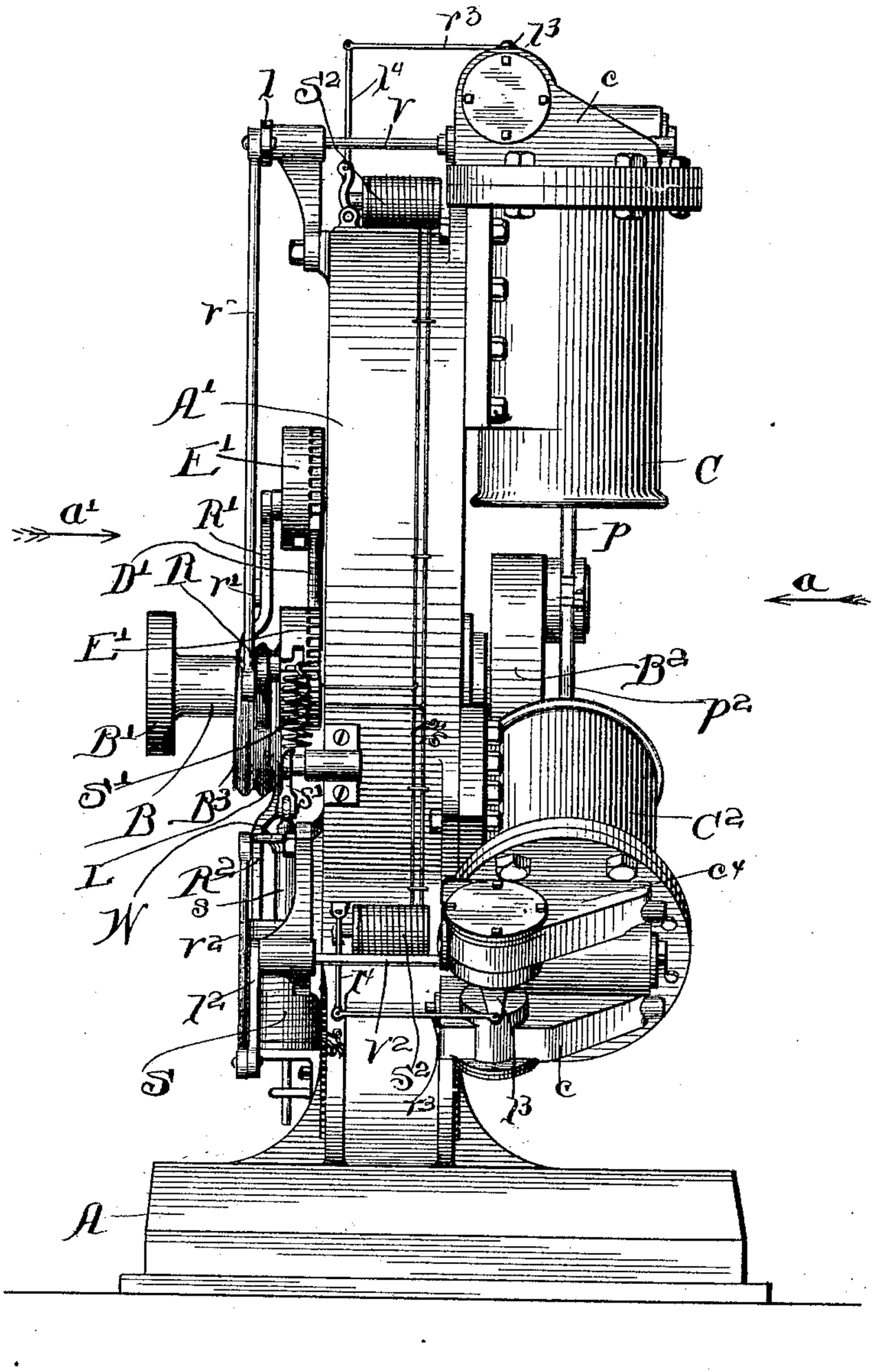
(No Model.) 4 Sheets—Sheet 1.

W. N. SMITH.

DYNAMOMETRIC GOVERNOR.

No. 544,696. Patented Aug. 20, 1895.

Fig. 1.



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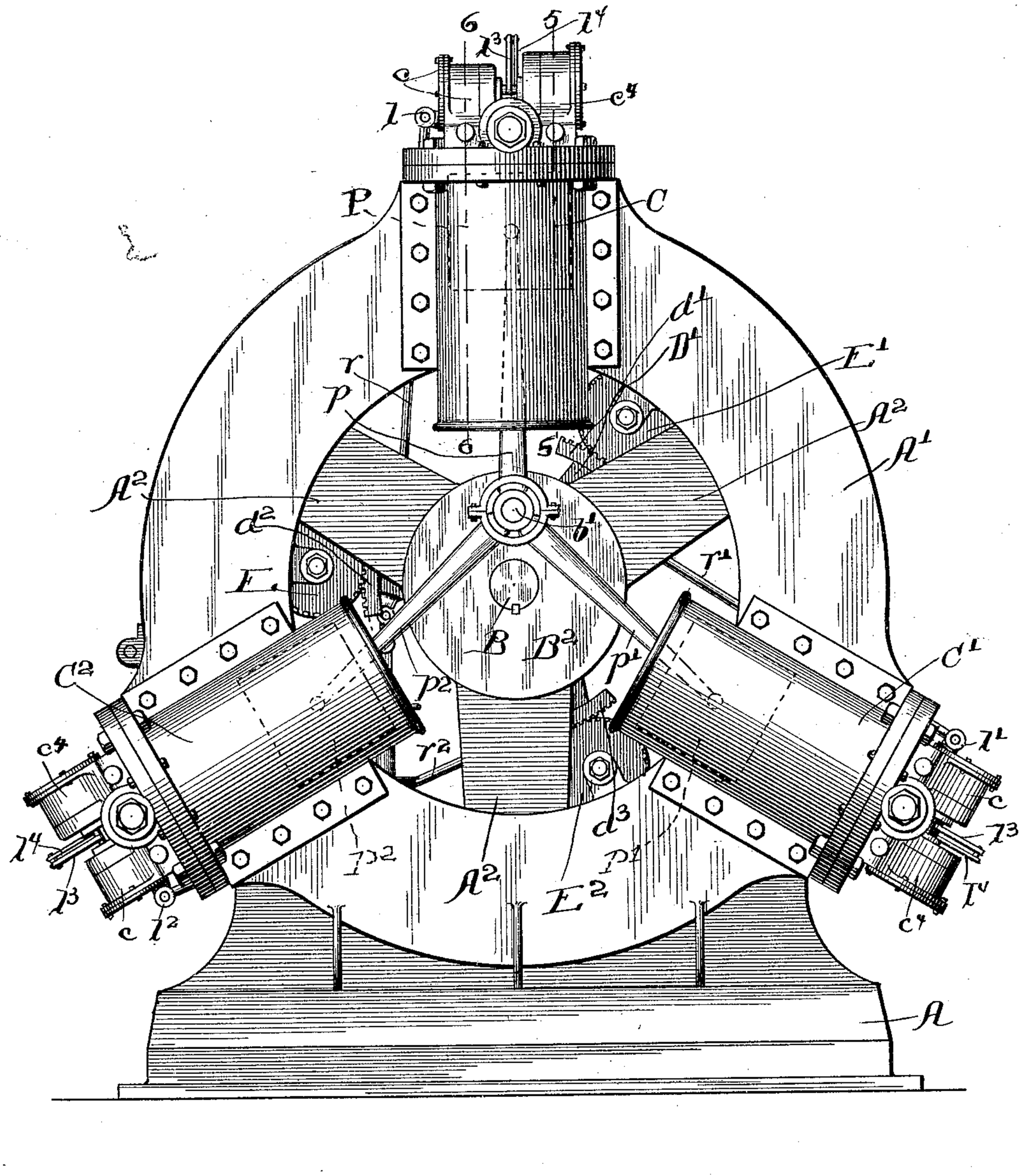
DYNAMOMETRIC GOVERNOR.

No. 544,696. Patented Aug. 20, 1895.

Fig. 2.



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DYNAMOMETRIC GOVERNOR.

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Fig. 3.

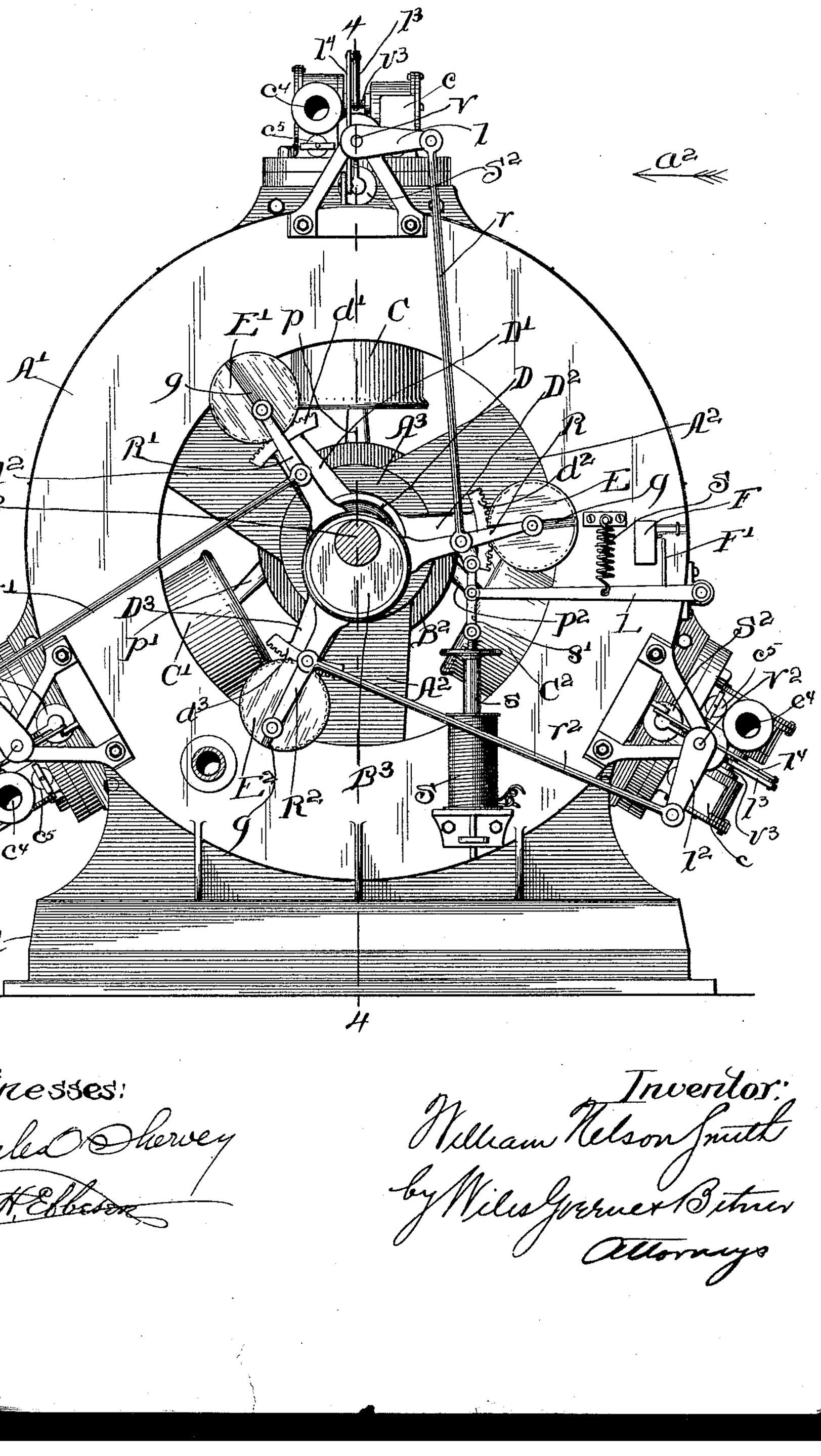

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Fig. 5.

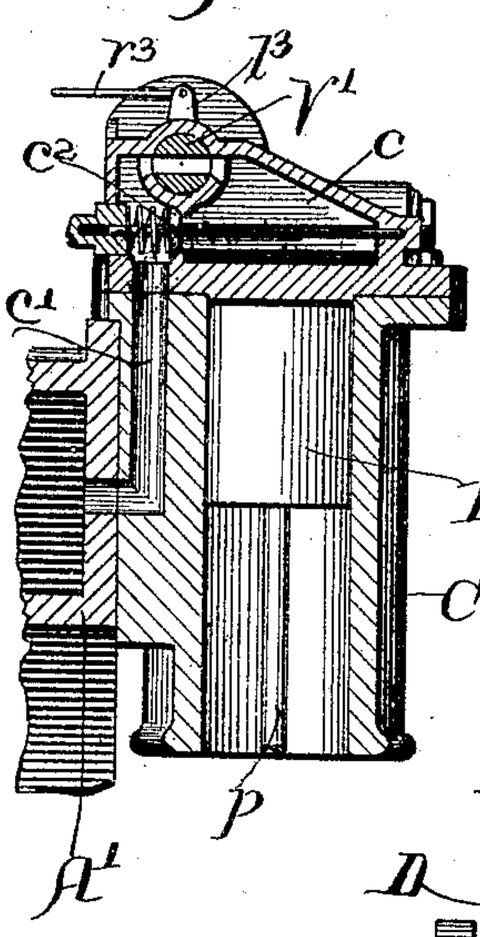


Fig. 4

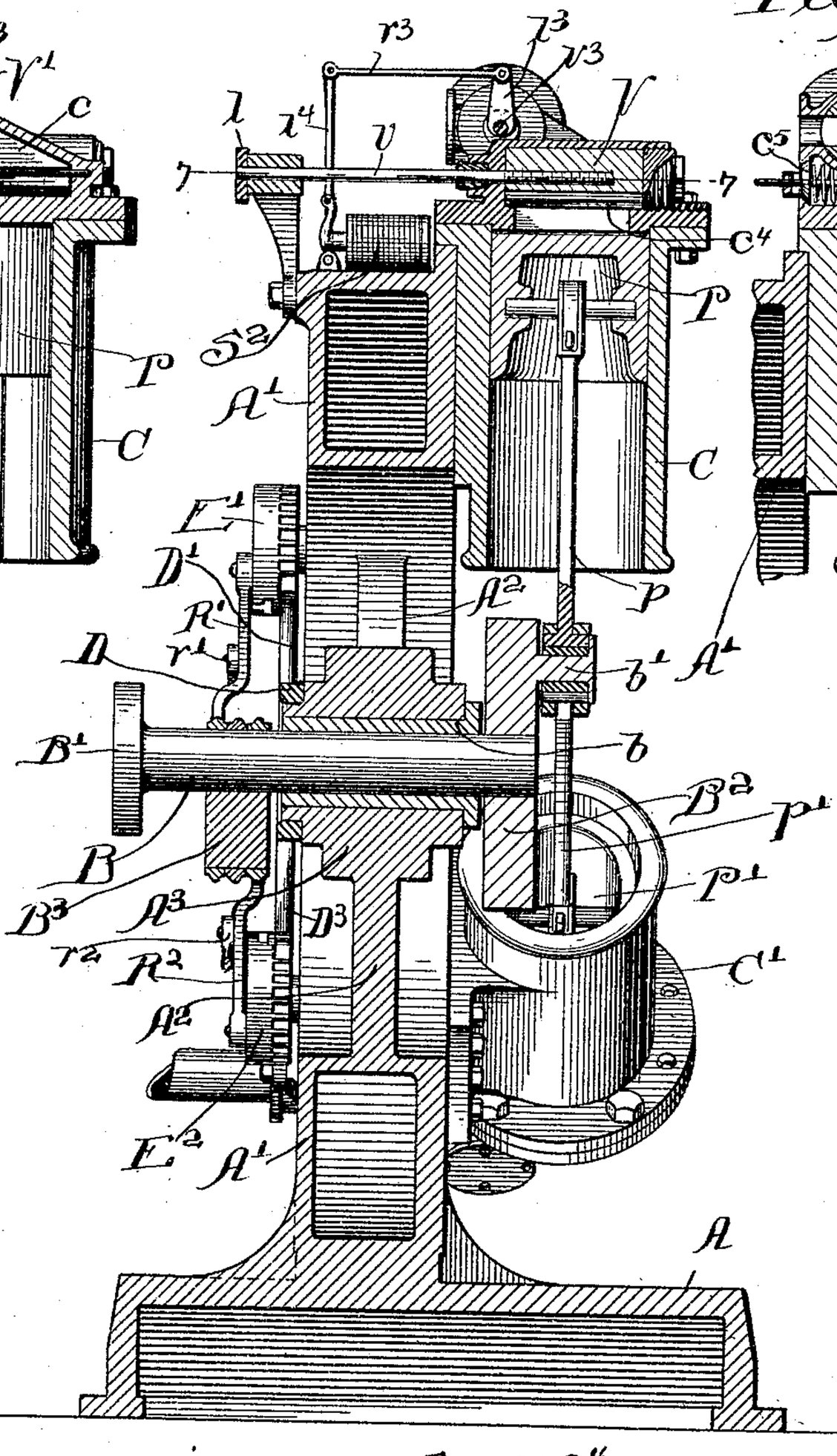


Fig. 6.

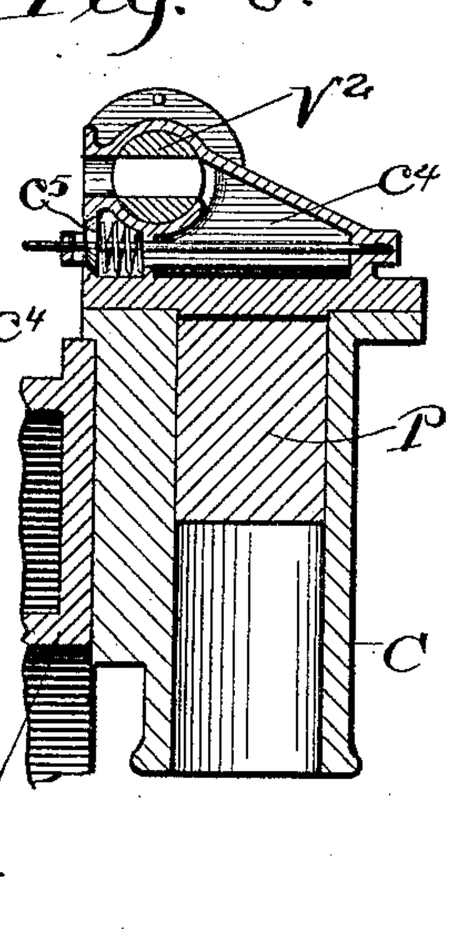
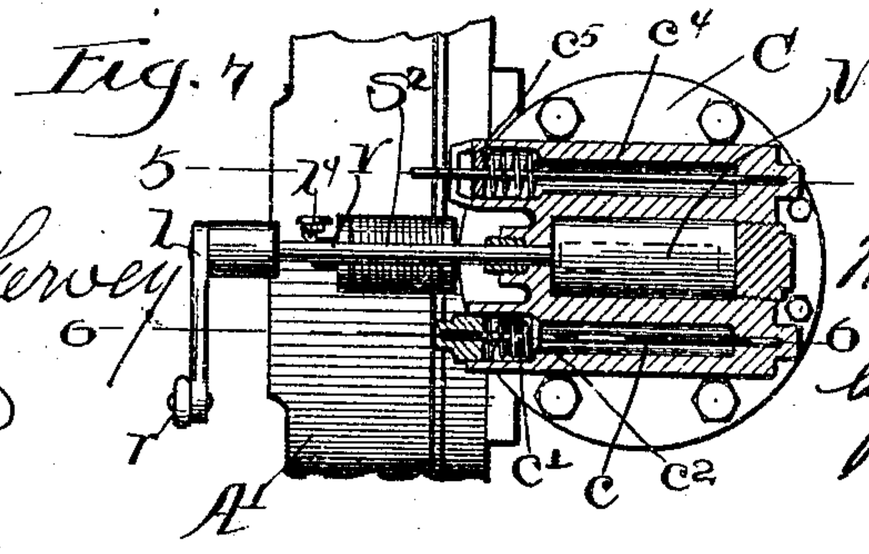


Fig. 7



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UNITED STATES PATENT OFFICE.

WILLIAM NELSON SMITH, OF CHICAGO, ILLINOIS.

DYNAMOMETRIC GOVERNOR.

SPECIFICATION forming part of Letters Patent No. 544,686, dated August 20, 1895.

Application filed August 16, 1894. Serial No. 520,466. (No model.)

To all whom it may concern:

Be it known that I, WILLIAM NELSON SMITH, a citizen of the United States of America, residing at Chicago, in the county of Cook and State of Illinois, have invented certain new and useful Improvements in Dynamometric Governors, of which the following is a specification.

My invention is a dynamometric governor for the regulation of electrically-operated machinery, subject to frequent fluctuations of load, and may be combined with any source of power-supply, though it is more especially adapted for use with machinery driven by water-power.

In general terms the object of the invention is to provide and combine with a source of power-supply a mechanism adapted either to store or give off energy and to act as an accumulator of power or as a motor, its change of function being automatically governed by a dynamometer actuated by the varying load to which the prime motor is subjected. The governor, thus outlined, may evidently be made in various forms and with various means for storing and using energy; but in the type shown and described in this application it consists essentially of an engine provided with reversing valve-gear, whose crank-shaft is directly coupled to the shaft of either prime mover, counter or jack shaft, or electrical generator, whichever appears most desirable, and it rotates continuously in the same direction. The working fluid is air, and one or more tanks connected with the engine are provided for storing it. The governor is not intended to displace water-wheel governors, such as they are, but to supplement their action and effect closer regulation in speed, under suddenly-varying loads, than is possible with any of the present common forms, and thereby increase the use of water-power for electrical purposes. The aforesaid engine and tanks are intended to constitute a combination that shall be reservoir, and also a source of energy in the form of compressed air. It is obvious that when a turbine is suddenly relieved of its load its tendency is to "race" or run away until its normal load is restored, when it will return to its normal speed; and if an extra heavy load is suddenly applied the turbine will slow down below its normal speed until relieved of the excess. This variation of speed is prejudicial to the operation of machinery whose success depends upon constancy of speed. It is proposed by means of this governor to substitute for the load removed an artificial temporary load in the form of an air-compressor at work storing compressed air as often as the external load is lessened or removed; and, on the other hand, when the load is temporarily too heavy it is proposed to turn this air-compressor into an air-engine without reversing its rotation, and thereby make use of the stored air to assist the water-wheel to the extent of handling its excess of load. If this can be done successfully, it will enable water-power to be more widely used in driving machinery that has always required an automatic steam-engine. It is evident that this changing of an air-engine into an air-compressor and vice versa can be effected by the use of a reversing valve-gear, which can be automatically "thrown over," and, moreover, that the amplitude of vibration of this reversible gear must be so controlled that, whether acting as a compressor or as an engine, it will cause the machine to act only to the extent demanded by the condition of the external load at that particular instant. If as a compressor, it should be obliged to compress air at a rate of working approximately equal to the diminution of the external load. If as an engine, it should perform work at a rate sufficient to handle the excess. It should be entirely automatic, and should therefore be controlled by a dynamometric device, powerful enough to overcome the friction of the valve-motion, and as nearly instantaneous in its action as possible, which shall automatically throw the valve-gear over and back and hold it at any intermediate point on either side of the zero or neutral point in proportion to the external load at the instant; and this zero or neutral point must also be variable in its position to correspond with variations in the amount of average external load—variations that occur at different hours in the day, or from hour to hour, but neither sudden nor violent.

With this enunciation of the principles and conditions of the problem, as nearly as can be determined at present, the details of the necessary mechanism will now be explained.

The type of engine chosen is the single-acting multicylinder, with the three cylinders having their axes in the same vertical plane, and with their open ends inclined toward a common center. Their axes make angles of one hundred and twenty degrees with each other, and the three connecting-rods take hold of a single crank-pin, after the manner of the Brotherhood engine. The cylinders are bolted against the side of a heavy vertical frame of cast-iron, which resembles a wheel with a heavy hollow rim of rectangular section and having three heavy solid spokes and a large hub, which is bushed for the crank-shaft. The crank-disk is close against this hub on one side and the eccentric is adjacent on the other side. The bottom of the frame may be extended into the base or bed plate by webs or solid metal. Frame and base can be cast in one piece. Each cylinder has the air distributed to and from it by a single valve of the Corliss type situated in the cylinder-head. The valve is practically a three-way cock, the central port opening directly into the cylinder and the side ports forming passages to the atmosphere and to the storage-tanks, respectively. For convenience sake and to avoid piping the live-air passages all communicate with the interior of the hollow frame, which thus forms a part of the tank system and is connected with it. The axis of the valve is parallel to the crank-shaft. The valve-spindle projects through a stuffing-box, and its outer end, after passing through a pedestal bracketed against the opposite side of the engine-frame, carries on its end the rocker-arm by which it receives its motion from the eccentric. As the valve is separated from the interior of the cylinder only by the thickness of the cylinder-head, the clearance is as small as possible.

When running as a compressor, it becomes necessary to employ check-valves—one between the atmosphere and the cylinder and one between the cylinder and the tank, both opening inward. It is evident that the compressed air cannot flow outward and operate the engine unless it can flow back through the valve, which would have to be opened for the purpose, or else flow around them. The latter method is adopted, and in each of the chambers in which the check-valves are set is placed a cock. The two cocks are turned simultaneously, having their spindles joined at the inner ends by the rocker-arm that operates them. One of them, the smaller, opens a passage through which the compressed air can flow around the inner check-valve and into the main valve-chamber. The larger cock, simultaneously opened, permits the exhaust-air to flow directly into the atmosphere from the main valve-chamber around the outer check-valve. Both the check-valves are thus short-circuited together for the time being, allowing the stored air to flow backward and drive the engine. The lever working each pair of short-circuiting or by-pass cocks is actuated by an electrical device to be explained later.

The reversible valve-gearing adopted is known as "Hackworth's," (see *Seaton on Marine Engineering*,) being very similar to the Marshall gear. Only one eccentric is used, and that is set opposite the crank-pin. By lengthening the eccentric axially it can carry the three straps and rods, one for each cylinder. The inner and outer eccentric-rods are bent or offset, so as to bring them into the same plane with the central one. The outer end of each rod is pivoted to a block that slides in a slot in a disk whose axis is horizontal and fixed. This disk can rotate about its axis, varying the inclination of the slot to a line joining the centers of the disk and the crank-shaft. The valve-rod is pivoted to a point about two-thirds of the length of the rod from the eccentric, and its farther end takes hold of the valve rocker-arm before mentioned.

The variation of the angular position of the slotted disk varies the valve travel and the consequent functions of the valve and the distribution of the air to and from the cylinder, and is thus the means of rendering the gear reversible. It has the merit of being simpler than the Stephenson link-gear, which would necessitate six eccentrics and would be very clumsy.

In order to vary the angular position of the three disks and do it simultaneously, each one of them has gear-teeth cut on that zone of its periphery lying back of the slot, and these mesh with three geared arcs on the ends of the arms of a three-armed spider, whose central boss is bored to fit on a shoulder of the hub of the engine-frame and turn upon it. Any movement of this spider thus moves the three disks and changes the three valve functions simultaneously. One arm of the spider is attached by linkwork to the plunger of a solenoid, through whose coils flows the current generated by the dynamo or set of dynamos whose speed is to be regulated. The pull of the solenoid is balanced against a spring to make its movements proportional to the current flowing in it. This, therefore, constitutes the necessary dynamometer, for its motion is proportional to the external load. When no current flows, the spring has the spider pulled up, so that the valve-gear makes the engine compress air, giving the prime mover a load. As the current increases to the average output, the spider is pulled back by the solenoid toward the center, which is reached when the average current actually flows. Up to this point the pair of by-pass valves attached to each cylinder, previously described, has been held shut by means of a small solenoid and plunger attached to its operating-lever. These three solenoids are in series with each other and with a reversing-switch operated by the linkwork attached to the main solenoid. The instant that the main solenoid pulls the linkwork past the neutral point, on account of an external load greater

than the average, the reversing-switch acts, the three auxiliary solenoids are reversed, and the three pairs of by-pass valves are opened all together, permitting the previously-stored air to flow freely backward against the pistons, and, after performing its work in aiding the prime mover, to be exhausted into the atmosphere. The auxiliary solenoids are actuated by current that can be tapped from the generator's mains or obtained from any suitable external source.

For a load decreasing instead of increasing the above series of operations would be reversed in order.

From time to time the average load may vary. Hence the neutral point of the machine ought to be adjustable, in order to secure the evenest working on both sides of the then average load. To effect this the plunger, instead of being rigidly attached to the vertical rod or spindle that imparts its motion to the valve-gear, is really a long cylindrical nut that screws up and down on the spindle, which is threaded for the purpose. (The spindle may be made of bronze.) In this way the plunger can be run into or out of the solenoid at will and the solenoid's pull on it be increased or diminished accordingly. If, for example, the average external load increases and it is desired to adjust the neutral point so that the machine's action will be more nearly equal in both its alternate functions, the plunger must be screwed outward on the spindle, for the greater average current then flowing will have the same effect upon it as the smaller average current did when it was set farther into the solenoid, for, within certain limits, the farther in the plunger is the greater the pull of the solenoid with a given current. To facilitate this adjustment a small hand-wheel is attached to the top of the plunger, so that it can be easily screwed up or down by the dynamo-tender.

The invention as embodied in the form of machine above described is illustrated in the drawings accompanying this specification, in which—

Figure 1 is a side elevation of the engine and compressor. Fig. 2 is a front elevation thereof, the view being in the direction indicated by the arrow *a*, Fig. 1. Fig. 3 is a rear elevation, the view being in the direction indicated by the arrow a', Fig. 1. Fig. 4 is a central transverse vertical section, the plane of section being through the line 4 4, Fig. 3, and the view being in the direction indicated by the arrow a^2 in said figure. Fig. 5 is a transverse vertical section through the line 5 5, Figs. 2 and 7. Fig. 6 is a similar section through the line 6 6, Figs. 2 and 7; and Fig. 7 is a horizontal section through the line 7 7, Fig. 4, the view being downward.

In the views, A is the base of the frame of the engine.

A′ is the hollow annular frame supported by the base.

A^2 A^3 are radial arms integral with the frame, and A^3 is the hub connecting the inner ends of the arms and provided with a bushing *b*, in which is journaled the main shaft B of the engine. The shaft is provided at one end with a disk or pulley B′, adapted to connect it with the motor, line-shaft, or other source of energy, and has at its opposite end a crank-plate B^2, provided with a crank-pin *b*′.

C C′ C^2 are the radially-placed cylinders bolted to the front face of the frame and provided with pistons P P′ P^2, all of which are connected with the crank-pin *b*′ by means of pitmen *p* *p*′ p^2, as explained above. Air is admitted to or discharged from the cylinders through ports at their outer ends controlled by rocking valves, one of which is shown at V, Fig. 4. The valves are provided with stems *v* *v*′ v^2, having levers *l* *l*′ l^2, which are connected by rods *r* *r*′ r^2 with the eccentric-rods R R′ R^2, respectively, the inner ends of the eccentric-rods being mounted on an eccentric B^3 on the shaft B and their outer ends being free to slide in grooves *g* in three pivoted disks E E′ E^2. The disks E E′ E^2 are formed with teeth on suitable arcs of their peripheries, and these teeth engage geared segments *d*′ d^2 d^3 at the the ends of the corresponding arms D′ D^2 D^3 of the spider, whose central boss D is fitted to and turns upon the hub A^3 of the frame, as shown in Fig. 4. The arm D^2 of the spider is pivotally connected with the two-part plunger *s* *s*′ of the solenoid S, which is secured to the frame of the machine, the coil of the solenoid being in the circuit which transmits electrical energy from the source of supply to the work. A spring S′, fastened at one end to the frame and at the other end to a swinging lever L, connected with the plunger of the solenoid, tends to draw the plunger in one direction, and the force exerted upon it by the current passing through the coil tends to draw it in the opposite direction. The relation of the two forces thus exerted on the plunger determines the position of the disks E E′ E^2, and thereby controls the valve-operating mechanism in the manner already described.

The passage of air from either of the cylinders to the chamber within the frame A′, when the device acts as a compressor, is through the valve-chamber *c* at the outer end of the cylinder and thence through a passage *c*′, formed in the wall of the frame, a check-valve c^2 being so arranged as to prevent the passage of air from the chamber in the frame to the cylinder. At the same time the exterior air enters the cylinders through chambers c^4 at their outer ends, check-valves c^5 being so placed as to prevent the exhaust of air from the cylinders. In order to permit the flow of air from the chamber in the frame to the cylinders and the exhaust of air from the cylinders when the device is working as an engine, valves V′ V^2, having a common stem v^3, are suitably seated at the outer end of each of the cylinders and afford by-passages around the check-valves c^2 c^5. Each of the stems v^3 is provided with an arm or crank l^3, which is

operated by a link r^3 and a lever l^4, connected with a solenoid S^2, as shown in Fig. 4. When the device acts as a compressor, the valves V' V^2 are closed; but when it acts as an engine these valves are open, as shown in Figs. 5 and 6. The change of position of the valves is effected by means of the solenoids S^2, which act upon the closing of a suitable circuit by means of a switch F F', one of whose parts is supported by the lever L, Fig. 3, governed by the main solenoid S in the manner already described.

The operation of the parts thus specifically indicated has been fully explained in the general description preceding the description of the figures of the drawings and need not be repeated. From that explanation it is evident that the mechanism shown and described is adapted to operate equally well either as an air-compressor or as an engine, and may thus be utilized either in storing superfluous energy or in giving off the stored energy as a means of assisting the motor in performing excessive work. The government and reversal of the valve mechanism by the main solenoid is instantaneous and automatic and may be so sensitive as to accommodate itself to every varying condition of the work, and the conversion of the mechanism from a compressor to an engine, or vice versa, by means of the auxiliary valves and solenoids is also instantaneous and automatic and may evidently be so timed as to co-operate perfectly with the other elements of the mechanism in adapting it for the performance of its functions.

While the solenoid forms a simple and practical dynamometer adapted, perhaps, better than any other to the purpose indicated, I do not intend to limit my invention to the use of this particular form of dynamometer, as other forms may evidently be substituted for it and made to operate successfully.

While the mechanism described and explained above is adapted to change its function from storing energy to giving it off in work, it is evident that where the force developed by the prime motor is at all times greater than is required for its work the governor may perform only the function of storing up the surplus energy of the motor—as, for instance, by compressing air, the energy thus stored being used for any desired purpose other than that of assisting the motor. It is therefore not essential to the operation of my invention that the governor shall have the double function hereinbefore set forth, since in many cases it may be made operative though it performs but one of those functions.

Having now described and explained my invention, what I claim as new, and desire to secure by Letters Patent, is—

1. The combination with a prime motor and a dynamo operated thereby and supplying an electric circuit, of air-compressing mechanism connected with and operated by the prime motor and an electrical dynamometer lying in said circuit and connected with and controlling the operation of said air-compressing mechanism, whereby the rate of compression of air thereby may vary with the current passing through the dynamometer.

2. The combination with an electrical supply and a circuit connected therewith and adapted to supply current to electrically operated machinery, of convertible mechanism adapted to compress air or to operate as a compressed air engine, and an electrical dynamometer lying in the circuit and connected with and controlling the operation of said mechanism whereby the function of said mechanism and the work performed thereby may change with the variation of the current passing through the dynamometer.

3. The combination with a source of electrical supply and a circuit connected therewith and adapted to supply current to electrically operated machinery, of an air-compressor and a suitable reservoir for storing the air compressed thereby, valves interposed between the compressor and reservoir and adapted by their reversal to convert the compressor into a motor operated by the compressed air in the reservoir, suitable valve gear connected with the valves and adapted to reverse them and to vary their vibration in either position and an electrical dynamometer lying in the circuit and connected with and controlling said valve-gear whereby the operation of the valves and the function and work of the mechanism may change with the variation of the current passing through the dynamometer.

4. The combination with a suitably operated dynamo and a circuit connected therewith and adapted to supply current to electrically operated machinery, of an air compressor coupled to the dynamo shaft and running continuously in the same direction, a suitable reservoir connected with the compressor and receiving the air compressed thereby, valves interposed between the compressor and reservoir and adapted by their reversal to convert the compressor into a motor operated by the compressed air in the reservoir, suitable valve-gear connected with the valves and adapted to reverse them and to vary their vibration in either position and an electrical dynamometer lying in the circuit and connected with and controlling said valve-gear, whereby the function and work of the compressor may change with the variation of the current passing through the dynamometer.

5. The combination with a source of electrical supply and a circuit connected therewith and adapted to supply current to electrically operated machinery, of suitable mechanism adapted to either store or give off energy and an electrical dynamometer lying in the circuit and connected with and governing the operation of said mechanism, the dynamometer being adapted when actuated by a predetermined current of electricity to hold the mechanism in its neutral position and to convert it into an accumulator, or a motor as the cur-

rent falls below or rises above said predetermined limit.

6. The combination with a source of electrical supply and a circuit connected therewith and adapted to supply current to electrically operated machinery, of suitable mechanism adapted to either store or give off energy, an electrical dynamometer lying in said circuit and an adjustable connection between the dynamometer and said mechanism, the dynamometer when actuated by a predetermined current being adapted to hold said mechanism in its neutral position and when actuated by a greater or less current to convert it into a motor or accumulator, and the adjustment of the connection between the dynamometer and the mechanism being adapted to vary the current required by the dynamometer for holding the mechanism in its neutral position.

7. The combination with a suitably operated dynamo and a circuit connected with it and adapted to supply a current to electrically operated machinery, of an air-compressor coupled to the shaft of the dynamo and running continuously in one direction, a suitable reservoir connected with the compressor and receiving the air compressed thereby, valves interposed between the compressor and the reservoir and adapted by their reversal to convert the compressor into a motor operated by the air in the reservoir, suitable valve-gear adapted to reverse the valves and to vary their vibration in either position, a solenoid lying in the circuit, means connecting the plunger of the solenoid with the valve-gear and means connected with the valve-gear and tending to counterbalance the force exerted by the solenoid thereon, the solenoid when acted on by a given predetermined current being adapted to hold the valves in their neutral position and when actuated by a greater or less current to throw the valves in one direction, or the other, and thereby to convert the mechanism into a motor or an accumulator.

8. The combination with a suitably operated dynamo and a circuit connected therewith and adapted to supply current to electrically operated machinery, of an air-compressor coupled to the shaft of the dynamo and running continuously in one direction, an air reservoir connected with the compressor, valves interposed between the compressor and the reservoir and adapted by their reversal to convert the compressor into a motor operated by the air in the reservoir, suitable valve-gear adapted to reverse the valves and to vary their vibration in either position, a solenoid lying in the circuit, an adjustable connection between the plunger of the solenoid and the valve-gear and means connected with the valve-gear and tending to counterbalance the force of the solenoid, the solenoid when actuated by a predetermined current being adapted to hold the valves in their neutral position and when actuated by a greater or less current to throw them in one direction or the other, thereby converting the mechanism into a motor or an accumulator and the adjustment of the connection between the plunger and the valve-gear being adapted to vary the current required by the solenoid for holding the valves in their neutral position.

9. The combination with a suitably operated dynamo a circuit connected therewith and adapted to supply current to electrically operated machinery, and a shaft coupled with the dynamo shaft and rotating constantly in one direction, of an engine cylinder, a piston sliding in the cylinder and operated by said rotating shaft, an air reservoir connected with the cylinder, a valve interposed between the cylinder and the reservoir and adapted by its reversal to convert the cylinder and piston into an air compressor or motor, an eccentric rod mounted at its inner end on a suitable eccentric, an adjustable guide regulating the travel of the outer end of the eccentric rod, suitable connections between the eccentric rods and the valve, an electrical dynamometer lying in said circuit and a connection between the dynamometer and the means for regulating the travel of the outer end of the eccentric rod, whereby the variation of the current passing through the dynamometer may vary the travel of the eccentric rod and thereby reverse the valve, or change its vibration.

10. The combination with a suitably operated dynamo and a circuit connected therewith and adapted to supply current to electrically operated machinery, of a shaft coupled to the dynamo shaft and rotating constantly in one direction, a series of suitably arranged engine cylinders, pistons sliding in said cylinders and operated by said rotating shaft, an air reservoir connected with said cylinders, valves interposed between said reservoir and said cylinders and adapted by their reversal to convert the mechanism into a compressor or a motor, eccentric rods mounted at their inner ends on a suitable eccentric and provided at their outer ends with adjustable means for regulating their travel, means connecting said eccentric rods with said valves, respectively, a dynamometer lying in said circuit and means connecting the dynamometer with the devices for regulating the travel of the outer ends of the eccentric rods, whereby the variation of the current passing through the dynamometer may vary the movement of the eccentric rods and thereby reverse the valves or vary their vibration.

11. The combination with a suitably operated dynamo and a circuit connected therewith and adapted to supply current to electrically operated mechanism, of the shaft, B, rotating constantly in one direction, the cylinders, C, C′, C^2, the pistons sliding in the cylinders and operated by piston rods connected with the shaft, the reservoir A′, connected with the cylinders, the valves, V, interposed between the cylinders and the reservoir, the

eccentric rods, R, R′, R², mounted at their inner ends on an eccentric on the shaft, the toothed and slotted disks, E, E′, E², regulating the travel of the outer ends of the eccentric rods, suitable connections between the eccentric rods and the valves, V, the spider, D, having arms, D′, D², D³, provided with toothed segments engaging the disks, the solenoid lying in the circuit and a suitable connection between the plunger of the solenoid and one of the arms of the spider, D, whereby the variation of the current passing through the solenoid varies the position of the spider, thereby adjusting the disks, E, E′, E², and reversing, or varying the vibration of the valves; substantially as shown and described.

12. The combination with the shaft, B, the cylinders, C, C′, C², the pistons and piston rods operated by the shaft, the reservoir, A′, the valves, V, the eccentric rods, R, R′, R², and means substantially as shown and described for varying the travel of the outer ends of the eccentric rods and thus reversing or changing the vibration of said valves, of the by-pass valves, V′, V², and means substantially as shown and described for reversing said by-pass valves at the instant of reversal of the valves, V; substantially as shown and described.

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