No. 690,420. Patented Jan. 7, 1902.

C. M. GREEN.

REGULATOR FOR DYNAMO ELECTRIC MACHINES.

(Application filed May 21, 1898.)

(No Model.) 2 Sheets—Sheet 1.

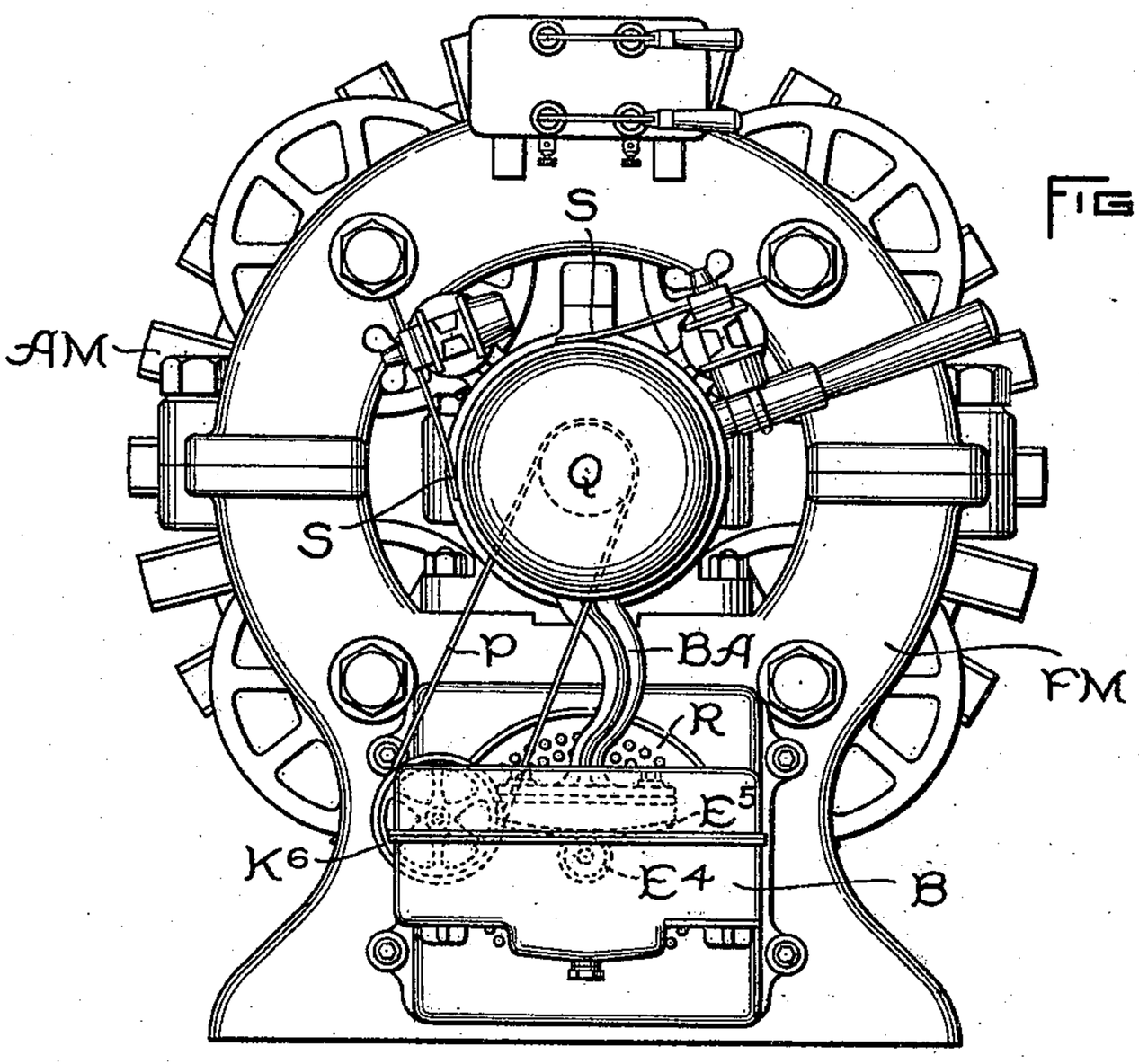

FIG. 1.

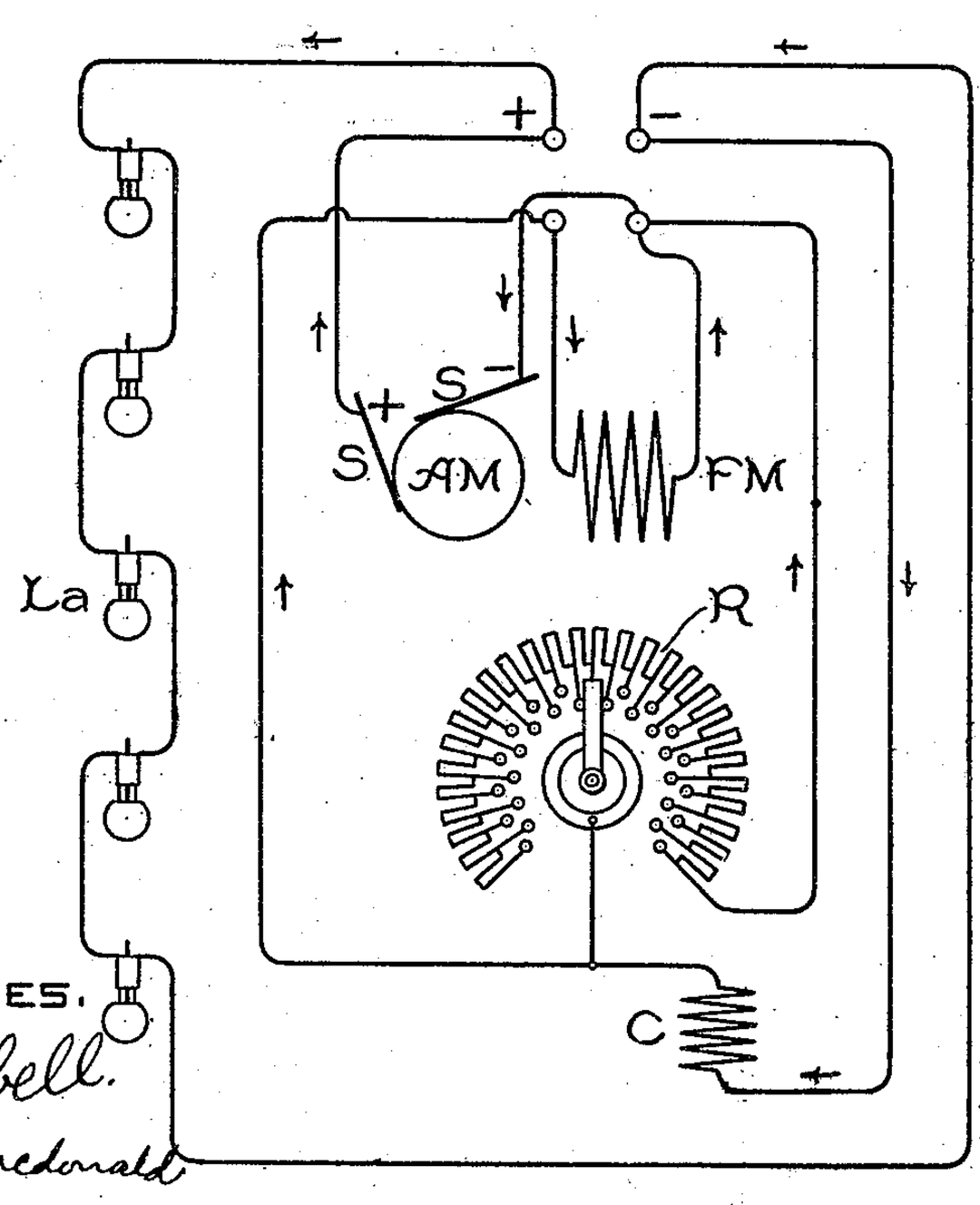

FIG. 2.

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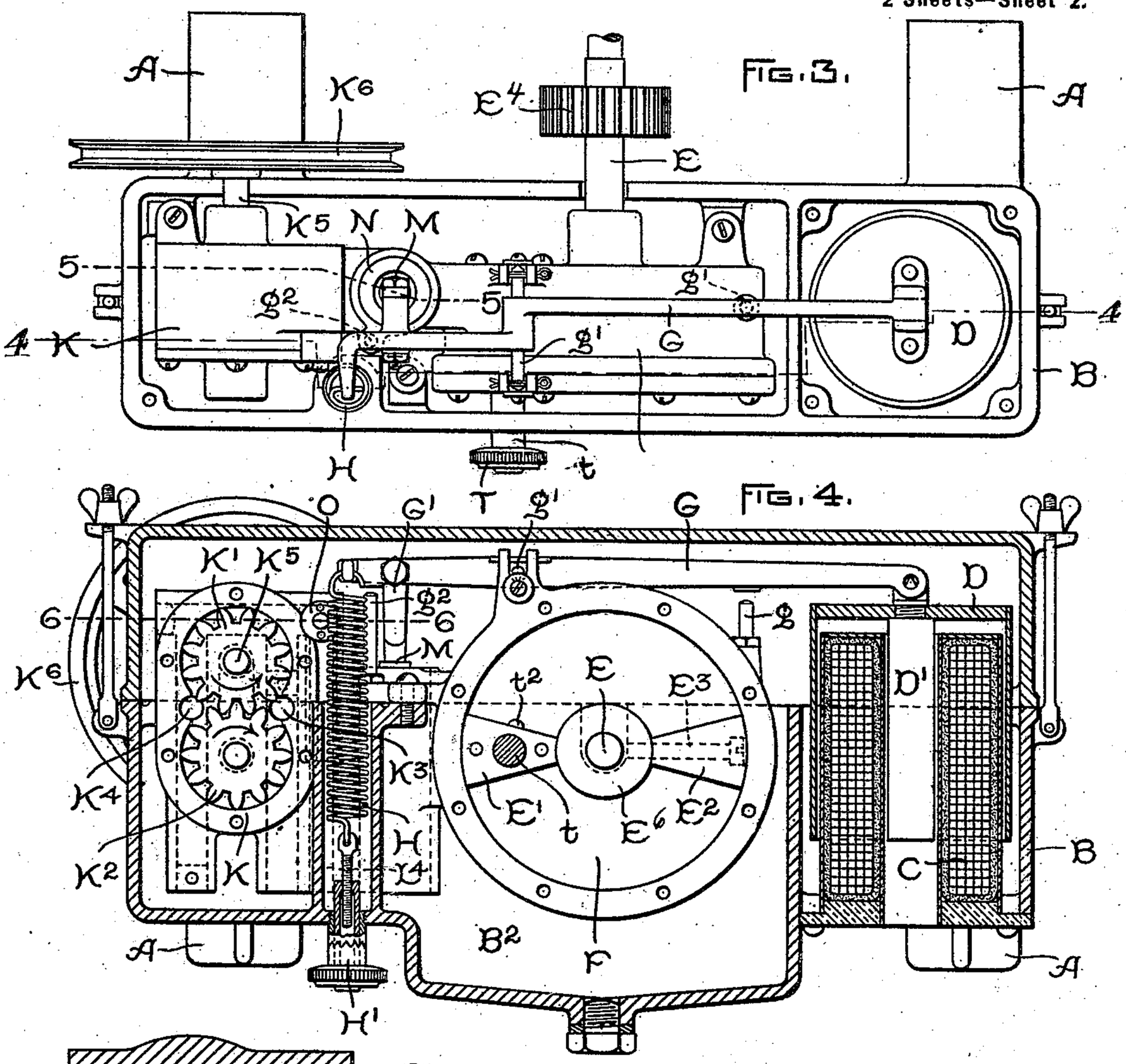

FIG. 3.

FIG. 4.

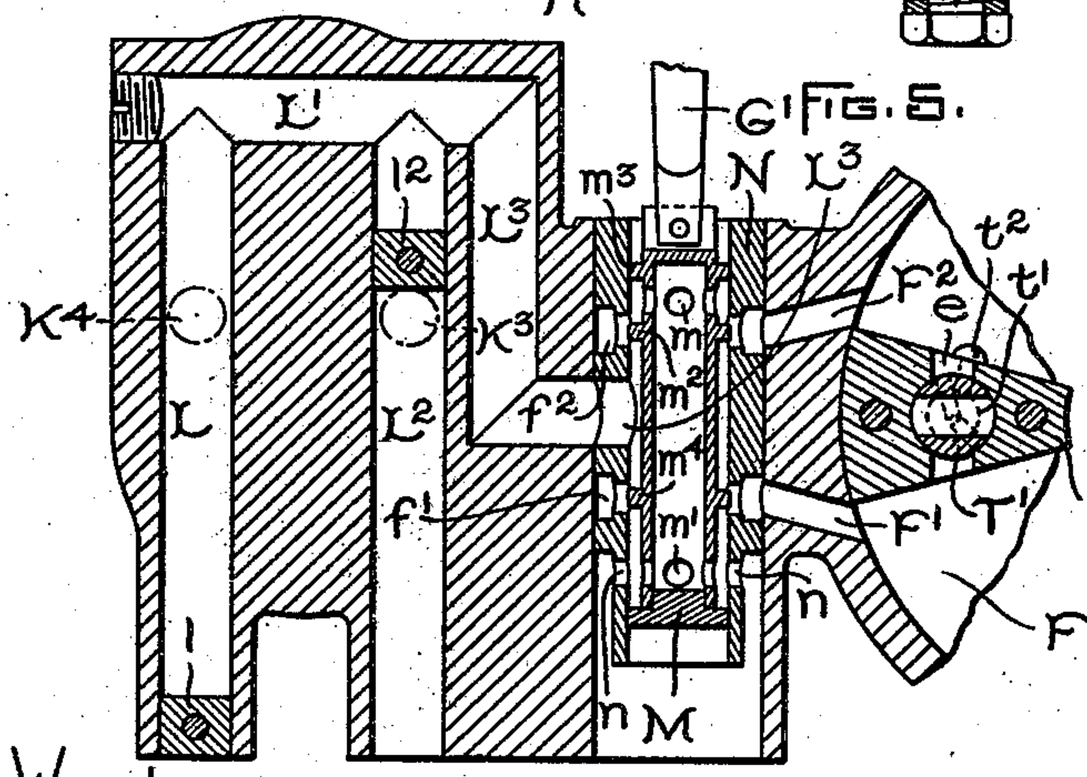

FIG. 5.

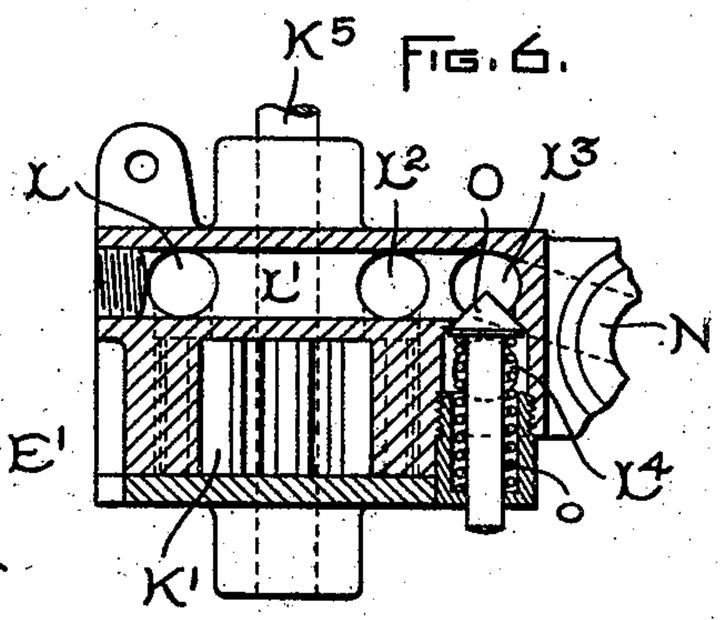

FIG. 6.

WITNESSES.

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UNITED STATES PATENT OFFICE.

CHARLES M. GREEN, OF LYNN, MASSACHUSETTS, ASSIGNOR TO THE GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

REGULATOR FOR DYNAMO-ELECTRIC MACHINES.

SPECIFICATION forming part of Letters Patent No. 690,420, dated January 7, 1902.

Application filed May 21, 1898. Serial No. 681,270. (No model.)

To all whom it may concern:

Be it known that I, CHARLES M. GREEN, a citizen of the United States, residing at Lynn, county of Essex, State of Massachusetts, have invented certain new and useful Improvements in Regulators for Dynamo-Electric Machines, (Case No. 667,) of which the following is a specification.

My invention relates to regulators for dynamo-electric machines, and has particular reference to those machines designed for constant current and used in operating arc-lights in series. Some of its features might be applied to other forms of regulator, and I do not mean by this statement of its utilities to limit the scope of the present application; but it is my present understanding that it is best adapted to arc-light machines.

In old forms of regulators there have been various disadvantages, which I have aimed to overcome in this improved type. In the regulator, for instance, which has gone into extensive use with machines of the Brush type the controlling device for the regulator which shifts the brushes and also shifts the rheostat-arm to change the field magnetization is separated from the machine, requiring a special support, and does not act so well if placed upon the machine itself, although it may be placed there, if desired. The adjustments are complicated and have electric contacts to be made and broken. These contacts must be made adjustable to compensate for wear due to arcing and are apt to get dirty and not make good contact. Acting, as it does, by a magnetic clutch, there are disadvantages from residual magnetism, which causes the regulator to be constantly "overset," so that it is apt to pass the proper point for regulation. Under some circumstances, as when the brush rocker-arm becomes loose and moves too easily, as current passes at all times in the clutch the regulator is apt to "pump," as it is called, or reciprocate first to one side and then to the other of its proper point of adjustment. It also has only a single rate of movement for different changes of current, so that if the current change is violent and requires to be rapidly corrected there is no way of accomplishing it, as it moves at the same speed for great and small changes of current. Some of these objections are also inherent in other types of regulator, as is well known to those skilled in the art. Some of these devices are of the friction type, with rapidly-revolving wheels, pulled together or separated by an electromagnet. The action of this type is not always certain, because one set of wheels is always moving. The other is stationary. Where the rapidly-revolving wheel touches the stationary wheel lightly, it is apt to wear it, making flat spots and causing the mechanism to work in a jerky and unsatisfactory way. In the well-known gravity type unless the dash-pot is made very stiff there is a tendency to pump.

The ratchet-regulator involves the use of rapidly-reciprocating parts, and thus gives only an intermittent and unsteady movement of the rocker-arm and brushes. To make this regulator act properly, it must be run at a fairly high speed; but its action is practically constant under all changes of current, great and small. All devices requiring the opening and closing of electric contacts, as do many regulators, are objectionable.

The greater part of the objections above noted I have been able to avoid in the construction of the improved regulator shown and described in this application. In its preferred form it embraces a rheostat in shunt to the field-magnet circuit of the machine, the dynamo being a series machine, a rotary pump driven from the shaft of the machine, mechanism for actuating the rheostat-handle and shifting the brushes proportionately, the mechanism being driven by the pump, and a controlling-magnet in the series circuit. When normal current is flowing in the controlling-magnet, the pump has no effect on the rheostat-arm. When the current rises, resistance is cut out, thus shunting a larger part of the current around the field-magnet winding. When it falls, the resistance is increased, and the field magnetization is thus governed in accordance with changes of current. A brush-shifting mechanism, by which the spark is adjusted and kept at a minimum, is also connected in the usual way to the rheostat-arm.

The whole of the mechanism may be, and preferably is, mounted directly upon the

frame of the machine. The pump is driven by a straight belt from the shaft, and the arrangement is such that by a simple change in the channels through which the pump drives the operating fluid its action may be reversed to accord with the direction of rotation, and thus the belt will be straight whichever way the shaft rotates. The entire operating mechanism is inclosed in a box, which prevents the access of dust or any change in the adjustment of the parts due to wear. I prefer to use oil for the fluid operated by the pump, as this makes the device entirely self-lubricated, so that little attention is required.

The arrangement of the valve controlled by the regulating-magnet is such that when a great change of current takes place, as when a large number of lamps are cut out at once, the passages through which the oil flows between the pump and the operating mechanism (connected to the rheostat-handle and brush rocker-arm) are wide open, and the handle is shifted with some rapidity, whereas if the current variation be small the ports are nearly closed and the motion is slight. No dash-pot is requisite, as the regulator has in practice but little tendency to pass the proper point to which it should be set to maintain the current constant. In the device there is but a single regulating-screw, by the operation of which its action may be adjusted either to raise or lower the amperage at which the regulator maintains the current constant. It is also feasible to change the speed of operation either forward or backward, or both, so that, if desired, the machine may regulate more quickly in one direction than in the other. By it I also use only a rotary motion, so that all parts having more than a limited speed will rotate and not reciprocate. I also so construct the controlling-magnet that it will not change by usage or by time, and its hysteresis will be a negligible quantity.

The accompanying drawings illustrate my invention. Figure 1 shows its application to the well-known Brush arc-light dynamo and is an end elevation of the machine with my improved regulator applied to it. Fig. 2 is a diagram of the circuits. Fig. 3 is a plan of the regulator with the lid of the containing-box removed, showing the mechanism. Fig. 4 is a section on the line 4 4 of Fig. 3. Fig. 5 is an enlarged detail of the ports and valve of the pump shown in section on the line 5 5 of Fig. 3. Fig. 6 is a section showing the safety-valve or overflow-valve, taken on the line 6 6 of Fig. 4.

In Fig. 1, FM shows the field-magnet, and AM the armature-coils, of the well-known Brush machine. The brushes are shown at S S. Q is the shaft, and P is the belt connecting the shaft to the wheel K^6, operating the oil-pump. B is the casing of the regulator-actuating mechanism. E^4 is a pinion actuating the rack E^5, shifting the brush-holder arm BA, which is attached to the rocker-arm of the brushes. The regulating mechanism is attached to the front of the box containing the field-rheostat R, and the gear E^4 is mounted on the shaft of the rheostat.

In Fig. 2 the parts of the machine are lettered as before. The lamps are marked L*a*, and a coil C. The series coil of the regulator is shown included in the circuit. The current passes from the + brush S of the machine to the positive terminal, through the lamps, back to the negative terminal, then through the coil C. After passing through this coil it divides, one part going to the left through the field-magnet FM and another part through the resistance R until it rejoins the current flowing through the field-magnet, from whence the circuit is completed to the — brush S of the machine. By shifting the arm of the rheostat a greater or less amount of current passes through the field-magnet coils, thus changing the magnetization, as is well understood. The mechanism which shifts the arm of the rheostat at the same time moves the brush-holders, so that the brushes are advanced or retracted to adjust them to the proper position.

The mechanical portions of the regulator are shown on Sheet 2 of the drawings. In Figs. 3 and 4, A A are the brackets which attach the device to its support, and B is the external case, which is ordinarily an iron box made tight enough to contain the fluid to operate the mechanism. I prefer oil for this purpose, for the reasons already pointed out and because of its well-known advantages, though air or any other suitable fluid or liquid might be substituted, if desired.

Referring now more particularly to Fig. 4, the oil-pump K, as shown on the left of the figure, consists of a pair of gears rotating in a tight casing having ports K^3 K^4. The gear K′ and the wheel K^6 are fixed to the same shaft K^5. Assuming that the direction of rotation is as shown by the arrows, the oil enters at the port K^3 and is driven out at the port K^4. The channels through which the oil flows are seen best in Figs. 5 and 6. They are shown in Fig. 4 in dotted lines. The oil to reach the port K^3 enters at the bottom of the channel L^2 (see Fig. 5) and passes up to the stop l^2, which for the direction of rotation assumed for the pump is fixed just above the port K^3, (indicated by the dotted circle.) A similar stop l is shown in the channel L, to which the oil passes from port K^4. This stop may be located at any point below the port K^4, the location of which is indicated by the dotted circle. The oil passes from the channel L through the channel L′, and so to the channel L^3 and through the valve M, to be presently described. Should it be desired to reverse the movement of the gears and still maintain the proper direction of flow, (as when the regulator is applied to a "left-handed" machine,) this may be effected without crossing the belt P (see Fig. 1) by removing the stops l l^2 and reversing their position—that is, by

putting the stop l above the port K^4, so that this port would be the entry or intake of the pump, and placing the stop l^2 below the port K^3, which would then form the outlet. The fluid after passing the valve M enters the chamber F, Fig. 4. Within this chamber is an abutment E′. A piston E^2 is secured to a central disk E^6 by the screw E^3, which also acts as a set-screw to hold the disk E^6 upon the shaft E. By the revolution of the piston E^2 the shaft E is rotated to shift the rheostat-switch and turns the gear E^4 to shift the rocker-arm of the brushes. The piston E^2 is actuated by the oil or other fluid flowing from the pump K. In the abutment E′ is a valve T′, Fig. 5, having a channel t', which may be brought into coincidence with the channel e through the abutment E′. The valve is free to rotate, but is secured from longitudinal movement by the screw t^2. It is turned by the shaft t and the handle T. (See Fig. 3.) When the channel through the abutment is opened, there is communication between the chambers on opposite sides of the piston E^2, so that the oil no longer moves the piston. This is a convenient way of throwing the regulator out of action when the machine is not delivering current. When the machine, however, has its load thrown on, the regulating-valve T′ would be turned to the position shown to throw the regulator into action.

On the right in Figs. 3 and 4 is shown the regulating series magnet. C is the coil of the magnet, of which D is the external armature, D′ being a core attached to the armature and forming a part of it. The armature is bell-shaped and shields the coil against external magnetic influences. The amount of iron is so proportioned as to be comparatively highly saturated, and the magnetic circuit is designed for reasonably high reluctance, so that the hysteresis is substantially negligible, and the magnet is not affected in practice by time or by external influences of any kind. The armature D is supported from one end of a lever G, which is pivoted on a knife-edge at g' and attached at its other end to a link G′, connected to the valve M. Its attraction is counterbalanced by a spring H, attached to the other end of the lever and provided with a regulating-screw H′ of common form. By the proportioning and adjustment of this spring the action of the device may be adjusted to maintain the current constant at the strength desired. If the spring be light, so that under small current changes the lever will move over a considerable distance, the regulator will be exceedingly sensitive, and this may often be carried to such an extent as to make it "pump," as it is called, or vibrate past the proper point in either direction. If, on the contrary, the spring be made stiff and strong, it will take considerable current change to affect it. The reasons for this will be apparent when the construction of the valve M and the operation of the device in connection therewith are explained. The extent of play of the lever G is determined by two set-screws g g^2. By the adjustment of these screws the play of the valve may be altered and its position with reference to the ports at either end of its stroke may be determined. I may, if it be desirable, by this means arrange the device so that in one direction of movement it will have a certain speed of operation and in the other a different speed. It may, for instance, in case of sudden decrease of load (as by cutting out a number of lamps at one time) be desirable to have the regulator immediately respond, so as to prevent undue rise of current, while it may not be desirable to have it respond so quickly when the lamps are thrown in, as the falling off of current would not be attended for a time with any particular ill results. Ordinarily, however, the device will be set to be operated with the same speed in either direction. The spring H and the set-screws g g^2 would be adjusted in installing the machine and in practice would require no further attention.

The proper working of the device is dependent upon the valve M. This is shown in section in Fig. 5, being only indicated in the other figures. It consists of a balanced piston-valve made hollow and having packing-rings m^2 m^3 m^4 and ports m m', leading into its interior. To an intermediate point in the valve-casing N, in which this valve moves, oil is fed from the channel L^3. Other channels F′ F^2 lead to the piston-chamber F. Further, one or more openings n communicate with the supply of oil in the case B.

The operation of the parts described is as follows: When the current in the main circuit rises, the coil C attracts its armature D D′ and pulls down the lever G, raising the valve M against the pull of the spring H, the valve being connected to the lever by the link G′. As the valve rises the ring m^2 opens wide the channel F^2 and the channel f^2, (which is formed in the exterior surface of the valve-casing N and communicates with F^2). At the same time the ring m^4 cuts off the channel F′ and its inlet f', corresponding to the channel f^2. Oil then passes into the top side of the piston E^2 (see Fig. 4) and carries it toward the bottom of the chamber F, turning the rheostat-arm, Figs. 1 and 2, to the right, cutting out resistance, shunting a greater proportion of the current around the field-magnet coils, thus weakening the field and at the same time shifting the brushes to the position of least spark. This movement continues until the current falls sufficiently to weaken the coil C, when the spring H overpowers the attraction of the armature D D′ and pulls down the valve M. When the latter reaches its illustrated position, the movement of the piston ceases, there being a free flow of oil through and around the valve by the ports and channels m m', n n, and f' f^2. In case the regulation has proceeded too far the spring H depresses the valve until the ring m^4 opens

the channels f' F' and ring m^2 closes the upper channels, when the operation above described is reversed until the valve is again in its intermediate or illustrated position and the current is at its proper strength. When the valve is depressed, so as to open the channel F' for the flow of oil, the fluid above the piston flows out through the channel F^2 and then through the ports m into the interior of the valve, from which it will flow through the openings m' of the valve and n of the valve-case into the box B^2, as before. If the piston be brought to the end of its stroke and still the regulation should be ineffective, as where a large number of the lamps were by any accident short-circuited or when for any reason the conditions were abnormal, the safety-valve O, (see Fig. 6,) which is provided at the top of the channel L^3, would open against the force of the spring o, and the oil driven by the pump would then pass from the channel L' into the vent-channel L^4 (shown in dotted lines in Fig. 4) and return to the box, preventing any damage to the apparatus. The adjustment of the position of the valve M will, as will be readily perceived, depend on the balance of effect between the spring H and the armature D, and the extent of its movement, as already pointed out, can be determined by the stops g g^2, the stop g limiting its upward play and the stop g^2 limiting its downward movement, and thus determining, respectively, the extent of opening of the channels F^2 F'.

What I claim as new, and desire to secure by Letters Patent of the United States, is—

1. In a regulating device for a dynamo-electric machine, a rheostat for controlling the output of the machine, a revoluble piston rigidly mounted on the rheostat-spindle, a pump driven from the machine and driving the piston, a valve between the piston and the pump, and an electromagnet in the circuit, controlling the position of the valve.

2. In a regulating device for a dynamo-electric machine, a rheostat in shunt to the field, a revoluble piston mounted on the rheostat-spindle to change the field-excitation, a pump driven by the machine and driving the piston in either direction according to the position of a valve interposed between the pump and the piston, and an electromagnet responsive to changes of current in the main circuit, controlling the position of the valve.

3. In a regulating device for a dynamo-electric machine, a rheostat controlling the field-excitation, a device for shifting the brushes adapted to be actuated therewith, a piston rigidly connected to the spindle of said rheostat, a pump driving the piston in either direction according to the position of an interposed valve, and an electromagnet in the main circuit controlling the position of the valve so that as the current rises, the piston is forced in one direction, and as it falls, in the other.

4. In a regulating device for a dynamo-electric machine, mechanism for shifting the brushes, means adapted to actuate said mechanism and to vary the resistance in shunt to the field-coils, a piston operatively connected to said means, a valve, a pump the effect of which is regulated or reversed by the valve, and an electromagnet in the main circuit controlling the position of the valve.

5. In a regulating mechanism for a dynamo-electric machine, the combination of a gear-pump driven from the machine and delivering fluid to one side or the other of a revoluble piston, a valve for controlling the admission of the fluid, a regulating electromagnet in the main circuit, a mechanical connection between the armature of the magnet and the valve, a spring opposing the pull of the magnet, and a rheostat-arm rigidly connected to the piston.

6. In a regulating mechanism for a dynamo-electric machine, the combination of a constantly-running pump, forcing a desired fluid through a suitable channel, a piston actuated by the fluid, a valve controlling the delivery of the fluid to the one side or the other of the piston, a magnet in the main circuit, a rocker-arm connected at one end to the magnet, and at the other carrying the valve, and stops for the rocker-arm by which its stroke in either direction may be adjusted.

7. In a regulating mechanism for a dynamo-electric machine, the combination of a constantly-running pump, a revoluble piston actuated by fluid delivered from the pump, a valve controlling the delivery of the fluid to one side or the other of the piston, resistance-changing and brush-shifting means connected to the piston, a magnet in the main circuit, a rocker-arm connected at one end to the magnet-armature and at the other end to the valve, a spring opposing the magnet-armature, and adjustable stops for the rocker-arm.

8. In a regulating mechanism for a dynamo-electric machine, the combination of a constantly-running pump, a rotary piston with a fixed abutment having a by-pass valve therein, and regulating mechanism operated by the piston and controlled by a magnet in the main circuit.

9. In a regulator for a dynamo-electric machine, the combination of a controlling-magnet, regulating mechanism, an operating-shaft therefor, a revoluble piston rigidly mounted on said shaft, and means controlling the direction and extent of the piston movement, and itself controlled by the magnet.

10. The combination of a regulator, means for operating it in either direction as desired, and means for so controlling the operation that the device acts at one rate in one direction of motion and at a different rate in the other direction.

11. The combination of a rotary piston, channels leading to the cylinder upon each side of a fixed abutment, a piston-valve opening or closing the channels, and a passage in the valve through which the contents of one

side or the other of the cylinder may escape, according to the position of the valve.

12. The combination in a regulating device, with a fluid-pressure pump, of a revoluble piston actuated thereby, a rotatable shaft upon which said piston is mounted, regulating means operated by the shaft, and means actuated by the current in the electric machine which is to be regulated, to control the operation of said piston.

13. The combination in a regulating device, with a rotary fluid-pressure pump, of means for mechanically operating said pump by a dynamo-electric machine, means actuated by said pump for regulating the dynamo-electric machine, means controlled by said machine to control said regulating means, and means for changing the relation of the pump with the regulating means to maintain a uniform direction of movement of the regulating means when the direction of motion of the pump-operating means is reversed.

14. The combination in a regulating device for an electric machine, with a fluid-pressure pump, of means for mechanically operating said pump from the machine, a regulating-piston, fluid channels and ports forming communication from said pump to said piston, and adjustable stops in said channels.

15. The combination in a regulating device, with a rheostat in shunt to the field-coils of a dynamo-electric machine, of a fluid-pressure pump driven from the machine, and a revoluble piston actuated thereby, and mounted on the rheostat-spindle.

16. The combination in a regulating device, with a rheostat in shunt to the field-coils of a dynamo-electric machine, of a fluid-pressure pump, a revoluble piston actuated thereby, and mounted on the rheostat-shaft, a gear on said shaft, a rack adapted to coöperate with said gear, and a rocker-arm carrying said rack and connected to the commutator-brushes, substantially as described.

17. The combination in a regulating device with means for regulating simultaneously the field-resistance and the commutator-brushes of a dynamo-electric machine, of a fluid-pump actuating said regulating means.

18. The combination in a regulating device for electric machines with a fluid-pressure pump driven by the machine, of a revoluble piston actuated by the pump, a rotatable rheostat-shaft upon which said piston is mounted, and means controlled by the electric machine to control the operation of said piston.

19. The combination in a current-regulator, of a fluid-tight box, a fluid-pump therein, a casing for said pump, ports forming communication between said casing and box, a piston-chamber also inclosed by said box, additional communications between said pump and chamber, and a revoluble piston in said chamber provided with a shaft extending outside said box.

20. The combination in an electric-current regulator, with a fluid-pressure regulating piston, of a pump therefor, means for rendering said piston inoperative independently of said pump, and an electromagnet operated by the current to be regulated for controlling said means.

21. The combination in an electric-current regulator, with a piston-chamber, of a revoluble piston therein, a radial abutment from said chamber, a channel through said abutment, and a valve in said channel.

22. The combination in a current-regulator, of means for controlling the speed of its regulating mechanism in either direction independently.

23. The combination in a device for controlling a regulating-valve in a current-regulator, with a controlling electromagnet and its armature, of a pivoted lever secured to said armature, adjustable means connected to the lever for balancing the electromagnetic force, and adjustable stops adapted to coact with said lever on each side of the fulcrum, substantially as described.

24. The combination in a current-regulator, of a fluid-pump, a revoluble piston driven by the fluid-pressure therefrom, a rheostat in shunt to the field-coils of the machine to be regulated, and a shaft for said piston rigidly connected to said rheostat-handle.

25. The combination in a current-regulator, with a fluid-pump, of pressure-operated regulating mechanism, a safety-valve adapted to permit the circulation within the regulator independent of said regulating mechanism, and an electromagnet operated by the current to be regulated for controlling said valve.

26. The combination in a current-regulator for electric machines with a fluid-tight box, of a pump-casing inside the box, a pump in the casing and operated by the electric machine, an inlet-passage from the interior of the box to the interior of the pump-casing, a cylinder in the box, a piston in the cylinder, current-regulating means controlled by the piston, a passage from the pump-casing to the cylinder, a valve in said passage and controlled by the electric machine, a vent-channel connecting said passage with the interior of the box, and a safety-valve operated by extra pressure of fluid to permit the latter to return to the box.

27. The combination in a current-regulator, of a fluid-tight box, a pump and a regulating mechanism in said box, a hollow perforated valve between the two, a valve-casing therefor, and means for establishing communication between said valve and box, and between said valve and said casing, substantially as described.

28. The combination in a regulating device for electric machines, of a pump driven from the machine, a piston operated by the pump, means operated by the piston for regulating the product of the machine, a piston-chamber, a valve-casing communicating therewith, a hollow valve adapted for simultaneously in either direction admitting fluid under pres-

sure to said chamber and permitting the exhaust to pass through itself, and an electromagnet operated by the current of the machine for controlling said valve.

29. The combination in a current-regulator for an electric machine, with a pump driven from the machine, a piston operated by said pump, means operated by the piston for regulating the current of the machine, of a valve-casing having annular channels, an inlet intermediate thereof, the said channels being normally in communication with said inlet, a valve for alternately cutting off communication from each channel, and an electromagnet operated by the current to be regulated for controlling said valve.

30. The combination in a regulator for an electric machine, with a pump driven from the machine, a piston operated by the pump, means operated by the piston for regulating the current of the machine, a valve-casing having annular channels, of an inlet intermediate thereof, a piston-valve, rings on said valve, and an electromagnet operated by the current to be regulated for controlling said valve.

31. The combination in a regulator for an electric machine, with a pump driven from the machine, a piston operated by the pump, means operated by the piston for regulating the current of the machine, of a valve-casing having outlet and inlet openings and a safety-exhaust, a hollow perforated valve, and an electromagnet operated by the current to be regulated for controlling said valve.

32. The combination in a dynamo-regulator, of a fluid-tight box, regulating mechanism in said box, a casing within said box, a gear-pump in said casing, and communication between said pump and regulating mechanism and between said pump and the interior of said box, substantially as described.

33. In a regulating device for an electric machine, the combination with a rheostat adapted to control the product of the machine, of a rotatable fluid-pump driven from the shaft of the machine, a cylinder, a movable piston mounted in said cylinder on the spindle of the rheostat, a valve between the pump and cylinder, and means controlled by the product of the machine for operating said valve.

34. In a regulating device for an electric machine, the combination with a rheostat adapted to control the product thereof, a casing adapted to contain fluid, a rotatable fluid-pump in the casing and driven from the shaft of the machine, a cylinder in the casing into which extends the spindle of the rheostat, a revoluble piston mounted in said cylinder on said spindle, a valve between the pump and cylinder, and means controlled by the product of the machine for operating said valve.

35. In a regulating device for an electric machine, the combination with a rheostat adapted to control the product thereof, of a casing having two compartments, a rotary fluid-pump in one compartment and driven from the shaft of the machine, a cylinder in the same compartment, into which cylinder extends the spindle of the rheostat, a valve between the pump and cylinder, a revoluble piston in said cylinder connected with the spindle of the rheostat, and an electromagnet in the other compartment of the casing, which magnet is electrically connected with the machine and adapted to operate said valve.

36. In a regulating device for an electric machine, the combination with means for controlling the product thereof, a fluid-pump driven from the shaft of the machine, a cylinder, a valve between the cylinder and the pump, a piston in the cylinder connected with said controlling means, a pivoted lever connected with the valve, an electromagnet connected to one end of the lever and electrically connected with the machine, and an adjustable spring connected to the other end of the lever.

37. In a regulating device for an electric machine, the combination with means for controlling the product thereof, of a fluid-pump operated from the machine, a piston operated by said pump for operating said controlling means, a valve between said pump and piston, means controlled by the product of the machine for operating said valve, and means for varying the limits of movement of the valve.

38. In a regulating device for an electric machine, the combination with a rheostat adapted to control the product thereof, of a casing adapted to contain a liquid, a gear-pump in the casing, a cylinder in the casing into which cylinder extends the spindle of the rheostat, a valve between the pump and cylinder, and an electromagnet controlled by the product of the machine and adapted to control said valve.

39. The combination with a fluid-pump, of a piston operated thereby, an intermediate hollow piston-valve, a casing therefor, an opening midway of the casing and communicating with the pump, openings to the interior of the valve on opposite sides of said opening, and an opening in one end of the casing and communicating with the pump.

40. The combination in a current-regulator for an electric machine with a fluid-pressure pump arranged to be operated by the machine, of a piston-box and piston therein constructed and arranged to control the current of the electric machine, a passage between said pump and piston, an independent valve in said passage, which is controlled by the electric machine, a vent-channel branching from said passage, and a safety-valve which is operated by extra pressure of the fluid to permit the latter to pass through the vent-channel.

41. The combination in a current-regulator for an electric machine with a fluid-pressure pump arranged to be operated by the electric machine, of a piston-box and piston

therein constructed and arranged to control the current of the electric machine, a passage connecting the pump and piston-box, a valve in said passage, and an electromagnet connected in the circuit of the electric machine and arranged to control said valve, a vent-channel branching from said passage to the electrically-controlled valve, and a safety-valve operated by extra pressure of the fluid to permit the latter to pass through the vent-channel.

In witness whereof I have hereunto set my hand this 13th day of May, 1898.

CHARLES M. GREEN.

Witnesses:
DUGALD KCKILLOP,
J. A. DALZELL.