No. 896,738. PATENTED AUG. 25, 1908.

W. C. MAYO & J. HOULEHAN.

REGULATOR FOR DYNAMO ELECTRIC MACHINES.

APPLICATION FILED JUNE 27, 1907.

3 SHEETS—SHEET 1.

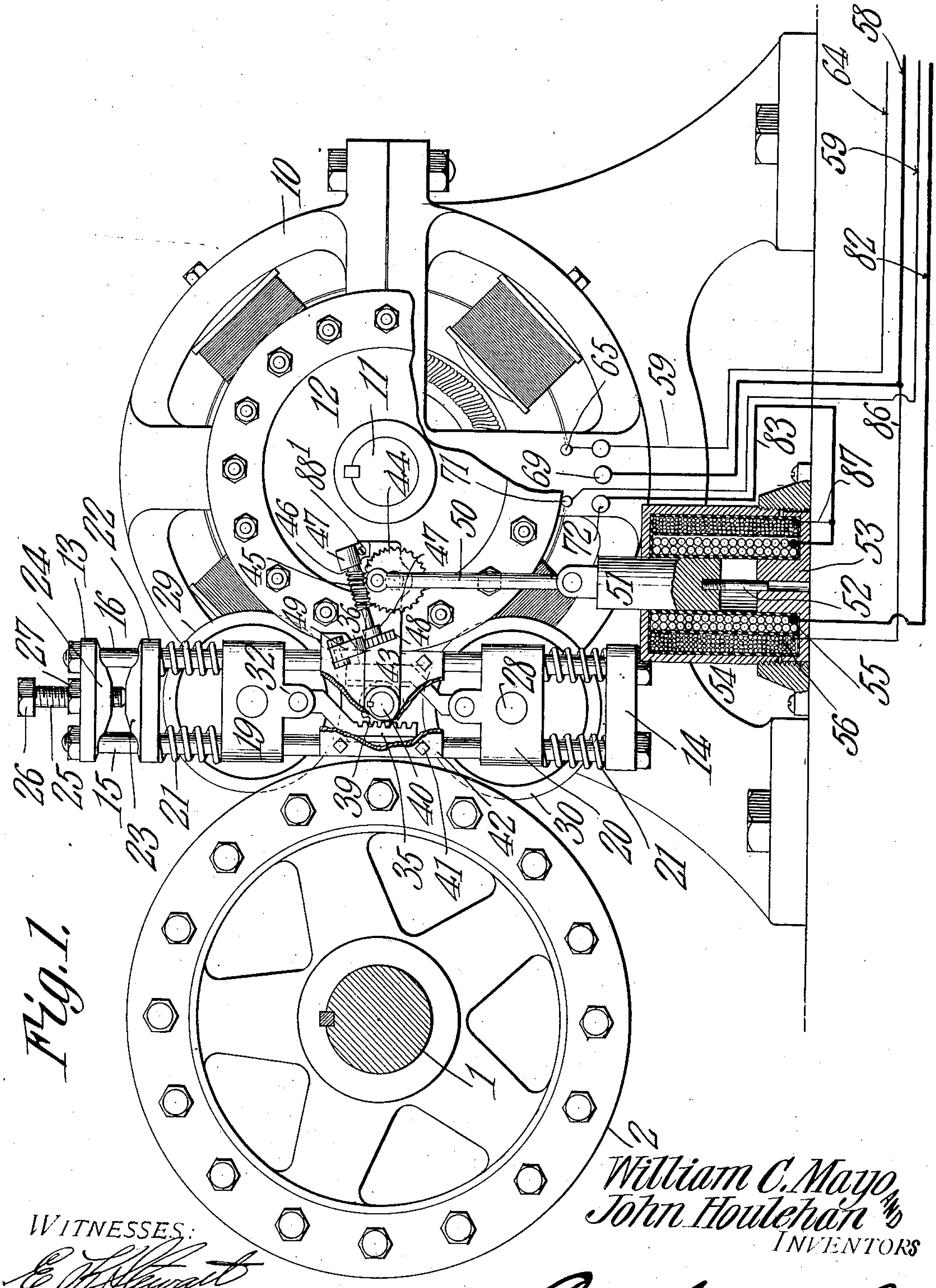

Fig. 1.

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Fig. 2.

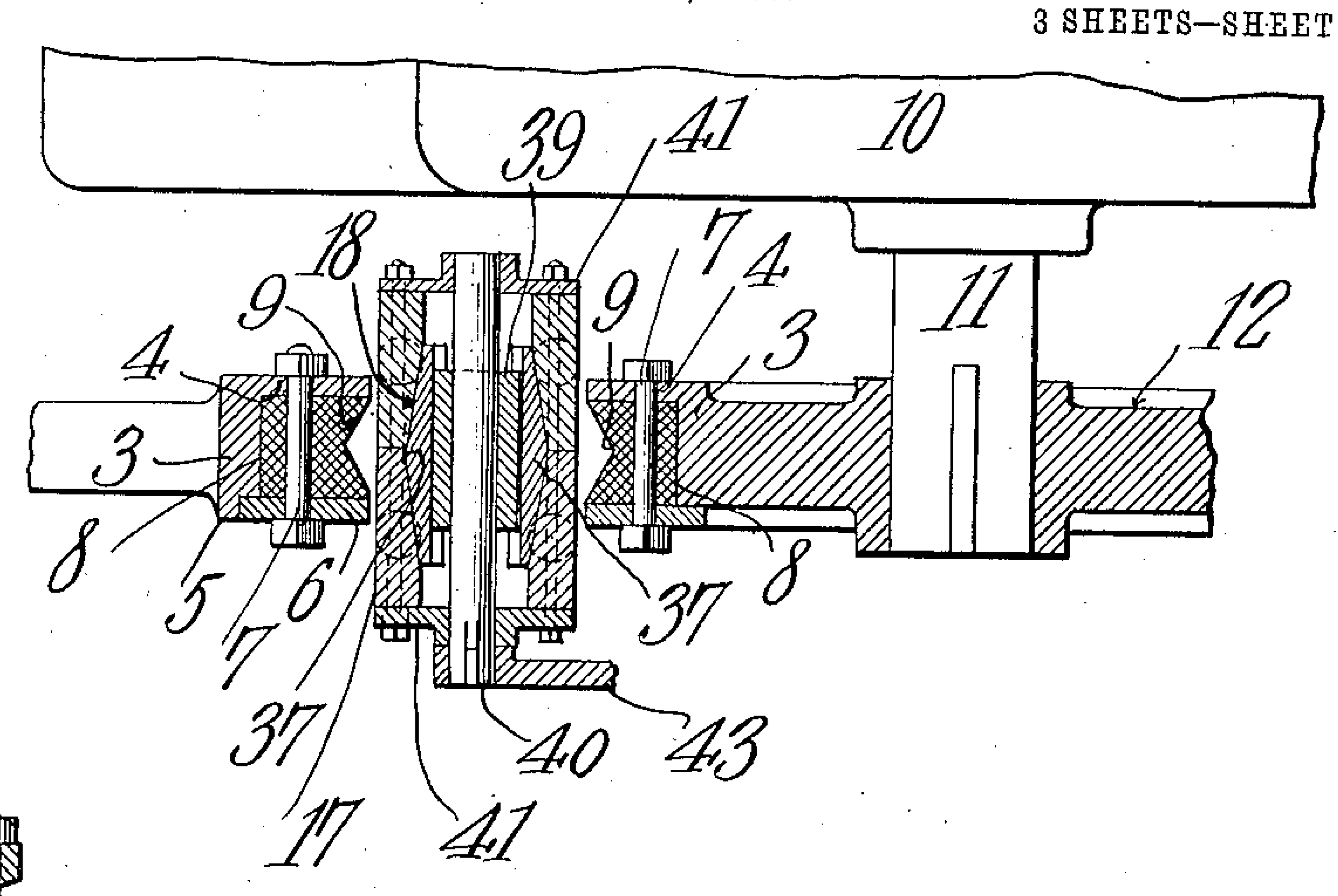


Fig. 3.

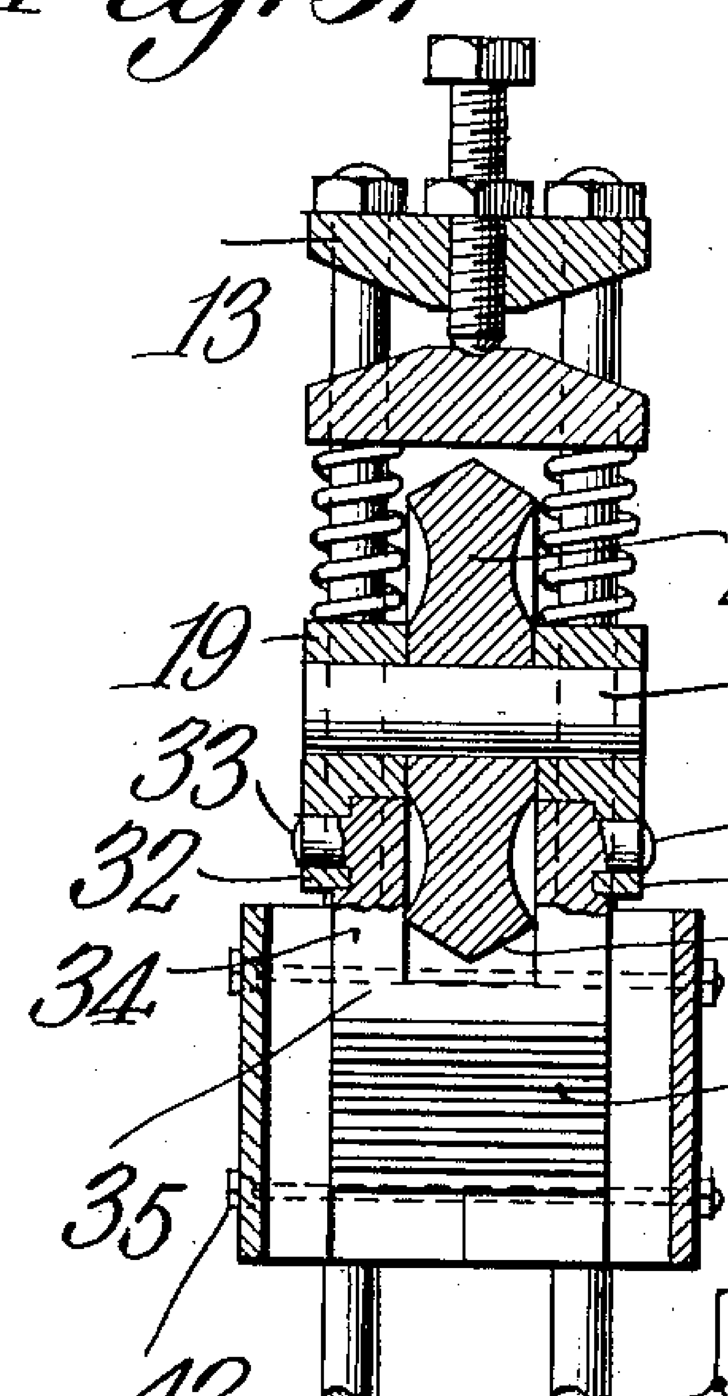
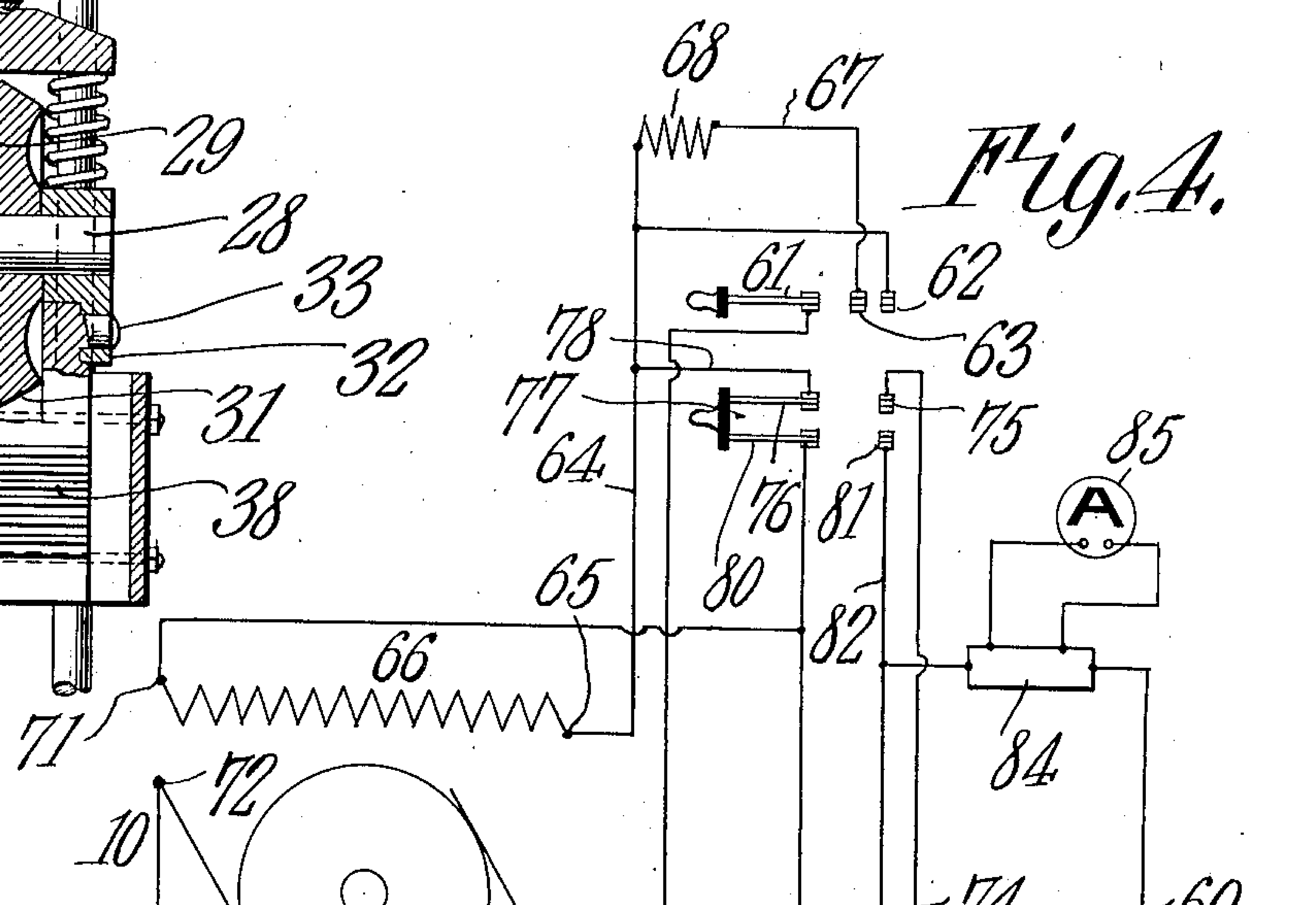
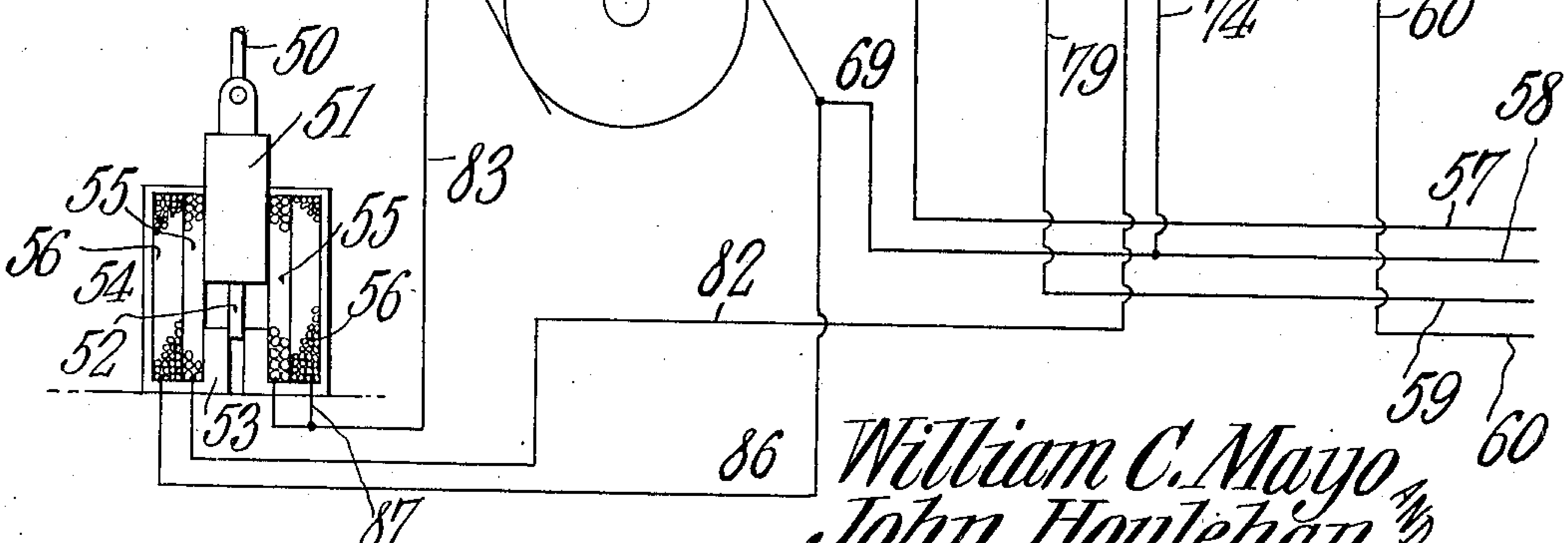


Fig. 4.

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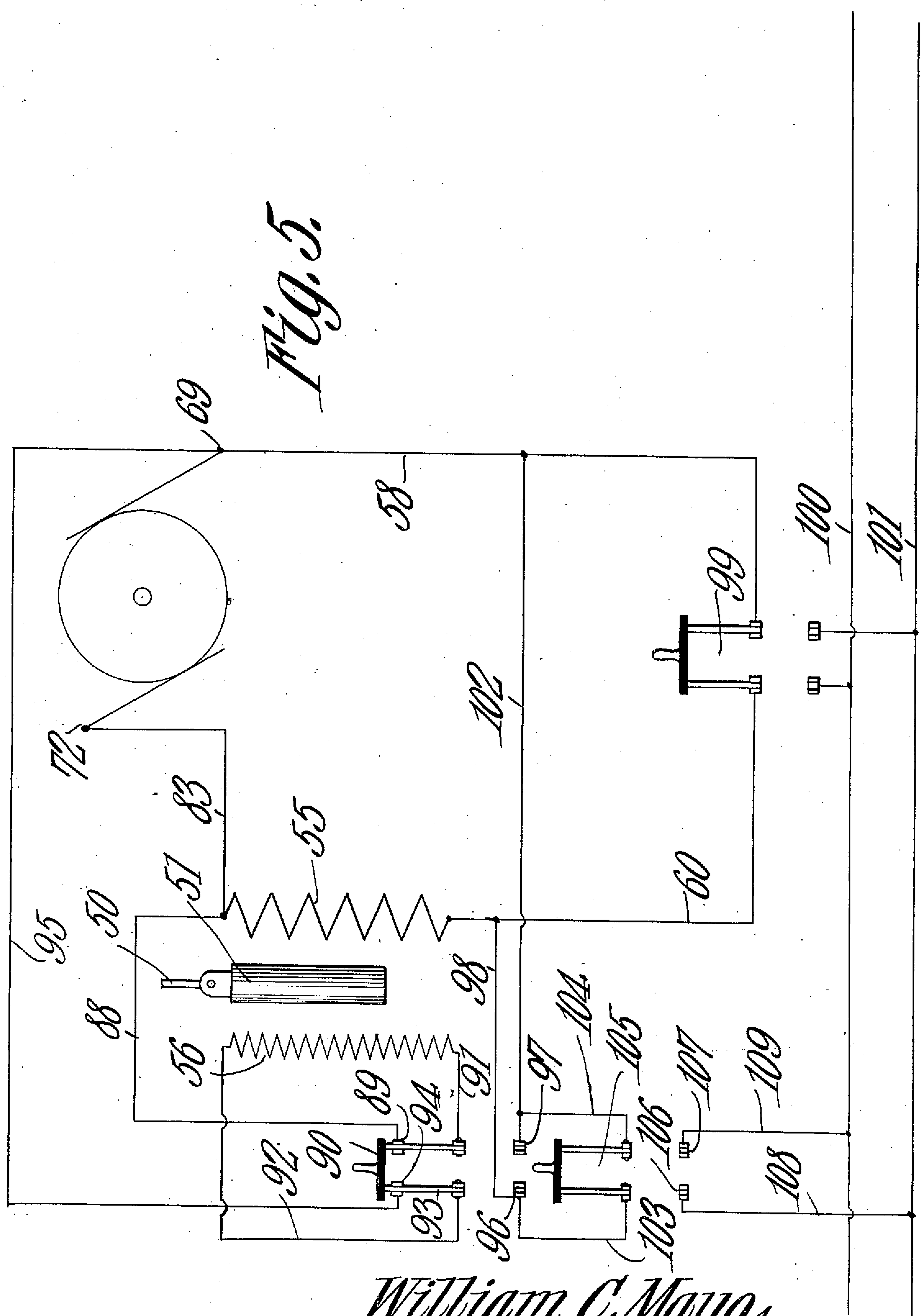

Fig. 5.

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UNITED STATES PATENT OFFICE.

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REGULATOR FOR DYNAMO-ELECTRIC MACHINES.

No. 896,738. Specification of Letters Patent. Patented Aug. 25, 1908.

Application filed June 27, 1907. Serial No. 381,072.

To all whom it may concern:

Be it known that we, WILLIAM C. MAYO and JOHN HOULEHAN, citizens of the United States, residing at El Paso, in the county of El Paso, State of Texas, have invented a new and useful Regulator for Dynamo-Electric Machines, of which the following is a specification.

This invention has reference to improvements in regulators for dynamo electric machines, and its object is to provide a means whereby the current strength of a dynamo may be maintained constant irrespective of the speed of the prime mover driving the dynamo and irrespective of the demand for current put upon the latter.

This invention is designed as a component part of our traction system, wherein each car is a unit utilizing an explosive engine as a prime mover and also utilizing electric current generated by power from the prime mover for various purposes connected with the operation of the train, whereby, through the coöperative action of the prime mover of the explosive or internal combustion type and a suitable electric generator or generators, all the necessary operations for the running of a car are made automatic except insofar as it may be necessary to place these operations, otherwise automatic, under the control of an operator, whose judgment is to be depended upon only where it is impossible to control certain operations automatically.

In our system an electric generator is employed for the production of current to be used in many ways. For instance, we propose to use a current from the generator for lighting, for the energization of magnets and solenoids operating valves and other parts, for supplying current for signaling purposes, for special tractive purposes on starting, and so on. While many such devices can be operated by alternating current, others are better operated by direct current, and since we believe that the use of direct current will be found more advantageous for our purposes the present invention has been directed more particularly to the use of a direct current generator of the bipolar or multipolar, shunt-wound type.

The prime mover, which, in itself, forms no part of the present invention, is designed to be an explosive or internal combustion engine, running at appreciably constant speed whatever may be the demand for power made upon the engine up to the limit of its output. It is, nevertheless, impossible to provide at all times so close a regulation of the engine as to permit the successful maintenance of a constant voltage at the dynamo. It is sufficient to state here, however, that for the purposes of our system as a whole constant voltage is desirable if not practically necessary.

It is the object, therefore, of the present invention to provide means whereby the current strength on the line shall be maintained sensibly constant even though there be wide variations in demand for current and even though the prime mover should vary to some extent from constancy of speed.

It is not to be understood that there are to be no variations whatever in voltage in the system, for it is upon the slight variations in voltage that we depend for the operation of our regulator, but the mechanism which we have devised for governing the speed of the dynamo with relation to the current strength is so sensitive to variations in current strength and so quickly establishes the dynamo speed for the predetermined voltage that these variations are not at all detrimental to the working of the system. Now, if but a single dynamo were to be used, a mechanical governor to maintain the dynamo at constant speed and the usual field rheostat to adjust the voltage to the load would be advisable and, to a limited extent, more efficient and more economical than the regulator which we have devised. But such a regulator is out of the question in our system since we provide each car of a train with a complete tractive and generating system. In other words, each car is a complete unit which may be separately operated as a motor car or a number of such units may be used together as a train in a manner similar to the electrical operation of trains by the master-control system, although we have devised means very different from those employed in such systems.

In our system each car of a train is provided with an engine and a dynamo, and the dynamos will be coupled up for parallel operation. In such case the amount of current each machine will send to line is directly proportionate to its voltage and size.

Hence, all the machines must be maintained at the same voltage in order that each machine may deliver current to the line in proportion to its size, although usually the several dynamos will be of the same size. Since it is impossible in such a system for an attendant to inspect each machine and so ascertain its output and variations and adjust the field rheostat from time to time, and since purely mechanical governors are out of the question, it becomes necessary to provide means for maintaining the voltage constant which shall be entirely automatic in action and maintain a very close regulation of each machine independent of every other machine and independent of variations in the speeds of the prime movers, but controlled entirely by and quickly responsive to voltage variations in each machine from a predetermined constant voltage to be maintained.

In order to meet the various conditions we have enumerated, we have devised a drive connection between the prime mover shaft and the dynamo shaft, which drive is of the friction type and is responsive to and governed by the current conditions in the dynamo.

To impart a clear understanding of the invention and the manner in which we incorporate it in practical form, we will now proceed to describe the embodiment of the invention, having particular reference to the accompanying drawings, in which,—

Figure 1 is a side elevation, with parts in section and other parts diagrammatically represented, of a dynamo, so much of a prime mover as is necessary for the understanding of the invention, and an interposed friction drive together with the electrical control therefor; Fig. 2 is a cross section through the friction drive and the adjacent parts on a line with the dynamo shaft, with parts shown in elevation; Fig. 3 is a vertical section through the upper portion of the friction drive to the axis of the intermediate drive pulley; Fig. 4 is a diagram of the electrical connections, including the switches; and Fig. 5 is a diagram of the electrical connections whereby the solenoid coils are connected up in different ways.

Referring to the drawings, there is shown a shaft 1 which may be considered as the main shaft or as connected to the main shaft of a prime mover. We may state that this prime mover, in our system, will consist of a multi-cylinder engine of the internal combustion or explosive type, with means which we need not here describe for maintaining the engine at a constant speed under reasonably close regulation, irrespective of the load placed upon the engine within the limits of its power output. Mounted upon the shaft 1 there is a drive wheel 2 which, because of the heavy load it is intended to transmit, is made of massive construction. The rim 3, it will be seen from Fig. 2, is formed on one side with an annular, radial flange 4 and on the other side with an annular groove or seat 5. Fitted to the seat 5 there is a ring 6 projecting radially from the rim 3 so that its outer edge is coincident with but spaced from the outer edge of the annular flange 4, and the ring 6 is secured to the drive wheel 2 by means of bolts 7 passing through the ring 6 and flange 4. There is thus formed an annular channel in the periphery of the wheel in which is seated a ring 8 of vulcanized fiber or other suitable material to constitute the friction driving portion of the wheel 2. After the parts of the wheel 2 have been properly assembled the wheel is placed in a lathe and the outer edge or periphery of the fiber member is turned down to true shape, with its surface in the form of an expanded V, as indicated at 9, although any other suitable shape may be given to the driving surface of the wheel.

The dynamo, indicated generally by the reference numeral 10, may be of any suitable type and since its structure forms no part of the present invention it is not necessary to give any particular description of this dynamo herein. It is sufficient to state that the dynamo is of the direct current, shunt-wound type, capable of close regulation for constant voltage.

Mounted upon the shaft 11 of the dynamo is a pulley 12 which, for fly-wheel purposes, may be made as massive as desired and by its inertia will aid in preventing sudden variations in the speed of the dynamo. This pulley is provided with a rim 3 and flange 4 with a fiber ring 8 having a V-shaped bearing face 9, all as described with reference to the wheel 2. In fact, the wheel 2 and pulley 12 are in all essential particulars identical, except as to diameter, since it may be advisable to make the pulley 12 smaller than the drive wheel 2 in order that the dynamo may run at a higher speed than the shaft 1 of the prime mover.

In order to transmit motion from the drive wheel 2 to the pulley 12 we have devised a friction drive which we will now proceed to describe. There are two end plates 13—14 connected together by two pairs of rods 15—16 passing through the corners of the plates 13—14, which are preferably rectangular in outline. Each rod 15 and each rod 16 is formed with a flat central enlargement 17 of such size that the two enlargements 17 of a pair of rods 15 or 16 are in contact between the rods and extend in the same plane beyond the latter, while the inner faces of one pair of enlargements 17 are parallel to the corresponding faces of the other pair of enlargements 17. These facing portions of the enlargements 17 are provided with V-shaped recesses or grooves 18 in the direction of the length of the rods 15 and 16, for a purpose which will presently appear. Sliding upon each set of rods 15 and 16 are two blocks 19 and 20, there being two blocks 19 and two blocks 20, and each block is provided with through passages for the rods 15 and 16. Interposed between each block 20 and the plate 14 are heavy helical springs 21 surrounding the rods 15 and 16, and similar springs 21 are interposed between each block 19 and a rectangular follower plate 22 carried by the rods 15 and 16 below the plate 13. The follower 22 is formed with a central boss 23 and the plate 13 is formed with a similar boss 24, and through this latter named plate 13 there is formed a suitable nut for an adjusting screw 25 having a head 26 by means of which it may be turned, and provided with a clamp nut 27 so that the screw 25 may be fixed in any adjusted position.

Suitably mounted in the pair of blocks 19 is the journal 28 of a transmission friction drive pulley 29, and suitably mounted in the blocks 20 is the journal 28 of another similar friction drive pulley 30. While these journals 28 are shown as mounted directly in the blocks 19 and 20, it will be understood that they may be mounted on roller bearings or any other anti-friction type of bearings may be used, or suitable journal boxes may be provided so that adjustment may be made for wear. Or, again, the journals may be held against rotation and the pulleys 29 and 30 may rotate thereon with any desirable or suitable type of bearing interposed between the pulleys themselves and their journals. These pulleys may, of course, be made of any material suitable for the purpose; but we prefer to make these pulleys 29 and 30 of aluminum since it has been found that the combination of aluminum with the vulcanized or indurated paper fiber constitutes one of the best known combinations for friction drives. The rims 31 of the pulleys are made V-shape to correspond with and seat themselves properly in the V-shaped grooves 9 of the friction surfaces of the wheel 2 and the pulley 12.

The enlargements 17 of the rods 15 and 16 are located in the plane of the drive shaft 1 and dynamo shaft 11, while the blocks 19 and 20 are located above and below this plane, respectively, so that the pulley 29 engages the drive wheel 2 and the pulley 12 above the common plane of the shafts, and the pulley 30 engages the drive wheel 2 and pulley 12 below the common plane of the shafts. The opposing edges of the blocks 19 and 20 are provided with ears 32 in which engage lugs 33 formed on and projecting oppositely from the legs 34 of yokes 35—36, the yoke 35 being carried by the blocks 19 and the yoke 36 being carried by the blocks 20. The legs 34 of the yokes are bent so that these yokes are brought into contact with the enlargements 17 on the respective pairs of rods 15 or 16; that is, the yoke 35 bears against the enlargements carried by the rods 15, while the yoke 36 bears against the enlargements carried by the rods 16. That face of the yoke 35 or 36 which is in engagement with the respective enlargement on the rods 15 or 16 is formed with an expanded, V-shaped projection 37 fitting the V-shaped groove 18 formed in the corresponding enlargements 17. Since, as will presently appear, these yokes have a certain amount of longitudinal movement, it will be seen that the parts 37 engaging in the grooves 18 serve to guide the yokes during their travel. The yoke 35 extends downward past the plane cutting the drive and dynamo shafts, while the yoke 36 extends upward past said plane, but these two yokes are spaced apart at this point and those faces of the yokes which are toward each other are provided with gear teeth 38. Arranged to be in constant engagement with these gear teeth is a pinion 39 mounted upon a journal 40 having bearings in end plates 41 fast on the projecting ends of the enlargements 17. These plates 41 are secured by through bolts 42 extending not only through the plates 41 but entirely through the enlargements 17, thus binding the whole structure together.

It will be seen that the friction pulleys 29 and 30 engage the drive wheel 2 and pulley 12 on opposite sides of the common plane cutting the shafts of these two structures, while the springs 21 tend to force the drive pulleys 29 and 30 toward each other. The space between the drive wheel 2 and pulley 12 is too small for these pulleys 29 and 30 to pass, and, consequently, they are brought into contact with the drive wheel 2 and pulley 12 with a force commensurate with the tension of the springs 21, which tension may be regulated by the screw 25, as will be readily understood. Therefore, when the drive wheel 2 is rotated the pulley 12 will receive motion therefrom through the intermediary of the friction pulleys 29 and 30, and these latter pulleys will impart to the pulley 12 a speed corresponding to the speed of the drive wheel 2 so long as the load upon the pulley 12 does not exceed the grip of the pulleys 29 and 30 upon said pulley 12. When, however, the load on the pulley 12 exceeds this frictional grip, the pulleys 29 and 30 will slip on the pulley 12 and the speed of the latter will then not be commensurate with the speed of the drive wheel 2.

Now, as has already been stated, it is necessary that the speed of the pulley 12, which means the armature speed of the dynamo 10, shall be sensibly constant or suitably varied in order that the voltage output of the dynamo may be kept sensibly constant. It is also the purpose to maintain the speed of the drive wheel 2 sensibly constant. But absolute uniformity of speed of the drive wheel 2 is out of the question, while a constant frictional contact between the pulleys 29 and 30 and the pulley 12 will not serve to maintain the pulley 12 at a proper speed, since the load on the dynamo 10 may vary to a considerable extent. Now, the variation of speed of the prime mover, so long as its minimum speed is sufficient for the purpose, and the variation of load upon the dynamo, may be both counteracted by adjusting the frictional contact of the pulleys 29 and 30 with the drive wheel 2 and pulley 12, so that the speed of the pulley 12 may be maintained as nearly constant as is necessary for all practical purposes, so as to maintain a sensible constancy of voltage output for the dynamo. For this purpose the shaft 40 of the pinion 39 is extended beyond one of the plates 41 in which it has journal bearings, and there it has keyed to it a lever 43. On the outer end of this lever there is mounted a worm wheel 44 engaging a worm 45 fast on a shaft 46 journaled at 47—47 upon the lever 43. This shaft 46 carries at the end toward the axis of the lever 43 a ratchet wheel 48 in the path of a pawl 49 carried by a corresponding end plate 41. The arrangement is such that when the lever 43 is moved in one direction about its axis, the pawl 49 will engage one of the teeth of the ratchet wheel 48 and rotate the shaft 46 a distance corresponding to the extent of movement of the lever 43, and when this movement becomes great enough the pawl 49 will ultimately engage a second tooth, and so on, causing the rotation of the worm wheel 44 about its axis.

Pivotally secured to the worm wheel 44 at a point eccentric to the axis thereof is a link 50, the other end of which is pivotally connected to a solenoid core or armature 51, which latter may be of the usual type and is provided with a guide stem 52 entering a suitable perforation in a base 53 constituting a pole piece of a solenoid 54. This solenoid is preferably of the iron-clad type for obvious magnetic and mechanical reasons.

The solenoid 54 is, in the present instance, composed of a coarse wire coil 55 and a fine wire coil 56. As will hereinafter appear, the coarse wire coil is in series with leads from the dynamo, while the fine wire coil is in parallel with leads from the dynamo, and these two windings will be referred to as the series and parallel windings of the solenoid. It is not necessary to enter into any particular description of the structure of the solenoid, since it may be of the familiar iron-clad type and will be suitably wound for the purposes of the invention.

Referring, now, to the electrical connection shown in Figs. 1 and 4, it may be observed that there are four train line wires 57, 58, 59 and 60, the purposes of which it is unnecessary to consider in this particular case but which, it may be stated, are necessary for the purposes of our general system. They are here used as the armature and field leads.

The train line wire 57 is connected to one terminal of a switch 61 which may be located upon a suitably organized switch-board, only diagrammatically represented in Fig. 4. In the path of the arm of the switch 61 there are two terminals 62 and 63. The terminal 62 is connected by a conductor 64 to one terminal 65 of the field winding 66 of the dynamo, and the other terminal 63 is also connected by a branch conductor 67 to the conductor 64, but includes a discharge resistance 68 between the terminal 63 and its point of connection with the conductor 64. This represents the usual discharge resistance switch contact.

The train line conductor 58 is connected to one terminal 69 of the armature winding, and is also connected by a branch conductor 74 to a switch-board terminal 75 in the path of one arm 76 of a double-arm switch 77. The arm 76 of the switch 77 is connected by a branch conductor 78 to the conductor 64 before referred to.

The conductor 59 is connected to the terminal 71 of the field winding and is also connected by a branch conductor 79 to the other arm 80 of the two-arm switch 77, and in the path of the arm 80 is a terminal 81 connected by a conductor 82 to one terminal of the series coil 55 of the solenoid, the other terminal of which latter is connected by a conductor 83 to the armature terminal 72. The conductor 82, after leaving the switch terminal 81, is connected to the usual ammeter shunt 84 including an ammeter 85 of suitable type, and to the other side of this shunt is connected the main line conductor 60.

Leading from the terminal 69 of the armature is a branch conductor 86 connected to one terminal of the parallel winding 56 of the solenoid, the other terminal of which winding is connected by a branch conductor 87 to the conductor 83 before referred to.

It is to be assumed, of course, that the various parts of the mechanism described are suitably proportioned for the purposes of the invention. No attempt has been made to show these proportions with exactitude, since this is a problem for the constructive engineer.

Assuming, therefore, that the machine is properly built for the purposes for which it is intended, the operation may be described as follows:—The mechanism is designed to cause the dynamo to have a constant voltage and to also adapt the machine to only such a given overload as will not injure the dynamo. The main switch, which will be hereinafter referred to, is included between the conductors 58 and 60, which conductors, it will be seen, lead from the dynamo terminals 69 and 72 and include the series winding 55 of the solenoid, and the other winding 56 of the solenoid is included in this circuit in shunt. The adjustment of the solenoid pull on the lever 43 and the adjustment of the screw 25 is such that the machine can carry its full load. First, however, consider the dynamo at no load. The engine is started and comes up to speed. Since a shunt dynamo will not build up on load, the main switch is opened. Now, when the dynamo is up to speed, the field switch 61 is closed, and when the voltmeter (not shown) indicates that a given voltage is reached, the main switch is closed. Now, assuming that the main switch is still open, and, therefore, there is no load on the dynamo, but that the proper voltage has been established, sufficient current now flows through the solenoid to produce an appreciable pull on the lever 43. Since but a very small separation between the pulleys 29 and 30 and the drive wheel 2 and pulley 12 would entirely disconnect the drive wheel from the dynamo, the lever may be so proportioned that a comparatively small pull will act to separate the drive. Now, it will take a given amount of voltage to compress the springs 21 sufficiently to cause the separation of the drive, and since the magnetism of the solenoid, acting through an air gap, is inversely proportional to the square of the distance, it will be understood that the length of the air gap should be such that the watt consumption of the solenoid will be sufficiently near to the necessary power to compress the springs as the mechanical construction of the device may require. With a given length of air gap and a given voltage, the main switch being open, the pull of the solenoid will be a constant factor. Should the engine shaft increase in speed, the dynamo will also increase in speed and the result will be an increased voltage, since no means are used to decrease the field strength on the increase of voltage. There will, however, be an increase of current in the parallel winding of the solenoid and the pull of the latter therefore becomes greater. The frictional contact between the parts of the friction drive will thereby be made lighter and a certain slip will be permitted until an equilibrium is established between the voltage output acting on the solenoid and the frictional contact at the friction drive. Thus a constant voltage is maintained at the dynamo terminals when there is no load on the dynamo. If, now, the main switch be closed and the load be gradually applied, the voltage, while maintained at a certain point irrespective of the variations of speed in the prime mover within a reasonably small limit, will be gradually lowered by the increasing load. This lowering of the voltage will result in lessening the pull on the lever 43 but it cannot bring the voltage up completely since when the dynamo is doing work more friction is needed at the drive both to take care of the load and to maintain a slightly greater speed for the extra voltage needed. If, now, the pull of the solenoid should be decreased in the same ratio as the load increases, the parallel winding would act to govern the voltage independent of the load. If this action were to directly decrease the magnetic effect of the turns of the parallel winding in the same ratio as the increase in load, then even though acting in opposition and on the parallel winding the governing factor would be undisturbed. This desirable effect we obtain from the series winding connected to oppose the parallel winding, since, with the exception of the current through the fields and parallel winding of the solenoid, constituting constant and therefore negligible factors, all the current flows through the series winding, the value of the magnetic effect of the series winding, and, hence, its effect to oppose the parallel winding, is in exactly the same ratio as the rise of current due to the increase in load, thus exerting such a pull on the lever 43 as will maintain the voltage constant regardless of speed or load variation.

Now, as before stated, our complete system requires the use of electric generators on each car of a train. Therefore we place all the dynamos in parallel so that each may do its proportion of the work irrespective of its size, though the dynamos are usually of a size, and to the end that the train line drop will be a constant factor from end to end of the train, and, therefore, to be allowed for with certainty. Moreover, this parallel coupling of the dynamos prevents the load from localizing due to a heavy demand for current, such as arc headlights; and, again, should a dynamo become crippled, its car can get current from the other dynamos since all the cars are connected through suitable coupling cables.

Since in the parallel operation of dynamos the voltage must, as is well known, be maintained constant and at the same point in the several dynamos, and since in a train system such as our complete system contemplates field rheostats and mechanical governors are out of the question, the necessity of truly automatic governors which will act with certainty becomes at once apparent.

When a number of dynamos are used upon a train and connected up in parallel the fields are connected across the line outside the main switch. In such case, the switch 77, which may be termed a field transfer switch, is closed, and not the field switch 61 as in single car operation, and the fields are charged at once from line. After the voltmeter shows the correct voltage the main switch may be closed. After starting all the dynamos the one which had the field switch closed first should now have the transfer switch closed and then only may its field switch be opened.

Under some circumstances it may be found necessary to vary the manner in which the windings of the solenoid are connected up. For instance, all the parallel windings of all the solenoids may be connected across the line instead of the dynamo terminals by means of a transfer switch similar to the switch 77, and other connections may be made as the exigencies of the particular case may demand.

The number of turns in the series windings of the solenoids will always be small and the number of ampere turns will be but a fraction of the number of ampere turns of the parallel windings upon which the bulk of the work will fall. Suppose a certain dynamo should attempt to hunt and start to furnish too much current to the line, thus taking too much load. This, of course, passing through the series coil of the solenoid would assist the parallel winding and the resultant pull on the lever 43 would be greater, thus lowering the speed of the machine and bringing the voltage back to its proper load condition. On the contrary, should a dynamo fail to supply its proper amount of current to the line, the parallel coil, robbed of the assistance of the series coil, would allow the solenoid pull to decrease, thus permitting the tension of the springs 21 to more strongly draw the friction pulleys into contact with the drive wheel 2 and dynamo pulley 12 and thus raising the speed of the dynamo and increasing the voltage until the equilibrium was again established. This is for multi-car operation, that is, when there is a train composed of two or more cars. For one car the series and parallel windings of the solenoid are in opposition, but for multi-car control the reverse is true.

The manner in which the parallel coil may be connected up for either single or multi-car control is shown in Fig. 5, in which figure the field and various connections shown in Fig. 4 are omitted for the sake of clearness of illustration.

In Fig. 5 it will be seen that there branches off from the armature side of the series coil 55 a conductor 88 leading to a terminal 89 in the path of one arm 90 of a suitable two-arm switch, which arm 90 is connected by a conductor 91 to one end of the parallel coil 56, the other end of which coil is connected by another conductor 92 to the other arm 93 of the aforesaid switch. In the path of the arm 93 is a terminal 94 connected by a branch conductor 95 to the terminal 69 of the armature. When the switch is closed on to the two terminals 89 and 94 it will be seen that the parallel coil 56 is connected up to the armature in the same manner as shown in Fig. 4.

In the path of the switch arms 90 and 93 are other two terminals 96 and 97. The terminal 96 is connected by a branch conductor 98 to the conductor 60 leading to the main switch 99, by means of which latter the armature is connected up to the main line conductors 100—101. The other terminal 97 is connected by a branch conductor 102 to the conductor 58. Branched off from the terminals 96 and 97 are other conductors 103—104 leading to a two-arm switch 105 in the path of which are terminals 106—107 connected by conductors 108—109 to the aforesaid main line conductors 100—101.

It will be seen that the switch arms 90 and 93 when placed in contact with the terminals 96 and 97 connect up the parallel winding 56 in the reverse direction to the armature than when these switch arms 90 and 93 are moved on to the terminals 89 and 94; and when the switch 105, which may be termed a transfer switch, is closed the coil 56 is likewise connected up to line. Now, since it is necessary in the operation of the system that for multi-car service the effect of the coils of the solenoid should be cumulative instead of in opposition, therefore, it is advisable to reverse that coil of the solenoid through which the least current passes irrespective of the energy developed in the coil. Although the coil 56 has the greater number of ampere turns, still since the entire current of the dynamo passes through the series winding such current is necessarily greater in this winding even though the energy developed is less because of its fewer ampere turns. For this reason it is advisable that the parallel or shunt winding be reversed rather than the series winding. By the arrangement shown in Fig. 5 it will be seen that the shunt winding can be thrown across the dynamo leads in opposition to the series winding of the solenoid for single-car operation, and when more than one car is included in the system this shunt winding can be thrown across either the dynamo leads or the line in a direction opposite to the first, so that it may then aid the series coil.

Considering a line through the train of suitable size to carry the average current and load properly distributed along the line in the various cars, it is clear that the voltage on said line is of a value which is an average of the voltage existing at the terminals of the several machines, and that such machine voltage, because of the various conditions present in each individual machine, will be slightly in excess or slightly below the general line voltage and each machine must therefore be adjusted to allow for this. To a limited extent this is also true of the solenoids and other coils. In operation, therefore, it may be found that a particular machine regulates better with the shunt winding directly across the line, while, on the contrary, another machine in the system may work most efficiently with the shunt winding of its solenoid across its own leads, without, however, entailing any change in the direction of the current through the shunt winding unless the reverse switch is thrown.

The discharge resistance 68 is of the usual type and is used for the usual purpose of protecting the field, etc.

It has already been stated, and may be here repeated, that the air gap in the solenoid must be kept constant. But account must be taken of the fact that there is wear between the bearing faces of the pulleys 29 and 30 and the bearing surfaces of the drive wheel 2 and pulley 12. The result of this wear is that these pulleys will be closer and closer together as their bearing faces or the fiber bearing faces wear away. Hence, the air gap between the end of the solenoid armature 51 and the pole piece 53 is therefore increased by the approach of the pulleys 29 and 30 toward each other. There is, of course, a permissible latitude of variation of the air gap, but in order that this variation may be kept within narrow limits the pawl-and-ratchet adjusting device for the worm gear controlling the link 50 is provided, so that as the pulleys 29 and 30 approach each other because of wear, the shaft 46 is correspondingly rotated by the engagement with the ratchet wheel 48 of the pawl 49, and the effective distance between the lever 43 and the solenoid armature 51 is increased in due proportion. The effect of this is that the air gap between the solenoid armature and the pole piece 53 is maintained as nearly constant as is found necessary for practical purposes. Ultimately, however, the worm gear is acted upon and the friction surfaces wear to such an extent that the pivotal point of the link 50 with the worm wheel 44, which, in starting, is vertically above the axis of said wheel, will reach a point directly beneath the axis of said wheel. When this condition of affairs takes place it is necessary to replace the wearing surfaces since the limit of automatic adjustment has been reached.

It may be noted that the pulleys 29 and 30 are of such thickness as to enter between the flange 4 and the ring 6 as the fiber 8 wears away.

While not so shown in the drawing, it will be understood that suitable means may be provided for adjusting the initial distance between the solenoid armature and the lever 43, so that the solenoid armature may be adjusted primarily to the most advantageous position. It is desirable, also, that the worm shaft should move stiffly in its bearings, and, therefore, the bearing 47 at the end of the lever 43 may be split and a tightening screw 88′ may be used to regulate the amount of grip the bearing may have upon the shaft.

We claim:—

1. A regulator for dynamo electric machines for maintaining a predetermined voltage, comprising a means for varying the application of power to the dynamo rotor, means responsive to different characteristics of the current generated by the machine, and means for causing the effects of the different characteristics of the generated current to act in the same sense or in opposition.

2. A regulator for dynamo electric machines for maintaining a predetermined voltage, comprising means for varying the application of power to the dynamo rotor, means responsive to variations in voltage to vary such application of power, means responsive to the current delivered by the dynamo to vary the application of power, and other means for causing the effects of the voltage variations and the effects of the current variations to act in the same sense or in opposition.

3. A means for maintaining a predetermined voltage in an electric power circuit, comprising a dynamo electric machine, means for varying the application of power to the dynamo rotor, a solenoid having two coils, one connected in series with the dynamo and the other across the dynamo leads, connections between the solenoid armature and the drive element, and means for coupling up the solenoid coils for action upon the armature either in the same sense or in opposition.

4. A means for maintaining a predetermined voltage in an electric power circuit, comprising a dynamo electric machine, means for varying the application of power to the dynamo rotor, a solenoid having two coils, one connected in series with one of the dynamo leads and the other across the dynamo leads, connections between the solenoid armature and the drive element, and a reversing switch in the circuit of one of the coils for coupling it up for action upon the solenoid armature either in the same sense as the other coil or in opposition thereto.

5. A regulator for dynamo electric machines, comprising a drive element for said machine, a solenoid having two coils, one connected up in series with one of the dynamo leads, a reversing switch in the circuit of the other coil for connecting it up for action on the solenoid armature either in the same sense as the series coil or in opposition thereto, and connections between the solenoid armature and the drive element.

6. A regulator for dynamo electric machines, comprising a drive element for the machine; a solenoid having a coil in series with one of the dynamo leads; another coil upon the solenoid connected across the dynamo leads; means for reversing the direction of current through the last-named coil, and connections between the armature and the drive element.

7. A regulator for dynamo electric machines, comprising a drive element for the machine; a solenoid having a coarse wire coil in series connection with one of the dynamo

leads, and a fine wire coil; a reversing switch and connections for the fine wire coil across the dynamo leads, and connections between the armature and the drive element.

8. A regulator for dynamo electric machines, comprising a drive element for the machine; a solenoid comprising a coarse wire coil in series with one of the dynamo leads, and a fine wire coil connected across the dynamo leads; means for reversing the direction of current through the fine wire coil; means for connecting the fine wire coil in shunt to the line, and connections between the armature and the drive element.

9. A regulator for dynamo electric machines, comprising a drive member, a driven member, intermediate friction pulleys between the drive member and the driven member, means for causing the pulleys to grip the drive and driven members, means for moving the pulleys away from the drive and driven members, a solenoid having a coil in series with one of the dynamo leads and another coil connected across the said dynamo leads, means for reversing the direction of current through the second coil, an armature for the solenoid, and connections between said armature and the means for separating the intermediate pulleys from the drive and driven members.

10. A regulator for dynamo electric machines, comprising a drive member, a driven member, intermediate friction pulleys between the drive member and the driven member, means for causing the pulleys to grip the drive and driven members, means for moving the pulleys away from the drive and driven members, a solenoid having a coil in series with one of the dynamo leads and another coil connected across said dynamo leads, means for reversing the direction of current through the second coil, means for coupling the said second coil in shunt connection to the line, an armature for the solenoid, and connections between said armature and the means for separating the intermediate pulleys from the drive and driven members.

11. A regulator for dynamo electric machines comprising a prime friction drive element; a driven element for the rotor of the dynamo; intermediate friction pulleys between the drive and driven elements; means for moving the intermediate pulleys in unison toward or from the drive and driven elements; a solenoid controlled by the current or voltage or both the current and voltage delivered by the dynamo, and a wear-compensating means between the solenoid armature and the friction drive responsive to increased range of movement between the solenoid armature and the friction drive to restore the relation of movement between these parts to keep the air gap in said solenoid constant.

12. A regulator for dynamo electric machines, comprising a prime power element, a friction transmission element between the prime power element and the rotor of the dynamo, a solenoid controlled by the current or voltage or both the current and voltage generated by the dynamo, and a wear compensating means between the solenoid armature and the friction drive rendered active by the wearing away of the friction surfaces to maintain the air gap in said solenoid constant.

13. A regulator for dynamo electric machines, comprising a friction drive for the dynamo rotor, a solenoid controlled by the current or voltage or both, means for moving the friction drive into and out of active relation with the dynamo rotor, an armature for the solenoid, connections between said armature and the means for controlling the friction drive, and a wear compensating means for changing the relation of the armature connection with the friction drive rendered active by the wearing away of the friction surfaces to take up such wear.

14. A regulator for dynamo electric machines, comprising a friction drive for the dynamo rotor, a solenoid controlled by the current or voltage or both, means for moving the friction drive into and out of active relation with the dynamo rotor, an armature for the solenoid, connections between said armature and the means for controlling the friction drive, and a wear compensating means for changing the relation of the armature connection with the friction drive to compensate for the wear of the friction surfaces, consisting in a link connected to the solenoid, a lever for controlling the friction drive, a rotatable eccentric connection between the link and lever, a ratchet and connections for rotating the eccentric carrying the link, and a pawl for moving the ratchet to vary the relative length of the link with reference to the lever as the said lever is moved by the solenoid armature.

15. A regulator for dynamo electric machines, comprising a prime friction drive element, a driven element for the rotor of the dynamo, intermediate friction pulleys between the drive and driven elements, journal supports for the friction pulleys, parallel rods upon which said journal supports are movable to carry the pulleys to and from the friction elements, springs upon the rods tending to force the journal supports in a direction to cause the pulleys to grip the friction elements, racks connected to the journal supports of the friction pulleys and located parallel to each other but spaced one from the other, a pinion engaging both racks to move them in opposite directions simultaneously, a lever connected to the pinion to rotate the same, a solenoid controlled by the current or voltage or both of the dynamo, and an armature for the solenoid connected to the lever.

16. A regulator for dynamo electric ma-

chines, comprising a friction drive element, a driven element for the rotor of the dynamo, intermediate friction pulleys between the drive and driven elements, journal supports for said pulleys, rods upon which said journal supports are movable, springs engaging said journal supports and carried by said rods, heads to which the ends of the rods are connected, another head movable on the rods and engaging the springs acting on one of the journal supports, a solenoid responsive to the current or voltage variations or both, and connections between the solenoid armature and the journal supports carrying the friction pulleys to vary the frictional grip of the pulleys with the drive and driven elements in accordance with the demand upon the dynamo.

In testimony that we claim the foregoing as our own, we have hereto affixed our signatures in the presence of two witnesses.

WILLIAM C. MAYO.
JOHN HOULEHAN.

Witnesses:
W. A. WARNOCK,
JOHN L. SPADER.