No. 753,510. PATENTED MAR. 1, 1904.

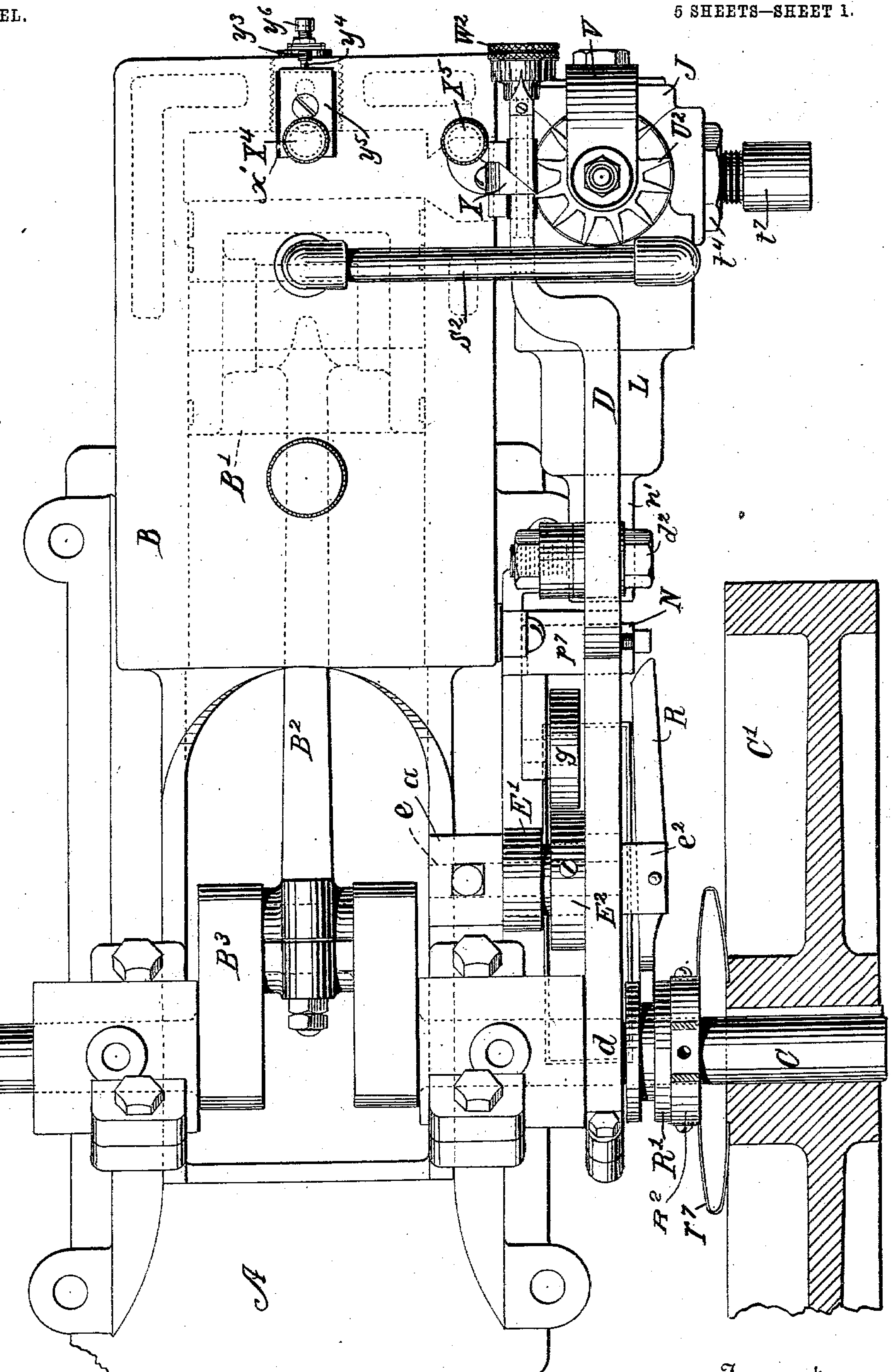
G. J. MURDOCK.

GAS ENGINE.

APPLICATION FILED FEB. 11, 1903.

NO MODEL. 5 SHEETS—SHEET 1.

Fig. 1.



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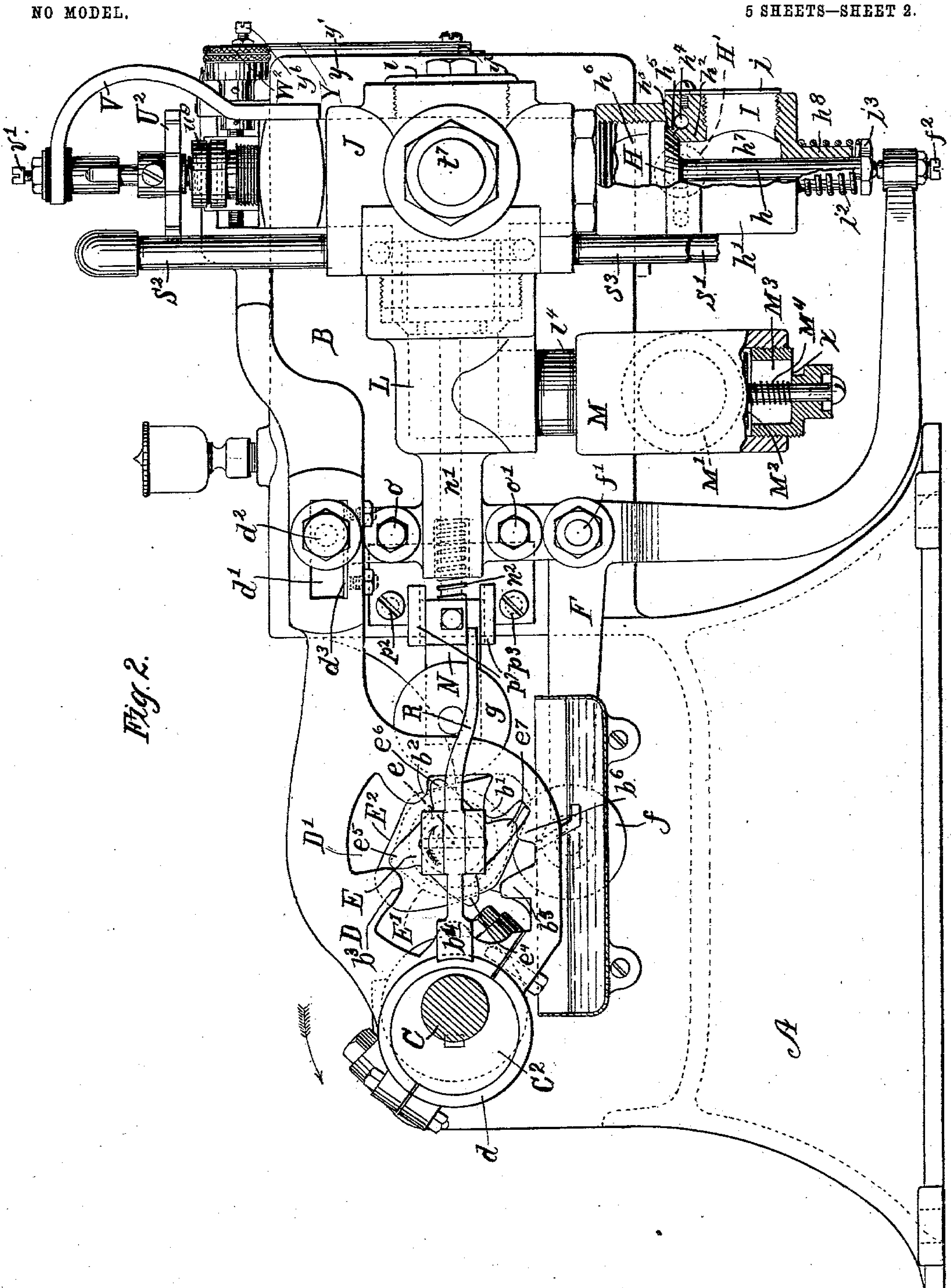

Fig. 2.

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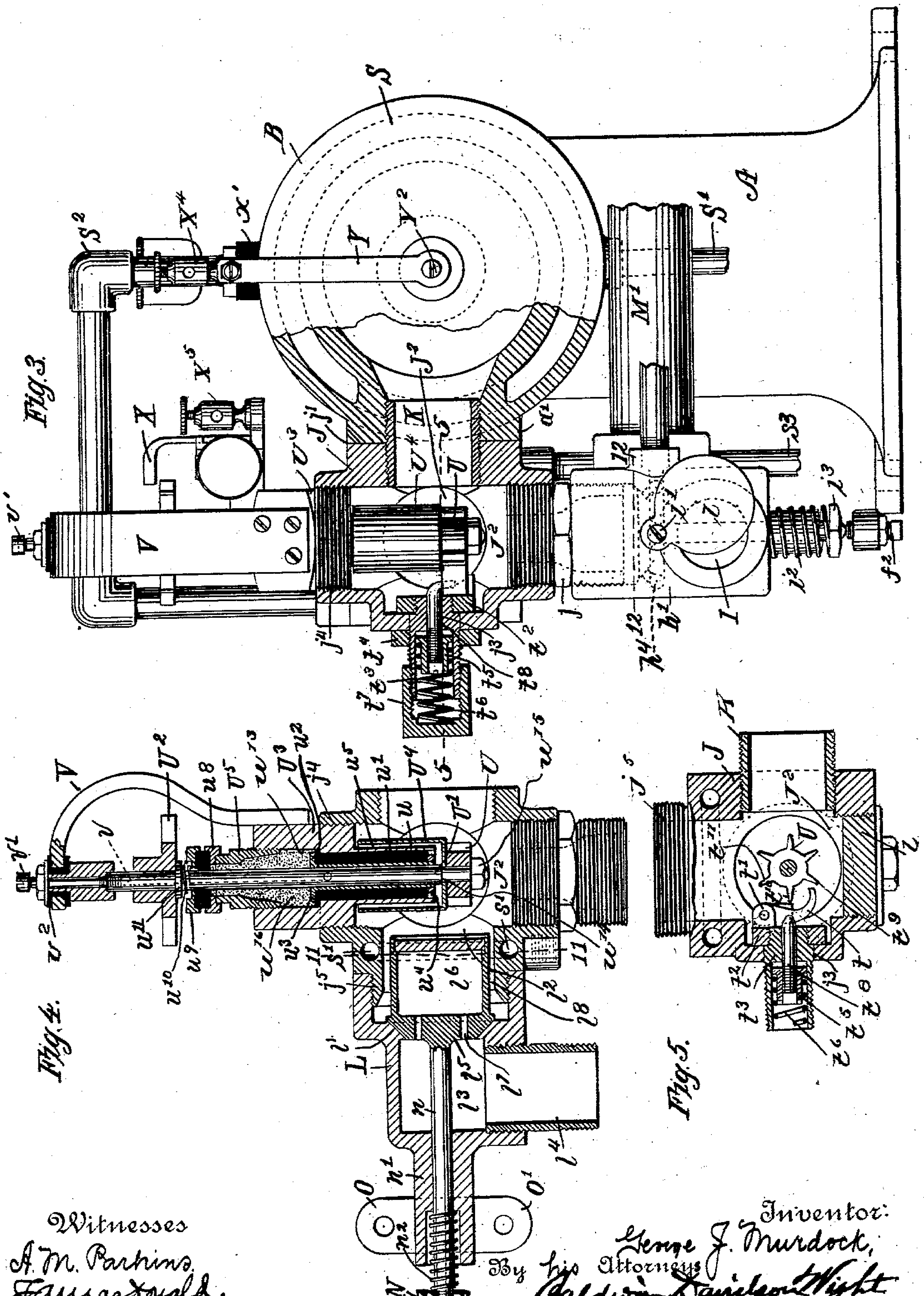

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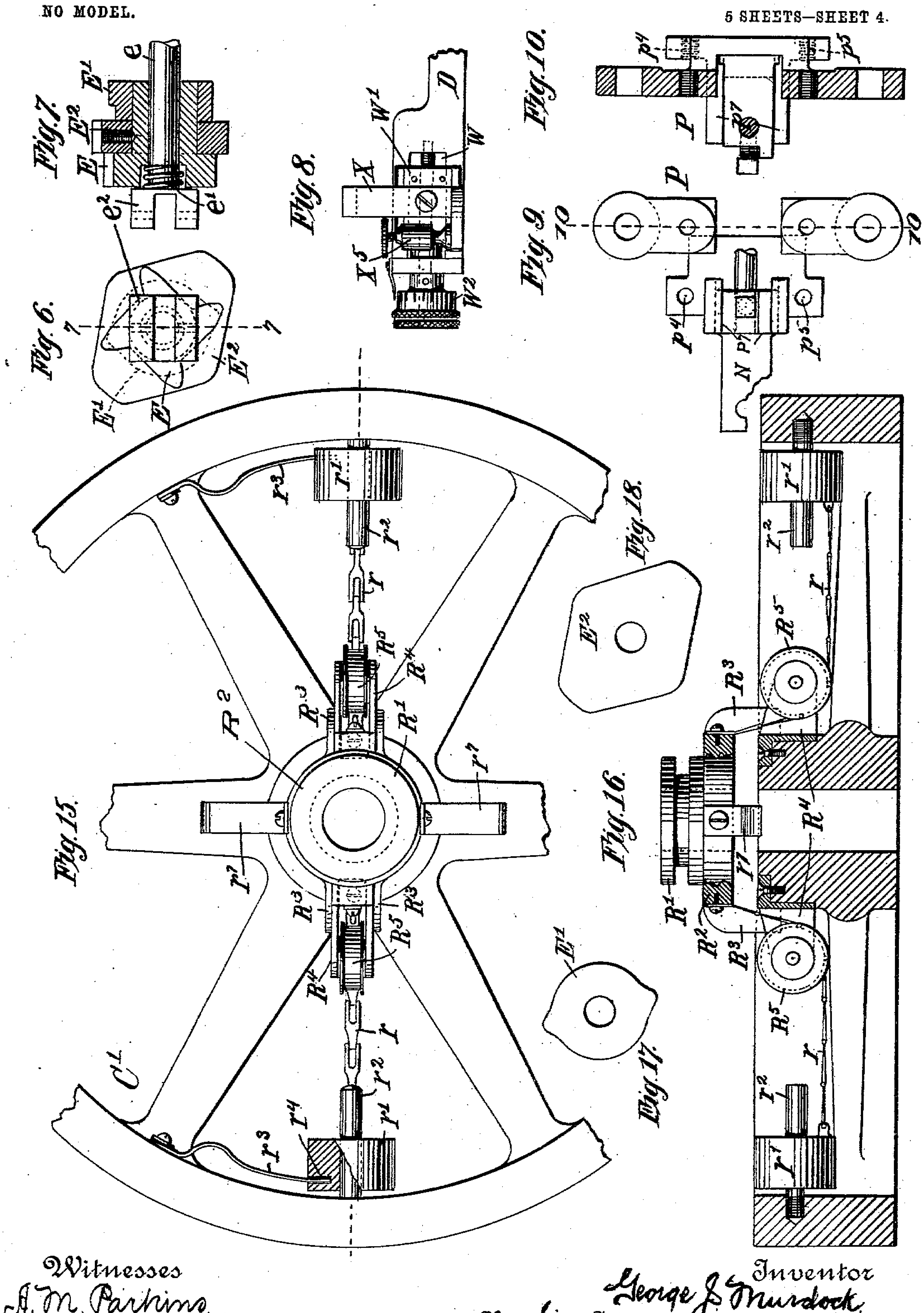
NO MODEL. 5 SHEETS—SHEET 4.



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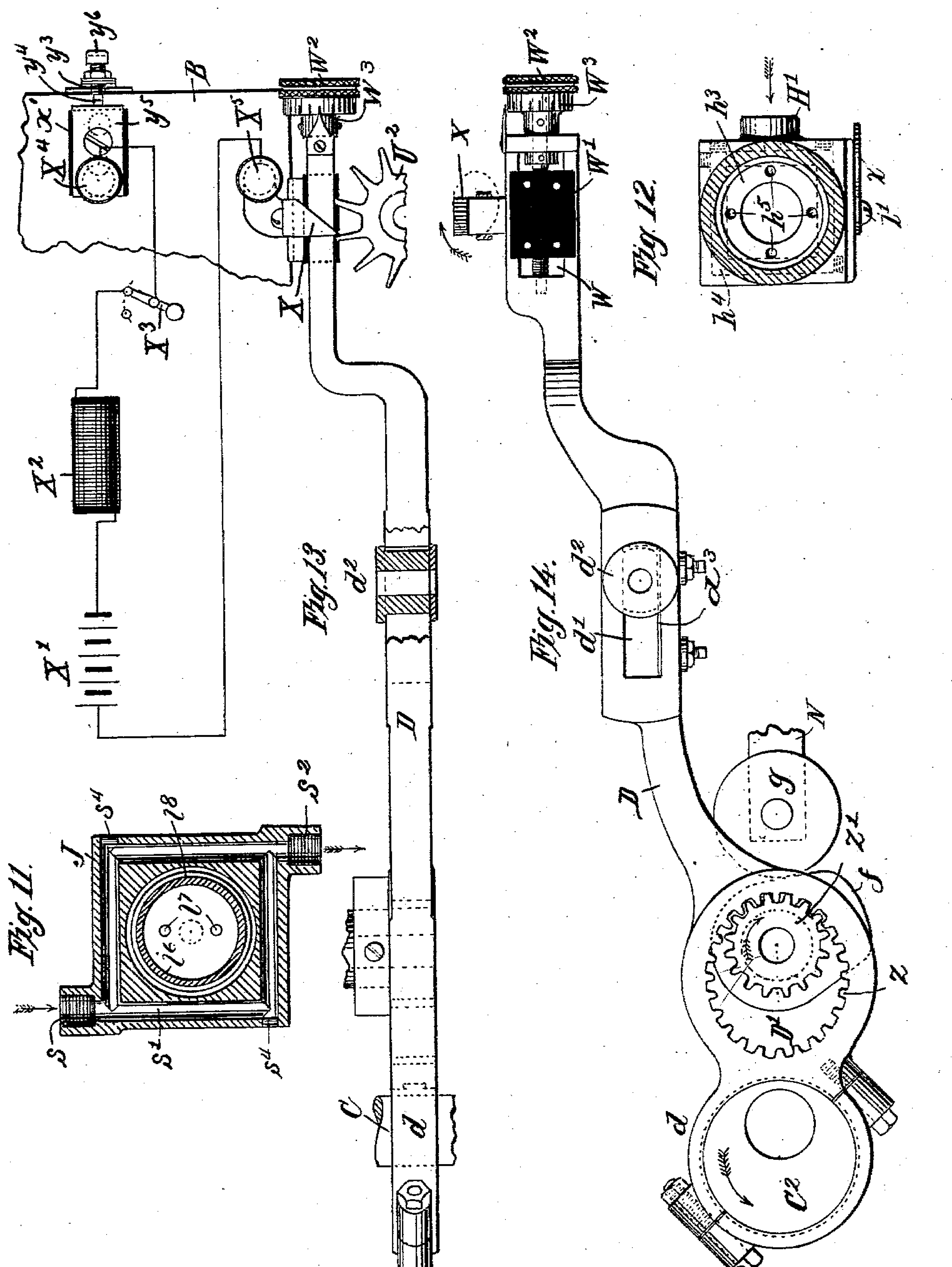
NO MODEL. 5 SHEETS—SHEET 5.



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No. 753,510. Patented March 1, 1904.

UNITED STATES PATENT OFFICE.

GEORGE J. MURDOCK, OF NEWARK, NEW JERSEY.

GAS-ENGINE.

SPECIFICATION forming part of Letters Patent No. 753,510, dated March 1, 1904.

Application filed February 11, 1903. Serial No. 142,902. (No model.)

To all whom it may concern:

Be it known that I, George J. Murdock, a citizen of the United States, residing at Newark, in the county of Essex and State of New Jersey, have invented certain new and useful Improvements in Gas-Engines, of which the following is a specification.

This invention relates to gas-engines of the type constructed to be operated by the explosion of a mixture of gas and air or other explosive mixture, which is first admitted to the engine-cylinder during one stroke of the piston, then compressed during the next return stroke, and then fired to give the piston a power-stroke, the products of combustion being expelled from the cylinder as the piston returns from the power-stroke.

The object of my invention is to improve the general construction of engines of this type; but some of my improvements may be embodied in gas or vapor engines of other kinds.

My invention relates particularly to the mechanism for operating the admission and exhaust valves, and in this connection includes improved means for opening and closing these valves during each normal operation and also improved means for governing the exhaust-valve should the speed of the engine vary.

My invention further consists in certain improvements in the general construction of the engine and in the manner of assembling and attaching the parts.

In the accompanying drawings, Figure 1 shows a top plan view of a single-acting four-cycle gas-engine embodying my improvements, with the fly-wheel and some parts associated therewith in section. Fig. 2 shows a side elevation thereof, with some of the parts broken away in order to better illustrate other parts. Fig. 3 is a view of the engine, partly in rear elevation and partly in section. Fig. 4 shows a vertical central section through the combustion-chamber, the exhaust-valve, the igniting devices, and some of the parts associated therewith. Fig. 5 shows a transverse section through the combustion-chamber and parts associated therewith on the line 5 5 of Fig. 3. Figs. 6 and 7 are detail views, in side elevation and in section, showing the double-ended cams for operating the admission and exhaust valves and the star-wheel which actuates these cams. Fig. 8 is a detail view of the lever which operates the admission and exhaust cams and of certain parts carried by the rear end of this lever. Figs. 9 and 10 are detail views of a bracket employed to guide parts of the mechanism for operating the exhaust-valve and to support the pivots about which the cam-operating lever and the lever for opening the admission-valve move. Fig. 11 is a detail view, in vertical section, on the line 11 11 of Fig. 4, illustrating the water-jacket formed around the exhaust-valve chamber. Fig. 12 is a detail view, in transverse section, on the line 12 12 of Fig. 3, illustrating the manner of admitting gas to the engine. Fig. 13 is a diagram of the electric circuits, and this figure also shows the lever for operating the cams and the devices by means of which the lever is caused to operate the igniter. Fig. 14 shows a side elevation of the cam-operating lever and parts connected therewith. In this figure of the drawings a modified way of operating the cams is illustrated. Fig. 15 is a detail view of the fly-wheel and the governing mechanism carried thereby. Fig. 16 shows a transverse section on the line 16 16 of Fig. 15. Fig. 17 shows a side elevation of the cam employed for operating the exhaust-valve, and Fig. 18 shows a side elevation of the cam employed for operating the admission-valve.

The main frame A of the engine may be of any construction suitable to support the working mechanism. The cylinder B and piston B′ are of usual construction, the piston-rod B^2 being connected to a crank B^3 on a crank-shaft C. On one end the crank-shaft carries a fly-wheel C′ and an eccentric C^2, which projects from the shaft in a direction diametrically opposite to that of the crank. Surrounding the eccentric is a strap *d*, formed on a lever D, which has teeth adapted to engage a star-wheel or pinion E on a shaft *e*, carrying cams E′ E^2, which are set at an angle of about forty-five degrees to each other and which operate through intermediate devices the admission and exhaust valves. The shaft *e* is secured to the frame A at *a*, and the star-wheel E and cams E′ E^2 are rigidly connected together in the manner illustrated in Fig. 7 and are mounted to turn on the shaft e. Preferably the star-wheel is recessed in the manner shown in Fig. 7 to receive a spring e', which bears against the head e^2 of the shaft e and presses the parts E E' E^2 inwardly toward the frame A at a. The lever D extends along the side of the cylinder, terminating near the upper rear end thereof, where it carries devices forming part of the igniting or sparking mechanism. About midway between its ends the lever D is formed with a horizontal slot d', through which extends a guide-bolt d^2, having a flattened surface fitting the slot. An adjustable gib d^3 may be employed at the bottom of the slot to take up wear, and flanges or washers may be used on opposite ends of the block for the same purpose. As the crank-shaft is rotated the eccentric C^2 gives to the lever D a back-and-forth and up-and-down elliptical movement at its opposite ends which causes it, through the connections above referred to and hereinafter fully described, to turn the cams E' E^2 of the admission and exhaust valve operating mechanism and to operate the igniting devices. The front portion of the lever D is formed with an opening D', from the walls of which project teeth b' b^2 b^3 b^4 b^5 b^6, that are adapted to engage the teeth e^4 e^5 e^6 e^7 on the star-wheel E. The tooth b^6 serves mainly as a detent to hold the star-wheel from accidental or premature movement, while the other teeth act positively on the wheel to propel it continuously, steadily, and without noise, the arrangement being such that two or more teeth on the lever D engage two or more teeth on the star-wheel at the same time, one tooth on the lever passing into engagement with the star-wheel just before another tooth on the lever passes out of engagement with said wheel. The cams E' E^2 are of the shapes shown in Figs. 6, 7, 17, 18 and are adapted to operate on rollers f and g, carried, respectively, by a bell-crank lever F and the reciprocating frame N. The lever F is pivotally connected at f' to the frame of the engine, and at its lower rear end it is adapted to engage the lower end of the stem h of the admission-valve H, while the frame N is connected to the exhaust-valve in the manner hereinafter described. The admission-valve is located within a hollow casting h', divided into two parts by a partition h^2, having a large central opening around which is formed the valve-seat h^3. The walls of the casting around the valve-seat are formed with passages h^4, communicating with the gas-supply pipe H', and these passages have a number of lateral branches h^5, through which the gas passes to the gas and air mixing chamber h^6 above the admission-valve. Air enters the chamber h^7 below the valve through a large lateral opening I, which is tapped with a screw-thread of standard size to receive a pipe which may connect it with a gasolene-vaporizer or other oil or vapor supply if it is desired to run the engine by fuel other than gas. When using gas, the opening I is partially closed by a plate i, pivoted, by means of a screw i', to the casting and adapted to be adjusted and held by the screw in any desired position to regulate or vary the admission of air. The casting h' is formed at its lower end with a boss or sleeve h^8, through which the stem of the admission-valve passes and by which it is guided. Surrounding this boss is a spring i^2, which bears against the bottom wall of the casting and against a nut i^3 on the lower end of the valve-stem. It tends to hold the valve closed or to return it to its closed position after a sufficient supply of gas and air has passed it. The lower rear end of the lever F is provided with an adjusting-screw f^2, which bears at all times against the stem of the admission-valve. When the rear end of the lever is raised, it opens the admission-valve, and as this end of the lever descends the admission-valve is allowed to close without noise.

The casting h' is located directly below a casting J, containing the combustion-chamber, the exhaust-valve, and the igniting devices. The casting h' is connected with the casting J by a sleeve-nut j, by means of which it may be readily detached when desired. The casting J is formed with a smooth flat side j', fitting a faced-off chipping-piece a' on the side of the cylinder B near its rear end.

The combustion-chamber J^2 within the casting is connected with the interior of the cylinder by a passage through a sleeve or nipple K, which latter serves to rigidly secure the casting J to the cylinder. Opposite the passage which connects the combustion-chamber with the cylinder the casting is formed with an opening j^3 to receive one member of the igniting or sparking devices, the other member of which is received through an opening j^4 in the top of the casting. On its front side the casting is formed with a threaded hollow projection j^5 to receive another casting L, carrying the exhaust-valve, and on its rear side the casting J is formed with an opening closed by a screw-plug l, through which access may be obtained to the combustion-chamber and through which the exhaust-valve may be withdrawn.

The casting L is formed with a valve-seat l', located between the valve-chamber l^2 and a chamber l^3, which connects, by means of a sleeve-nut l^4, with the interior of the casting M, to which the exhaust-pipe M' is attached. The exhaust-valve has a head l^5, adapted to fit the valve-seat, and an inwardly-extending hollow portion l^6, which is closed at all points except at the openings l^7. The walls of this extension are quite close to the surrounding walls of the valve-chamber, a comparatively narrow annular space l^8 being provided for the passage of the exploded gases or products of combustion from the combustion-chamber.

In this way the valve-head l^5 is protected and its durability is considerably enhanced. By making the extension hollow and opening it by means of the holes l^7 I prevent it from becoming overheated. The hollow projection l^6 serves to fill the valve-chamber or enlargement between the valve proper and the combustion-chamber, this space being occasioned by the fact that the walls of the combustion-chamber are made hollow or formed with passages for the circulation of a cooling medium. Unless the chamber or enlarged opening were thus filled incombustible gases might be trapped, and thus impair the efficient operation of the engine.

The stem n of the exhaust-valve extends through a boss n' on the front end of the casting L. The front end of the valve-stem is connected with the sliding frame N, to the front end of which the roller g is pivoted. A spring n^2, interposed between the boss and the frame N, tends to hold the exhaust-valve closed or to close it at the proper time. On its front end the boss n' is formed with lugs O O′, perforated to receive bolts o o', which connect them with a bracket P. (Shown detached in Figs. 9 and 10.) This bracket has a vertical portion, the upper and lower ends of which are perforated to receive the bolts d^2 and f', about which the levers D and F rock.

The bracket P is secured to the main frame by means of bolts or screws p^2 p^3, which pass through the holes p^4 p^5. (Shown in Figs. 9 and 10.) By the construction described the casting J and parts connected therewith are held firmly in engagement with the engine-cylinder and are held in proper alinement. The casting J cannot be detached without first removing the bolts o o'; but when these bolts are removed the castings L and J may be separated from each other and the casting J may be detached from the cylinder B. By attaching the parts in this way I avoid the necessity of packing the joints. The forward extension of the bracket is formed with guide-rails p^7 for the sliding frame N, the arrangement being such that as the frame N is moved back and forth by the cam E^2 and the spring n^2 the exhaust-valve may be reciprocated in a true horizontal direction. Normally the exhaust-valve is opened once during each two revolutions of the crank-shaft; but when the speed of the engine becomes excessive the exhaust-valve is for a time held opened by means of devices controlled by a governor.

In Fig. 1 a lever R is shown pivoted to the head e^2 of the shaft e. The front end of the lever enters an annular groove in a collar R′, adapted to slide on the crank-shaft, while the rear end of the lever is adapted to engage the frame N. It will be observed that the end of the lever which engages the frame N is rounded or inclined. This is for the purpose of holding the exhaust-valve open to a greater or less extent, as occasion may require. The collar R′ is connected with an annular frame R^2, carrying forked arms R^3, that embrace brackets R^4 on the hub of the fly-wheel, which carry rollers R^5, across which extend chains r, connected with weights r', sliding radially on rods r^2, attached to the rim of the wheel. The weights are pressed radially inward by means of springs r^3, secured to the rim of the fly-wheel and entering at their free ends recesses r^4 in the weights r'. The springs tend to keep the chains taut, and by adjusting the springs the speed at which the engine is set to run may be regulated. The greater the tension of the springs on the weights the faster the speed of the engine. The collar R′ and frame R^2 are pressed away from the fly-wheel by means of springs r^7, attached to the frame R^2 and bearing against the hub of the fly-wheel in the manner indicated in Fig. 1. Normally the adjustment of the governor is such that the weights remain in a fixed position and the lever R is outside the path of the reciprocating frame N; but should the speed of the engine become excessive the weights will fly out, draw in the collar R′, and cause the rounded or inclined end of the lever R to move into the path of the frame N, and thus hold the exhaust-valve open against the force of the spring n^2. This general method of governing has heretofore been employed—*i. e.*, it is old to regulate the speed of a gas-engine by holding the exhaust-valve open, and thus reduce the supply of combustible gas and air or other fuel admitted to the cylinder; but my invention in this connection differs from others in this. I have adapted the well-known "hit and miss" governor to act on the exhaust-valve in such manner as to hold it open to a greater or less extent by forming the end of the striker rod or lever R with an inclined or rounded portion adapted to engage the stem or frame of the exhaust-valve. By this arrangement any part of a charge may be taken and compressed and great steadiness of speed obtained, as the distance the exhaust-valve is held open depends entirely on the movement given to the lever R by the weights r'. The weights slide easily on their guide-rods and their motion is transmitted to the lever R with but little friction. I further provide means for admitting air to the combustion-chamber during the idle strokes of the engine or when the exhaust-valve is held open while governing, as above described, in contradistinction to readmitting the exhaust gases or products of combustion.

By reference to Fig. 2 it will be observed that in the bottom of the casting M is located a valve M^2 above an opening M^3 through which air may be admitted. This valve is held normally raised or open by means of a spring M^4. In the normal operation of the engine when the products of combustion pass to the exhaust-pipe M′ the valve M^2 is closed by the pressure of these gases, and when the exhaust-valve closes the valve is opened by the spring M^4; but when governing with the exhaust-valve held open ordinarily when no valve M^2 is used spent gases are drawn back into the combustion-chamber and engine-cylinder, thus fouling the valves and other parts and overheating them; but by the use of the normally open valve M^2 the reëntrance of the foul gases is prevented, because as soon as the valve M^2 is relieved of pressure it will rise and air will enter at x and pass by the exhaust-valve to the combustion-chamber while the spent gases continue in their passage through the main exhaust-pipe M'. In this way the parts are kept cool and the cylinder, combustion-chamber, &c., are cleansed from any foul or spent gases that may have been left behind. It is desirable to use a spring to hold the valve M^2 open. A weight and lever or other equivalent of a spring might be used; but I have found that it is quite important that some means for holding the valve normally open should be employed. So far as I am aware it is new with me to use a normally open valve in this connection and it also is new with me, so far as I am aware, to employ means for admitting air to the cylinder or combustion-chamber during the time that the exhaust-valve is open while governing. Some means may be provided for suspending the admission of gas during the idle strokes of the engine while governing, or I may use an automatic suction-valve and omit the valve-operating lever F.

The cylinder B is provided with the usual water-jacket S, to which water is admitted from a pipe S' and from which it passes by pipe S^2. The latter pipe connects at s, Fig. 11, with passages s' in the projection j^5, into which the part l^6 of the exhaust-valve extends. As will be observed by reference to Fig. 11, a water-jacket is formed completely around the exhaust-valve and the water passes out at s^2 into a pipe S^3. The passages s' may be conveniently formed by drilling into the casting, the proper ends of the holes being closed by plugs s^4, as indicated. By this means the exhaust-valve and the parts associated therewith are cooled, and as their water-jacket is close to the igniting devices the temperature of the latter is also materially reduced and their life thereby prolonged.

The sparking or igniting devices are located within the combustion-chamber in line with the passage connecting this chamber with the interior of the cylinder B. A finger t is pivoted to lugs t', attached to a nut t^2 on the end of a sleeve t^3, which passes through the opening j^3 on one side of the casting J. This finger is adapted to engage with a star-wheel U, operated in the manner hereinafter described. It is curved or segmental in outline, and as it wears away and is adjusted inward its inner end will always maintain a proper relation with the star-wheel U. As the end of the finger wears away a rounded surface is produced by sparks, which will allow the finger to move freely without becoming locked with the star-wheel. The sleeve t^3 has an exterior screw-thread and receives a nut t^4, the nuts t^2 and t^4 serving to clamp the sleeve in place on the casting J in the manner illustrated in Fig. 3. Within the sleeve is arranged a sliding block t^5, which is pressed inwardly by means of a spring t^6, the outer end of which bears against a cap t^7, adjustably attached to the sleeve t^3. This sleeve carries a rod t^8, which extends through the sleeve t^3, and is adapted to slide back and forth therein. The inner end of this rod is bent downwardly in the manner indicated in Fig. 3 and engages the pivoted finger t. By the arrangement shown when the finger t is moved on its pivot the rod t^8 may be moved outward against the force of the spring t^6 and inward by means of the spring. The finger t constitutes one electrode, which I call the "ground-contact" of the igniter-circuit. It will be observed that most of the parts are located outside the combustion-chamber, the spring and all the adjusting devices being so arranged. The inward movement of the finger is limited by the inward movement of the sliding block t^5, and by adjusting the block on the outer end of the rod t^8 this movement may be regulated. The sleeve t^3 may also be adjusted radially toward and from the star-wheel to control the engagement of the finger with said wheel. I may fill the cap t^7 with powdered graphite to lubricate the moving parts. By removing the plug l the igniting devices may readily be reached for inspection or repair. No packing is required, and yet the connections are all gas-tight. The other electrode is the star-wheel U, before referred to. This wheel is adapted to be revolved to engage and to break connection at proper times with the finger t, and it is secured to the lower end of a vertical shaft U', which extends up through the top of the casting J and carries at its upper end a star-wheel U^2, which is operated step by step by devices carried by the upper rear end of the cam-operating lever D. The drawings show the wheel U^2 as being provided with twelve teeth, while the wheel U is formed with six teeth. By this arrangement the igniting devices are operated to produce a spark after each two actuations of the wheel U^2, and as a plurality of teeth are employed on the wheel U the life of the wheel is made much longer than would be the case if only one tooth were used.

It is not necessary, of course, to insulate the ground-contact from the frame of the engine; but it is important to provide efficient means for insulating the other electrode from the engine-frame. Difficulty has heretofore been encountered in preventing short-circuiting and in preserving the insulation from destruction by the heat, flame, and deposits resulting from the exploded gases. In Fig. 4 I have shown most efficient insulating means and very effective devices for preserving such insulation. The opening j^4 in the top of the casting J is closed by means of a screw-plug U^3, and to this plug all the parts of one member of the igniting devices are attached. The plug U^3 is formed with a sleeve u, which extends down into the combustion-chamber around the shaft U'. Within this sleeve is located insulating material u', preferably consisting of a vertical series of mica disks carried by a metal spool u^2. The spool is flanged at its upper end u^3 and is provided at its lower end with a nut u^4, the disks being held securely between the flange and nut. As shown in Fig. 4, the nut u^4 is of smaller diameter than the sleeve u, being out of contact therewith, while the disks fit the sleeve closely. The flange u^3 is arranged slightly above the bottom of the recess u^{13} in the upper portion of the plug u^3 and is of less diameter than this recess, so that its edges do not come in contact with the walls thereof. A few of the mica disks at the top of the spool are of larger diameter than the others and rest on the bottom wall of the recess u^{13} and insulate the flange therefrom. In this way the spool is completely insulated from the plug. The shaft U' near its lower end is shouldered at u^{14} and receives a cup or bell u^4, which is held on the shaft against the shoulder by the wheel U and nut u^{15}. The cup extends upwardly from the lower end of the shaft and surrounds the sleeve u, leaving an annular space u^5. The space u^5 becomes filled with spent gases after the first explosion; but it thereafter remains filled with these gases, preventing the admission of explosive mixture after the first admission thereto when the engine is started. It will be observed that the space between the nut u^4 and the sleeve u is a small one. If this space should become filled by a deposit of carbon forming on the lower mica disks resulting from repeated explosions, the current would be short-circuited or grounded at this point, passing from the shaft U' through the nut u^4 to the sleeve u and thence to the frame of the engine. By using the cup U^4 this deposit of carbon is entirely prevented. The cup also prevents overheating of the insulation.

The recessed upper end of the plug U^3 is filled with asbestos u^{16}, held in place by a gland U^5, above which is located a recessed washer u^8, insulated from another washer u^9 above it, upon which bears a spring u^{10}, surrounding the shaft U' and bearing against the under side of a collar u^{11} thereon. This spring tends to force the shaft upward, thus avoiding any contact or packing at the lower end of the sleeve where it would be subject to heat and also providing sufficient friction to prevent the star-wheel U^2 from turning or moving, except when positively moved by the cam-operating lever D. The upper end of the rod U' is connected with a frame V, attached to the plug U^3; but the shaft is insulated from the frame V in the manner indicated at v^2.

It will be observed that the asbestos u^{16} extends up through the gland and also through the washer u^8, thus surrounding the shaft U' and completely insulating it from the gland as well as from the washer. This precise arrangement is, however, not essential, as the insulation is maintained properly by reason of the fact that the shaft cannot make contact with the gland as it passes centrally through a comparatively large opening therein, and the washer is held concentric on the gland by the boss on the upper end of the latter, which fits a corresponding recess in the bottom of the washer. The asbestos, therefore, primarily serves as a packing to prevent products of combustion from being forced out along the shaft. The shaft U' is bored axially, as indicated at v, the passage in the shaft extending downward in the manner indicated to permit lubricating material to be carried to the point where it is needed. The top of the passage v is closed by a bolt v'.

The upper rear end of the lever D is formed with a slot W, in which is adjustably mounted a block W', of insulating material. This block may be adjusted by means of a thumb-screw W^2, and the amount of adjustment to obtain the required lead may be read by means of an index W^3. To this block is attached a pawl X, adapted to engage with the star-wheel U^2 in the manner indicated in Figs. 3 and 13. As before stated, the rear end of the lever D is given a back-and-forth and up-and-down movement, resulting in an elliptical movement, which gives to the pawl X an elliptical movement. (Indicated by dotted lines in Fig. 14.) As the rear end of the layer D is moved backward, it also rises, thus clearing the teeth of the wheel U^2; but as the lever D moves forward it also moves downward and engages the teeth of the wheel U^2 and turns this wheel and correspondingly moves the wheel U within the combustion-chamber. The arrangement is such that a quick break is given at the electrodes as the peripheral speed of the wheel U is made the same as that of the engine-shaft, and two impulses must be given to the wheel U^2 before the wheel U can be operated to break the circuit and produce a spark within the combustion-chamber.

The electric circuit of the igniting devices is indicated in Fig. 13. The battery X' is connected on one side with induction-coil X^2, which latter is connected with a switch X^3, in turn connected with a binding-post X^4, connected to ground in the manner hereinafter described. The other pole of the battery X' is connected to a binding-post X^5 on the end of the lever D. The binding-post has a metallic connection with the pawl X, which latter makes contact with the wheel U^2, and through the wheel U^2, shaft U', and wheel U electrical connection is made with the ground contact *t*. While the pawl X engages each tooth of the wheel U^2, the electric circuit is made and broken every other time that the pawl and wheel thus engage, because the wheel U has only half as many teeth as the wheel U^2. The arrangement is such that no sparking occurs at the wheel U^2, because when the pawl X breaks connection with the wheel U^2 the circuit is open at the wheel U and contact *t*. In Fig. 5 the end of the contact *t* is shown as being arranged between two of the teeth of the wheel U, having just passed the tooth t^9 and produced a spark. When the wheel U^2 is moved one step by the action of the pawl X on one of its teeth, the wheel U will be moved until the next tooth t^{10} is brought close to the end of the contact *t*, but not into connection with it. The next movement given to the wheel U^2 by the pawl X will cause the wheel U to move in such manner as to cause the contact *t* to wipe across the tooth t^{10}, producing a spark and then assuming a position between the tooth t^{10} and the tooth t^{11} similar to the relative position of the teeth and contact shown in Fig. 5. The other teeth on the wheel U operate in connection with the contact *t* in a similar way. It will now be understood that the contact *t* leaves the teeth on the wheel U and assumes a position such as shown in Fig. 5 before the pawl X leaves the wheel U^2, and therefore no sparking occurs at U^2.

Accidents sometimes occur in gas-engines by reason of the fact that the circulation of water is stopped when the engineer forgets to turn on the water or the water falls below the proper level in the stand-pipe. When this occurs, the excessive heat causes the oil to carbonize and the piston to cut the cylinder. To guard against accidents of this kind, I employ a thermostat, which is adapted to open and close the circuit of the igniter and stop the engine by suspending the operation of the igniting devices when the heat of the engine rises to a predetermined degree. The thermostat Y is attached to the rear end of the cylinder. It may be of any suitable construction, but preferably consists of two strips *y* y' of dissimilar metal, such as brass and soft steel. The brass strip is preferably placed next to the cylinder, as the brass expands more than the steel. Both strips are attached to a plug y^2, secured to the cylinder, and the upper end of the strips carries a contact-point y^3, coöperating with a contact-point y^4 on the base y^5 of the binding-post X^4. The binding-post X^4 is insulated from the engine by means of a block of insulating material *x*. The sensitiveness of the thermostat may be regulated by means of a set-screw y^6, and by this device the thermostat may be set to operate—that is, to break the circuit when any desired degree of heat has been reached. Normally the circuit is closed through the thermostat; but when excessive heat occurs the upper end of the thermostat will tip outward, and thus break the circuit at the contacts y^3 y^4, and therefore the operation of the igniting devices is suspended, and as no explosion will occur the engine will come to rest and will remain at rest until the circulation of water is commenced again and the heat of the cylinder falls to the predetermined degree.

In Fig. 14 I have shown a modified way of operating the admission and exhaust cams. In this case the hole D' in the cam-operating lever has its walls formed with a continuous regular series of teeth *z*, coöperating with a pinion z' on the shaft *e*. The teeth *z* are arranged in an elliptical series and engage at all times about one-third of the teeth in the pinion z'. I prefer, however, the arrangement shown in Fig. 2, as a construction of this sort is easier to make and runs with less noise. Of course the number of teeth either in the star-wheel pinion or toothed operating-lever may be varied according to circumstances and the size of the engine.

In the construction shown in Fig. 2 the star-wheel E is given one complete turn to every four revolutions of the crank-shaft. Double-ended cams E' E^2 are employed for operating the admission and exhaust valves, and these valves are operated once for every two revolutions of the main shaft. The object of this construction is to secure greater durability than would be the case if one cam did all the work. In large engines, where it is desirable to use a strap and eccentric instead of cams, the teeth on the cam-gear and in the operating-lever may be varied, so as to cause the cam-gear or star-wheel to revolve once for every two revolutions of the main shaft. Double-ended cams are not essential. By varying the form and dimensions of the star-wheel E and operating-lever D and by properly regulating the stroke of the eccentric single-ended cams may be employed.

In the drawings the mechanism is shown in position to take in an explosive charge. The cam E' having started to open the admission-valve continues to do so as the piston advances in its forward stroke, and just as the piston reaches the end of its stroke the cam has been turned around far enough by the action of the star-wheel E to cause the lever F to resume its first position and the admission-valve is instantly closed by both gravity and the spring i^2, which is of sufficient tension to insure a perfect seating of the valve. After this the piston begins to return on its compression-stroke and the eccentric C^2 (which works exactly opposite to the piston) has traveled around in such manner as to throw the cam-operating lever D back into position to engage a tooth on the wheel U^2 of the igniting devices, at the same time turning by an elliptical motion the star-wheel E. Just before the piston reaches the end of its backward compression-stroke the continued motion of the lever D has turned the wheel U^2 about one-half a tooth-space forward and the circuit is broken within the explosion-chamber, the mixture of gas and air being exploded. As it takes a moment for the explosive mixture to unite, by the time it has done so the crank has reached the center and begins its forward movement or power-stroke. During this movement the eccentric C^2 has carried the lever D to a position where one end of the exhaust-cam E^2 engages the roller g, thus opening the exhaust-valve. This movement takes place just before the piston has reached the end of its forward movement. There is a dwell on the face of the cam E^2 of such length that the exhaust-valve is held open until the piston has returned, thus forcing out the products of combustion. The lever D follows the motion of the eccentric C^2, being free to reciprocate back and forth on the bolt d^2. Five of the teeth b', &c., are adapted to drive the star-wheel, while the sixth tooth b^6 is for the purpose of holding the star-wheel against forward movement ahead of the tooth on the lever D when the exhaust-valve is about to close. After the dwell of the cam E^2 has passed the tension of the spring n' would tend to cause the valve to close too soon, therefore trapping part of the products of combustion and interfering with the efficiency of the engine. The tooth b^6 is for the purpose of preventing this. After the exhaust the parts are again brought to the position shown in the drawings and the operations before described are repeated. When governing, the closing of the exhaust-valve is interrupted in the manner before described.

I have described in detail one way of embodying my invention in a single-acting four-cycle gas-engine; but some of my improvements may be embodied in engines of other kinds. The igniting devices instead of being applied to an outside or supplemental combustion-chamber, as shown, may be applied to the rear end of a cylinder, as is sometimes done, and the devices for automatically stopping the engine by opening the ignition-circuit may be applied to explosive-engines of various types.

In lieu of the contact-finger or pawl t a wheel having a greater number of teeth than the spark-wheel U may be used. Preferably such a wheel would have twice as many teeth as the sparking-wheel. The teeth on the two wheels would interlock and the sparking would be produced at the same times as with the device constructed as shown in Fig. 5.

I do not herein claim the improved igniting devices which I have shown and described nor do I herein claim the before-described means for automatically opening the igniting-circuit when the heat of the engine becomes excessive, as such subject-matter is claimed in my application for patent, Serial No. 148,982, filed March 21, 1903.

I claim as my invention—

1. The combination of a crank-shaft, a cam-shaft, a star wheel or pinion thereon, a cam connected therewith, a cam-operating lever having teeth engaging the star wheel or pinion, and an eccentric on the crank-shaft engaging the cam-operating lever.

2. The combination of a crank-shaft, a cam-shaft in front of the crank-shaft, a star wheel or pinion thereon, a cam-operating lever having teeth engaging the star wheel or pinion, an eccentric on the cam-shaft, and means for guiding the cam-operating lever in rear of the cam-shaft.

3. The combination of a crank-shaft, a cam-shaft, a star wheel or pinion thereon, a cam-operating lever having teeth engaging the star wheel or pinion to propel it, and another tooth for at times preventing the movement of the star-wheel, and an eccentric on the crank-shaft operating the cam-operating lever.

4. The combination of a crank-shaft, a cam-shaft, cams thereon, admission and exhaust valves operated by said cams, a lever operated by the crank-shaft and operating the cams, and igniting devices also operated by said lever.

5. The combination of a crank-shaft, a cam-shaft, cams thereon, a lever operated by an eccentric on the crank-shaft, gearing between the lever and the cams, igniting devices operated by the lever and means for guiding the lever and coöperating with the eccentric to give to the front and rear ends of said lever an elliptical movement.

6. The combination of a crank-shaft, a cam-shaft, a star wheel or pinion thereon, cams connected with said star wheel or pinion, a cam-operating lever engaging the star wheel or pinion, an eccentric on the crank-shaft operating the cam-operating lever, admission and exhaust valves, and connections between said valves and said cams, substantially as described.

7. The combination of an admission-valve, a casing therefor provided with a valve-seat formed with a plurality of gas-openings, a chamber below the valve-seat formed with an air-inlet tapped with a screw-thread of standard size, and a plate for adjusting the size of said opening.

8. The combination of the engine-cylinder, a casting containing the combustion-chamber detachably connected with the cylinder, a casting below the combustion-chamber for the admission-valve, means for detachably connecting the lower chamber with the upper one, a casting containing the exhaust-valve, and means for detachably connecting this latter casting with the casting containing the combustion-chamber.

9. The combination with the engine-cylinder, of a casting containing the combustion-

chamber, a nipple connecting this casting with the cylinder, a plug carrying igniting devices detachably connected with said casting, a casting carrying the exhaust-valve detachably connected with said first-mentioned casting, and a removable plug closing an opening in the combustion-chamber in rear of the exhaust-valve.

10. The combination of the combustion-chamber, a casting containing the exhaust-valve detachably connected therewith, a casting connected with the exhaust-pipe detachably connected with the casting containing the exhaust-valve, and a screw-plug removably connected with said exhaust-pipe and containing a valved opening for admitting air.

11. The combination with the combustion-chamber, of an exhaust-valve, and a valve tending to open inward for at times admitting air to the combustion-chamber past the exhaust-valve.

12. The combination with the engine-cylinder, of an exhaust-valve, a governor for at times holding the exhaust-valve open, and a valve for admitting air to the cylinder past the exhaust-valve normally held closed by the pressure of exhaust-gases and open only when the exhaust-valve is held open by the governor, and the pressure decreases.

13. The combination with the combustion-chamber, of an exhaust-valve, a valve for at times admitting air to the combustion-chamber past the exhaust-valve, and a spring for opening said valve.

14. The combination of a combustion-chamber, an exhaust-valve chamber, having an exit-port at its outer end removed from the combustion-chamber, an exhaust-valve fitting said port and having an enlargement extending toward the combustion-chamber and reducing the size of the passage for the products of combustion from the combustion-chamber past the exhaust-valve, and a water-jacket surrounding the exhaust-valve.

15. The combination of a combustion-chamber, an exhaust-valve chamber, having an exit-port at its outer end removed from the combustion-chamber, an exhaust-valve fitting said port and a hollow enlargement extending from the exhaust-valve toward the combustion-chamber and reducing the size of the passage for the products of combustion from the combustion-chamber past the exhaust-valve, and a water-jacket surrounding the exhaust-valve.

16. The combination of the engine-cylinder, a casting containing the combustion-chamber detachably connected with the cylinder, a casting containing the exhaust-valve detachably connected with the combustion-chamber, a bracket attached to the main frame of the engine, and means for detachably connecting the said bracket with the casting containing the exhaust-valve chamber.

17. The combination of the exhaust-valve, its stem, a sliding frame to which the valve-stem is connected, a casting within which the exhaust-valve is located, and by which said valve-stem is guided, a bracket secured to the main frame of the engine, and to which the exhaust-valve casting is detachably connected, and guides on the bracket for the sliding frame to which the valve-stem is connected.

18. The combination with the main frame of the engine, of a bracket attached thereto, a casting containing the exhaust-valve detachably connected with said bracket, a lever for operating the admission-valve pivoted to said bracket, cams for operating the admission and exhaust valves, and a lever for operating said cams pivotally connected with the aforesaid bracket.

In testimony whereof I have hereunto subscribed my name.

GEORGE J. MURDOCK.

Witnesses:
EZEK. FIXMAN,
EDWARD C. DAVIDSON.