No. 776,800. PATENTED DEC. 6, 1904.

F. J. ROCHOW.

EXPLOSIVE ENGINE.

APPLICATION FILED DEC. 7, 1901.

NO MODEL. 5 SHEETS—SHEET 1.

Fig. 1.

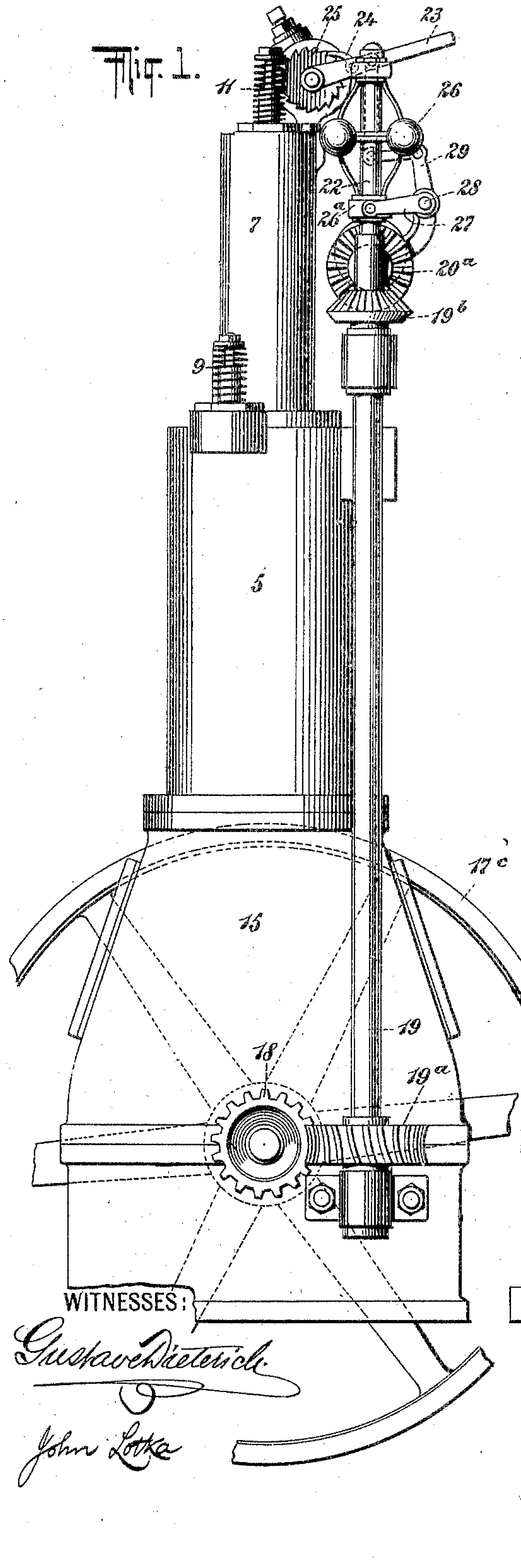
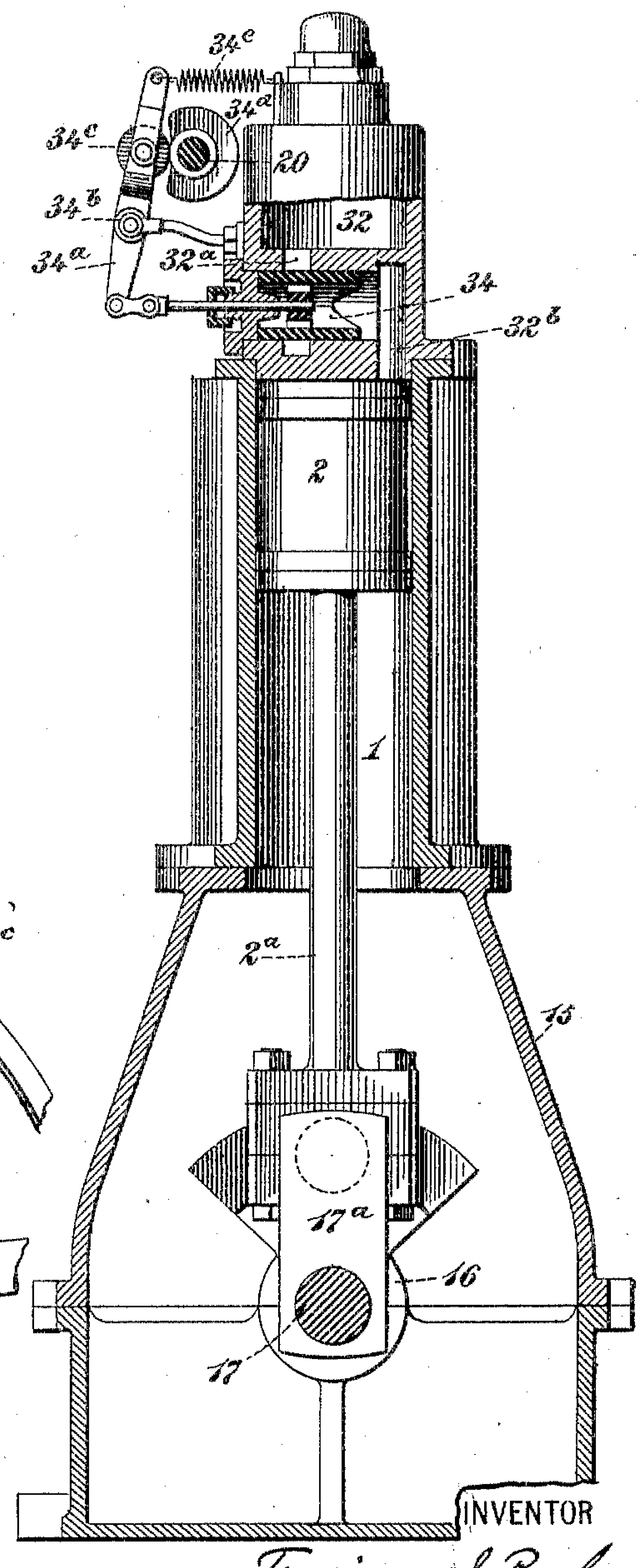


Fig. 2.



WITNESSES:

Gustave Dieterich

John Lotka

INVENTOR

Ferdinand J. Rochow

BY Briesen & Knauth

ATTORNEYS

No. 776,800. PATENTED DEC. 6, 1904.

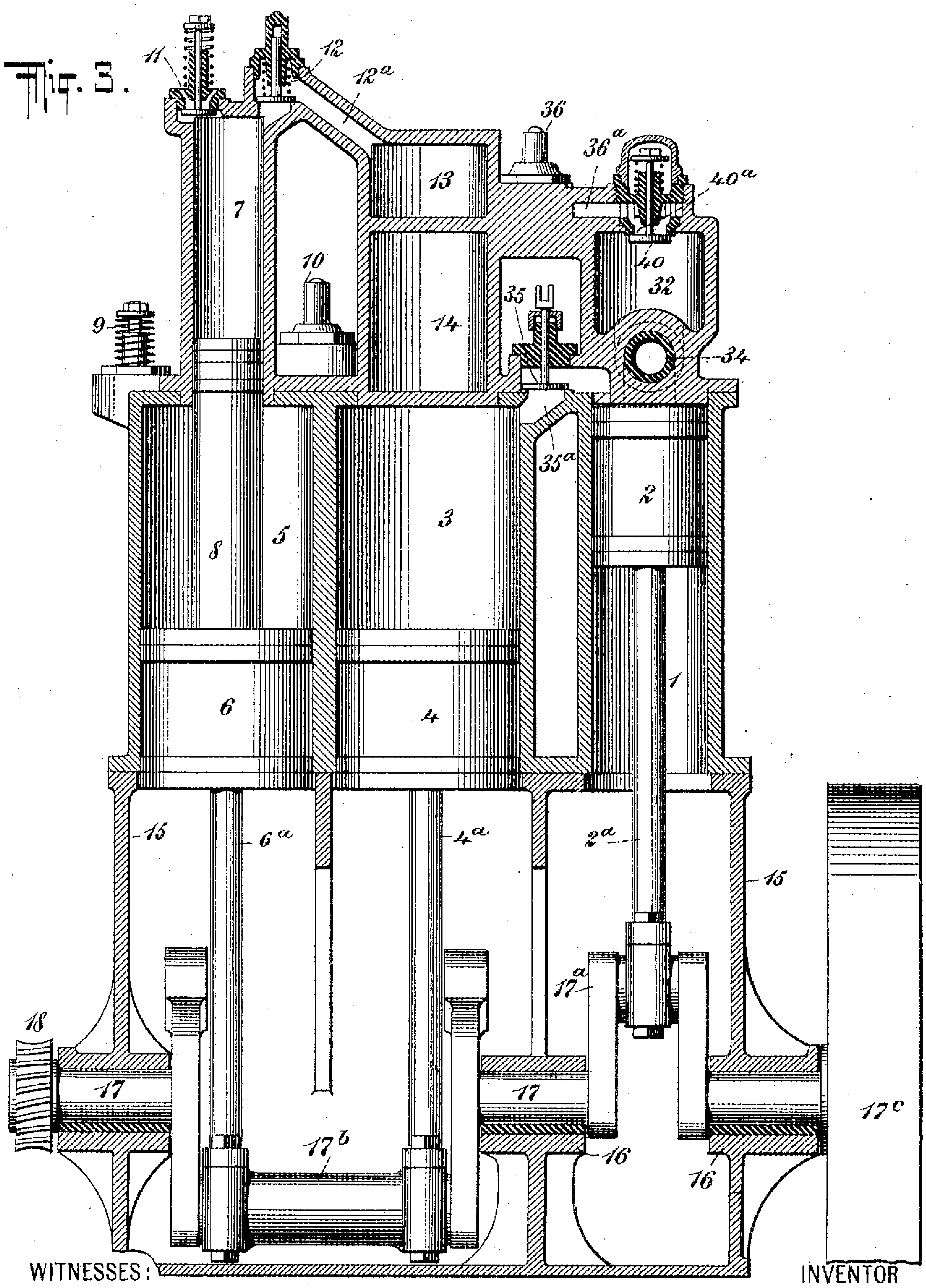
F. J. ROCHOW.

EXPLOSIVE ENGINE.

APPLICATION FILED DEC. 7, 1901.

NO MODEL. 5 SHEETS—SHEET 2.

Fig. 3.



WITNESSES:

Gustave Dieterich.

John Lotka

INVENTOR

Ferdinand J. Rochow

BY Briesen & Knauth

ATTORNEYS

No. 776,800. PATENTED DEC. 6, 1904.

F. J. ROCHOW.

EXPLOSIVE ENGINE.

APPLICATION FILED DEC. 7, 1901.

NO MODEL. 5 SHEETS—SHEET 3.

Fig. 4

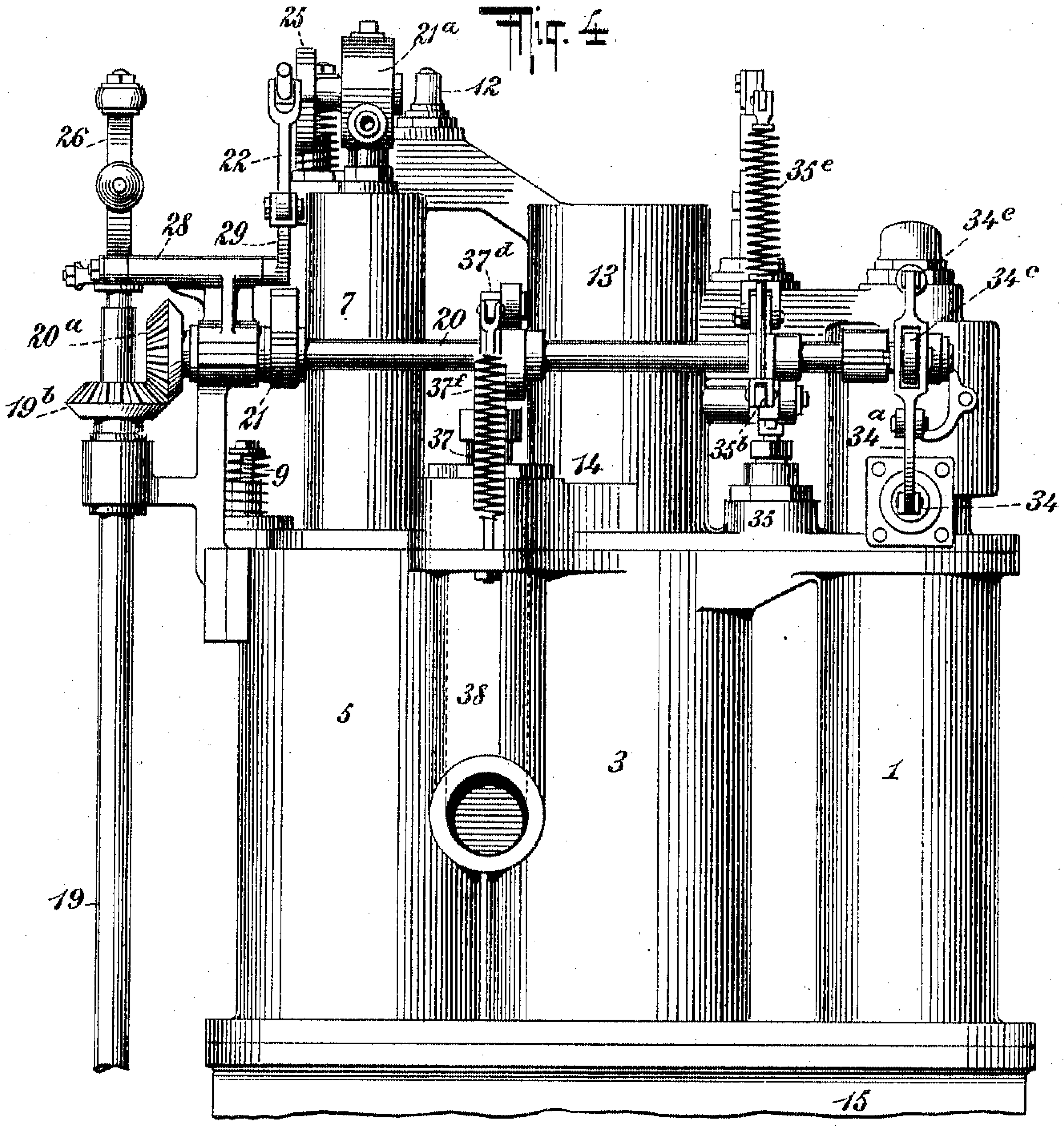
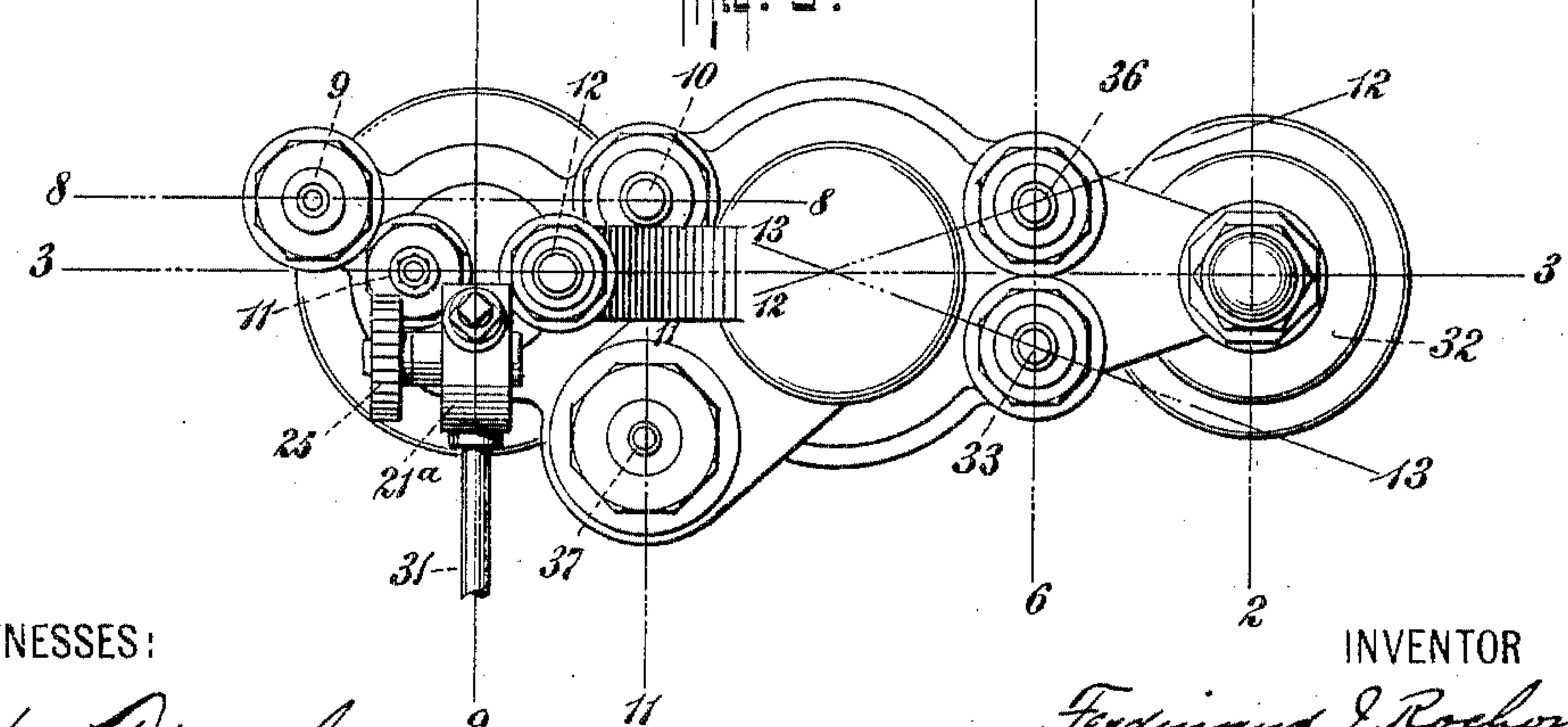


Fig. 5.



WITNESSES:

Gustave Dieterich

John Lotka

INVENTOR

Ferdinand J. Rochow.

BY Briesen & Knauth

ATTORNEYS

No. 776,800. PATENTED DEC. 6, 1904.

F. J. ROCHOW.

EXPLOSIVE ENGINE.

APPLICATION FILED DEC. 7, 1901.

NO MODEL. 5 SHEETS—SHEET 4.

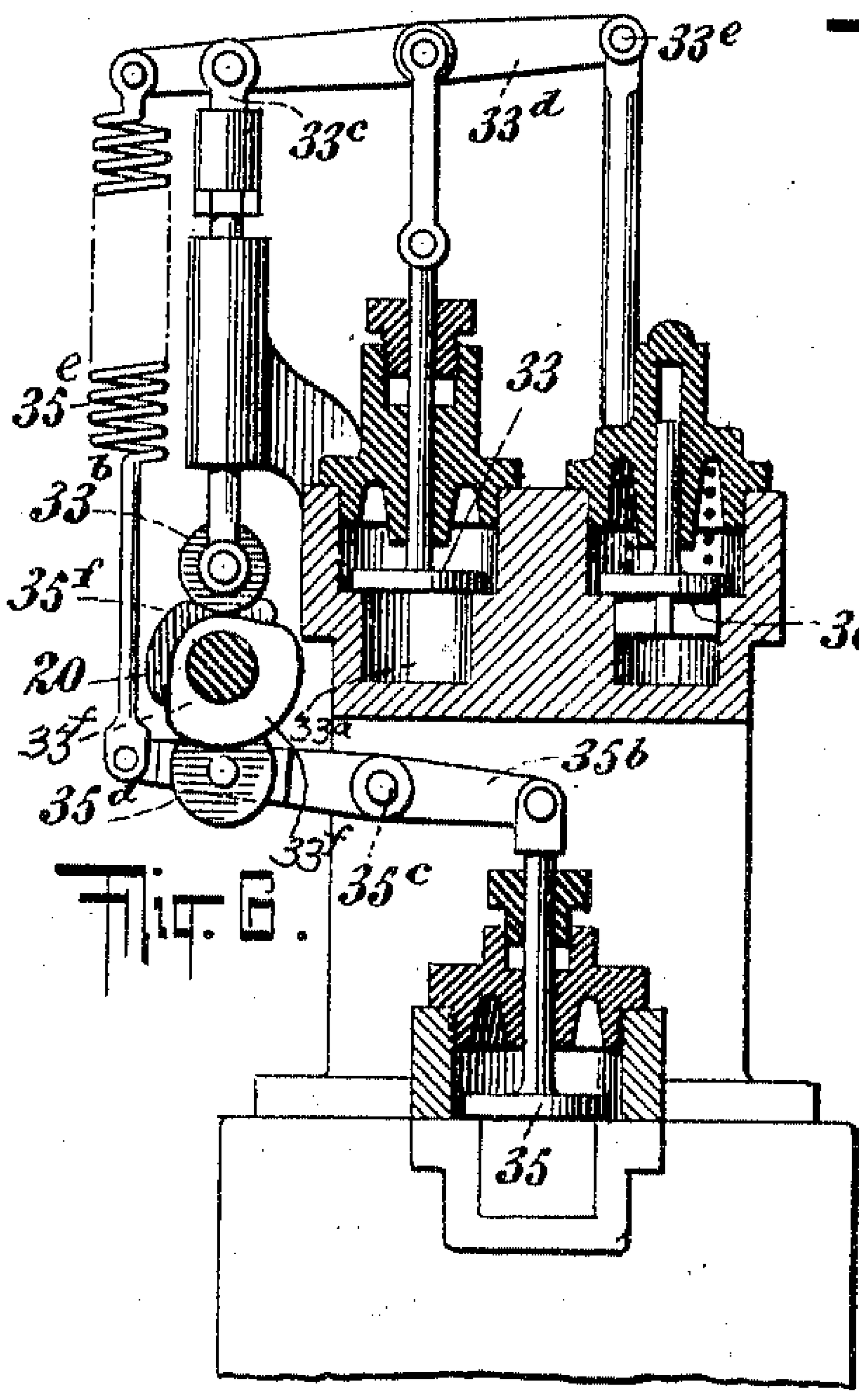


Fig. 6.

Fig. 7.

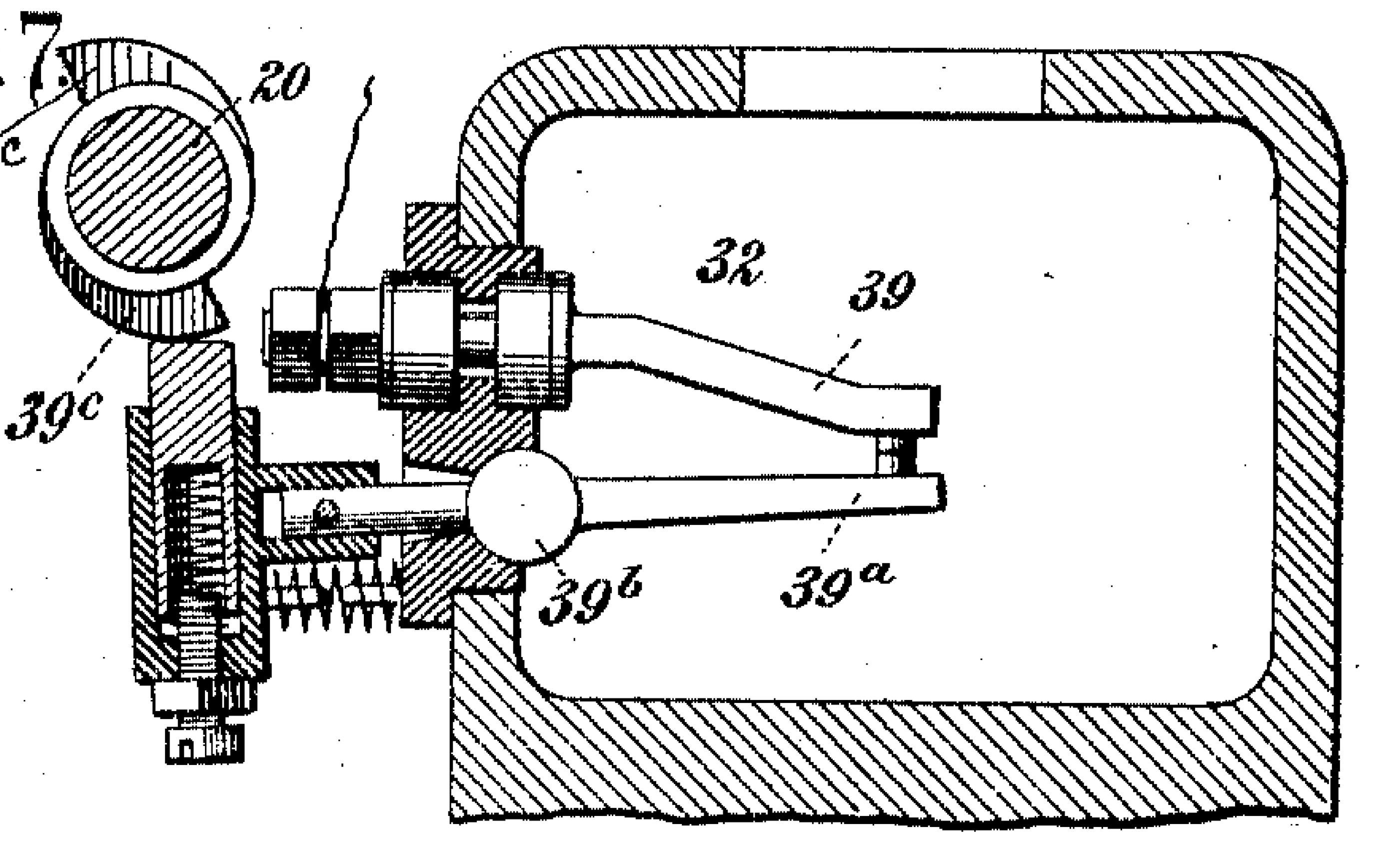


Fig. 8.

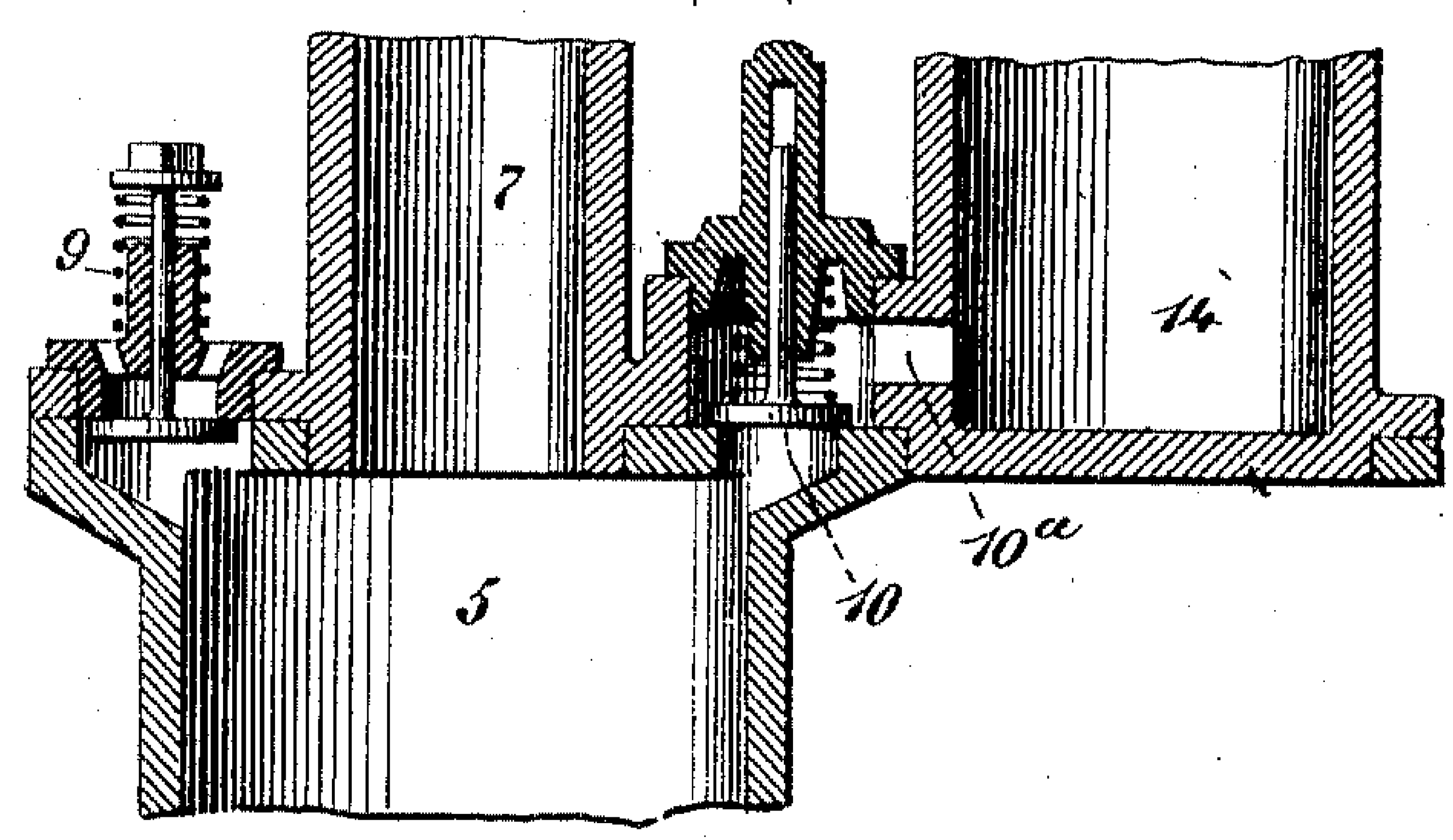


Fig. 9.

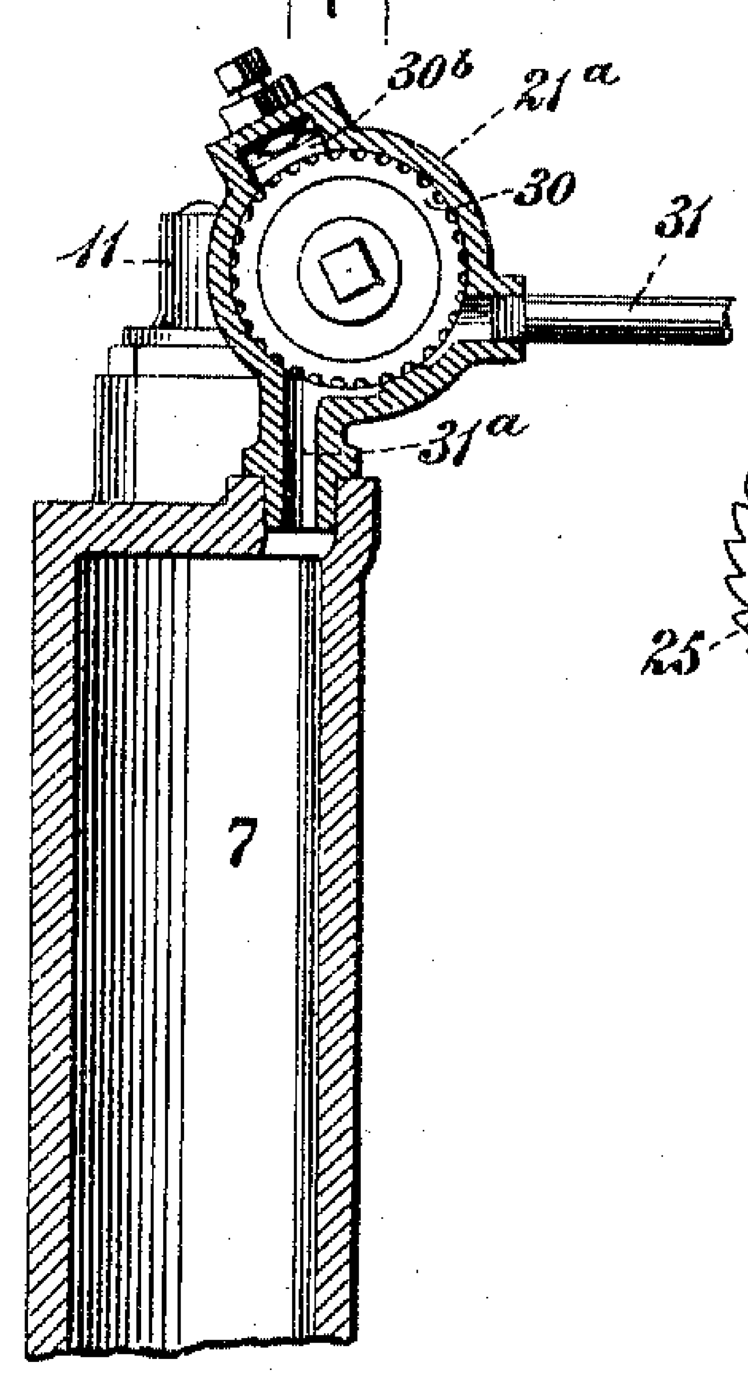


Fig. 10.

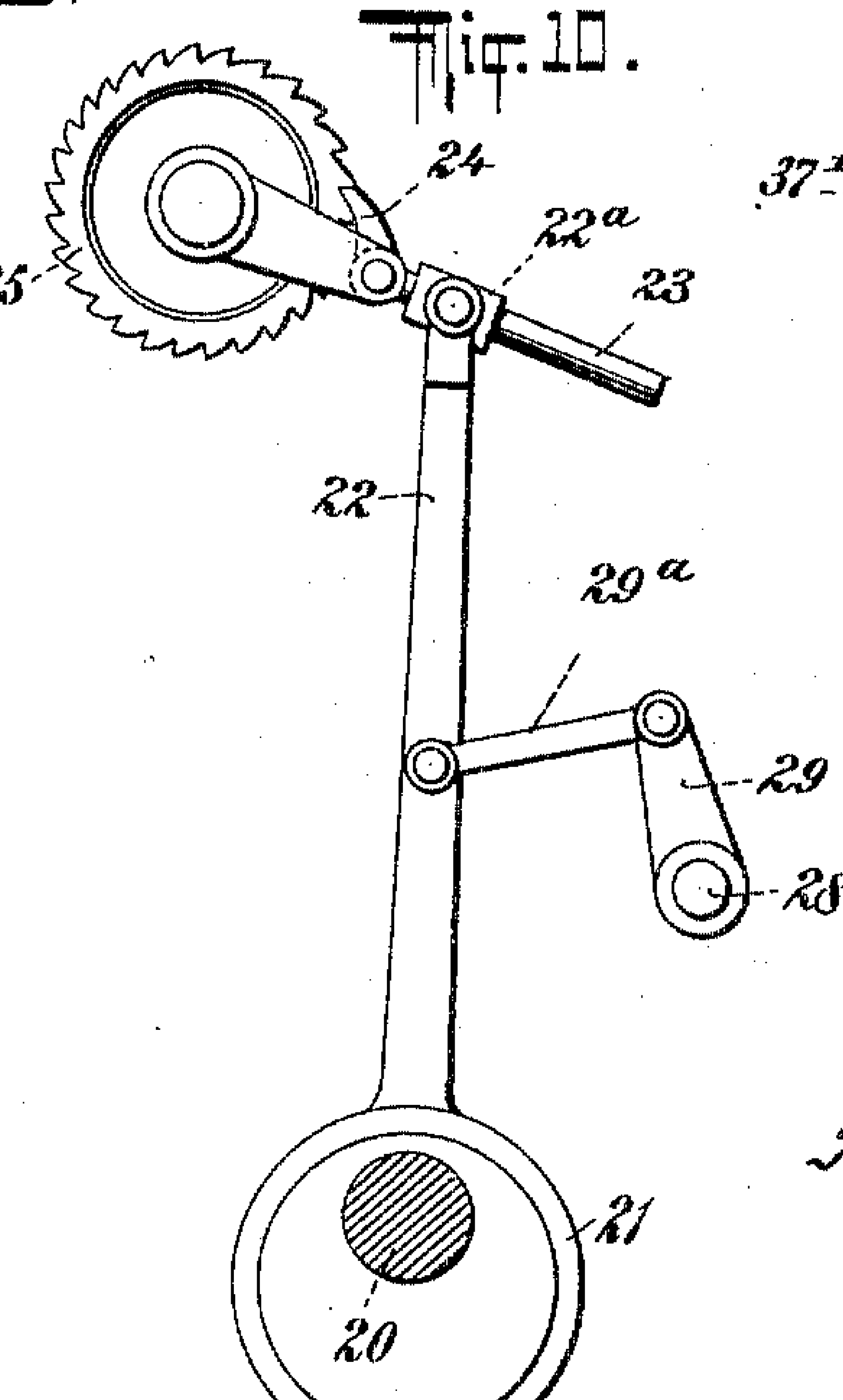
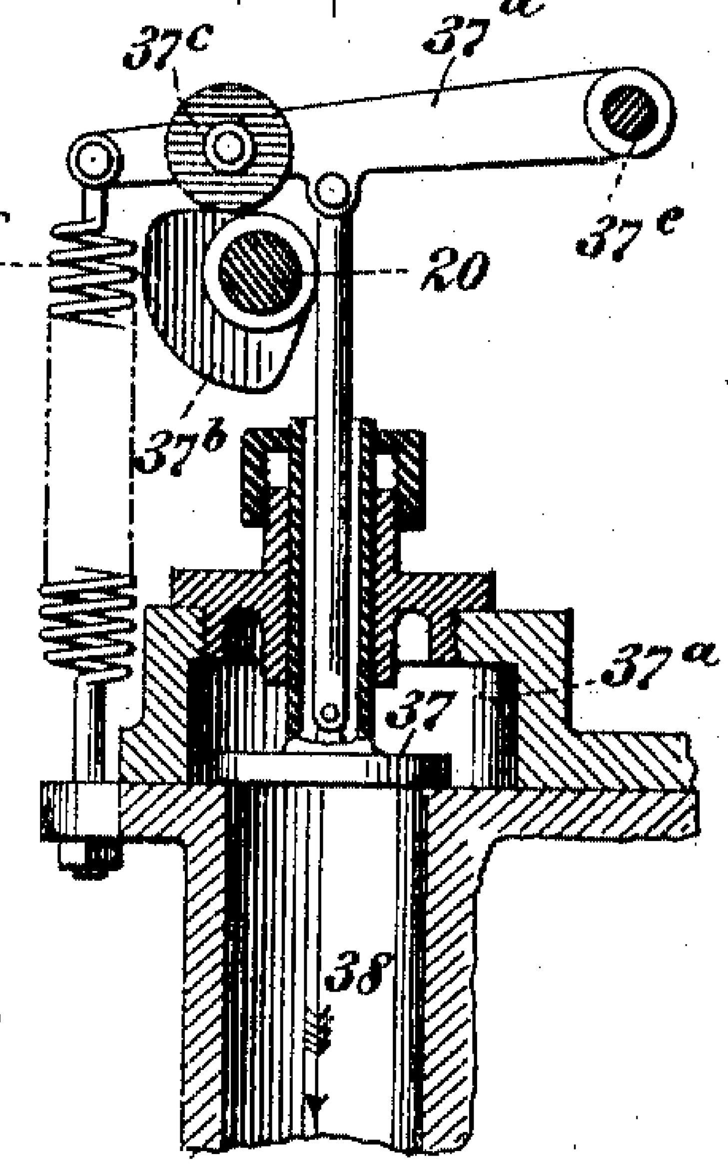


Fig. 11.



WITNESSES:

Gustave Dieterich

John Lotka

INVENTOR

Ferdinand J. Rochow

BY Briesen & Knauth

ATTORNEYS

No. 776,800. PATENTED DEC. 6, 1904.

F. J. ROCHOW.

EXPLOSIVE ENGINE.

APPLICATION FILED DEC. 7, 1901.

NO MODEL. 5 SHEETS—SHEET 5.

Fig. 12.

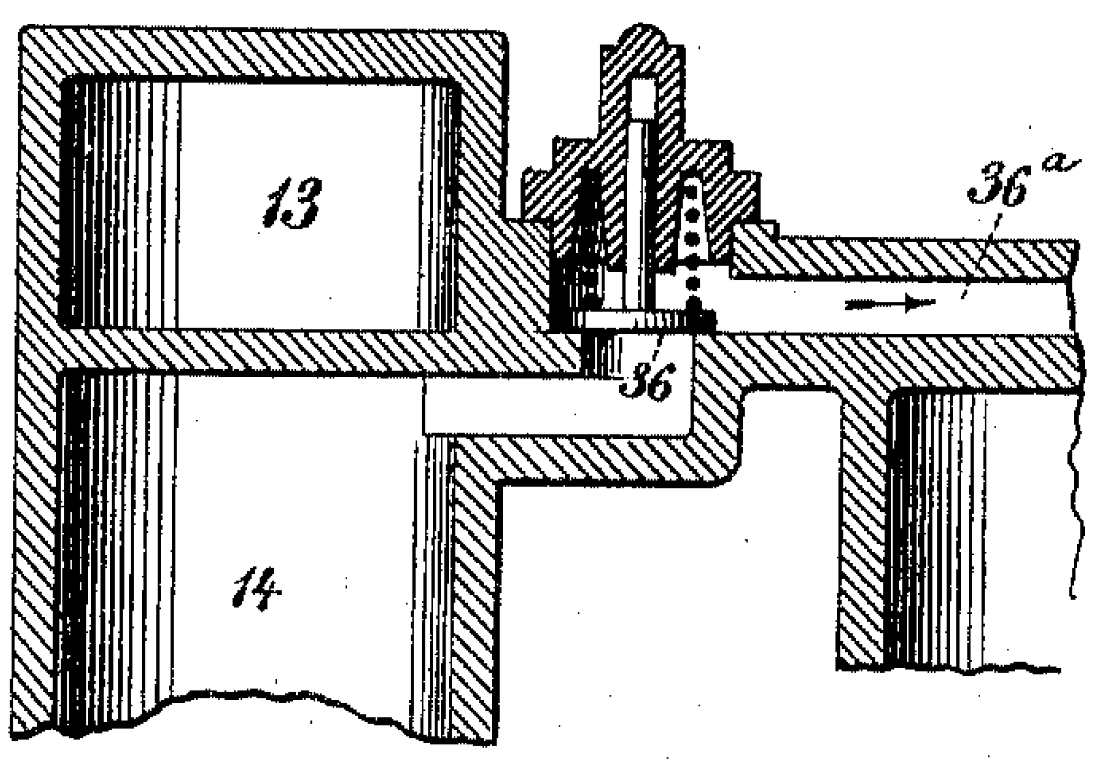


Fig. 14.

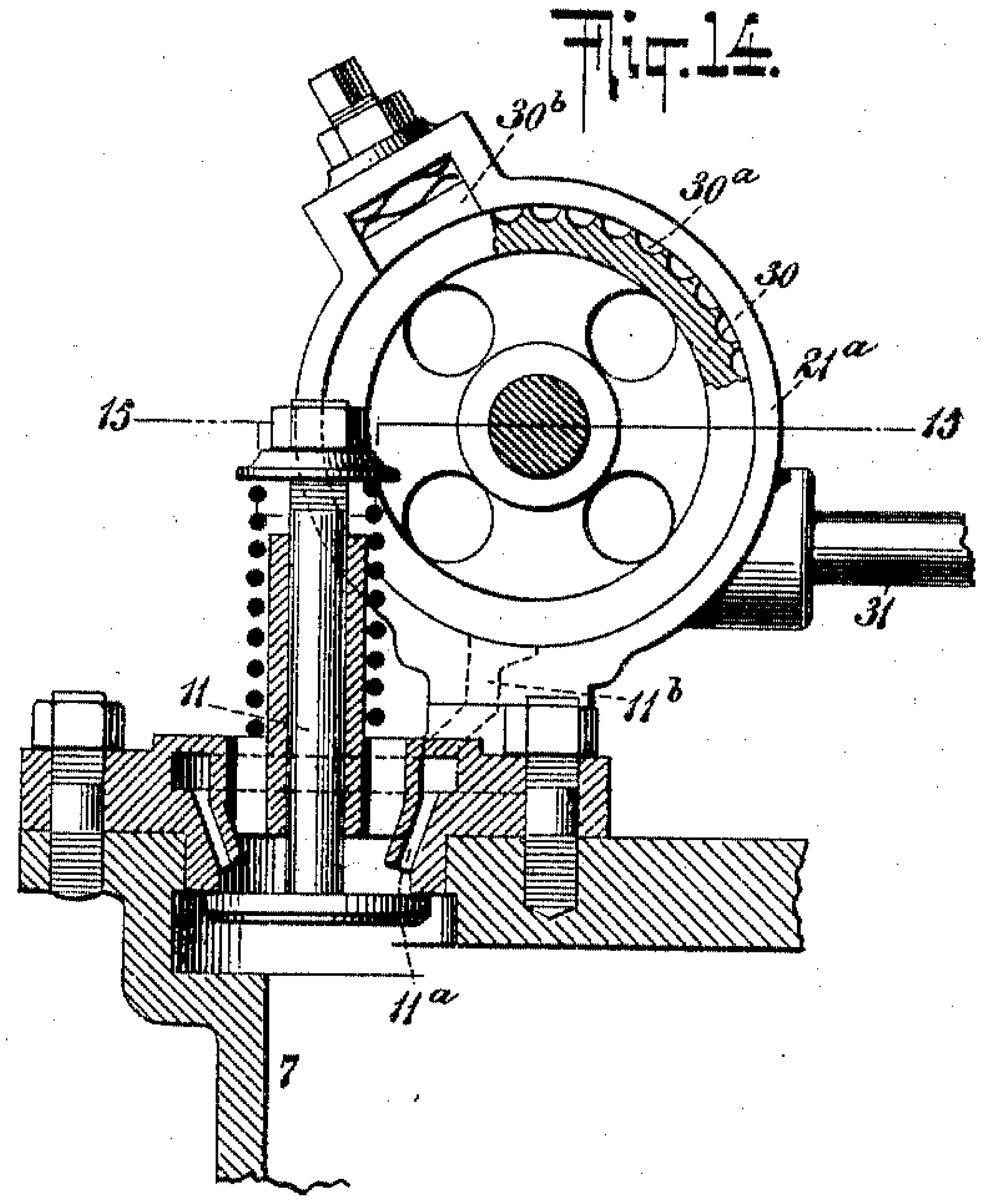


Fig. 13.

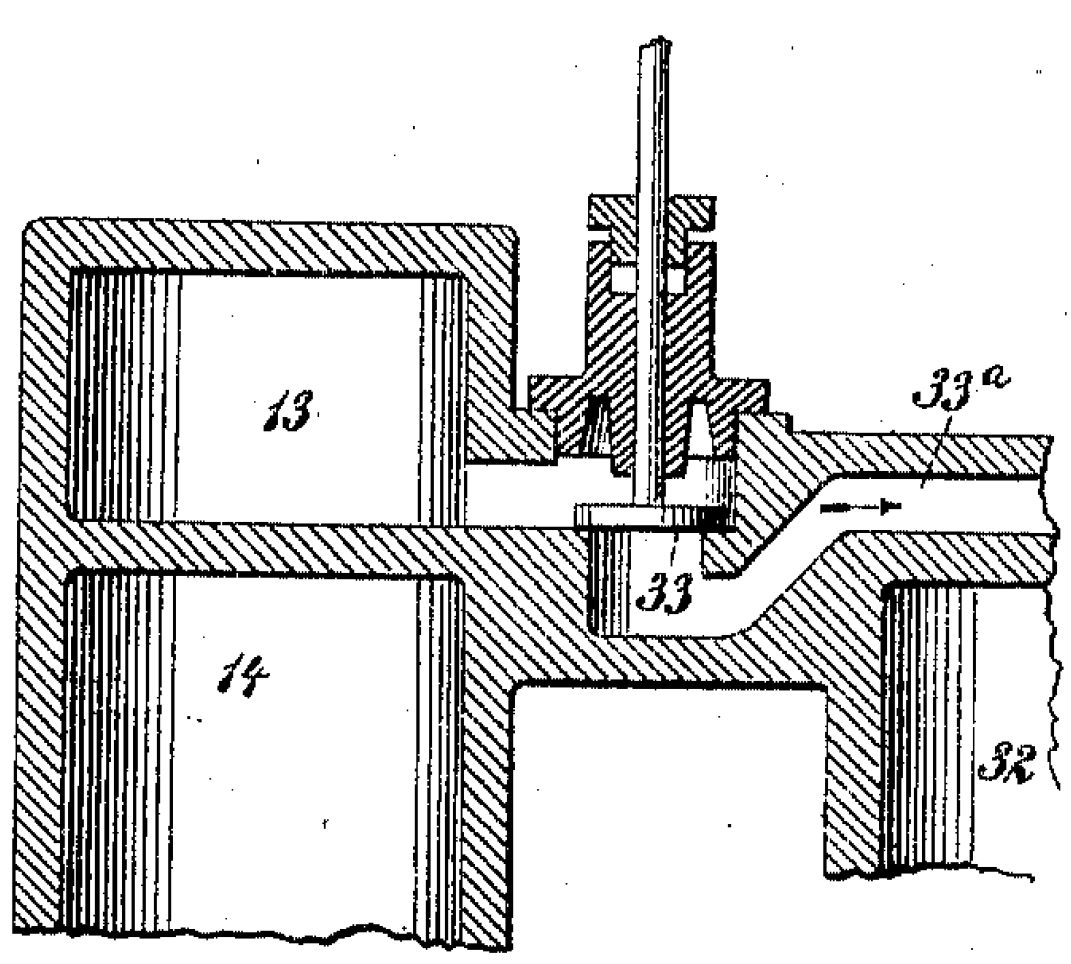
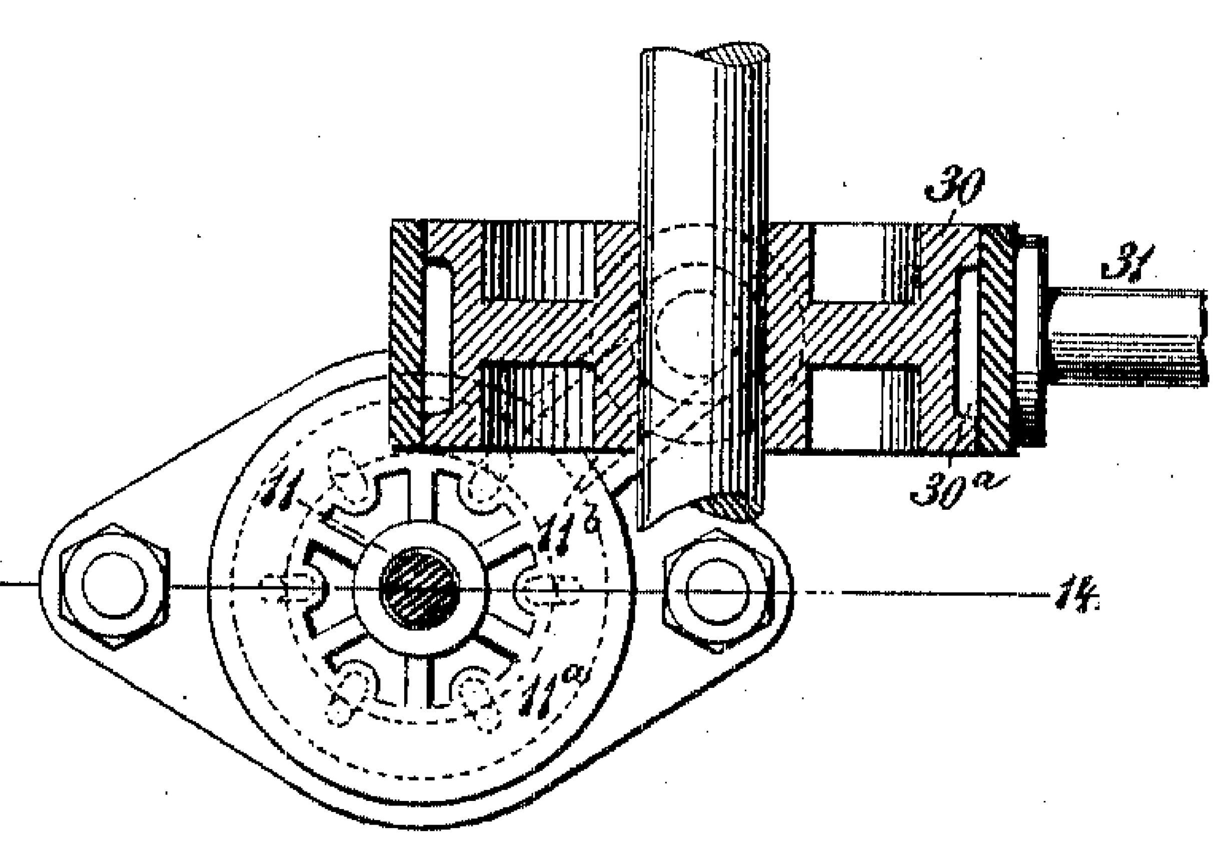


Fig. 15.



WITNESSES:

Gustave Dieterich.

John Lotka

INVENTOR

Ferdinand J. Rochow.

BY Briesen & Knauth

ATTORNEYS

No. 776,800. Patented December 6, 1904.

UNITED STATES PATENT OFFICE.

FERDINAND J. ROCHOW, OF BROOKLYN, NEW YORK, ASSIGNOR OF THREE-FOURTHS TO ANTHONY FRANCIS LUCAS, OF WASHINGTON, DISTRICT OF COLUMBIA.

EXPLOSIVE-ENGINE.

SPECIFICATION forming part of Letters Patent No. 776,800, dated December 6, 1904.

Application filed December 7, 1901. Serial No. 85,049. (No model.)

To all whom it may concern:

Be it known that I, FERDINAND J. ROCHOW, a citizen of the United States, residing in the borough of Brooklyn, city of New York, county of Kings, State of New York, have invented a certain new and useful Improvement in Explosive-Engines, of which the following is a specification.

My invention relates to explosive or internal-combustion engines in which a fuel—such as gas, gasolene, fuel-oil, or the like—is consumed to generate power; and the object of my invention is to obtain a very high degree of heat and pressure by a practically-perfect and accurately-proportioned mixture of fuel with the air.

A further object of my invention is to utilize the pressure and the heat obtained by the explosion or internal combustion as completely as possible for the generation of power, the pressure being reduced almost to atmospheric pressure during the expansion and the surplus of heat in the explosive mixture being utilized to produce power by heat and expanding compressed air, which then also acts on the propelling mechanism.

Another object of my invention is to properly time the explosion and to prevent the spread of a premature explosion into the cylinder.

Other features of my invention will appear from the description and claims following hereinafter.

Reference is to be had to the accompanying drawings, in which—

Figure 1 is a partial side elevation of my improved engine. Fig. 2 is a sectional elevation thereof on line 2 2 of Fig. 5. Fig. 3 is a longitudinal sectional elevation on line 3 3 of Fig. 5. Fig. 4 is a front elevation of the upper part of the engine. Fig. 5 is a plan thereof. Fig. 6 is a sectional detail on line 6 6 of Fig. 5. Fig. 7 is a sectional detail of the igniter. Figs. 8, 9, 11, 12, and 13 are sectional elevations on the corresponding lines of Fig. 5. Fig. 10 is a detail view of the mechanism for feeding the gas or other fuel. Fig. 14 is a detail view of the mechanism constructed for liquid fuel and combined with a spraying device, the parts being shown partly in section on line 14 14 of Fig. 15; and Fig. 15 is a horizontal section on line 15 15 of Fig. 14.

My improved engine is a compound engine, and the explosive gases are made to act first on a high-pressure piston, whereupon having lost part of their power they are made to act on a larger low-pressure piston, and together with these partly-spent explosion-gases I admit to the low-pressure cylinder compressed air which has been previously heated to increase its expansive force.

In detail the construction is as follows: 1 is the high-pressure cylinder in which reciprocates the piston 2, having a piston-rod 2^a connected loosely with the piston and with a crank 17^a on the main shaft 17. This shaft is journaled in bearings 16, secured to the frame 15. On the shaft is also mounted a fly-wheel 17^c. Adjacent to the high-pressure cylinder 1 is located the low-pressure cylinder 3 and farther along the compressor-cylinder 5. In these cylinders are mounted to move pistons 4 and 6, respectively, the piston-rods of which, 4^a and 6^a, are connected with a crank 17^b of the main shaft. The cranks 17^a and 17^b are preferably located at the angle of one hundred and eighty degrees to each other—that is, so the pistons 2 and 4 will move in opposite directions and the pistons 4 and 6 will move in the same direction. It will of course be understood that the piston-rods 4^a and 6^a are loosely connected with their pistons. Above the compressor 5 is located a smaller compressor-chamber 7, into which extends a plunger 8, projecting from the upper end of the piston 6. The chamber 5 is an air-compressing chamber, and the chamber 7 is a fluid-compressing chamber. I desire it to be understood, however, that the substance compressed in the chamber 7 is not fluid exclusively, but a mixture of fluid with a proper amount of air. Air is admitted to the compressing-chamber 5 through a spring-pressed inlet-valve 9, which opens automatically upon the downward or suction stroke of the piston 6. During the upward stroke of said piston the valve 9 remains closed, and air is gradually forced into a holder 14 through a passage 10^a, in which is located an automatic spring-pressed valve 10. (See Fig. 8.) In practice I believe a pressure of about forty-five pounds to the square inch would be the proper one to give to the air in the compressor 5 and the holder 14. From the holder 14 a passage 36^a (see Figs. 3 and 12) leads to a chamber 40^a, located adjacent to the explosion-chamber 32. The communication of this chamber 40^a with the explosion-chamber 32 is controlled by an inwardly-opening spring-pressed valve 40. From the explosion-chamber 32 channels 32^a and 32^b lead to the working chamber of the high-pressure cylinder. The connection is controlled by means of a sliding valve 34, which in the position shown in Fig. 2 cuts off the working chamber from the explosion-chamber; but in the event of the piston-valve or slide 34 being moved over to the right, so as to uncover the port 32^a, a communication will be established from the explosion-chamber 32 through the port 32^a and the hollow valve 34 to the channel 32^b and the working chamber of the high-pressure cylinder. To operate the slide-valve 34, I provide a lever 34^a, fulcrumed at 34^b and carrying a roller 34^c, operated by a cam 34^d on a shaft 20. A spring 34^e serves to hold the roller 34^c against the cam. The shaft 20 carries at one end a beveled wheel 20^a, (see Figs. 1 and 4,) which engages a smaller wheel 19^b upon a vertical shaft 19, which is driven from the main shaft 17 through the medium of a worm-wheel 18 and another worm-wheel 19^a.

From the working chamber of the high-pressure cylinder a passage 35^a (see Fig. 3) leads to the working chamber of the low-pressure cylinder 3. In this passage is interposed a valve 35, which is operated from a shaft 20 (see Fig. 6) by means of a lever 35^b, fulcrumed at 35^c and carrying a roller 35^d, which engages the cam. The spring 35^e keeps the roller 35^d in contact with the cam 35^f of the shaft 20. From the working chamber of the low-pressure cylinder leads an exhaust-channel 37^a, which leads to the exhaust-pipe 38, the exhaust being laterally opened or closed by means of a valve 37, (see Figs. 4 and 11,) which is operated by means of a cam 37^b on the shaft 20, said cam engaging a roller 37^c on a lever 37^d, fulcrumed at 37^e and under the influence of a spring 37^f. The igniter is preferably located in the explosion-chamber 32 and may be of any suitable construction. For instance, I may employ a stationary igniter-point 39 (see Fig. 7) in combination with a movable igniter-point 39^a, mounted to rock about a cylindrical joint 39^b and operated by means of a cam 39^c on the shaft 20. This shaft is so geared as to perform one revolution to each revolution of the main shaft. Thus a spark would be produced for each complete or double stroke of the high-pressure piston. I find, however, that in most cases the explosion is not perfect and the gases which have given the high-pressure piston its working stroke and are to further expend their power on the low-pressure piston still contain explosive substances, and to secure an absolutely complete utilization of the fuel I may find it advisable to produce another spark at the time the low-pressure piston is to begin its working stroke, so that if any explosive substances are left they will be ignited at this moment. All that is necessary to secure this action is to provide two cams like 39^c on the shaft 20 at diametrically opposite points, so that the igniter will be operated twice for each revolution of the main shaft.

The fuel-compressing chamber 7 is provided with an inlet-valve 11, which is spring-pressed in the usual way to open during the suction-period and to close during the compression-stroke of the plunger 8. The fuel, be it gas or a liquid, passes into the chamber 7 through a meter or fuel-feeder, the simplest form of which is shown in Fig. 9. Here 31 indicates a fuel-supply pipe—that is, a pipe so connected with the gas-main—and 21^a indicates a casing, within which is mounted to turn the feeder 30, provided at its periphery with a series of pockets 30^a. A spring-pressed block 30^b is employed to produce a tight joint at the upper portion of the feeder 30. From the lower portion of the feeder-casing 21^a a passage 31^a leads to the top of the fuel-compressor 7. The principle of this construction is to periodically rotate the feeder 30 by mechanism that will be described in detail presently, and it will be understood that the fuel arriving through the pipe 31 will fill the cavities 30^a successively and will also be discharged gradually through the channel 31^a into the compressor. The extent of the angular movement of the feeder will of course govern the number of pockets that will register with the passage 31^a at each operation, and therefore the amount of fuel admitted to the compressor. It will therefore be understood that if the driving mechanism of the feeder 30 is connected with a governor, as described hereinafter, the supply of fuel will be controlled in accordance with the greater or smaller speed of the engine, and a perfect regulation may thus be obtained.

When a liquid fuel is employed which is to be sprayed or atomized before injection into the fuel-compressor, I prefer to employ the construction shown in Figs. 14 and 15, which is substantially the same as that shown in Fig. 9 with the exception that the fuel instead of passing from the pockets 30^a directly to the compressor 7 is led through a channel 11^b into an annular space 11^a, which opens slightly above the inlet-valve 11. Thus when the said inlet-valve is opened by the suction of the plunger 8 the air rushing in through the valve will draw along with it the liquid fuel contained in the space 11^a and will throw said fuel against the upper surface of the valve, thereby breaking the fuel up into minute particles. I find it preferable to make the cavities or pockets 30^a of the feeder larger when the feeder is used for gas than when it is used for liquid fuel.

To periodically operate the feeder, I place on the shaft 20 an eccentric 21, (see Fig. 10,) from which a rod 22 extends to a lever 23, fulcrumed on the shaft of the feeder and provided with a pawl 24, adapted to engage the ratchet-wheel 25, which is rigid with the feeder 30. It will be understood that this mechanism will periodically impart a partial rotation to the ratchet-wheel 25 and feeder 30. In order to regulate the speed of the engine by varying the amount of fuel admitted, the throw of the lever 23 is placed under the control of a governor. For this purpose the rod 22 is not fixedly connected with the lever 23; but the connection is made through the medium of a slide 22^a, which may be moved lengthwise of the lever 23, so as to vary the purchase which the rod 22 has on the lever 23, and consequently the amount of throw given to the lever by the constant movement of the rod 22. For this purpose I provide a governor 26, the sleeve of which, 26^a, is connected with an arm 27 upon a rock-shaft 28, (see Figs. 1 and 10,) this shaft also carrying a lever or arm 29, connected by a link 29^a with an eccentric-rod 22. Thus when the speed of the engine increases the rod 22 will be moved to shift the sleeve 22^a outward on the lever 23, and thus the throw of the lever and the amount of fuel admitted will be diminished, thus reducing the speed to the normal rate.

The mixture of fuel and air compressed in the chamber 7 passes through the channel 12^a, containing an automatic check-valve 12, Fig. 3, into a holder 13. From there the mixture passes through a channel 33^a to the chamber 40^a, previously mentioned. In the passage or channel 33^a is located a valve 33, (see Figs. 6 and 13,) which is operated from the shaft 20 by means of a cam 33^f acting on a roller 33^b and through the medium of a rod 33^c on a lever 33^d, fulcrumed at 33^e and connected with the valve 33. One end of a spring 35^e, previously mentioned, is secured to this lever 33^d, so that the said spring keeps both rollers 33^b and 35^d in contact with their respective cams.

The compressor 7 is to be so constructed that the proportion of air to fuel will be comparatively small, so that the mixture will be entirely non-explosive, the object of said compressor being merely to atomize, vaporize, or dilute a more or less volatile fluid into a harmless thoroughly-mixed compound of air and fuel and to compress this to a proper degree—say about sixty pounds per square inch—the compression producing a corresponding increase of temperature, as is well known. Thus it will be understood that the chamber or holder 13 contains a heated mixture of fuel with a small proportion of air, and this mixture is admitted by opening the valve 33 quickly and for a short time only immediately before the high-pressure piston 2 reaches the end of its upstroke. At this stage of the cycle the explosion-chamber 32, as will be seen later, is filled with pure air of a pressure of about eighteen pounds per square inch, so that the moment the valve 33 is opened by the mechanical means described the mixture from the holder 13 will pass quickly into the small chamber 40^a and into the explosion-chamber 32, and a momentary equilibrium of pressure will be obtained in the two chambers. The chamber 32 is so proportioned that the amount of air contained therein and the amount of the mixture rushing in will form a proper explosive mixture to insure perfect combustion. The explosion should occur immediately after the valve 33 has become closed. The valve 34 should open a little after the piston 2 has reached its uppermost position and has begun to move downward. By this construction the explosive gases will enter the high-pressure cylinder at the proper time independently of the time of the explosion, even if the latter should have been premature, and, further, the temperature and pressure of the gases after explosion can be very accurately determined, as there is very little loss of heat by radiation in the explosion-chamber, and no water-jackets or other artificial cooling means are necessary in my engine. The valve 34 remains open, and the expanding gases force the piston 2 downward to the end of its working stroke. The capacity of the working chamber of the high-pressure cylinder is so calculated that when the gases have expanded to, say, about forty-five-pounds pressure the piston is at the end of its working stroke, and at this time the low-pressure piston 4 is in its uppermost position, and this is the moment at which the valve 35 is opened by the means fully explained hereinbefore. The hot gases contained in the high-pressure cylinder then pass through the channel 35^a into the low-pressure cylinder 3 and propel the piston 4 downward. Meanwhile during the working stroke of the high-pressure piston the piston 6 of the air-compressor has forced air through the valve 10 into the holder 14 at a pressure of about forty-five pounds. The check-valve 36 does not open until shortly after the pistons 4 and 6 have commenced to travel downward. Then the compressed air passes through the channel 36^a into the chamber 40^a and into the explosion-chamber 32, from which it travels through the valve 34, which is still open, to the working chamber of the high-pressure cylinder and, together with the remainder of the explosive mixture, into the low-pressure cylinder 3. During its passage through the highly-heated explosion-chamber 32 and by its contact with the hot explosion-gases this air will be heated, thereby receiving an increased expansive power and at the same time cooling the explosion-chamber and the other parts of the machine with which it comes in contact. It will be obvious that by thus heating the air I not only dispense with the usual cooling arrangements, but actually secure an increase of the available motive power. The valve 34 closes when the mixture of air and explosion-gases has expanded to a pressure of about eighteen pounds—that is, about three pounds above atmospheric pressure. This leaves the chamber 32 filled with pure air at a pressure slightly above atmospheric pressure, and shortly before the low-pressure piston 4 reaches its lowermost position the valve 35 is closed and the valve 37 opened. This valve remains open during the upward stroke of the low-pressure piston, and during this stroke the two compressor pistons or plungers 6 and 8 increase the pressure in the chambers 13 and 14 from about forty-five pounds and eighteen pounds, respectively, to about sixty and forty-five pounds, respectively.

While I have described a compound engine having two working cylinders, it will be understood that the same principle may be applied to a multiple-expansion engine having a greater number of pistons, and the terms "high pressure" and "low pressure" as used in the claims are to be interpreted as relative terms and not as implying that there are two pressures only. Further, it will be understood that certain features of my invention may be applied to simple engines as well as to compound engines. When using a single cylinder, I would, at least for engines of a relatively small size, dispense with valve 34 between the explosion-chamber and the working chamber—that is, practically one chamber would in this case fulfil the duties both of an explosion-chamber and of a working chamber.

It will be understood that compressed air is admitted after the explosion has taken place, but during the same complete (back-and-forth) stroke of the piston and before the exhaust occurs, so that the compressed air will mix with the hot explosion products and will by absorption of heat acquire additional expansive force. It will also be observed that air is discharged into the high-pressure cylinder in the opposite direction to that in which the explosion products are propelled by the piston on its return movement, so that the two mediums are thrown toward and into each other, thus bringing about a rapid and thorough mixture and a ready absorption of heat by the compressed air.

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

1. In an explosive-engine, the combination of an air-compressor, a fuel-compressor, an explosion-chamber, a holder or receptacle arranged to receive air from the air-compressor and connected with the explosion-chamber to supply air thereto, a check-valve located in the delivery connection of said holder and arranged to open automatically toward the explosion-chamber when the pressure in the latter falls to a predetermined point, a connection from the fuel-compressor to the explosion-chamber, a valve in said connection, and mechanism, operated by the engine, for opening said valve.

2. In an explosive-engine, the combination of a high-pressure cylinder and a low-pressure cylinder having a channel connecting them, a valve located in said channel, means operated by the engine for opening said valve, an air-compressor connected with the high-pressure cylinder, an explosion-chamber located in the connection of the said compressor with the high-pressure cylinder, so that the compressed air must pass through the explosion-chamber on its way from the compressor to the high-pressure cylinder, a fuel-compressor likewise connected with the explosion-chamber, a valve in the connection of the fuel-compressor with the explosion-chamber, and means, operated by the engine, for opening the last-mentioned valve at about the beginning of the working stroke of the high-pressure piston, while the valve in the connection of the two cylinders is opened at about the end of the working stroke of the high-pressure piston.

3. In an explosive-engine, the combination of an air-compressor of a capacity largely in excess of the requirements of a single explosive charge, a fuel-compressor, the capacity of which does not exceed the requirements of a single charge, a holder arranged to receive air from the air-compressor, an explosion-chamber connected with the holder, check-valves located in the supply and delivery connections of said holder, and both arranged to open automatically toward the explosion-chamber, a separate holder arranged to receive the fuel from the fuel-compressor and to deliver it to the explosion-chamber at a pressure above the pressure to which the charge is compressed before ignition, a check-valve in the connection of the fuel-compressor with the fuel-holder, said check-valve opening toward the holder, another valve in the connection of the fuel-compressor with the explosion-chamber, and means actuated by the engine for operating the last-named valve.

4. In an explosive-engine, the combination of a high-pressure cylinder, a low-pressure cylinder, a connection or channel between said cylinders, a valve located in said channel, means operated by the engine for opening and closing said valve, an air-compressor, the capacity of which is largely in excess of the requirements of a single explosive charge, a holder arranged to receive the air from said compressor, a connection from the air-com-

pressor to the high-pressure cylinder, an explosion-chamber located in this connection so that the compressed air is compelled to pass through the explosion-chamber on its way from the compressor to the high-pressure cylinder, a fuel-compressor, a fuel-holder connected therewith and arranged to contain fuel compressed to a higher pressure than that of the explosive charge before ignition, a connection from the fuel-holder to the explosion-chamber, a valve located in this connection, and means operated by the engine for opening and closing said valve at about the beginning of the working stroke of the high-pressure piston, while the valve in the connection of the two cylinders is opened at about the end of the working stroke of the high-pressure piston.

5. The combination of a high-pressure cylinder, a low-pressure cylinder connected therewith, an explosion-chamber connected with the high-pressure cylinder, an igniter in the explosion-chamber, and means operatively connected with the engine for producing a spark through the said igniter at the beginning of the working stroke of the high-pressure piston and again at the end of the working stroke of the said piston.

6. The combination of the main shaft having cranks extending in opposite directions, a high-pressure piston connected with one of said cranks, a low-pressure piston and a compressor-piston connected to the other crank, cylinders in which said pistons work, a plunger carried by the compressor-piston, a fuel-compressor cylinder in which the said plunger works, a receptacle connected with each compressor to store the compressed gas, connections from the said receptacles to the high-pressure cylinder, a valved connection from the high-pressure cylinder to the low-pressure cylinder, and means for operating the valve in said connection.

7. In an explosive-engine, the combination of an air-compressor, a chamber adapted to contain compressed air, and connected with said air-compressor, an explosion-chamber connected with said compressed-air chamber, a working cylinder connected with said explosion-chamber, a mechanically-governed valve controlling the connection of the explosion-chamber with the working cylinder, and means adapted to cause a current of compressed air to pass first through said explosion-chamber, after the explosion has taken place, and afterward through said working cylinder.

8. In an explosive-engine, the combination of an air-compressor, a chamber adapted to contain compressed air and connected with said air-compressor, an explosion-chamber connected with said compressed-air chamber, a high-pressure working cylinder connected with said explosion-chamber, a low-pressure working cylinder, and means adapted to cause a current of compressed air to pass first through said explosion-chamber, after the explosion has taken place, and afterward through the high and low pressure working cylinders successively.

9. In an explosive-engine, the combination of a power-cylinder, an explosion-chamber connected with the working chamber of the power-cylinder, a valve interposed between the explosion-chamber and the working chamber, means controlled by the engine for actuating said valve, a source of compressed air of a capacity largely in excess of the requirements of a single explosive charge and so arranged as to acquire a predetermined pressure before the air is admitted to the cylinder, and a connection from said source of compressed air direct to the explosion-chamber, so that the said valve when closed will separate the air-supply from the working chamber.

10. In an explosive-engine, the combination of an air-compressor largely in excess of the requirements of a single charge, a holder adapted to receive the compressed air, an explosion-chamber connected with said holder, a high-pressure cylinder connected with said explosion-chamber, a low-pressure cylinder connected with the high-pressure cylinder, and means for causing a current of compressed air to pass from the said holder first through the explosion-chamber after the explosion has taken place, and then through the high-pressure cylinder and the low-pressure cylinder successively.

11. In an explosive-engine, the combination of a fuel-compressor, a separate receptacle or holder connected therewith, a check-valve located in the connection of the compressor with the holder and opening toward the latter, an explosion-chamber connected with the outlet of said holder, a valve controlling the connection of said holder with the explosion-chamber, and mechanism governed by the engine for operating said valve in such a manner that a charge of fuel will be injected from said holder into the explosion-chamber during the time between the opening and closing of said valve under a pressure higher than the maximum pressure of the charge shortly before ignition.

FERDINAND J. ROCHOW.

Witnesses:

JOHN LOTKA,

EUGENE EBLE.