106 on the shaft S′, and, as indicated in the drawings, a splined clutching member 110, operated by a lever 108, pivoted at 109, serves to impart to the shaft S′ the rotation of the shaft S^3 of the motor A′ through the spur-gear 106 on this shaft S′.

In starting a heavy load it is very desirable to impart thereto the energy stored up in the momentum of a revolving body. For this reason I have the armatures B permanently connected to the load to be driven, while with the levers 103 and 108 and the two levers 96 occupying the positions shown in the drawings the field-magnets B′ are free to revolve independently of the load, and because they are free to revolve they readily reach a rate of rotation where the counter electromotive force generated thereby is sufficient to protect the windings b on the armatures B. By moving the levers 103 and 108 to the right the rotation of each of the fields B′ is imparted to the shaft S′, so as to secure the lowest possible rate of rotation of such shaft S′ for the potential then impressed upon the motors. By moving the lever 103 to the left the rate of rotation of the shaft S′ relative to the rate of rotation of the field B′ of the motor A is increased.

Referring to Fig. 1, my regulator consists of a dynamo-electric machine having field-magnets A^2, which may be of the usual type and wound with insulated wire a^2, connected in shunt across the main feeders, as will be explained later. The armature B^2 of this machine is of substantially the usual laminated construction and secured upon the shaft S^2, revolving in bearings J. This armature B^2 is wound with insulated wire e, f, g, and h in four distinct windings connected, respectively, to the commutators E, F, G, and H. Bearing on the commutator E are seen brushes 54 and 55, on commutator F brushes 56 and 57, on commutator G brushes 58 and 59, and on commutator H brushes 60 and 61. The winding e consists of a single wire in each slot or space, the winding f of two wires in each slot or space, the winding g of two wires in each slot or space, and the winding h of one wire in each slot or space. These windings constitute two pole-drum windings, the connections from which are so made to their respective commutators that the brushes occupy practically the positions shown. From the brushes bearing on each of these commutators wires lead to the controller C. The terminals of the field-coil a^2 also lead to the controller C. The main feeders 62 and 63 also are connected with this controller. This controller C is connected by a wire through electromagnet 114 with switch 69 of motor A and by another wire with contact-point 46 of switch 44 and contact 51 of switch 50. Another wire connects the controller with contact-point 49 of switch 47, and still another wire connects this controller C with contact-point 52 of switch 50. Contact-points 45 and 48 are connected together, as indicated.

Refer now to Fig. 3. The controller C consists of a series of contacts and switches so arranged that the armature of either motor or the armatures of both motors may be connected between the main feeders in parallel with any desired one or ones of the windings on the armature of my regulator in the following manner: A rod c' carries a series of switches c^2 c^3 c^4 c^5 c^6 c^7 c^8, but insulated therefrom, and is operated by a crank-lever c^9. The switch c^8 is arranged to connect a continuous contact-strip 15 with any desired one of a series of contacts 1 2 3 4 5 6 7. Similarly the switch c^7 is arranged to connect a continuous contact-strip 16 with any desired one of a similar series of contacts 14 13 8 9 10 11 12. The switch c^6 is arranged to connect a continuous strip 17 with either one of the contacts 18 19 20. The switch c^5 is arranged to connect together the contacts 24 and 23 or 25 and 22 or 26 and 21. The switch c^4 is arranged to connect together contacts 30 and 29 or 31 and 28 or 32 and 27. The switch c^3 is arranged to connect contacts 36 and 35 or 37 and 34 or 38 and 33. The switch c^2 is arranged to connect the continuous contact-strip 39 with either one of the contacts 40, 41, or 42. Brush 60 is connected with contacts 40 and 42 of switch c^2, contact 37 of switch c^3, and contacts 5 and 7 of switch c^8. Brush 58 is connected with contact 41 of switch c^2 and with contacts 36 and 38 of switch c^3 and with contact 6 of switch c^8. Brush 56 is connected with contacts 30 and 32 of switch c^4, with contact 25 of switch c^5, and with contact 3 of switch c^8. Brush 54 is connected with contact 31 of switch c^4, with contacts 24 and 26 of switch c^5, and with contacts 2 and 4 of switch c^8. Brush 61 is connected with contacts 9 and 13 of switch c^7, contact 28 of switch c^4, and contacts 35 and 33 of switch c^3. Brush 59 is connected with contact 8 of switch c^7, contacts 29 and 27 of switch c^4, and contact 34 of switch c^3. Brush 57 is connected with contact 11 of switch c^7, contact 19 of switch c^6, and contacts 23 and 21 of switch c^5. Brush 55 is connected with contacts 10 and 12 of switch c^7, contacts 18 and 20 of switch c^6, and contact 22 of switch c^5. The main feeder 63 is connected with the pivotal point of switch c^{10}, and passing thence on through the controller it goes to contact-point 49. Main feeder 62 is connected with contact 39 of switch c^2 and also with one terminal of the field-coil a^2 of the regulator, and from thence it passes on through the controller and is connected with contact-points 46 and 51. The pivotal point of switch 69 of the motor A is connected with a continuous contact-strip 16 of switch c^7 through electromagnet 114, and the contact-point 52 is connected with the continuous contact-strip 15 of switch c^8. The continuous contact-strip 17 of switch c^6 is connected with the resistance r, while the continuous contact-strip 43 is connected with the other terminal of the field-coil a^2, whereby when switch c^{10} is moved upon the contact-strip 43 the field-coil a^2 of my regulator is cut into circuit across the main feeders 62 and 63.

The brushes 60 and 61, 58 and 59, 56 and 57, and 54 and 55 constitute the terminals, respectively, of the armature-windings h g f e, wherefore when the switch c^{10} is moved to the first contact of the resistance r the circuit then is closed through the resistance r and the several armature-windings of my controller, as follows: starting then with feeder 63, switch c^{10}, resistance r to contact 17, through switch c^6 to contact 18, thence to brush 55, thence through the winding e to brush 54, thence through contact 24, switch c^5, contact 23, thence to brush 57, winding f, brush 56, thence to contact 30, switch c^4, contact 29, thence to brush 59, thence through winding g to brush 58, thence to contact 36, switch c^3, contact 35, thence to brush 61, winding h, brush 60, contact 40, switch c^2, contact-strip 39, and thence to main feeder 62, connected therewith.

With all the switches in the position shown in Fig. 3, except switch c^{10}, which has been moved over to its extreme left-hand position, it will at once be seen that the full-line pressure is applied to the terminals of the regulator-armature, but that the motors A and A′ are out of circuit. With the switches moved over to the right, so that the contacts 13 and 2 of switches c^7 and c^8, respectively, are in connection with the contact-strips 16 and 15, it will be seen at once that there is no change yet made in the circuit through the several windings on the regulating-armature, but that the motors A and A′ are placed in parallel, respectively, with the windings h and e. Hence each of such motors is subjected to one-sixth of the full potential between the feeders 63 and 62. These connections, as well as the connections resulting from each of the succeeding positions of the controller-lever, are more fully illustrated in Figs. 3^a, 3^b, 3^c, 3^d, 3^e, 3^f, and 3^g. With the controller-lever advanced, so as to connect contact 8 with contact-strip 16 and contact 3 with contact-strip 15, it will be noticed that the order of the coils of the regulator-armature has been changed and that for this position of the switches, as seen in Fig. 3^c, the armatures of the motors A and A′ are placed, respectively, in parallel with the armature-windings g and f of the regulator, and there is at this time impressed upon each of the motors A and A′ two-sixths of the full potential between the feeders 63 and 62. Again, when the controller-lever is advanced another step it will be seen that the motors A and A′, as more clearly indicated in Fig. 3^d, are in parallel, respectively, with the armature-windings g and h and with the armature-windings e and f. Thus there is impressed upon each of the motors A and A′ three-sixths of the full potential between the feeders 63 and 62. Again, for the next step of the controller-lever, as seen in Fig. 3^e, the armature of the motor A is connected in parallel with the series of windings g, h, and e, and the armature of the motor A′ is connected in parallel with the series of windings h, e, and f. There is at this time, then, impressed upon each of the motors A and A′ four-sixths of the full potential between the feeders 63 and 62. Again, for the next step of the controller-lever, as shown in Fig. 3^f, the armature of the motor A is connected in parallel with the series of windings h, g, and f and the armature of the motor A′ is connected in parallel with the series of windings g, f, and e of the regulator. There is, then, at this time impressed upon each of the motors A and A′ five-sixths of the full potential between the feeders 63 and 62. At the next step of the controller-lever, as shown in Fig. 3^g, it will be seen that the motors A and A′ have their armatures connected in parallel across the main feeders 63 and 62, the full potential between which is impressed upon such armatures.

Attention is called to the fact that at all times the windings h, g, f, and e of the regulator are connected together in series across the main feeders 63 and 62 and that such windings when made use of for the purpose of regulating the potential at the terminals of the motors A and A′ are differently grouped relatively to such motors in such a way that each of such motors is connected across the main feeders in series with some of such windings and in parallel with the remainder of such windings of such regulator.

Attention is called to the fact that with the arrangement shown in Fig. 3 and in Figs. 3^a to 3^g, inclusive, there are only four armature-windings on the regulator, which by the several arrangements indicated for the different steps in the controller give six different electromotive-force conditions.

Referring now to Figs. 1 and 3, it will be seen that by the movement of switches 44, 47, and 50 to the left the motors A and A′ are connected together in series between switch 69 of the motor A and contact-point 51 of switch 50. Then when the controller-lever is moved over its successive contacts in the manner just above described we have the motors A and A' in series, connected first in parallel with the winding *h*, then in parallel with the winding *g*, then in parallel with the windings *g* and *h*, then in parallel with the windings *g*, *h*, and *e*, then in parallel with the windings *h*, *g*, and *f*, and then connected directly across the main feeders and in parallel with the windings *h*, *g*, *f*, and *e*. We have thus six different regulator conditions with the motors in series and six different regulator conditions with the motors in parallel; but it should be borne in mind that the maximum speed which will be reached by the motors with full-line potential impressed upon them in series will be just the same as that speed which is secured by that condition of the controller which impresses upon each of such motors three-sixths of the full potential between the feeders 63 and 62. This condition is that which results when the controller-lever is at the center of its movement or throw.

Refer now to Fig. 4, which shows in outline diagram the means which I employ to regulate the lead of the brushes on the commutators E, F, G, and H of the regulator. As the means employed in each case—that is, for each commutator—is the same, it will be sufficient to describe such means with reference to only one of such commutators—for instance, the commutator E and the brushes 54 and 55—the same plan of lettering being adopted in the case of each of such commutators. These brushes 54 and 55 are carried by a rocker-arm e^6, which may be rotatably supported in the usual manner by means of any suitable mechanism. (Not shown.) On this rocker-arm e^6, carrying brushes 54 and 55, are formed radial extensions inclosed by the coils e^3 e^3, located in series with the brushes 54 and 55, and hence in series with the winding *e*, connected to the commutator E. The core e^4 of each of these coils e^3 is extended downward in the form of an arc of a circle whose center is the center of the commutator E, so as to form also when taken with the rest of the rocker-arm a core for the solenoid e^5, which is connected across the main feeders 62 and 63 in series with the other similar solenoids f^5 g^5 h^5. Hence it will be seen that the direction of the current in these coils e^5, f^5, g^5, and h^5 is constant, while the direction of the current in each one of the coils e^3, f^3, g^3, and h^3 varies according to the direction of the current in the armature-windings connected to their corresponding commutators and with which they are directly in series. The entire rocker-arm e^6 and the extensions e^4 thereof, it will of course be understood, should be of magnetic material, preferably iron. We have then the solenoid-coil e^5, when taken in connection with the extensions e^4 on the rocker-arm e^6 and inclosed by the coils e^3, acting as a solenoid with a polarized core, whereby the rocker-arm carrying the brushes 54 and 55 is caused to be moved over to the left or over to the right, according to the direction of the current through the winding *e*, connected to the commutator E.

Attention is called in Fig. 4 to the points *h'*, *g'*, *f'*, *e'*, and e^2 as being those points in the connections between the windings of the regulator-circuit connected across the main feeders in series where the connections are made in the arranging and rearranging of the order of the windings *e*, *f*, *g*, and *h*. Attention is also called to the fact that when the armatures B of the motors A and A' are connected across the main feeders in series with any one of the windings of the regulator such connections are made at points *e'*, *f'*, and *g'*.

Refer now to Figs. 7, 7^a, and 7^b. These figures show the means which I employ for regulating the lead of the brushes on the commutators of the motors A and A' according to the direction of the rotary effort exerted between the armatures and fields of such motors. The brushes 76 and 77, bearing on the commutator O of each of such motors, are carried by suitable arms projecting from the spur-gear *u*, rotatably supported upon the disk and hub L by means of the flange-collar *v*. This spur-gear *u* engages another spur-gear *m*, carried by a shaft *t*, having a bearing at its right-hand end in the disk L and with its left-hand end supported in a bearing *q*, secured upon the field B'. On the left-hand end of this shaft *t* is seen a spur-gear *o*, engaging a segmental rack *p*, carried by the stop *n*, projecting through a suitable opening therefor through the disk K. This stop *n* is secured to the spur-gear 92, which is rotatable upon the hub of the disk K, the amount of such rotation being limited by the size of the opening through such disk K relative to that of the stop *n*, projecting inwardly from this gear 92, which is so proportioned that the extreme angular motion of such gear 92 relative to the disk K shall transmit through the segmental rack *p*, engaging the spur-gear *o*, a rotation to the shaft *t* such in amount that the angular movement thereby transmitted from the spur-gear *m* to the spur-gear *u*, carrying the brushes 76 and 77, shall be sufficient to cover double the angle of lead of such brushes 76 and 77. The rotary effort of the field B' is transmitted to the gear 92 by the sides of the opening in the disk K engaging the stop *n*, rigidly secured to such gear 92 and carrying the segmental rack *p*. The operation of this mechanism is substantially as follows: Any tendency of the field to rotate on account of the rotary effort between it and the armature causes the disk K to revolve first independently of the gear 92 until one of the sides of the opening in the disk K engages the stop *n*. This results in such a rotation of the shaft *t* and of the spur-gears *m* and *u* as will cause the brushes 76 and 77 to travel for a brief period of time in advance of the rotation of the field B′, which is just the action necessary to secure the proper lead of the brushes—that is, a negative lead of the brushes 76 and 77 when the motors act as motors proper, or a positive lead of such brushes when the action of such motors is reversed and they become generators.

Referring to Fig. 8, on each of the shafts S of the armatures of my motor is located a pulley P′, and on the shaft S′ is located a similar pulley P^2. The belt Q is arranged to partially encircle the pulleys P′ and also partially encircle the pulley P^2. On this pulley P^2 is seen a belt Q′, by means of which power may be transmitted to any machinery to be driven. This belt Q′ is driven, as will at once be understood, by means of the pulley P^2 and also by means of the belt Q in contact therewith over an extent of surface nearly or quite equaling the periphery of any one of the pulleys in question. The arrows indicate the relative directions of rotation of the several pulleys.

In Fig. 8 the gear R is removed in order to more clearly bring out the arrangement of the belts Q and Q′ and the pulleys P′ and P^2. Gear R may be used instead of the pulleys and belts to transmit power to a load.

Refer now to Figs. 9, 10, and 11. In these figures the relative arrangement of the brake-levers 96 and of the switches 111 and 88 and of the clutching-levers 103 and 108 is purposely distorted in order that they may be so grouped as to more clearly show the operation of each of such levers in connection with the motor to which it belongs. In Fig. 10 the brackets under the letters A and A′ show such groupings of the switches 111 and 88 and of the brake-levers 96 of each of such motors, while the clutch-levers 103 and 108 are shown at the extreme right in the figure. The brake-levers 96 are curved, as seen in end view in Fig. 9, so as to extend upward through suitable slots therefor in the cam-plate V in the same straight line with the clutch-levers 103 and 108 and parallel with the axis of the shaft S′, and in this same straight line are seen the upper ends of levers connected to the switches 111 and 88 for each of the motors A and A′, arranged to engage each one its own slot in the cam-plate V. Each of the slots y' y^2 y^3, &c., to y^8, inclusive, in this cam-plate V is so formed that when this cam-plate V, working in suitable guides w, as indicated, is operated by means of the crank 129, carrying the spur-gear 130, engaging the rack 131 on such cam-plate V, the series of speed conditions provided for by the slots in such cam-plate will regularly follow each other in the proper order. These conditions are indicated by dotted lines x' x^2, &c., to x^{12}, inclusive. When the upper ends of all these levers lie in the line x', with the switches 44, 47, and 50 (seen in Fig. 1) moved upon contacts 45, 48, and 51, respectively, we have the motors A and A′ in series, but with the fields B′ of such motors free to revolve. When by the forward movement of the plate V the upper ends of these levers are caused to fall in the line x^2, then we have the fields B′ of the motors A and A′ clutched so as to transmit to the shaft S′ rotation at the lowest rate obtainable. The further movement of this cam-plate V, causing the levers 111, 88, 96, 103, and 108 to occupy, successively, the positions indicated by lines x^3 x^4, &c., to x^{12}, results in a continual increase in the speed of the shaft S′ until the maximum rate of rotation of such shaft has been reached for the potential then impressed upon the armatures of such motors A and A′ through the regulator by means of the controller C. At the same time that the cam-plate V is moved from the position indicated by the dotted line x^3 to the position indicated by the dotted line x^4 switches 44, 47, and 50 (seen in Fig. 1) are moved to contacts 46, 49, and 52, respectively, thus placing the armatures of the motors A and A′ in parallel and making it possible to transfer the load to either one alone. When this maximum speed for the potential then impressed upon the armatures of such motors A and A′ has been reached, the speed of the shaft S′ may be further increased by means of the controller in the manner already described by increasing the potential impressed upon the armatures of such motors.

Refer now to Figs. 1 and 11. In series with the armatures of each of the motors A and A′ is seen an electromagnet 114, whose armature 116 is arranged to communicate its motion through a connecting-link 118 to a lever 121. Links 118 work in suitable guides 117. Lever 121 is connected at its middle point to a latch 123, working in suitable guides 122 and engaging the ratchet 128 on the cam-plate V. Springs 119 oppose the action of the electromagnets 114. A suitable stop 120 prevents too great a movement to the left of the lever 121. A lever 126, having a suitable handle and pivoted at 125, is provided in order that the latch or pawl 123 may be operated by hand when desired.

When for any reason the current in the armature of either or both of the motors when used alone or together in parallel or in series exceeds a predetermined limit, its corresponding electromagnet 114 draws its armature 116 to the left, and thereby draws latch or pawl 123 out of engagement with the ratchet 128, allowing the weight W, secured by the cord 132 to cam-plate V and working over the pulley 133, to draw back the cam-plate V and establish a condition of the switches and clutch and brake levers which will increase the rotary effort exerted upon the load and at the same time also increase the counter electromotive force generated for any given rate of rotation of the shaft S′, thus reducing the current to a safe limit by increasing the rotary effort and also increasing the counter electromotive force generated. This action results as well from an excessive current in only one armature as in both armatures.

The operation of my machine is as follows: First, the regulator is started in the usual manner common to motors by means of a rheostat, as shown in Fig. 3, wherein the lever c^{10} serves to cut in, first, the field-coil a^2 and then the armature-windings e, f, g, and h in series with the resistance r, which is gradually cut out by the operation of such lever c^{10}. Then, if it is desired to impress upon the load the energy stored up in the momentum of the revolving fields B′ of the motors A and A′ the clutches 105 and 110 are released and the brake-levers 96 are moved so as to release shafts S^3. Immediately then upon the closing of the switches 111 and the moving of the switches 44, 47, and 50 onto the contacts 45, 48, and 51, respectively, the motors A and A′ are connected together with their armatures in series, and then the controller-lever c^9 is advanced one notch from the position shown in the drawings. This causes the fields of the motors A and A′ to revolve, and the speed of such rotation may be regulated by the controller, in the manner already clearly indicated and described, by varying the potential impressed upon the motors A and A′. The speed which the fields of these motors will be allowed to reach will be determined largely by the initial speed which it is desired to impart to the load and also the inertia of the load which it is desired to start. When the desired speed of such fields has been reached, then the clutches are closed and the rotary effort exerted by each of such motors is imparted to the shaft S′. The retarding of the fields of such motors serves to increase the current flowing through the armatures of such motors, and at the same time also the energy stored up in the momentum of the revolving fields is imparted to the load to aid in overcoming its inertia.

In the case in the drawings the relations of the gears are supposed to be such as to secure the following relative rotations between the fields of the motors A and A′ and the shaft S′: The lowest speed of the shaft S′ relative to the speed of the field B′ of the motor A is as one to five, while the other speed ratio is as one of the shaft S′ to one-half of a revolution of the field B′ of the motor A. The only speed ratio between the field B′ of the motor A′ and the shaft S′ is as two to one. We will suppose the normal rate of rotation between either field and its armature subjected to the full potential and for the minimum magneto-motive force in each of such fields to be two thousand revolutions per minute and for the maximum magneto-motive force just six-tenths of that speed. Then for the successive positions of the cam-plate V (indicated by the dotted lines x' to x^{12}, inclusive) we have for the different impressed electromotive-force values indicated below, which are secured by means of the controller and regulator, the following speeds of the load in revolutions per minute:

Positions of cam-plate V.	Portion of line electromotive force impressed upon motors.					
	$\frac{1}{6}$.	$\frac{2}{6}$.	$\frac{3}{6}$.	$\frac{4}{6}$.	$\frac{5}{6}$.	$\frac{6}{6}$.
x^2	22	44	67	89	111	133
x^3	37	74	111	148	185	222
x^4	55	111	166	222	277	332
x^5	67	133	200	267	333	400
x^6	89	178	266	355	444	533
x^7	111	222	333	444	555	667
x^8	133	267	400	533	667	800
x^9	178	356	533	711	889	1,067
x^{10}	222	444	667	889	1,111	1,333
x^{11}	267	533	800	1,067	1,333	1,600
x^{12}	333	667	1,000	1,333	1,667	2,000

Attention is called to the fact that the relative rotation between the field and armature of the motor A, with its field B′ revolving and with gear 102 clutched to the shaft S′, is twice that of the relative rotation between the armature and field of the motor A′ when its field B′ is revolving and gear 106 is clutched to the shaft S′. Again, also, it will be seen that the relative rotation between the armature and field of the motor A′ when its field is revolving and when gear 106 is clutched to shaft S′ is twice that of the relative rotation between the armature and field of the motor A when its field B′ is revolving and when gear 95 is clutched to the shaft S′. It will also be noticed that the relative rotation between the armature and field of the motor A, with the field B′ of such motor revolving and with the gear 95 clutched to shaft S′, is just three-halves of that between the armature and field of the motor A′ with the field B′ of such motor A′ at rest. Again with the field of the motor A at rest and with the field of the motor A′ revolving and with the gear 106 clutched to the shaft S′ we have a relative rotation between the field and armature of the motor A which is just one-third of that between the field and armature of the motor A′. It should be borne in mind that at all times in the operation of the motors A and A′ the armatures thereof revolve at a uniform speed relative to the shaft S′, which is maintained by means of mechanism already described and by which preferably the same rate of rotation is secured for each of such armatures and for such shaft S′. Hence the speed of the shaft S′ may be said to be the speed of the motor proper.

Figs. 3^h, 3^i, and 3^j show arrangements of the coils in my regulator which may be effected by a modified form of my controller and which admit of a potential being impressed upon the motor A just twice that impressed upon the motor A′. Three different potentials are shown for each of such motors bearing such relations. Figs. 3^k and 3^l show in a similar way an arrangement whereby the potential impressed upon the motor A may be just three-halves of that impressed upon the motor A′, while Figs. 3^m and 3^n show also in a similar way an arrangement whereby the potential impressed upon the motor A may be one-third of that impressed upon the motor A'. In each of these last two arrangements there are shown only two speed conditions.

The process of transferring the load from one motor to the other, as described above, may be carried as far as desired, according to the conditions, and at whatever point this process is ended the motors, whether connected to the load at equal or unequal rates of relative rotation, requiring that either equal or unequal potentials be impressed on such motors, whatever the condition existing, the controller and regulator coöperate with the gearing and clutching mechanism to secure the further regulation of such motors in series or in parallel, and if in parallel whether the potentials impressed upon the motors A and A' are equal, as shown in Figs. 3^b to 3^g, inclusive, or unequal, as shown in Figs. 3^h to 3^n, inclusive, and as already fully described in reference to such figures. The gears must be proportioned and the cam-plate and mechanism operated thereby designed to suit the condition under which the motors are to be operated.

When it is desired to use the regulator upon a circuit of high potential, a larger number of windings may be used in the armature thereof. For instance, coils having values of one, two, four in two series would give fourteen different conditions, or with eight sections of winding having values as follows—one, two, four, eight, eight, four, two, one—would give thirty different conditions with a maximum potential impressed upon any one regulator-armature winding of only eight-thirtieths of the total potential between the main feeders, while in the case of two series of three windings each the maximum potential impressed upon any one winding of the regulator would be four-fourteenths, and in the case illustrated in the drawings the maximum potential upon any one winding is one-third of that between the main feeders.

Attention is called to the fact that in the use of this controller in any of the above-indicated methods, whether for two motors in series or for one motor alone or for two motors in parallel, the current which traverses any one of the windings of the regulator never reaches what is supplied to one of such motors alone.

It will of course be understood that in the operation of the regulator, irrespective of the connections thereof effected by the controller, the proper angle of lead of the brushes upon the commutators E, F, G, and H is maintained by means of the mechanism shown in Fig. 4 and already fully described.

It will be noticed that when the motors A and A' are in parallel with each other and with different counter-electromotive-force values for a common speed of the load and are regulated by my controller and regulator the general plan of regulation is exactly the same as though both motors had the same counter-electromotive-force value. Attention is called, further, to the fact that if the normal speed of either of such motors alone is two thousand revolutions per minute for the minimum field excitation we have then for such motors in series on one-sixth of the full-line potential and with the clutch conditions giving us the lowest speed of the load twenty-two revolutions per minute for the shaft S'. Under these conditions the rate of rotation of the fields B' will be something like one hundred and ten for the motor A and forty-four revolutions per minute for the motor A'. For maintaining the speed of the load at this very low rate it will be noticed, of course, that comparatively small power is required, while the rotary effort exerted may be great.

By referring to the above table of speeds it will at once be seen that the same speed occurs at several different points in the table. It will at once be understood that this repetition of the same speed means that the same speed is maintained for the different conditions indicated, but with varying rotary efforts exerted upon the load resulting from the varying clutch conditions which may be secured, while the current which is supplied to the motors A and A' for these varying speeds may come wholly from the line or may come partly from the line and partly from the winding or windings of the regulator acting at that time as generative windings, the amount of current taken from the line varying, of course, in accordance with the actual amount of work performed.

In describing the operation of my regulator I shall first consider its operation when used to regulate the potential at the terminals of a single motor. In this case such of the windings *e f g h* as are in series with such motor between the main feeders act as motor-windings, while those of such windings as are in parallel with such motor act as generative windings. The volume of current supplied by such generative winding or windings varies inversely with the electromotive force impressed upon the motor, whereby as the speed of the motor increases the amount of current supplied from the line increases relative to that supplied from the generative winding or windings of the regulator.

It will be understood that for all conditions of operation of my regulator, neglecting the losses due to resistance, the algebraic sum of the generated electromotive forces in the motor or motors connected therewith and in that portion of the regulator-windings in series with such motor or in series between such motors is always equal to the line potential and that with two motors connected to the regulator the numerical sum of the electromotive forces generated in such motors and that portion of the regulator-windings in series between such motors may have any value from the full-line potential to three times that value, which last condition obtains when each motor has the full-line potential impressed thereon. From this it will be seen, first, that with two motors connected to the regulator when the sum of the electromotive forces generated in the motors is less than the line potential the windings of the regulator in series between such motors act as motor-windings and the remainder of such regulator-windings act as generator-windings; second, that when such sum is equal to the line potential all of the regulator-windings act as motor-windings, and, third, that when such sum is greater than the line potential the windings of the regulator in series between such motors act as generator-windings, and the rest of the regulator-windings act as motor-windings.

Refer now to Figs. 3^a, 3^b, &c., to 3^g. From the above description it follows that in such figures the motor-windings are, in Fig. 3^a, *h*, *g*, *f*, and *e;* in Fig. 3^b, *g* and *f;* in Fig. 3^c, *h* and *e;* in Fig. 3^d, *g*, *h*, *e*, and *f;* in Fig. 3^e, *g* and *f;* in Fig. 3^f, *h* and *e*, and in Fig. 3^g, *h*, *g*, *f*, and *e;* and the generator-windings are, in Fig. 3^b, *h* and *e;* in Fig. 3^c, *g* and *f;* in Fig. 3^e, *h* and *e*, and in Fig. 3^f, *g* and *f*.

When the armatures B become generator-armatures by the application of a negative load, the above conditions are reversed.

The lowest speed at which the combined system may be caused to return energy to the line, it will be understood, is at a little above the lowest speed at which the motors A and A′ may be caused to revolve for the lowest clutch condition with maximum field in each of such motors and with the lowest speed condition obtainable by means of the controller C.

Whatever may be the operation of the regulator, the motor effort exerted upon the regulator-armature must at all times exceed the generator effort of such armature by an amount sufficient to maintain the normal rotation of such armature when running light.

It will be understood that the regulator performs the function of absorbing or consuming the electromotive force between the main feeders 62 and 63 and that by means of the controller any proportionate part of such electromotive force between the main feeders may be consumed in the regulator, while the remainder is impressed upon the armature or armatures B. It will be further understood that this feature of my invention is equally applicable when either one or both motors are replaced by any translating devices, whether there be an electromotive force generated therein independent of the supply-circuit or not.

Attention is called to the following points: Each armature B constitutes a separate and electrically-independent translating device. Hence such armatures serve as illustrations of two translating devices. When power is applied to the pulley P′, as in the case of a car going down a grade, the armatures B become generating-armatures and are then sources of electric energy. In regulating the potential at the terminals of the armatures B there is generated between the feeders 62 and 63 an electromotive force practically equal to the potential between such feeders, and the amount of such electromotive force generated in series is varied inversely with that generated in parallel with each of such armatures.

What I claim is—

1. A supply-circuit, an electromotive-force generator connected across the terminals thereof, a translating device, and means whereby such translating device may be variously connected across the terminals of such supply-circuit in series with any desired portion of such generator and in parallel with the remaining portion thereof.

2. A supply-circuit, an electromotive-force generator connected across the terminals thereof, a translating device, means whereby such translating device may be variously connected across the terminals of such supply-circuit in series with any desired portion of such generator and in parallel with the remaining portion thereof, means for varying as desired that portion of such generator in series and that portion of such generator in parallel with such translating device, and means whereby energy from such supply-circuit absorbed in such generator in excess of that required to meet the losses in such generator, is utilized in supplying energy from such generator to such translating device.

3. A supply-circuit, an electromotive-force generator connected across the terminals thereof, a translating device, and means whereby such translating device may be variously connected across the terminals of such supply-circuit in series with any desired portion of such generator and in parallel with the remaining portion thereof, such generator so divided into sections that, by their different arrangements, the total electromotive force thus generated in series with such translating device will vary in value in practically an arithmetical progression, and whereby also the total electromotive force thus generated in parallel with such translating device will vary in value in practically an arithmetical progression.

4. A supply-circuit, an electromotive-force generator connected across the terminals thereof and arranged to generate an electromotive force constant in direction, and practically equal in amount and counter to the potential at the terminals of such supply-circuit, a translating device, and means whereby such translating device may be variously connected across the terminals of such supply-circuit in series with any desired portion of such generator and in parallel with the remaining portion thereof.

5. A supply-circuit, an electromotive-force generator connected across the terminals thereof and arranged to generate an electromotive force practically equal to the potential at the terminals of such supply-circuit, a translating device, and means whereby such

translating device may be variously protected against the full potential between the terminals of such supply-circuit, by the electromotive forces in any desired portions of such generator.

6. A supply-circuit, an electromotive-force generator connected across the terminals thereof, a source of electric energy, means whereby such source of electric energy may be variously connected across the terminals of such supply-circuit in series with any desired portion of such generator and in parallel with the remaining portion thereof, and means whereby a portion of the energy from such source of electric energy may be utilized in that portion of such generator in parallel therewith, in supplying energy to such supply-circuit in series with such source of electric energy.

7. A supply-circuit, an electromotive-force generator divided into sections and connected across the terminals thereof, with the values of the electromotive forces generated in such sections forming one or more progressions practically geometrical, a translating device, and means whereby such translating device may be variously connected across the terminals of such supply-circuit in series with any desired one or ones of the sections of such generator and in parallel with the remaining one or ones.

8. A supply-circuit, an electromotive-force generator connected across the terminals thereof, two translating devices, and means whereby each of such translating devices may be variously connected independently across the terminals of such supply-circuit in series with any desired portion of such generator and in parallel with the remaining portion thereof.

9. A supply-circuit, an electromotive-force generator connected across the terminals thereof, two translating devices, means whereby each of such translating devices may be variously connected independently across the terminals of such supply-circuit in series with any desired portion of such generator and in parallel with the remaining portion thereof, means for varying as desired that portion of such generator in series and that portion of such generator in parallel with each of such translating devices, and means whereby energy from such supply-circuit absorbed in such generator in excess of that required to meet the losses in such generator, is utilized in supplying energy from such generator to one or both of such translating devices.

10. A supply-circuit, an electromotive-force generator connected across the terminals thereof, two translating devices, and means whereby each of such translating devices may be variously connected independently across the terminals of such supply-circuit in series with any desired portion of such generator and in parallel with the remaining portion thereof, such generator so divided into sections that by their different arrangements the total electromotive force thus generated in series with each of such translating devices will vary in value in practically an arithmetical progression, and whereby also the total electromotive force thus generated in parallel with each of such translating devices will vary in value in practically an arithmetical progression.

11. A supply-circuit, an electromotive-force generator connected across the terminals thereof, and arranged to generate an electromotive force constant in direction and practically equal in amount and counter to the potential at the terminals of such supply-circuit, two translating devices, and means whereby each of such translating devices may be variously connected independently across the terminals of such supply-circuit in series with any desired portion of such generator and in parallel with the remaining portion thereof.

12. A supply-circuit, an electromotive-force generator connected across the terminals thereof and arranged to generate an electromotive force practically equal to the potential at the terminals of such supply-circuit, two translating devices, and means whereby each of such translating devices may be variously protected independently against the full potential between the terminals of such supply-circuit, by the electromotive forces in any desired portions of such generator.

13. A supply-circuit, an electromotive-force generator connected across the terminals thereof, two sources of electric energy, means whereby each of such sources of electric energy may be variously connected independently across the terminals of such supply-circuit in series with any desired portion of such generator and in parallel with the remaining portion thereof, and means whereby a portion of the energy from each of such sources of electric energy may be utilized in such generator, in supplying energy to such supply-circuit in series with such sources of electric energy.

14. A supply-circuit, an electromotive-force generator connected across the terminals thereof, two translating devices, and means for so generating an electromotive force in such generator and for so connecting variously each of such translating devices across the terminals of such supply-circuit in series with any desired portion of such generator and in parallel with the remaining portion thereof, that the current traversing any portion of such generator can never exceed that traversing one of such translating devices.

15. A supply-circuit, an electromotive-force generator connected across the terminals thereof, means for generating an electromotive force in such generator practically equal in amount and counter to the potential at the terminals of such supply-circuit, two translating devices, means whereby each of such translating devices may be variously connected independently across the terminals of

such supply-circuit in series with any desired portion of such generator and in parallel with the remaining portion thereof, and means whereby the electromotive force generated in that portion of such generator connected across the terminals of such supply-circuit in series with and between such translating devices, is utilized in supplying the difference between the sum of the potentials impressed upon each of such translating devices taken singly, and the potential impressed by such supply-circuit upon the terminals of the circuit containing such translating devices and the portion of such generator in series with and between such translating devices.

16. A supply-circuit, an electromotive-force generator divided into sections and connected across the terminals thereof, with the values of the electromotive forces generated in such sections forming one or more progressions practically geometrical, two translating devices, and means whereby each of such translating devices may be variously connected independently across the terminals of such supply-circuit in series with any desired one or ones of the sections of such generator and in parallel with the remaining one or ones.

17. A supply-circuit, a series of windings, means for connecting such windings together in series across the terminals of such supply-circuit, means for generating an electromotive force in each one of such windings, a translating device, and means whereby such translating device may be variously connected across the terminals of such supply-circuit in series with any desired one or ones of such windings and in parallel with the remaining one or ones.

18. A supply-circuit, a series of windings, means for connecting such windings together in series across the terminals of such supply-circuit, means for generating an electromotive force in each one of such windings, a translating device, means whereby such translating device may be variously connected across the terminals of such supply-circuit in series with any desired one or ones of such windings and in parallel with the remaining one or ones, and means whereby energy from such supply-circuit absorbed in such windings in excess of that required to generate such electromotive forces in such windings, is utilized in supplying energy to such translating devices.

19. A supply-circuit, a series of windings, means for connecting such windings together in series across the terminals of such supply-circuit, a translating device, means whereby such translating device may be variously connected across the terminals of such supply-circuit in series with any desired one or ones of such windings and in parallel with the remaining one or ones, and means for generating such an electromotive force in each one of such windings that, by their different arrangements, the total electromotive force thus generated in series with such translating device will vary in value in practically an arithmetical progression, and whereby also the total electromotive force thus generated in parallel with such translating device will vary in value in practically an arithmetical progression.

20. A supply-circuit, a series of windings, means for connecting such windings together in series across the terminals of such supply-circuit, means for generating electromotive forces in such windings constant in direction and together practically equal in amount and counter to the potential at the terminals of such supply-circuit, a translating device, and means whereby such translating device may be variously connected across the terminals of such supply-circuit in series with any desired one or ones of such windings and in parallel with the remaining one or ones.

21. A supply-circuit, a series of windings, means for connecting such windings together in series across the terminals of such supply-circuit, means for generating electromotive forces in such windings together practically equal to the potential between the terminals of such supply-circuit, a translating device, and means whereby such translating device may be variously protected against the full potential between the terminals of such supply-circuit, by the electromotive forces in any desired ones of such windings.

22. A supply-circuit, a series of windings, means for connecting such windings together in series across the terminals of such supply-circuit, a source of electric energy, means for variously connecting such source of electric energy across the terminals of such supply-circuit in series with any desired one or ones of such windings and in parallel with the remaining one or ones, and means whereby a portion of the energy from such source of electric energy may be utilized in the winding or windings in parallel therewith, in supplying energy to such supply-circuit in series with such source of electric energy.

23. A supply-circuit, a series of windings, means for connecting such windings together in series across the terminals of such supply-circuit, means for generating an electromotive force in each one of such windings, with the values of the electromotive forces in such windings forming one or more progressions practically geometrical, a translating device, and means whereby such translating device may be variously connected across the terminals of such supply-circuit in series with any desired one or ones of such windings and in parallel with the remaining one or ones.

24. A supply-circuit, a series of windings, means for connecting such windings together in series across the terminals of such supply-circuit, means for generating an electromotive force in each one of such windings, two translating devices, and means whereby each of such translating devices may be variously connected independently across the terminals

of such supply-circuit in series with any desired one or ones of such windings and in parallel with the remaining one or ones.

25. A supply-circuit, a series of windings, means for connecting such windings together in series across the terminals of such supply-circuit, means for generating an electromotive force in each one of such windings, two translating devices, means whereby each of such translating devices may be variously connected independently across the terminals of such supply-circuit in series with any desired one or ones of such windings and in parallel with the remaining one or ones, and means whereby the energy from the supply-circuit absorbed in such windings in excess of that required to generate such electromotive forces in such windings, is utilized in supplying energy to one or both of such translating devices.

26. A supply-circuit, a series of windings, means for connecting such windings together in series across the terminals of such supply-circuit, two translating devices, means whereby each of such translating devices may be variously connected independently across the terminals of such supply-circuit in series with any desired one or ones of such windings, and in parallel with the remaining one or ones, and means for generating such an electromotive force in each one of such windings that, by their different arrangements, the total electromotive force thus generated in series with each of such translating devices will vary in value in practically an arithmetical progression, and whereby also the total electromotive force thus generated in parallel with each of such translating devices will vary in value in practically an arithmetical progression.

27. A supply-circuit, a series of windings, means for connecting such windings together in series across the terminals of such supply-circuit, means for generating electromotive forces in such windings constant in direction and together practically equal in amount and counter to the potential at the terminals of such supply-circuit, two translating devices, and means whereby each of such translating devices may be variously connected independently across the terminals of such supply-circuit in series with any desired one or ones of such windings and in parallel with the remaining one or ones.

28. A supply-circuit, a series of windings, means for connecting such windings together in series across the terminals of such supply-circuit, means for generating electromotive forces in such windings together practically equal to the potential between the terminals of such supply-circuit, two translating devices, and means whereby each of such translating devices may be variously protected independently against the full potential between the terminals of such supply-circuit, by the electromotive forces in any desired ones of such windings.

29. A supply-circuit, a series of windings, means for connecting such windings together in series across the terminals of such supply-circuit, two sources of electric energy, means whereby each of such sources of electric energy may be variously connected independently across the terminals of such supply-circuit in series with any desired one or ones of such windings and in parallel with the remaining one or ones, and means whereby a portion of the energy from each of such sources of electric energy may be utilized in such windings, in supplying energy to such supply-circuit in series with such sources of electric energy.

30. A supply-circuit, a series of windings, means for connecting such windings together in series across the terminals of such supply-circuit, two translating devices, and means for generating such an electromotive force in each one of such windings and for so connecting variously each of such translating devices across the terminals of such supply-circuit in series with any desired one or ones of such windings and in parallel with the remaining one or ones, that the current traversing any portion of such windings can never exceed that traversing one of such translating devices.

31. A supply-circuit, a series of windings, means for connecting such windings together in series across the terminals of such supply-circuit, means for generating an electromotive force in such windings practically equal in amount and counter to the potential at the terminals of such supply-circuit, two translating devices, means whereby each of such translating devices may be variously connected independently across the terminals of such supply-circuit in series with any desired one or ones of such windings and in parallel with the remaining one or ones, and means whereby the electromotive force generated in the winding or windings connected across the terminals of such supply-circuit in series with and between such translating devices, is utilized in supplying the difference between the sum of the potentials impressed upon each of such translating devices taken singly, and the potential impressed by such supply-circuit upon the terminals of the circuit containing such translating devices and such winding or windings in series with and between such translating devices.

32. A supply-circuit, a series of windings, means for connecting such windings together in series across the terminals of such supply-circuit and for generating an electromotive force in each of such windings with the values of the electromotive forces in such windings forming one or more progressions practically geometrical, two translating devices, and means whereby each of such translating devices may be variously connected independently across the terminals of such supply-circuit in series with any desired one or ones of such windings and in parallel with the remaining one or ones.

33. A supply-circuit, a system of magnetic poles, an armature in operative relation thereto and connected across the terminals of such supply-circuit, a translating device, and means whereby such translating device may be connected across the terminals of such supply-circuit in series with any desired portion of the conductors of such armature and in parallel with the remaining portion thereof.

34. A supply-circuit, a system of magnetic poles, an armature in operative relation thereto and connected across the terminals of such supply-circuit, two translating devices, and means whereby each of such translating devices may be connected independently across the terminals of such supply-circuit in series with any desired portion of the conductors of such armature and in parallel with the remaining portion thereof.

35. A supply-circuit, a series of windings each connected to a commutator, means for connecting such windings together in series across the terminals of such supply-circuit and for generating an electromotive force in each one of such windings, a translating device, and means whereby such translating device may be connected across the terminals of such supply-circuit in series with any desired one or ones of such windings and in parallel with the remaining one or ones.

36. A supply-circuit, a series of windings each connected to a commutator, means for connecting such windings together in series across the terminals of such supply-circuit and for generating an electromotive force in each of such windings, two translating devices, and means whereby each of such translating devices may be connected independently across the terminals of such supply-circuit in series with any desired one or ones of such windings and in parallel with the remaining one or ones.

37. A supply-circuit, a device of practically-constant electromotive-force-absorbing value connected across the terminals thereof, a translating device, and means whereby such translating device may be variously connected across the terminals of such supply-circuit in series with any desired portion of such electromotive-force-absorbing device and in parallel with the remaining portion thereof.

38. A supply-circuit, a device of practically-constant electromotive-force-absorbing value connected across the terminals thereof, two translating devices, and means whereby each of such translating devices may be variously connected independently across the terminals of such supply-circuit in series with any desired portion of such electromotive-force-absorbing device and in parallel with the remaining portion thereof, such that for any such arrangement of such translating devices relative to such portions of such electromotive-force-absorbing device the volume of current traversing any portion of such electromotive-force-absorbing device can never exceed that traversing one of such translating devices.

39. Two pairs of elements, means for connecting one element of the first pair to a load to be driven at two or more different speed ratios, and means for imparting to the load rotary effort, first from said first pair of elements, then transferring the load to the second pair of elements at a different speed ratio, and then back again to said first pair at still a different speed ratio.

40. Two pairs of elements, means for connecting one element of the first pair to a load to be driven at two or more different speed ratios, means for imparting to the load rotary effort, first from said first pair of elements, then transferring the load to the second pair of elements at a different speed ratio, and then back again to said first pair at still a different speed ratio, and means for varying the rate of relative rotation between the elements of each pair while one of the elements of such pair is connected to the load.

41. Two pairs of elements, a first element of each pair permanently connected to a common load to be driven, and means for first connecting the second element of the first pair to the load at a given speed ratio, then transferring the load to the second pair at a different speed ratio for the second element of such second pair, and then back again to the first pair at still a different speed ratio for the second element of such first pair.

42. Two pairs of elements, a first element of each pair permanently connected to a common load to be driven, means for first connecting the second element of the first pair to the load at a given speed ratio, then transferring the load to the second pair at a different speed ratio for the second element of such second pair, and then back again to the first pair at still a different speed ratio for the second element of such first pair, and means for varying the rate of relative rotation between the elements of each pair while both of the elements of such pair are connected to the load.

43. Two pairs of elements, means for connecting one element of the first pair to a load to be driven at two or more different speed ratios, means for imparting to such load rotary effort from each of such pair of elements, and means for so varying the normal rate of relative rotation between the elements of each pair that such motors will both of them communicate rotary effort to such load when working together at each of such different ratios.

44. Two pairs of elements, means for connecting one element of the first pair to a load to be driven at two or more different speed ratios, means for communicating to such load rotary effort from each of such pair of elements, a supply-circuit to the terminals of which the armature of each of such pair of elements is arranged to be connected, means for generating an electromotive force be-

tween the terminals of such supply-circuit practically equal to the potential at such terminals, and means for so varying the amount of such electromotive force generated in series and that generated in parallel with the armature of each of such pair of elements that both of such pairs of elements when working together at each of such different ratios will communicate rotary effort to such load.

45. In an electric motor, means whereby a revoluble and load-carrying element of such motor may move angularly in either direction over a portion of a revolution of such element independently of the load, and means whereby during such independent motion from one extreme to the other thereof, the angle of lead of the brushes on the commutator of such motor is reversed.

WM. H. COOLEY.

Witnesses:

ALBERT C. BELL,

ETHA M. SMITH.