No. 666,838. Patented Jan. 29, 1901.

H. L. ARNOLD.

EXPLOSIVE ENGINE.

(Application filed Apr. 2, 1898.)

(No Model.) 4 Sheets—Sheet 1.

Fig. 1.

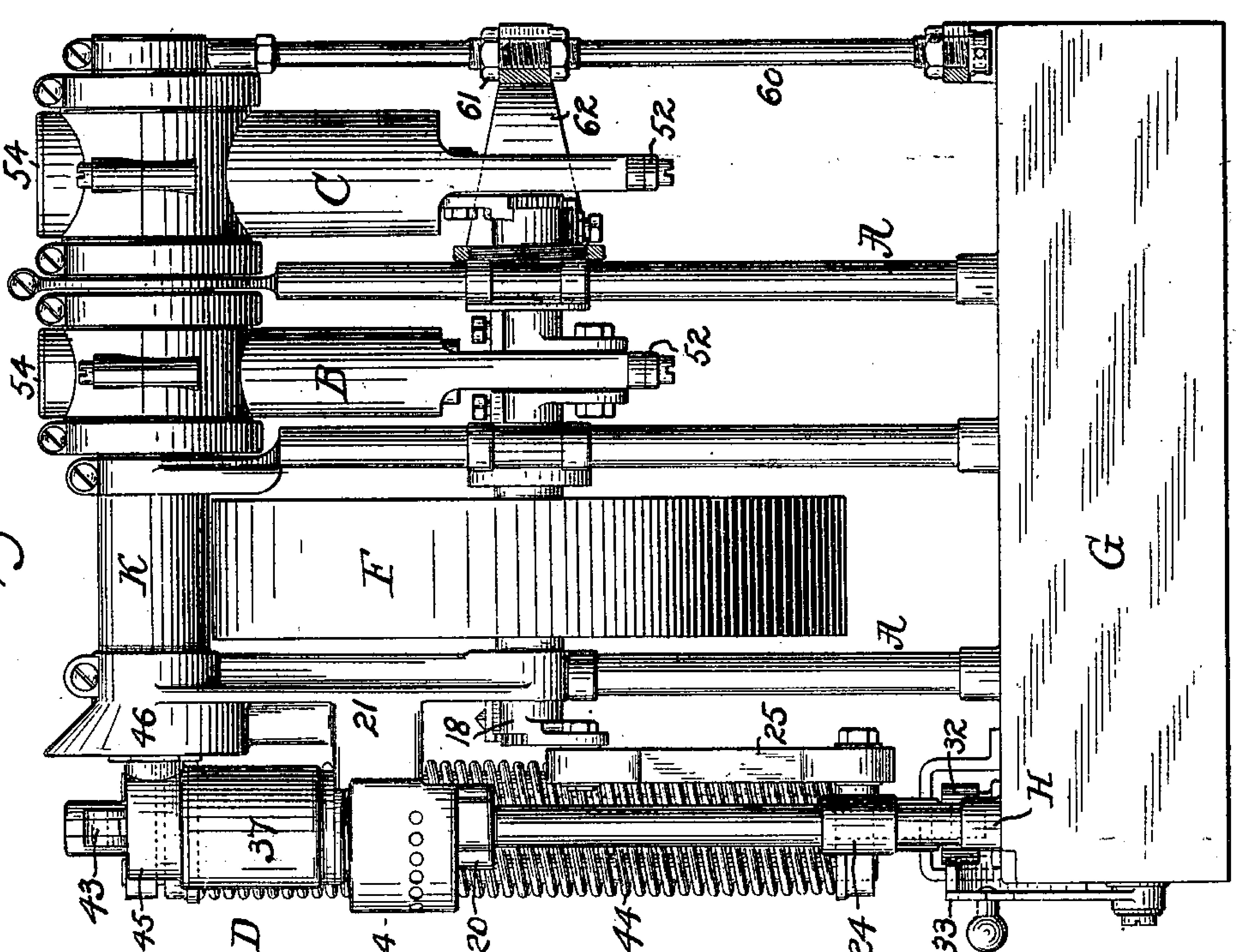
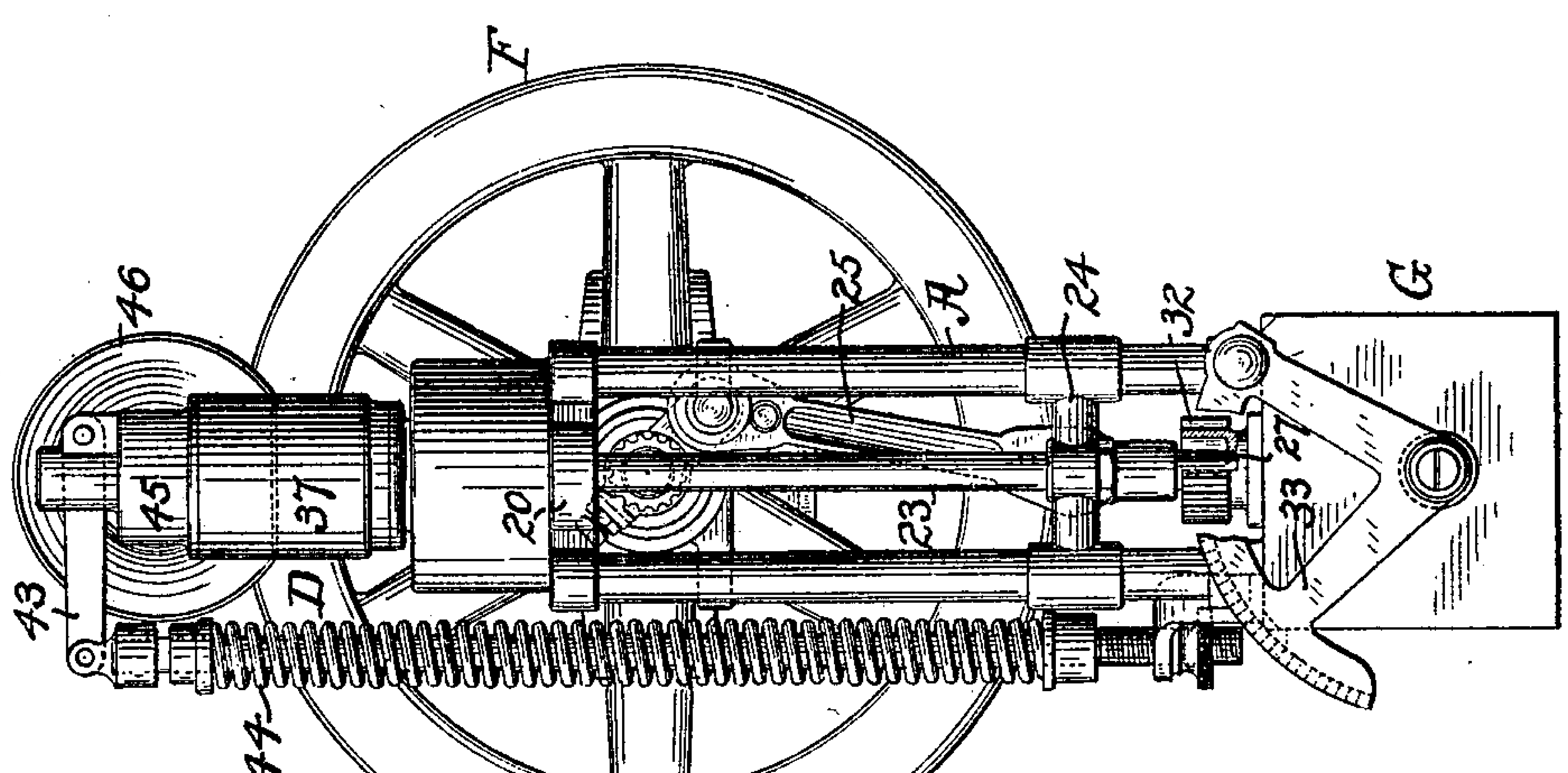


Fig. 2.



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4 Sheets—Sheet 2.

Fig. 3.

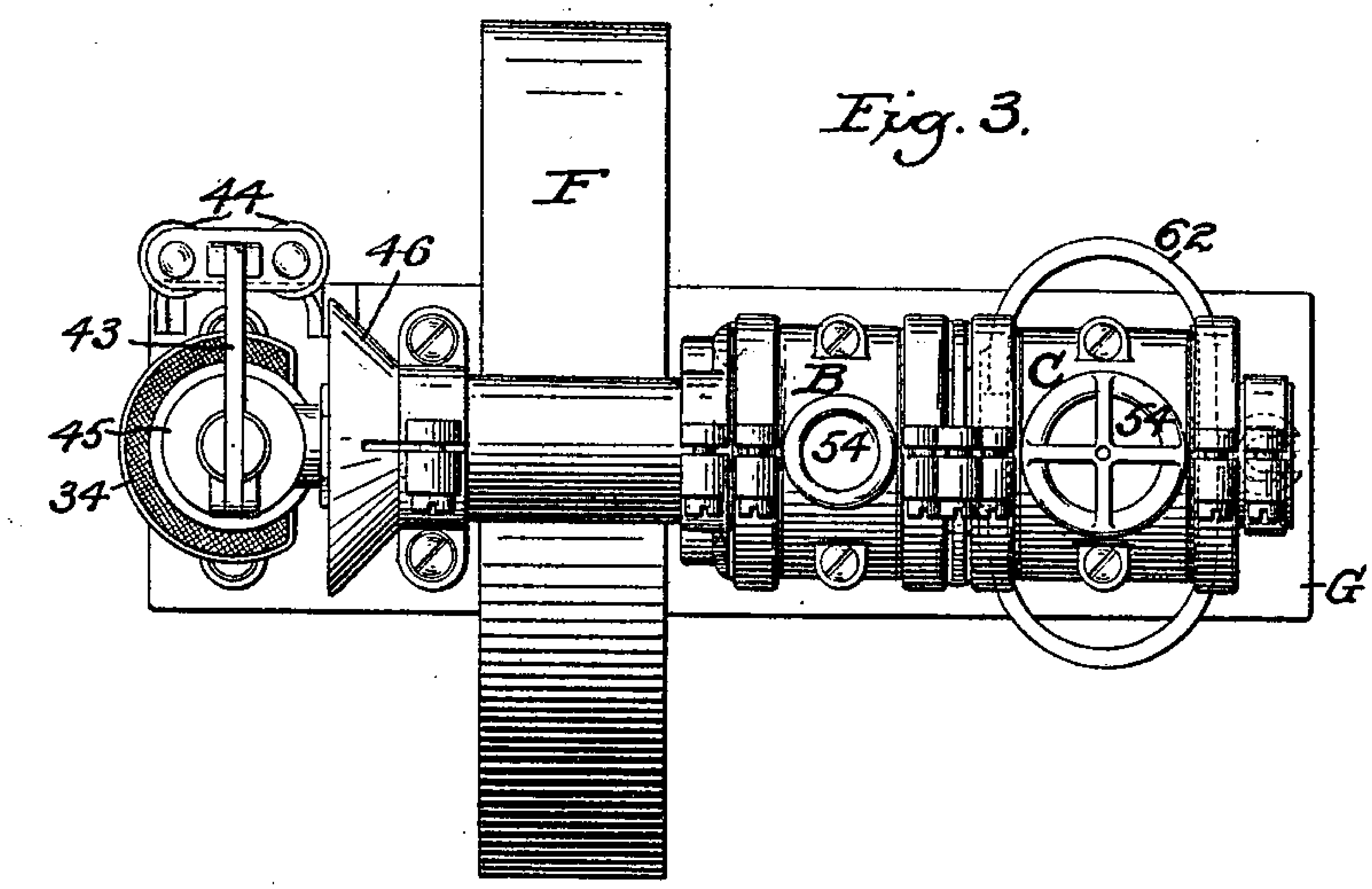


Fig. 12.

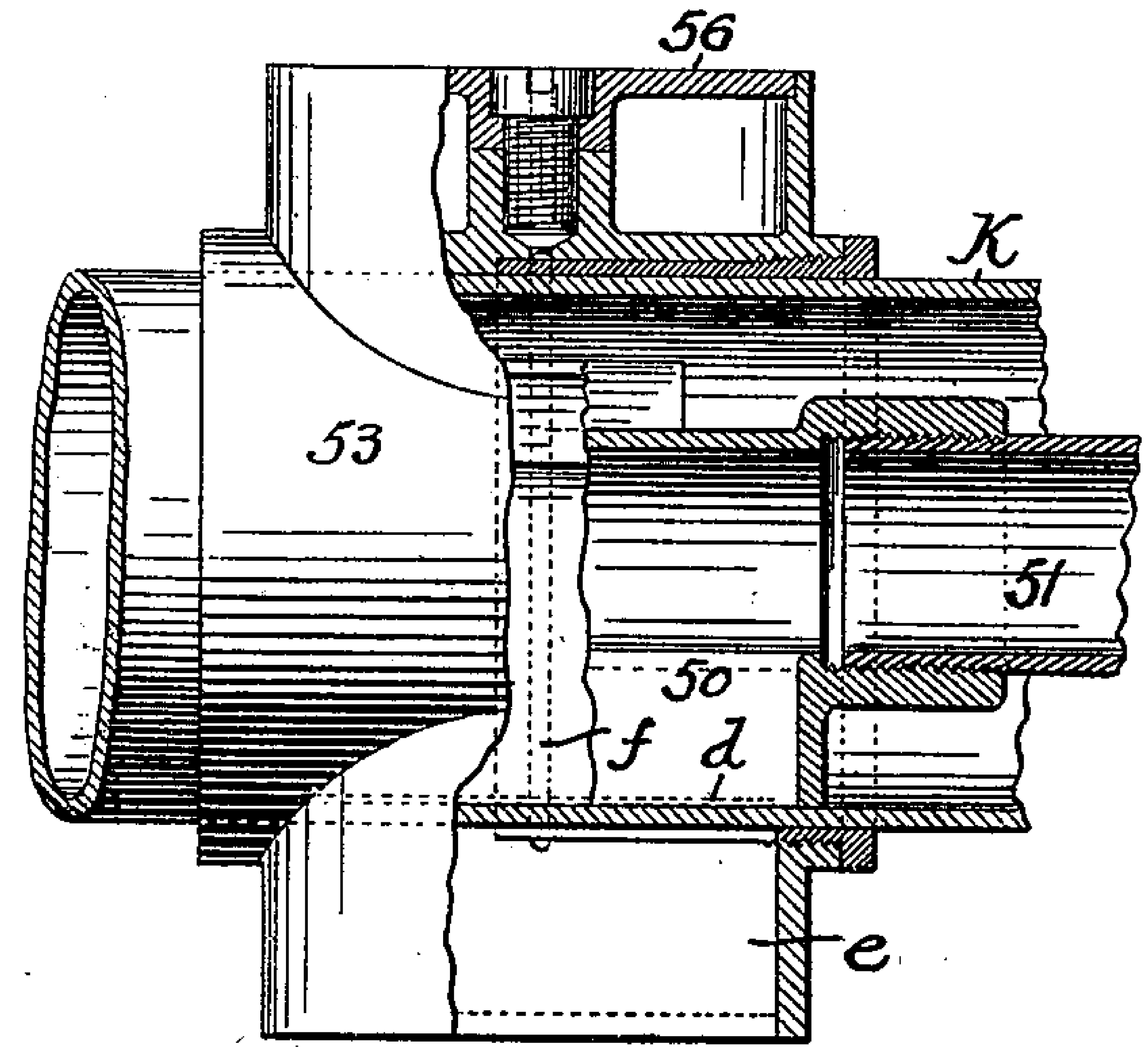


Fig. 14.

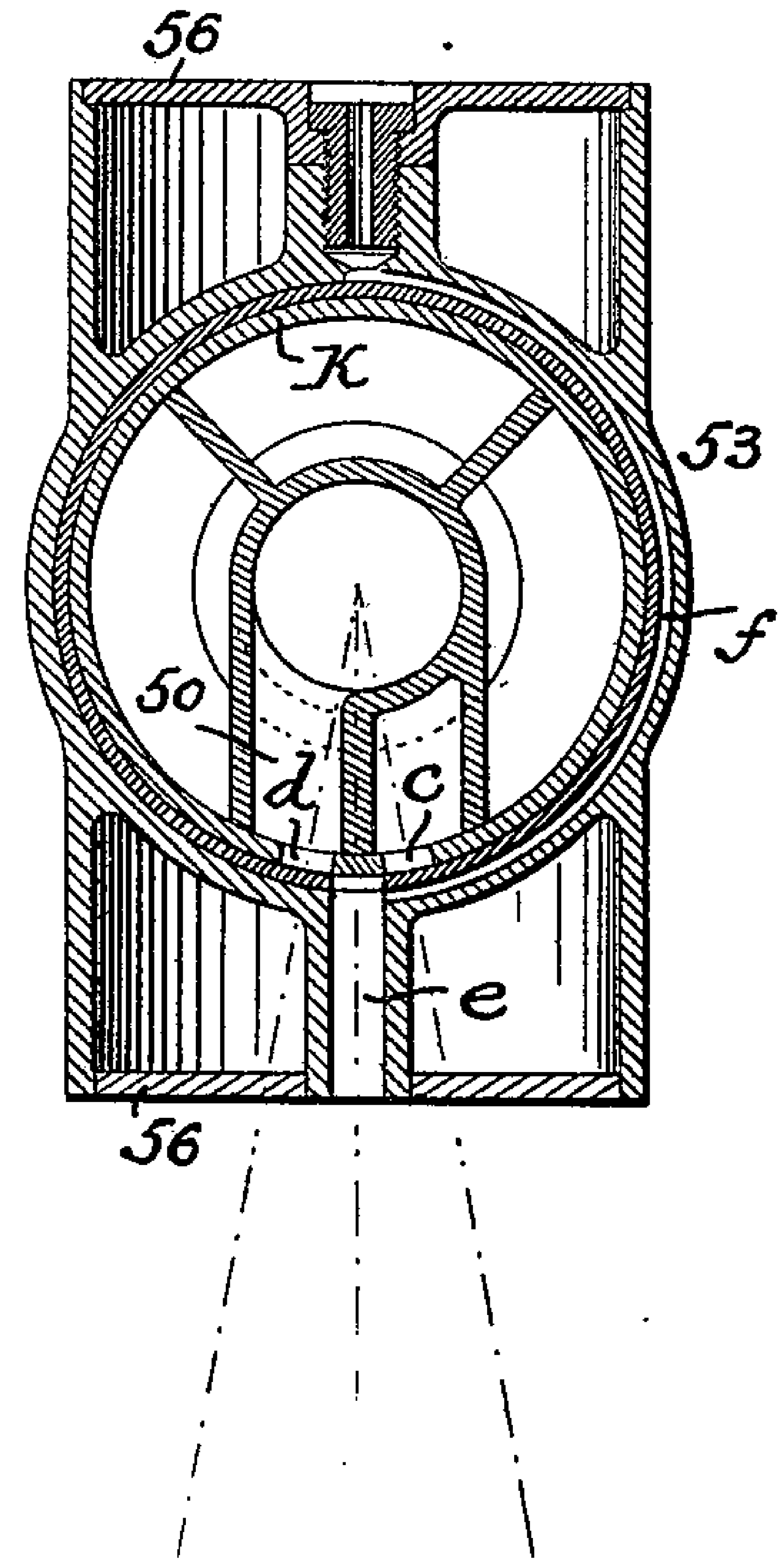
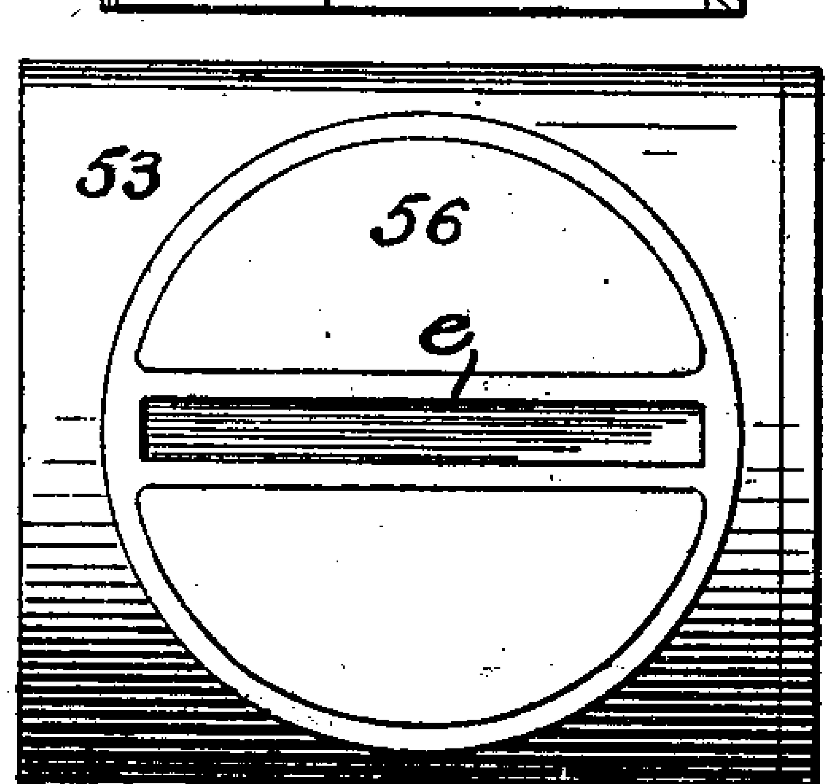


Fig. 13.



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No. 666,838. Patented Jan. 29, 1901.

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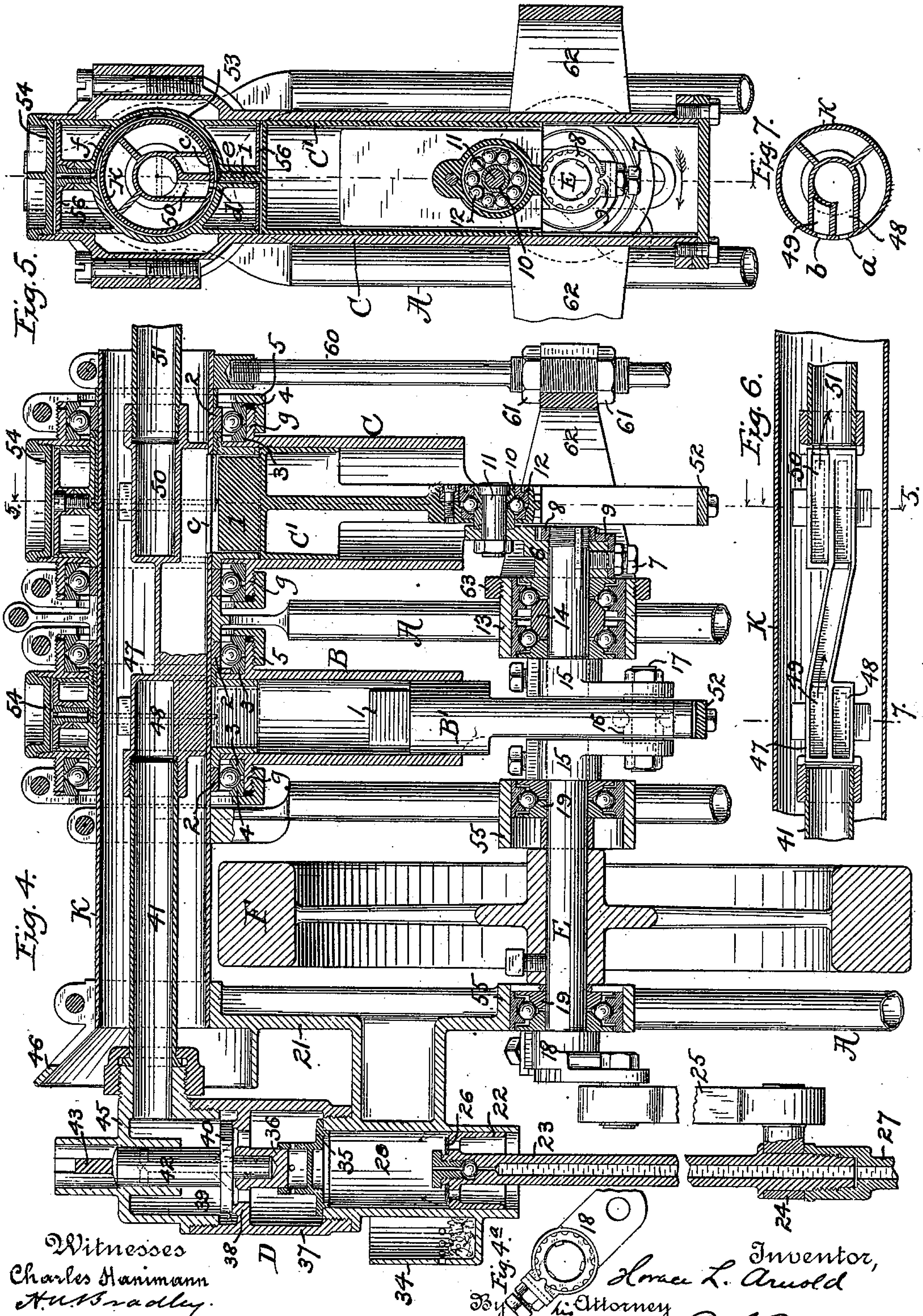
(No Model.) 4 Sheets—Sheet 3.



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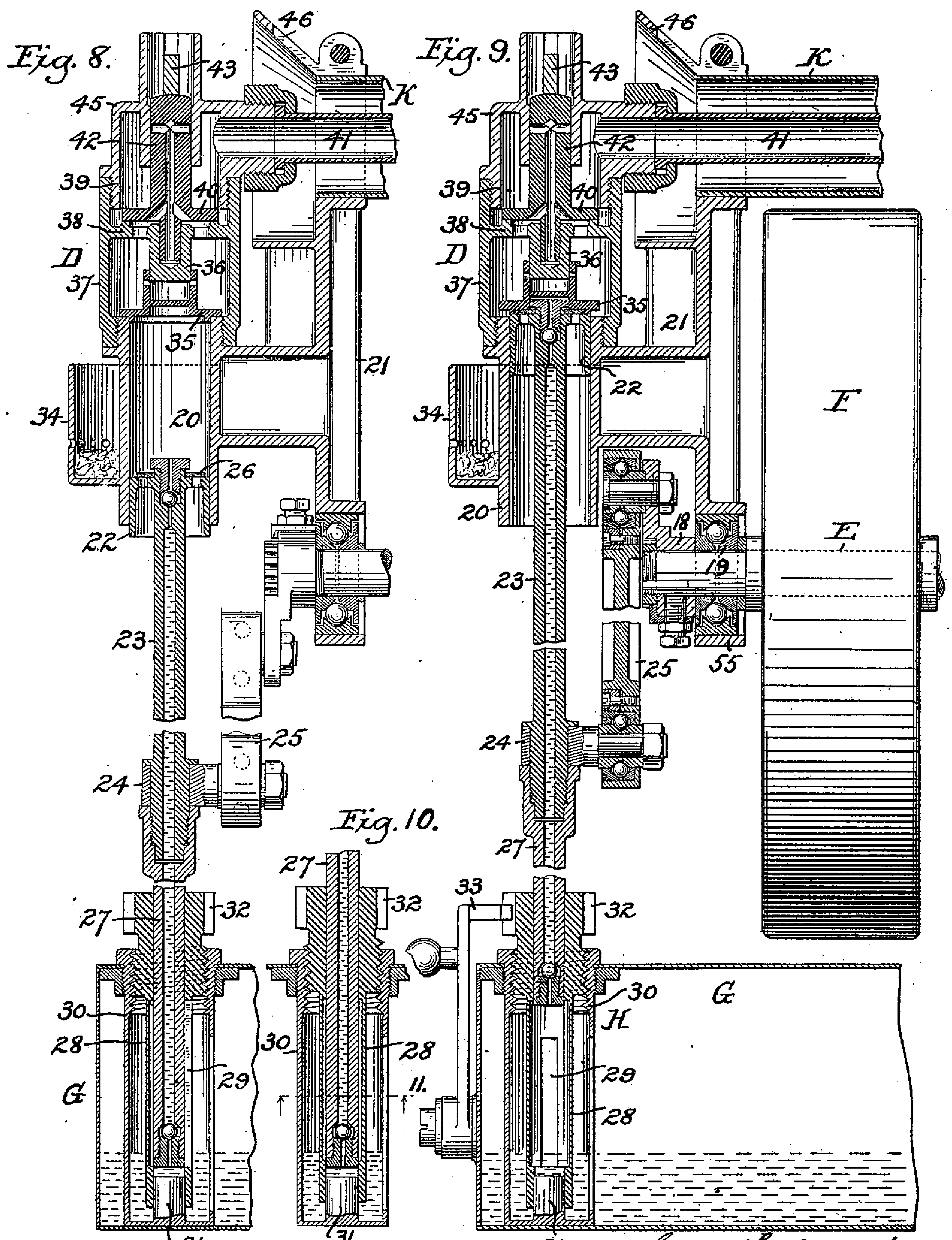
(No Model.) 4 Sheets—Sheet 4.



Witnesses
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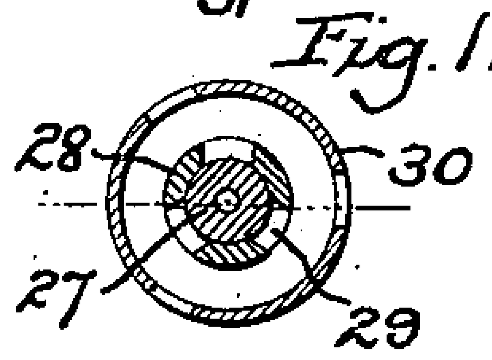
H. W. Bradley



Horace L. Arnold,
Inventor

By his Attorney Geo. C. Graham

UNITED STATES PATENT OFFICE.

HORACE L. ARNOLD, OF NEW YORK, N. Y., ASSIGNOR TO JOHN A. HILL, OF SAME PLACE.

EXPLOSIVE-ENGINE.

SPECIFICATION forming part of Letters Patent No. 666,838, dated January 29, 1901.

Application filed April 2, 1898. Serial No. 676,211. (No model.)

To all whom it may concern:

Be it known that I, HORACE L. ARNOLD, a citizen of the United States of America, residing at New York, borough of Brooklyn, Kings county, State of New York, have invented certain new and useful Improvements in Explosive-Engines, of which the following is a specification.

The present invention relates generally to gas or vapor engines, but includes devices, apparatus, and constructions applicable to other engines, motors, compressors, and the like.

The object of this invention is to produce a gas or vapor engine better adapted for driving road-vehicles than those hitherto constructed which are up to the present time mainly operated on the Otto cycle and make three idle strokes to one working stroke, the one of the idle strokes which compresses the charge requiring considerable stored-up energy from some source outside of the motor itself. Hence the gas or vapor engine, although very largely and successfully used for road-driving, because it is very simple and has no boiler, must be larger and heavier in its cylinders than if more of its strokes were effective and must also have a fly-wheel to store up the power for making the charge-compressing stroke of the piston. The gas or vapor engine as now used has also the fault of being too hot, and hence requiring the carriage of water for cooling certain parts which would otherwise become ingrievously heated. The infrequency of the working strokes of the Otto cycle single engine makes its turning effect on the crank-shaft extremely irregular, with the result of unpleasant vibration and weak hill-climbing, and if enough cylinders are provided to produce a constant turning effect on the crank-shaft the weight and number of parts of the vehicle are undesirably augmented. To obviate these defects of the Otto gas or vapor engine, the present improvements provide, among other things, a combustion-chamber separate from the working cylinders having numerous novel features, and the vapor placed under pressure in this chamber is led through cooling devices to the working cylinder or cylinders, which are preferably at least two in number—single-acting and working compound.

The drawings herewith show engines of the pendulum type, which form has several advantages over the single-acting trunk-engine commonly used in the Otto cycle-engine; but any type of cylinder, piston, and valves may be used with a separate combustion-chamber and cooling devices intermediate between said chamber and the cylinders without departing from the spirit of this invention. By cooling the vapor under pressure before it reaches the working cylinder a large part of the work-producing possibilities of the vapor is lost; but so far it has been found impossible to avoid losses by cooling in the gas-engine, because the vapor under pressure generated by combustion is very much hotter than practicable working temperatures of metallic surfaces sliding on each other. By cooling the vapor before it enters the working portions of the engine instead of generating the pressure by the combustion of the charge in contact with the working portions of the engine, and thus exposing them to the high temperature of burning gases, and then cooling the working cylinders and pistons with water, it becomes possible to effect all needful cooling by currents of air which are always available in a moving vehicle, and by generating the pressure in a separate combustion-chamber it becomes possible to make a single double-acting cylinder and piston give two turning impulses to each revolution of the crank-shaft, the same as is given by a single-cylinder double-acting steam-engine.

Two single-acting cylinders are preferred to one double-acting cylinder, because by having one end of the cylinder open it can be twice filled with cold air for each working stroke made, thus aiding in keeping the cylinders cool, and pendulum-engines are preferred because of the simplicity and certainty of the valve motion given by the vibration of the cylinder and because the vibration of the cylinder in a current of cold air aids greatly in keeping it cool, and with a pair of pendulum-cylinders working compound advantages of expansion may be realized, although three cylinders working triple expansion would perhaps give a still better effect; but as simplicity and light weight are the first requirements of road-vehicle engines two cylinders are here shown.

It is essential that a road-vehicle should have as few surfaces under sliding friction as possible, and the pendulum-cylinders are therefore provided with ball-bearings on the trunnion-tube, and ball-bearings are provided for the crank-pins and crank-shaft and for the air-pump connecting-rod.

An essential feature of the design of this engine consists in placing the necessarily hot parts above the parts which must be kept cool, thus taking advantage of the reluctance of heat to travel downward, and currents of cold air are introduced between the tubes which convey the highly-heated vapor to the engines and the surfaces on which the cylinders vibrate.

The fuel intended to be used is kerosene-oil, and a peculiar oil-feed pump is shown, which can be regulated to inject the proper minute quantity of oil into the air and gas compressing cylinder when the piston of this cylinder is about to begin its compression-stroke, and various novel devices are introduced between the combustion-chamber proper and the engines, whereby a working pressure is first established and held in the combustion-chamber and then when it has attained a certain defined tension is automatically admitted to the engines, and a safety-valve is provided as security against over pressure. By means of these various novel contrivances an engine is produced which is light and cool in its working parts and gives two turning impulses to each revolution of the crank-shaft and is capable of running at a very high speed, which is so greatly reduced before it reaches the driving-wheels of the vehicle as to make the driving impulse of a very light vehicle practically uniform, which gives a smooth motion and adds to hill-climbing powers.

The cranks of the high-pressure and low-pressure cylinders are set one hundred and eighty degrees apart, so that the high-pressure cylinder can exhaust as directly as possible into the low-pressure cylinder. The air-compressing-cylinder crank is set forty-five degrees in advance of the high-pressure crank, so that the high-pressure working stroke ends with the charge-compressor crank auvanced by the forty-five degrees crank-angle in its working stroke. The pressure in the charge-compressing cylinder due to a crank-angle of forty-five degrees is very small. The low-pressure cylinder now begins its working stroke and completes the charge compression. Full combustion of the charge is expected at about one hundred and thirty-five degrees of the effective travel of the compressing-crank or at ninety degrees working crank travel of the low-pressure cylinder. As shown, the strokes of the high-pressure cylinder, the low-pressure cylinder, and the charge-compression cylinder are all the same, and the piston areas of the high-pressure cylinder and the compression-cylinder are the same, and the piston area of the low-pressure-cylinder piston is two and one-fourth times as great as that of the high-pressure cylinder. These proportions may be varied within considerable limits, and it is not essential that the charge-compressing cylinder should make the same number of strokes made by the working piston or pistons.

The charge-compressing cylinder has its valves so arranged as to be nearly without clearance. This is economical of power and also insures a clean fresh charge of mixture without any dilution of burned gases, and thus aids perfect combustion, which is very essential, as perfect combustion of the charge makes the vapor under pressure odorless.

The oil-pump is placed in the oil-tank, which secures simplicity and at the same time agitates and mixes the oil continually, so that there is no tendency to deliver the lighter or heavier parts of the oil to the compression-cylinder separately.

The fuel-charge-regulating devices are shown in these drawings as hand-operated, which is suitable for a vehicle-motor or a marine engine. The regulating devices employed are of a type which enables them to be readily placed under control of any of the ordinary forms of engine-governors.

The ignition may be either by hot tube or electric spark. As shown in the drawings, however, a brazier which has an asbestos wick in the bottom is made to partly surround the charge-compression cylinder, with the intention of supplying this wick with a sufficient quantity of any suitable fluid fuel when the engine is to be started and by the burning of this limited quantity of fuel in the brazier to so heat the upper part of the compression-cylinder as to cause combustion to begin and a pressure to be established in the combustion-chamber. As soon as combustion begins the upper part of the charge-compressing cylinder is maintained at combustion temperature, and when the limited charge of fuel first placed in the brazier has burned out combustion continues to take place without the use of any special igniting device, all in accordance with late practice in engines of this class.

The brazier ignition is suitable for a motocycle or a motobicycle, as it demands no attention after starting. The brazier fuel charge simply burns out and is gone, and the driver or rider is not called upon to do anything whatever.

The compression-cylinder opens through a valve into a chamber above, which is called the "pressure-receiving and combustion" chamber. This chamber is of limited capacity and opens through a valve which is adjustably loaded to resist the passage of the vapor from said chamber to the upper chamber, which is at all times in direct communication with the main supply-pipe which conducts the vapor to the engines. If the loaded valve placed between the pressure-receiving and combustion chamber and the engines were omitted, little or no compression-pressure could be established in the compression-cylinder, because the cylinders would begin to work very feebly and pass the lightly-compressed and consequently unconsumed charge out into the atmosphere; but with the loaded valve, as shown, any desired pressure may be obtained in the compression-cylinder, and as soon as combustion begins the pressure in the presure-receiving and combustion chamber can never fall below that demanded by the load placed on the outlet-valve of said chamber. Still above the pressure-receiving and combustion chamber is another small chamber forming simply an enlarged initial portion of the engine-supply pipe. At the upper part of this final upper chamber a safety-valve is introduced, as is needful, since overpressure is possible. In the drawings the safety-valve and the chamber exit-valve are formed in one integral structure and are both loaded by the same resistance, and the exit-valve is given a vastly-greater area than the safety-valve, so that a much less vapor-pressure is needed to lift the exit-valve than is needed to cause the safety-valve to act. If the exit-valve and safety-valve of the pressure-receiving and combustion chamber are made and loaded separately, then the pressures needed to bring them into action need bear no relation to each other. If the two valves are combined in one and loaded with the same load, which is a part reducing construction of advantageous simplicity, then the respective valve areas will define the difference between the pressures needed to obtain exit from the pressure-receiving and combustion chamber and the safety-valve blowing-off pressure. The relative diameters of the two valves shown as controlled by the safety-valve spring may bear any desired relation to each other, so that the pressure in the chamber may be either greater or less than the blow-off pressure, while at the same time the pressure in said chamber can never rise above the pressure due to the load placed on its exit-valve.

As shown in the drawings, no throttle-valve is placed between the pressure-receiving and combustion chamber and the engines. The whole capacity of the chamber and engine-supply pipe is only enough to fill the high-pressure cylinder of the engines a few times, and combustion ceases as soon as the fuel-supply is cut off, so that the engines are under reasonable control without a throttle-valve. Again, a safety-valve-raising device may be introduced, by which all pressure in the engine-supply pipe can be instantly released. For use as a vehicle-motor a clutch will be introduced between the engine-shaft and the driving-wheels, so that the engine can continue to run through short stops of the carriage, and thus avoid the necessity of starting the engine afresh when it is desired to resume the journey.

The cylinders are mounted on ball-bearings of the three-point type, and the valves, which are a pressure-proof fit on the trunnion-tube, are separate from the cylinder and are provided with an upward extension acting as a balancing-piston in an upward extension of the cylinder-bore, so that the valve is almost wholly relieved from pressure, and the engine-piston finds its abutment, not in the working valve-face bearing as the trunnion-tube, but in the ball-bearings interposed between the cylinder trunnion-eyes and the outer surface of the trunnion-tube mainly. The frame is shown as made up of tubing and rods, the fuel-tank serving as a base. The engine-shaft and crank-wrists are also fitted with ball-bearings. The high-pressure-cylinder crank and the charge-pressure crank are splined on the shaft and are capable of endwise adjustment by outside means to effect the adjustment of the crank-shaft ball-bearings. The left-hand upright-frame member is made of a single casting, of which the charge-compressing cylinder forms an integral part.

With this general understanding of the improvements a detailed description thereof will be given with reference to the accompanying drawings, in which—

Figure 1 is a side elevation of the engine. Fig. 2 is an end view thereof, and Fig. 3 is a plan view. Fig. 4 is a vertical longitudinal section of the main parts of the engine, and Fig. 4[a] is a view of the compressor and oil-pump crank. Fig. 5 is a vertical cross-section on the line 5 of Fig. 4. Fig. 6 is a horizontal section of the trunnion-tube exposing to view the under side of the ported distributing-chambers, the supply and exhaust pipes being shown in section. Fig. 7 is a cross-section of the same on the line 7 of Fig. 6. Figs. 8 and 9 are enlarged vertical sections of the pressure-generating part of the engine in changed positions. Fig. 10 is a vertical section of the oil-feed pump, its cylinder having been adjusted from the position shown in Fig. 8. Fig. 11 is a horizontal section on the line 11 of Fig. 10. Fig. 12 is a sectional elevation of the working-cylinder valve detached from the cylinder. Fig. 13 is an elevation looking at the under side of Figs. 12 and 14, and Fig. 14 is a vertical cross-section taken centrally through Fig. 12.

The engine shown comprises a suitable framework A, formed in the main of tubes and castings, carrying as its upper member a horizontal tube K, on which is supported a pair of vibrating single-acting cylinders B C, working compound, and a portion of the pressure-generating means D. The framework also supports a crank-shaft E, having a fly-wheel F, and said framework is formed with a hollow base, serving as an oil-reservoir G, containing an oil-feed pump H.

The pressure-generating means consists of a charge-compressing cylinder 20, open-ended and formed integral with the casing 21, constituting the left-hand upright member of the engine-frame. The cylinder is provided with a piston 22, integral with its hollow piston-rod 23, having fast to its lower end a cross-head 24, sliding on two adjacent frame-tubes as guides and having a wrist to take a connecting-rod 25, by which the charge-compressing piston is driven. The piston is perforated and provided with a disk valve 26, and the upper end of the oil-feed duct through the rod and piston is provided with a ball-valve opening upwardly. The lower end of the compression-piston is connected to the upper end of a hollow oil-pump plunger 27, the lower end of the oil-feed duct in the plunger having a ball-valve opening upward. The pump-plunger fits a pump-cylinder 28, having one or more lengthwise openings 29, and is supported to be vertically adjustable by threading its upper end into a stationary part constituting the well 30, which has reaching upward from its lower end a cylindrical part 31, which fits into and forms the lower head of the pump-cylinder and on which the cylinder slides to vary the effective stroke of the oil-pump plunger. The stroke of the pump does not become effective until the lower end of its plunger passes the lower extremity of the opening in the vertically-adjustable cylinder, and hence it is possible to adjust said cylinder and its openings with reference to the pump-plunger so that it will deliver at each stroke any desired quantity of oil into the charge-compressor from nothing to the maximum permitted by the cylinder adjustment.

Any means for adjusting the cylinder may be employed. As shown, it is adjusted by hand, as is suitable for a locomotive or marine engine, the head of the cylinder being provided with gear-teeth 32, engaged by a toothed segment 33, pivoted to the hollow base and provided with a hand-knob for operating the same. (See Figs. 1, 2, and 9.) An obvious variation would place the segment under control of a governor, thus automatically regulating the speed of the engine.

The upper part of the charge-compressor forms the combustion-chamber and is therefore extremely hot. Hence the oil-feed-pump plunger is placed a considerable distance below, so that it may remain cool, notwithstanding it forms a continuous part of the compressor-piston. This construction leads to a long slender column of oil supported within the oil-pump plunger and the compressor-piston and rod. It is a matter of indifference at what point in this column vaporization of the oil begins, as the column is augmented by an increment at each stroke of the plunger variable at the will of the operator. If the engine runs too fast, the oil-pump cylinder is adjusted to deliver less fuel to the compressor, and if too slowly the adjustment is made to cause more oil to be delivered to the compressor. The only essential condition is that the pump-plunger shall not be heated to such a degree as to vaporize the oil in the reservoir.

Any form of charge-igniting device may be used, that shown being a brazier 34, partly surrounding the compressor-cylinder and containing an asbestos wick, the brazier being charged at starting with a sufficient quantity of fuel to heat the cylinder to such temperature that charge combustions will begin. From this point the heat of the successive combustions will keep the upper part of the cylinder at ignition temperature. The charge-compressor is single acting, and combustion of the charge takes place preferably at three-quarters or one hundred and twenty-five degrees of the effective crank-stroke, although this may be regulated as desired.

The top of the compressor-cylinder is closed by a valve 35, its under side being shaped to closely fit the upper surface of the compressor-piston to avoid clearance. When the combustion takes place, the valve 35 will be lifted, and to prevent a too-rapid lift of this valve the upper part of it is formed into a dash-pot which is entered by a piston 36, forming an integral part of a vapor-pressure receiving and combustion chamber 37, which forms one compartment of a cylindrical extension threaded to the upper end of the compressor-cylinder. A diaphragm 38, formed intermediate of the length of this extension, forms the top of the receiving-chamber and the bottom of a pressure-valve and safety-valve chamber 39. The pressure-valve 40 is loaded and obstructs the passage of vapor under pressure from the pressure-chamber to the engine-supply pipe 41 until the vapor in the pressure-chamber attains sufficient tension to lift the loaded valve 40, so that there is compression-pressure established in the compressor-cylinder 20 sufficient to insure the ignition of the charge.

For the sake of economy in construction the pressure-valve 40 is formed with an upward cylindrical extension constituting a piston safety-valve 42 and is loaded by any desired means, as by the lever 43 and connected adjustable springs 44. The valves have passages formed, as shown, forming a communication between the vapor under tension and the atmosphere when the valves are sufficiently lifted. It is to be understood that the parts are so proportioned that the pressure-valve 40 can lift to open communication between the vapor-pressure receiving and combustion chamber and the supply-pipe without release of the vapor under pressure; but if the pressure continues to increase an additional rise of the valve will take place, bringing the safety-valve into action. Screwed into the top of the cylindrical extension of the chamber 37 is an L-head 45, having the piston-safety-valve cylinder formed in its upper part and a communication at right angles to the pressure-supply pipe 41, to which it is coupled in any proper manner.

The supply-pipe 41 is concentric with and surrounded by the trunnion-tube K, which is supported in an eye in the casting 21, the eye forming a continuation of an intake-funnel 46, that projects outwardly from the casting, the office of the wind-funnel being to collect and deliver a current of air to the inside of the trunnion-tube surrounding the supply-pipe. The inner end of the supply-pipe 41 is secured in the left-hand end of a ported distributing-chamber 47, Figs. 4 and 6, which is supported by the trunnion-tube and communicates with ports formed in the said tube as follows: Passage 48 communicates with the admission-port *a* of the high-pressure cylinder B, passage 49 communicates with the exhaust-port *b* of the high-pressure cylinder and leads diagonally to the admission-port *c* of the low-pressure cylinder C, and passage 50 communicates with the exhaust-port *d* of the low-pressure cylinder and with the exhaust-pipe 51.

The engine-cylinders are prolonged to form guides for the piston extensions which take hold of the crank-wrists of the crank-shaft E, the prolongations being tied together at their lower ends with a tie 52. The valve-faces of the cylinders might form an integral portion of the same; but in such case they would form the abutment to the pressure applied to the piston, and thus be subjected to undesirable wear. To avoid this, a separate valve 53 is introduced in each cylinder and is seated in the cylinder-bore and in an extension of said bore on the opposite side of the trunnion-tube, this extension being fitted with a head 54, making a short closed cylinder of the same diameter as the working cylinder extending on the side of the trunnion-tube opposite the crank. The general shape of the valve is that of two cylinders crossing each other, the interior of one of these cylinders being fitted to slide on the trunnion-tube and the two exterior portions of the intersecting cylinder being fitted in the cylinder-bore and its closed extension, as described.

The upper end of each working cylinder B C is divided transversely in the horizontal plane of the center of the trunnion-tube and secured together in such a manner that one part can be removed to permit the valve to be put in place. It is to be understood that when the valve is in position two of its ends form short pistons seated in the cylinder bore and extension, so that the valve may partake of the vibrating motion of the cylinder.

The valves 53 are each provided with a single port *e*, so located as to communicate at the proper time with the admission and exhaust ports in the trunnion-tube, and a passage *f* is formed within the walls of the valve which establishes communication at all times between the two ends of the valve, so that the pressure is always the same on each, whereby the valve is placed approximately in equilibrium.

To avoid clearance, the cylinder-extension heads are made to just give a clearance to the valve extensions, and both the upper and lower extensions have secured to them heads 56, as in Figs. 13 and 14. Also to reduce clearance the high and low pressure pistons B′ C′ are provided with upward projections 1 to nearly fill the ports in the valves. (See Fig. 5.)

A cylindrical lateral projection *g* of each working cylinder on each side of its bore and at right angles thereto surrounds the trunnion-tube, leaving an annular space between the trunnion-tube and the internal surface of said cylinder, thus constituting projections of sufficient width to contain a three-point ball-bearing, consisting of a cylindrical ball-track 2, mounted on the trunnion-tube, an inner stationary ball-cup member 3, an outer adjustable ball-cup member 4, and an interposed circle of balls, adjustment being effected by a flanged ring 5, threaded onto the exterior of the cylinder projection, split on one side, and provided with a pinching-screw to retain the adjustment, all as shown in Fig. 4.

The crank-shaft E at its right-hand end is splined to take the low-pressure crank 6, having a coacting feather formed on the exterior surface of its eye and being supplied with a set-screw 7, tapped through the crank-hub to bear against the shaft. A fluted retaining-nut 8 is threaded on the end of the shaft, and a keeper 9 engages the nut to hold it in position. The crank-wrist is formed of a double solid cone 10, recessed into the body of the crank and secured with a through-bolt 11. A circle of balls surrounding the wrist, a stationary ball-cup member seated in the piston extension, and an adjustable ball-cup member with means for securing the same complete the crank-wrist ball-bearing 12 for the low-pressure cylinder. The crank-shaft bearing between the high and low pressure cranks is formed of an eye 13 in the framework surrounding said shaft at a sufficient distance therefrom to form an annular space of sufficient width to receive a double ball-bearing 14. The two high-pressure cranks 15 are splined to the two lengths of the shaft E in the same manner as the low-pressure crank and have their hubs provided with set-screws having points entering the shaft members. The crank-wrist is formed of a double cone-sleeve 16 and through-bolt 17, and the ball-bearing connection between the high-pressure-piston extension and the crank-wrist is the same as shown on the low-pressure-piston connection. The left-hand end of the crank-shaft E carries the charge-compressor-operating crank 18, which is the same in construction as the low-pressure crank and is connected to the charge-compressor by the connector 25, before referred to. As shown, the high and low pressure cranks are set one hundred and eighty degrees apart, and the charge-compressor crank is set so as to have forty-five degrees effective angular advance when the high-pressure piston reaches the end of its working stroke. Any other desired angular relation of crank positions on the shaft may be employed. As shown in Fig. 14, the charge-compressing piston has made a small part of its working stroke when the high-pressure piston ends its working stroke and the low-pressure piston begins its working stroke. The combustion of the charge will take place at about one hundred and thirty-five degrees of the working stroke of the compressor-crank when the low-pressure crank stands at ninety degrees of its effective stroke.

Two four-point ball-bearings 19 are supported in eyes 55 in the framework between the left-hand high-pressure crank and the compressor-crank, and between these ball-bearings the fly-wheel F is secured to the shaft, the hub of the fly-wheel forming a member of the ball-bearing adjustment, as described in my said application.

To secure a stable support for the right-hand end of the trunnion-tube, Fig. 1, a screw-brace 60, having an eye surrounding the extremity of said tube and secured at its lower end to the engine-base, is provided. The intermediate portion of this screw-brace is fitted with nuts 61 for supporting the outer end of a key-bow extension 62, Figs. 1, 3, 4, and 5, having an inner eye 63 threaded onto the right-hand end of the crank-shaft-bearing eye.

No claim is herein made to the vapor-generating mechanism shown and described, for it constitutes the subject-matter of my application filed February 17, 1900, Serial No. 5,575.

What is claimed is—

1. The combination of a vibrating cylinder and its piston, a pressure-supply pipe for said cylinder, and an open-ended cooling-chamber surrounding said supply-pipe.

2. The combination of a vibrating cylinder and its piston, a pressure-supply pipe for said cylinder, and a cooling-chamber surrounding said pipe and supporting said cylinder.

3. The combination of a vibrating cylinder and its piston, a pressure-supply pipe for said cylinder, and a chamber surrounding said pipe and supplied with a current of cooling fluid and supporting said pipe in a fixed relation thereto.

4. The combination of a vibrating cylinder and its piston, a pressure-supply pipe for the cylinder, and a surrounding tube supporting said cylinder and providing a cooling-chamber between the pipe and tube.

5. The combination, with a cylinder and its piston, of a pressure-supply pipe for said cylinder, and a cooling-chamber having a funnel-shaped end surrounding said supply-pipe.

6. The combination, with a vibrating cylinder and its piston, of a pressure-supply pipe for said cylinder; a cooling-chamber; and a distributing-chamber mounted within the cooling-chamber and communicating with said supply-pipe.

7. The combination of a vibrating cylinder and its piston, a tube, and a pair of independent three-point ball-bearings interposed between the tube and cylinder, each comprising a plain ball-track on the tube, one stationary and one movable ball-cup member, a circle of interposed balls, a surrounding sleeve integral with the cylinder, and means for adjusting the movable cup member.

8. The combination of a vibrating cylinder and its piston, a tube on which said cylinder is supported and vibrates, a pressure-supply pipe interior of the tube connected to a ported distributing-chamber secured to said tube, and coacting ports moved by vibration of the cylinder.

9. The combination of two vibrating cylinders working compound and their respective pistons, a tube on which said cylinders are supported and vibrate, a pressure-supply pipe interior of the tube connected to a ported distributing-chamber secured to said tube and connected to a second ported distributing-chamber by such passages as will lead the exhaust from the first cylinder to the inlet of the second cylinder, and an exhaust-pipe from the second chamber.

10. The combination of a vibrating engine, a tube on which the engine is supported and vibrates, a balanced valve therefor supported in the bore of the cylinder and rotatably mounted on said tube, and provided with ports to coact with the inlet and outlet ports in the tube.

11. The combination of a vibrating cylinder, a tube upon which the cylinder is supported and vibrates, an extension to the bore of the cylinder on the side opposite the crank, and a head closing the bore of said extension.

12. The combination of a vibrating cylinder, a tube upon which the cylinder is supported and vibrates, an extension to the bore of the cylinder, and a valve fitting the cylinder and extension bore and having connection within the walls of the valve between the port of the valve and the opposite extension of the cylinder, whereby the pressure in the cylinder extension is kept the same as that on the engine-piston.

In witness whereof I have hereunto set my hand in the presence of two witnesses.

HORACE L. ARNOLD.

Witnesses:
GEO. H. GRAHAM,
HERBERT GRAHAM.