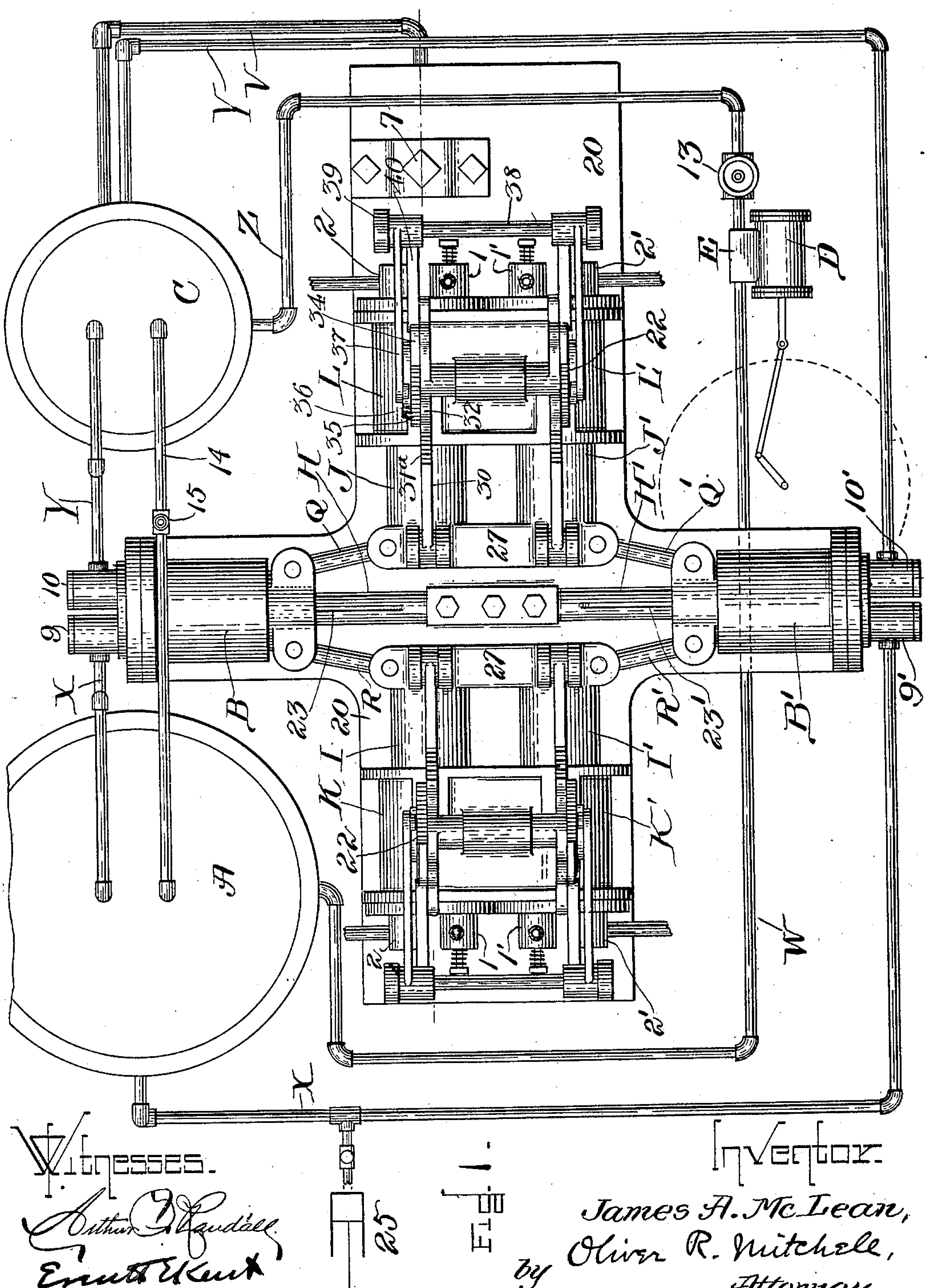
No. 674,979. Patented May 28, 1901.

J. A. McLEAN.

MULTIPLE CYLINDER EXPLOSIVE ENGINE.

(Application filed Nov. 23, 1899.)

(No Model.) 3 Sheets—Sheet 1.



Witnesses.

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Ernest ... Kent

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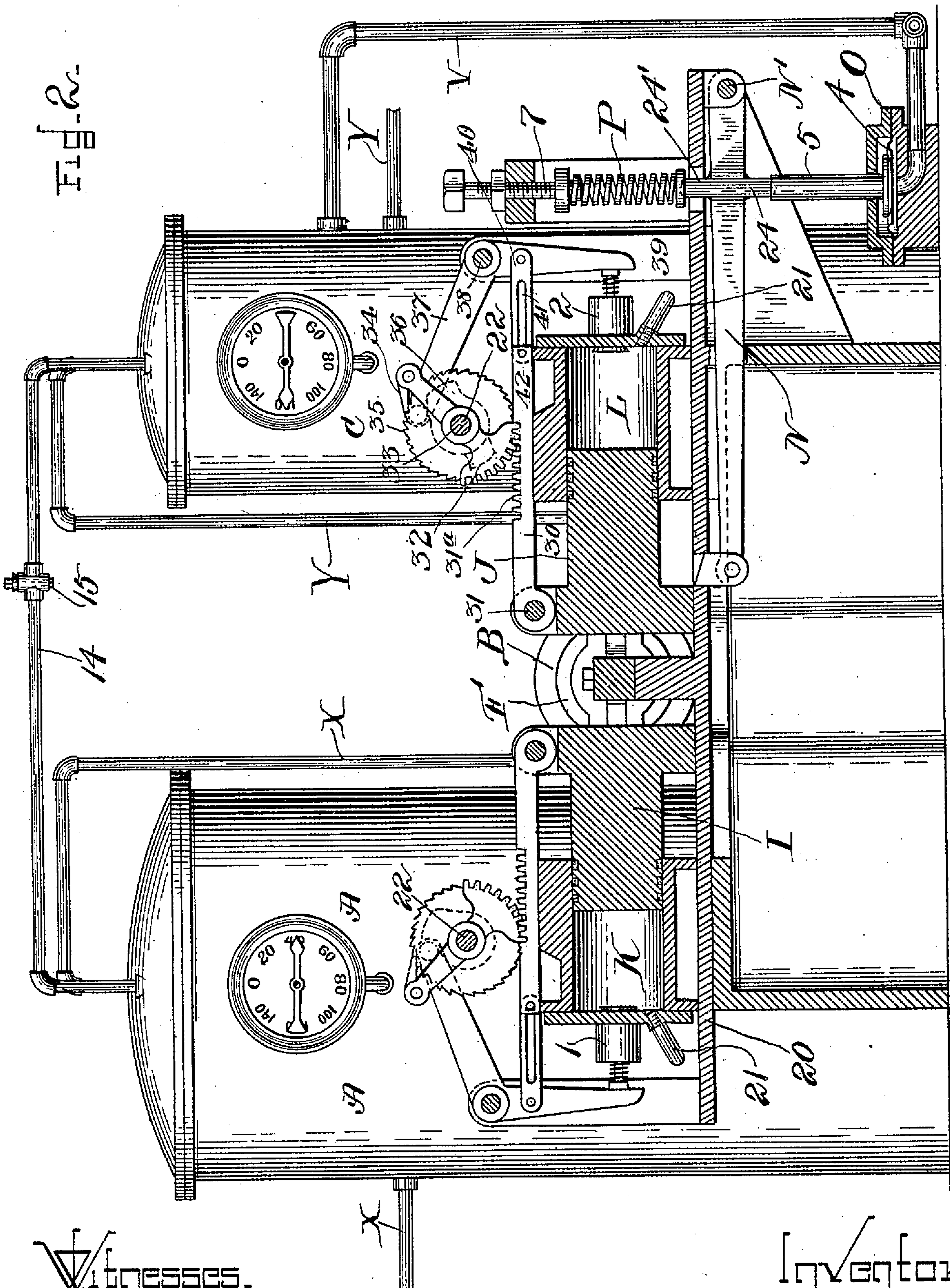
3 Sheets—Sheet 2.

Fig-2-



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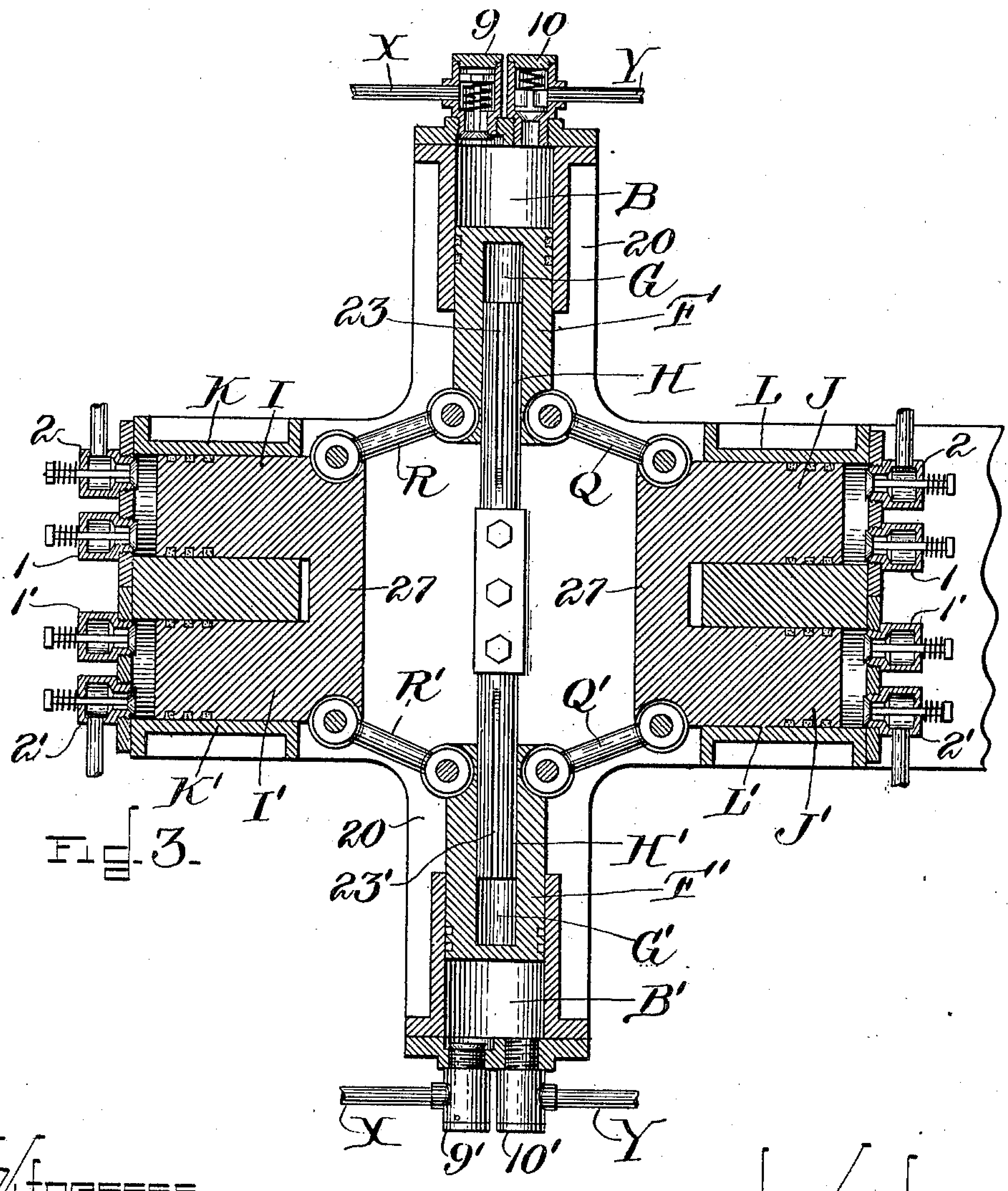

Fig. 3.

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UNITED STATES PATENT OFFICE.

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MULTIPLE-CYLINDER EXPLOSIVE-ENGINE.

SPECIFICATION forming part of Letters Patent No. 674,979, dated May 28, 1901.

Application filed November 23, 1899. Serial No. 738,010. (No model.)

To all whom it may concern:

Be it known that I, JAMES A. McLEAN, a subject of the Queen of Great Britain, residing at Boston, in the county of Suffolk and State of Massachusetts, have invented a new and useful Engine or Transformer of Energy, of which the following is a specification, reference being had to the accompanying drawings.

My invention relates to means for converting latent energy of fuel into mechanical power.

My objects are to secure increased efficiency of transformation with less waste, and to do this by simple, light, and steady-running mechanism, certain in action, conveniently operated, and inexpensively constructed. I attain these objects by the mechanism and system illustrated in the accompanying drawings. The mechanism itself shows for its chief feature of novelty and utility a link-motion so organized and arranged with the other parts as to serve to convey the motion of a motor-piston to another piston with decreasing speed and increasing power or force, while at the same time never approaching so nearly to the dead-point as to be incapable of reversing its action. To the utility of this device and arrangement it is necessary that the two pistons connected should be single-acting in effect, for reasons which will hereinafter appear.

Figure 1 is a plan view of my engine and its connections, showing the piston positions at one end of the stroke. Fig. 2 is an elevation of the same. Fig. 3 is a plan view of my engine, partly in section, showing piston positions at the other end of the stroke.

Similar characters refer to similar parts throughout the several views.

In the drawings, K K' and L L' are cylinders supported on the bed-plate 20 and are constructed as is usual in internal-combustion motors, or "engines," as they are popularly called, with admission-valves 1 1' and exhaust-valves 2 2'. They are fitted with ignition-tubes 21 (although electric sparkers or any other ignition device might be used) and a suitable valve-operating device 22, the elements of which (designated collectively by the symbol 22) are constructed and operate as follows: 30 is a rod attached at one end by the pin 31 to the outer end of the piston J. It carries at its other end a small pin 42, which projects into the slot 41 in the link 40, in which slot the pin travels to and fro with the travel of the piston J. One end of the link 40 is attached to the lower portion of a rocker-arm 37, which turns upon the shaft 38, supported by the standard 39. The rocker-arm is so placed that its lower portion is adapted when swung to press upon and open the exhaust-valve 2. In the top of the rod 30 is cut a rack 31[a], which engages a segment of a pinion 32, pivoted upon a journal 33 and carrying at its other end a pawl 34, which engages with a ratchet-wheel 35, that turns upon the same journal 33. Rigidly connected with the ratchet and turning about the same journal therewith is a cam 36, arranged to engage the upper arm of the rocker 37. The cam is shaped and adjusted to throw outward the upper arm of the rocker 37, thereby throwing inward the lower arm thereof and opening the exhaust-valve 2 at alternate quarter-revolutions of the cam. It is also so adjusted that the projection on the cam strikes the rocker-arm at the beginning of an inward stroke of the piston J and releases it at the end thereof—that is, the cam 36 holds the exhaust-valve 2 open during the whole of each alternate inward stroke of the piston J. The weight and adjustment of the parts of the rocker-arm hold its lower arm normally away from the valve 2. The length of the slot 41 is such that just before the piston J, traveling on its outward stroke and carrying with it the rod 30 and pin 42, reaches the outward limit of its stroke the pin 42 reaches the end of the slot 41 in which it is traveling, and therefore engages with the link 40 and pulls the link along with it. This pulls the rocker-arm and brings it into contact with the exhaust-valve 2, opening it. It will be obvious, therefore, that by this mechanism the exhaust-valve is opened by a positive mechanical motion just before the end of each outward stroke of the piston J and that the cam 36 holds it open during alternate return strokes.

The admission-valves 1 are simple puppet-valves.

In the cylinders K K' L L' travel the pistons I I' J J', which are connected by the arms R R' Q Q' with the pistons F F', which in turn travel in the motor-compressor cylinders B B', which are also supported by the bed-plate 20. I find it most satisfactory to make these all trunk-pistons. The cylinders B B′ of the motor-compressor are so fixed that the line of travel of their pistons is at right angles to the line of travel of the pistons I I′ J J′ of the motor. The arms R R′ Q Q′ are pivoted to I I′ J J′, respectively, at points such that at corresponding piston positions the points are equidistant from the line of travel of pistons F F′. It will be seen that by this arrangement of pistons all are made to work in unison, the pistons I I′ J J′ being all upon their outward strokes together, while the pistons F F′ are engaged upon their inward strokes together, and vice versa.

H H′ are guides adapted, in connection with the sockets G G′, to steady their respective pistons F F′ when the pistons are partly withdrawn from their cylinders. The sockets are vented by the air-passages 23 23′. The cylinders B B′ of the motor-compressor are provided with admission-valves 9 9′ and discharge-valves 10 10′, all of ordinary construction, the admission-valves being adapted to operate automatically by excess of external pressure and the discharge-valves by excess of internal pressure. All are normally kept in position upon their seats by weak springs. The discharge-valves communicate through the pipes Y with the high-pressure tank C, from which the pipe Z leads through the throttle-valve 13 to the motor E D, hereinafter sometimes called the "ultimate" motor, in which E indicates the valve-chest and D the working parts. From the exhaust-valve of the ultimate motor the pipe W leads to the low-pressure tank A, from which the pipes X lead to the admission-valves 9 9′ of the motor-compressor cylinders B B′.

14 is a pipe with a by-pass valve 15 leading direct from the high to the low pressure tank.

The tank C, the motor D, the tank A, and the motor-compressor B, with their incidental communicating passages and valves, constitute an endless circuit adapted to hold without leakage a fluid, hereinafter referred to as a "secondary" fluid. I have thus far found air most satisfactory to use for this secondary fluid, though some other gas or liquid or a combination of both might be used. 25 is an auxiliary pump. By it fluid may be pumped into the circuit both to fill it in the first instance and to replenish for any losses that occur by leakage or otherwise.

V is a pipe leading from the high-pressure tank to one side of the diaphragm 4, allowing free communication of the pressure in the tank C to one side of the diaphragm. The other side of the diaphragm 4 is in contact with the head of the rod 5. The diaphragm 4 is inclosed in the usual manner in the box O, which is supported from the bed-plate 20 or in any other convenient manner.

N is a lever pivoted at N′ on a support from the bed-plate and adapted to turn about the pivot through a small arc. The bosses 24 24′ on opposite sides of N, near its fulcrum N′, are centered, one of them in the free end of the rod 5 and the other in the end of the spiral balancing-spring P, which in turn has one end held by the boss 24′, centered in it, and the other by the set-screw 7, which set-screw is supported by the bed-plate or other means which supports the box O. At the outer end of the lever N is a stop device to engage with and hold the pistons when the pressure of the fluid in the high-pressure tank C has exceeded a predetermined point. The tension of the balancing-spring P may be adjusted by the set-screw 7, so that at such predetermined pressure the lever N is balanced between opposing pressures of the spring and of the fluid.

The valve and valve-gear in the motor are arranged to operate upon the well-known Otto or four-cycle principle; but it will be obvious as I proceed that any other workable cycle might equally well be used. The valve-gear 22 is set so that explosions will occur in diagonally opposite cylinders K L′ on one stroke (the pistons in the cylinder K′ L being then engaged in drawing explosive charges into their combustion-chambers) and in the other pair of diagonally opposite cylinders K L′ on the next stroke, during which the cylinders K L′ are being charged.

To understand the operation of the engine, let it be assumed that the circuit is filled with air and the pressures in the high and low pressure tanks A and C are, say, forty and one hundred and twenty pounds per square inch, respectively, which pressures I have found suitable. Let it be also assumed that pistons I I′ J J′ are nearing the ends of their outstrokes, being driven by expansion of gases burned behind pistons I and J′. The pistons I′ and J are then completing their suction-strokes, being driven by I and J′, and the pistons F F′, also driven by I and J′, are compressing the contents of B B′. The pressure within B and B′ will have closed the admission-valves 9 9′ and will have opened the discharge-valves 10 10′, forcing the compressed contents of B and B′ through them into the high-pressure tank C. The pressure in B and B′ is therefore about one hundred and twenty pounds per square inch. At the end of stroke the valve-gear opens the exhaust-valves in the cylinders K and L′, thereby relieving the pressure behind I and J′ and closes the admission-valves to cylinders K′ and L. The inward pressure upon pistons F F′ is thus suddenly relieved and the compressed contents expand and drive pistons F F′ outward. By the action of the links R R′ Q Q′ the motion of pistons F F′ is communicated to the pistons I J′ I′ J, driving them all inward, expelling products of combustion from cylinders K L′ and compressing the charge in cylinders K′ L. The expansion in B and B′ reduces the pressure of air therein to less than the pressure in tank

C, and the check-valves 10 10′ close automatically. Expansion continues, driving out the pistons F F′ till the pressure in B and B′ has fallen below the pressure in low-pressure tank A, when admission-valves 9 9′ open automatically and air flows in from A at about forty pounds pressure and completes the driving of pistons I′ J inward, compressing their charges until they ignite. The explosion at ignition overcomes the pressure in B and B′ and drives pistons I′ and J violently outward. Coincidently the pistons I J′ are thereby driven outward and the pistons F F′ inward. At the time of ignition the valve-gear closes the exhaust-valves in cylinders K and L′. The admission-valves therein open, so that as the stroke proceeds new explosive charges are drawn into those cylinders. The inward stroke of pistons F F′ increases the pressure of air in cylinders B and B′, and thereby causes valves 9 9′ to close. Continuance of the inward stroke continues the compression in B and B′ till the pressure exceeds that in the high-pressure tank C, when the discharge-valves 10 10′ automatically open and the contents of B and B′ are forced into C until the end of stroke—that is, until the opening of exhaust-valves in K′ and L relieves the inward pressure on pistons F F′, as before. The outward stroke of F F′ begins under the influence of the pressure in B and B′, as before, expelling products of combustion from K′ and L and compressing the new charge in cylinders K and L′. The cycles of operations continue in this manner until the pressure in tank C exceeds the pressure (which in the case assumed would be one hundred and twenty pounds) at which the spring P is adjusted to balance the fluid-pressure on the diaphragm 4. Then the spring yields slightly and permits the lever N to turn upon its pivot N′ and bring its free end into engagement with the stop-motion, thereby catching the pistons near the end of the outward strokes of I I′ J J′ and holding them still. When pressure in tank C decreases, the spring P forces the lever N back again, the pistons are disengaged, the pressure in cylinders B B′ sets them in motion, and the cycles of operations proceed as before. Whether the primary motor and motor-compressor shall run or not depends, therefore, on the condition of pressure in the tank C. The mechanism works automatically to keep tank C at full pressure, the primary motor and the motor-compressor running intermittently as required. The power thus developed is utilized by the ultimate motor D, which may be of any suitable type. The motor D also works under conditions of high efficiency, because it works always between fixed and calculated pressure-limits—viz., the pressure of the tank C and that of the tank A. In the drawings, Fig. 1, a reciprocating motor is indicated; but the valve-gear of the motor, and, indeed, the type of the motor itself, may be selected as desired and may consist of several units arranged in series or multiple, or any transformer of energy other than a motor may be employed to utilize the potential differences in the circuit between the high-pressure tank C and the low-pressure tank A.

The arms R R′ Q Q′ are so connected and organized between the pistons of the primary motor and the motor-compressor and the length of stroke of the two pistons is so designed and adjusted that the arms R R′ Q Q′ at the end of the stroke remain at an angle, as shown in Fig. 1, which is sufficiently far from the dead-point to insure the operation of either piston by the other piston upon its outward stroke. When one piston—I, for illustration—is nearing the end of an outward stroke under the impulse of expanding burned gases, the pressure of which is falling and approaching its minimum while the opposing pressure of air in the motor-compressor is increasing, the link connection continuously alters the leverage in favor of the combustion-cylinder from start to finish of stroke, so that the air-compressing pistons continuously and regularly slow their speed in relation to the speed of the combustion-pistons, thus enabling the weakening expansive forces to drive them into their cylinders against the increasing resistance of compression. Upon the return stroke the same interaction of speed and pressures takes place between the then outward-moving air-pistons of the motor-compressor and the pistons of the motor, which are then compressing the charges for another explosion. It will also be observed that the absence of dead-centers from the connections between the sources of power and of resistance—*i. e.*, for illustration, between the pistons I and F—and the comparatively small intensity of resistance in the compression-cylinders during the early part of each compressing stroke coöperate to permit a high piston velocity in the combustion-cylinder immediately after ignition, thereby allowing much heat to be utilized in expansion which would otherwise be wasted in heating the cylinder-walls and jacket-water. Another feature which contributes greatly to the same effect is the small weight and therefore small inertia of moving parts. No fly-wheel or other device depending upon the principle of momentum being used to accomplish the return stroke, the moving parts may and should be made very light, so that the pistons acquire full velocity quickly after explosion occurs. The moving parts being light, with no crank to retard the bullet-like speed of the pistons, there is quicker expansion, giving a higher mean effective pressure and less transmission of heat to the cylinder-walls. The cylinders therefore run cooler and less heat goes to waste in radiation or in jacket-water. Indeed, I have found that the saving is so great that jacket-water and other cooling devices may be entirely dispensed with about the combustion-cylinders of my motor. A greatly-increased efficiency of transformation of energy from heat into potential energy and motion is obtained by these means, and a large part of the energy which in types of motors I have hitherto known has been wasted as heat is in my engine saved in the form of useful work.

My invention marks a great advance, I believe, in the art of converting heat into work and is applicable in many forms. I have shown in the drawings and this specification the form which I have thus far found best; but it is obvious that many variations of construction and arrangement might be made without altering the essential features of my engine and system. Thus the pistons are not necessarily trunk-pistons, though I have found that form most satisfactory. The number of interacting pistons is not necessarily six, but a greater or less number (down to two) may be employed. I have found six the most satisfactory, because that number gives a balanced machine that is self-contained and runs smoothly without requiring heavy setting, one set of pistons furnishing resistance for the opposing pistons. The struts 27, in connection with the equal and opposite pressures upon pistons F F′, keep the pistons I I′ J J′ always in alinement. If desired, however, the cylinders K′ L′ B′ and their connections might be dispensed with, pistons I and J then being kept in alinement by an ordinary cross-head and ways or other suitable means, or if the two-cycle system of operations in the combustion-cylinder were employed instead of the four or Otto cycle, as is possible with several types of motors now known, the number of cylinders might be reduced to two—viz., combustion-cylinder K of the motor and the motor-compressor cylinder B. So, also, the scope of my invention is not limited to gas-engines; but any source of power may be substituted therefor, whether gasolene, oil, steam, or other, it being obvious that the device by which I obtain the return stroke—viz., from energy remaining latent in a secondary working fluid instead of from the momentum of a fly-wheel or other moving parts, as is usual in engines—is not dependent upon the particular nature of the primary source of energy. I have, however, found my system well adapted to gas or vapor engines, and I show and describe the best form I know.

Another marked improvement of my engine over other types of internal-combustion motors is that there is no critical point of ignition and no premature explosion is possible, for the pistons are always in position ready to be driven outward even though ignition occurs before the full instroke is finished. The occasional shortening or lengthening of a stroke or hastening or delaying it is a matter of small importance, for the secondary motor by which the energy is utilized derives its power from the tank C, which serves as an equalizer. There can be no "misfires" after the engine is well heated, because whenever the special ignition device provided fails to do its work the inward travel of the piston in the combustion-cylinder continues until the compression of the explosive charge is great enough for it to ignite spontaneously.

I am enabled to get the highest possible initial pressure of expansion in the combustion-chambers of my motor. I do this by cutting out the ignition device after the cylinder has been heated. The charge will then be compressed upon each stroke to the highest possible degree—to wit, until a sufficient pressure corresponding to the local temperature conditions is reached and combustion occurs spontaneously.

When an ignition-tube is used, the ignition device is cut out by simply extinguishing or removing the flame by which the tube is heated. If an electrical sparker be employed for ignition, it is obvious that the device may be readily cut out by opening the electrical circuit permanently.

In the drawings, Fig. 2, an ordinary ignition-tube 21 is conventionally indicated as the ignition device and the temporary flame used for heating it at the start has been removed, and therefore does not show in the drawings.

The motor is easily adjusted to suit the calorific value of any particular brand of oil, either by varying the setting of valves that admit fuel and air or by varying the load (pressure in tank C) against which the motor works, or in both ways. The variation of load is effected by adjusting the set-screw 7. This changes the pressure at which the diaphragm-balance will overcome the spring P and cause the stop-motion to catch and hold the pistons. In the drawings I have shown this diaphragm as adjusted by the spring-balance. I have found that form most desirable for general use, particularly if the engine is to be mounted upon trucks in an automobile conveyance; but it is obvious that any other suitable form of balance might be used without affecting the merits of my invention.

The primary motor of my engine works under conditions of load, speed, and fuel charges which are practically constant. The load against which the primary motor works is the pressure of the tank C, which pressure is maintained practically constant by the governing device. The operator of the engine having determined the normal pressure of the tank C may then by adjustment of valves regulate the quality and the quantity of fuel charge admitted at each stroke. As this adjustment of valves remains permanent the charge admitted at each stroke is constant in quantity and quality and the impulse given to the piston is substantially the same at each stroke. The impulse and the resistance being each substantially constant, the speed per stroke is constant, although, of course, the velocity of the piston differs at different parts of its stroke. Since each stroke is like each other stroke, the fuel charge may be designed and the valves permanently adjusted so as to give the piston speed under which the engine develops the greatest efficiency. The engine will then run always at its highest efficiency, however small or great the load may be upon the secondary motor. So, likewise, all other parts of the primary motor may be designed for the precise conditions of expansion, load, and speed under which the engine is to work, and the explosive charge may be so proportioned that perfect combustion will be secured and the odor attendant upon imperfect combustion of gases avoided.

When operating under usual working conditions, my invention, including my combination of a primary source of power and the secondary motor operated thereby through the medium of a secondary fluid, constitutes a system of cheap, efficient, and convenient generation, transmission, and utilization of energy which is, as far as I know and believe, the best yet produced. My generator or primary motor may possess the high efficiency of transformation that is afforded by internal-combustion motors, with the lightness, convenience, and cheapness of installation and operation which characterize this type of motors. Features of my motor which in connection with its high piston speed and high initial pressure render it an improvement over the internal-combustion motors I have hitherto known are its freedom from heavy working parts and the arrangement by which it operates always at highest efficiency. As a means of transmission of power it is obvious that the secondary fluid may easily be conveyed from the high-pressure tank C to whatever place it is desired for use, even though at a distance from the primary motor. Thus the primary motor and motor-compressor may be located in the basement of a building and the stored energy delivered to a motor located at any point required in the building without the danger, frictional losses, and constant care attendant upon shafting and belting. So, also, several motors at widely-separated places may be operated from one high-pressure tank with almost as great efficiency as though placed close by it. Furthermore, the engine and other parts are so light that they may be readily transported and are therefore suitable for automobile conveyances. When used for such purposes, my system has the great advantage that there is no danger of a boiler explosion, as in carriages operated by steam, and the mechanism being automatic requires very little care. Furthermore, if a carriage equipped with my system is stopped *en route* there is no need to keep an engine running meanwhile. The power which drives the ultimate motor—viz., the fluid in the high-pressure tank C—is always available for use upon the mere turning of a valve, being automatically maintained.

What I claim is—

1. In a mechanism for converting energy, a primary single-acting actuating-cylinder and a piston therein; a secondary single-acting actuating-cylinder and a piston therein, the cylinders being arranged at an angle the one to the other; a link connection between the two pistons; all organized in such fashion that the link will at the end of the stroke form an angle with each piston adapted to transmit the motion of each piston upon its outward stroke to the other piston and to give a constantly-increasing leverage in favor of the actuating-piston, substantially as described.

2. In a mechanism for converting energy, primary single-acting actuating-cylinders and pistons therein; secondary single-acting actuating-cylinders and pistons therein, the secondary cylinders being arranged at an angle to the primary cylinder; link connections between pairs of primary and secondary pistons, the two sets of cylinders being symmetrically disposed in such fashion that the stress generated by the interaction of one primary cylinder with its connected secondary cylinder will be neutralized and counterbalanced by the stress generated by the other pairs of primary and secondary cylinders; and all parts organized in such fashion that each link will form an angle with a primary piston and an angle with its connected secondary piston at the end of the stroke, adapted to transmit the motion of each piston upon its outward stroke to the other piston, and to give a constantly-increasing leverage in favor of the actuating-piston, substantially as described.

3. In a mechanism for converting energy, a primary single-acting actuating and compression cylinder and a piston therein, a secondary single-acting compression and actuating cylinder and a piston therein, the cylinders being arranged at an angle the one to the other; a link connection between the two pistons; all organized in such fashion that the link will, at the end of the stroke, form an angle with each piston adapted to transmit the motion of each piston upon its outward stroke to the other piston and to give a constantly-increasing leverage in favor of the actuating-piston, substantially as described.

4. In a mechanism for converting energy, a primary single-acting actuating-cylinder and a piston therein; a secondary single-acting actuating-cylinder and a piston therein, the two cylinders being arranged at an angle the one to the other; a link connection between the two pistons; a circuit adapted to contain fluid under pressure, to actuate the secondary piston on its outward stroke; a valve mechanism whereby alternate in-and-out strokes of the secondary piston force the fluid along the circuit; all organized in such fashion that the link will, at the end of the stroke, form an angle with each piston adapted to transmit the motion of each piston upon its outward stroke to the other piston and to give a constantly-increasing leverage in favor of the actuating-piston, substantially as described.

5. In a mechanism for converting energy, primary single-acting actuating-cylinders and pistons therein; secondary single-acting actuating-cylinders and pistons therein, the primary and secondary cylinders being arranged at an angle the one to the other; link connections between the two sets of pistons; the two sets of cylinders being symmetrically disposed in such fashion that the stress generated by the interaction of one primary cylinder with its connected secondary cylinder will be neutralized and counterbalanced by the stress generated by the other pairs of primary and secondary cylinders; a circuit adapted to contain a fluid under pressure to actuate the secondary pistons on their outward stroke, and valve mechanism whereby alternate in-and-out strokes of the secondary pistons force the fluid along the circuit; all organized in such fashion that the link will, at the end of the stroke, form an angle with each piston adapted to transmit the motion of each piston on its outward stroke to the other piston, and to give a constantly-increasing leverage in favor of the actuating-piston, substantially as described.

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