F. REYNOLDS.

STARTING DEVICE FOR EXPLOSIVE ENGINES.

APPLICATION FILED NOV. 9, 1904.

1,016,522.

Patented Feb. 6, 1912.

4 SHEETS—SHEET 1.

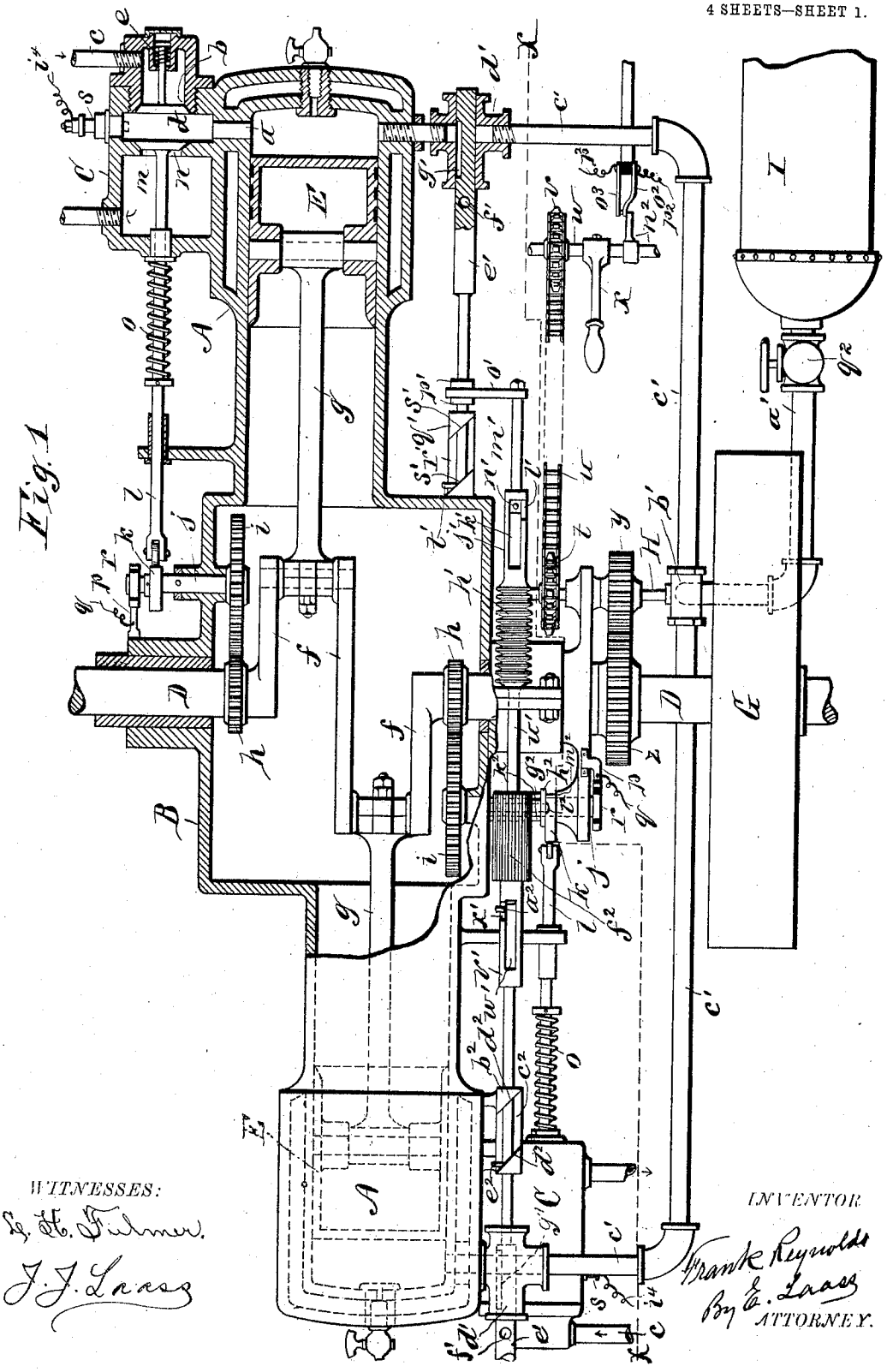

Fig. 1.

WITNESSES:

E. F. Tilmer.

J. J. Laass

INVENTOR

Frank Reynolds

By E. Laass

ATTORNEY.

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4 SHEETS—SHEET 2.

Fig. 2

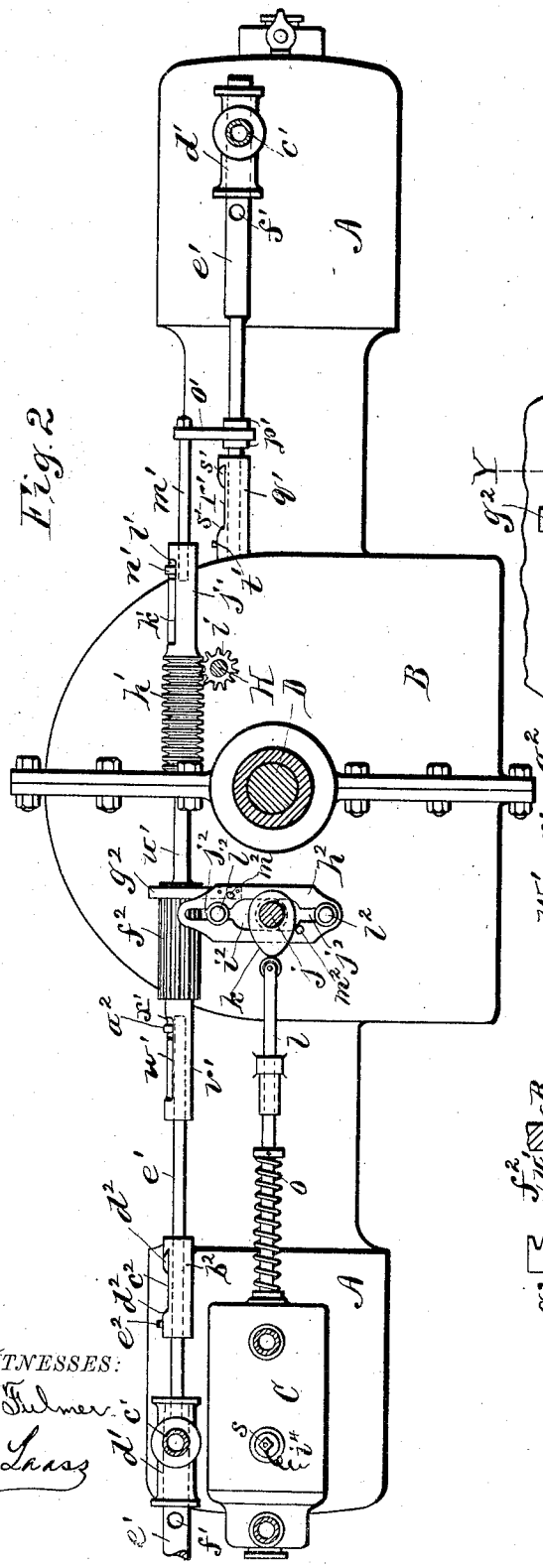


Fig. 3

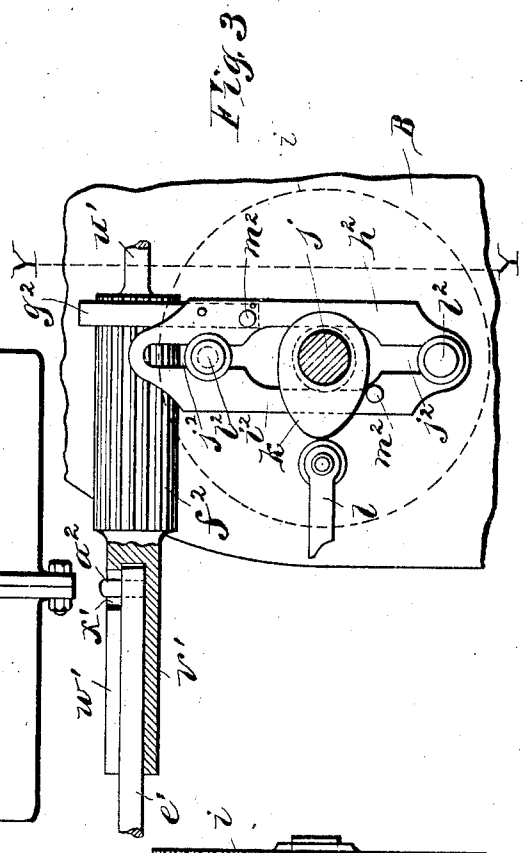
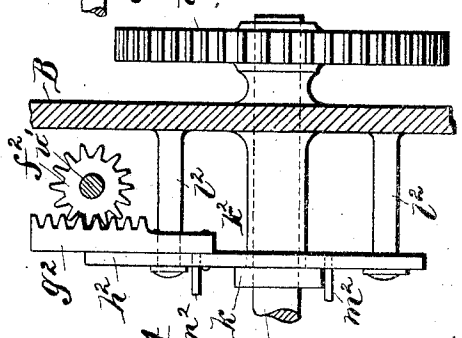


Fig. 4



WITNESSES:

E. H. Fulmer.

J. J. Laass

INVENTOR

Frank Reynolds

By E. Laass

ATTORNEY.

F. REYNOLDS.

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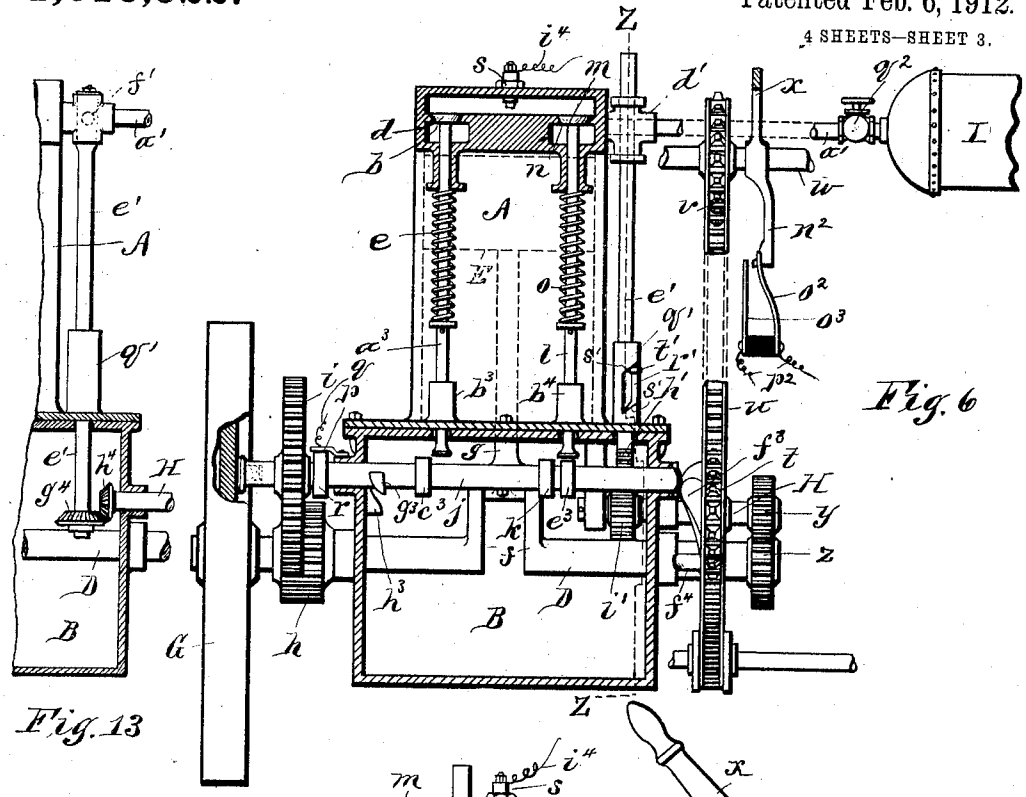

Fig. 6

Fig. 13

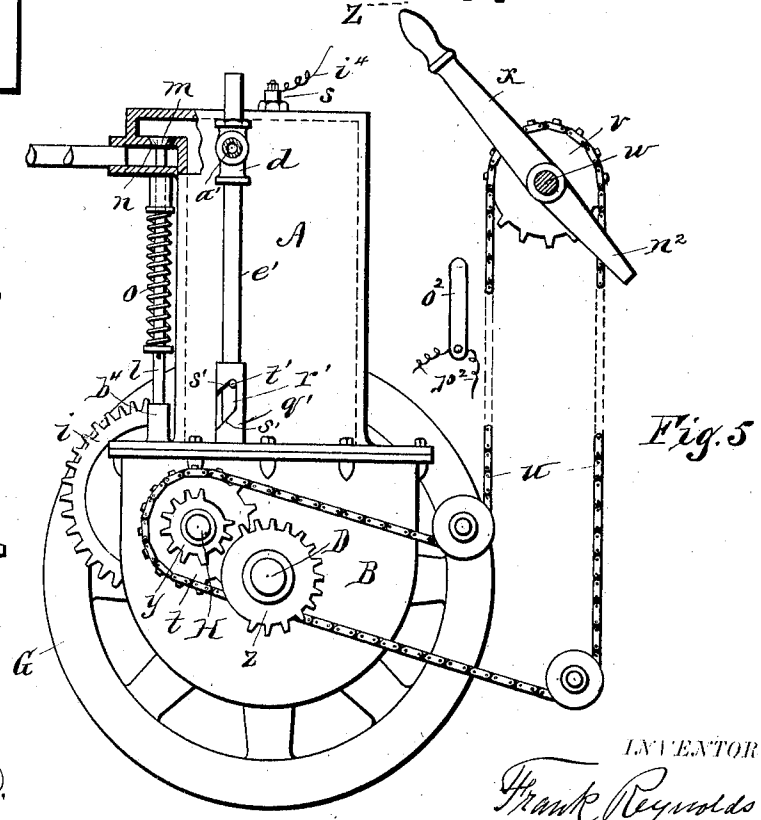

Fig. 5

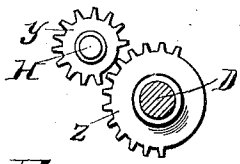

Fig. 11

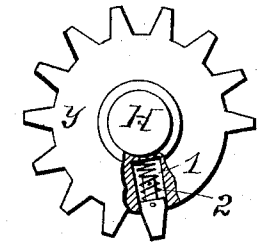

Fig. 12

WITNESSES:

G. H. Fulmer.

J. J. Laas

INVENTOR

Frank Reynolds

By E. Laas

ATTORNEY.

F. REYNOLDS.

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4 SHEETS—SHEET 4.

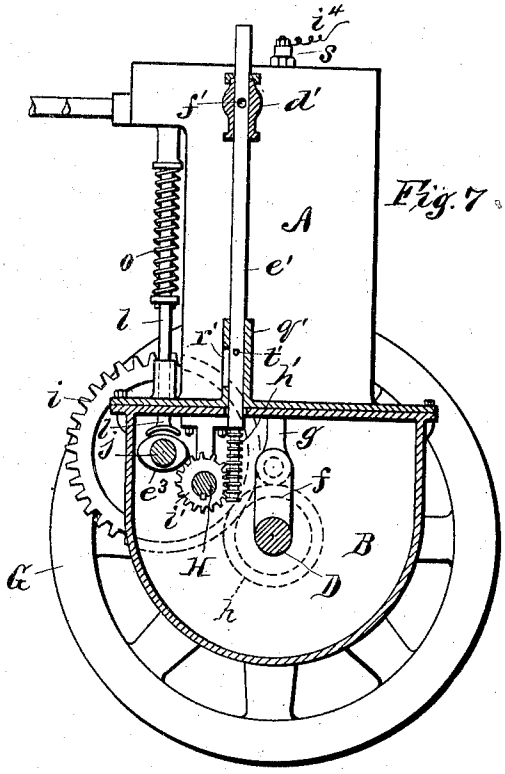

Fig. 7

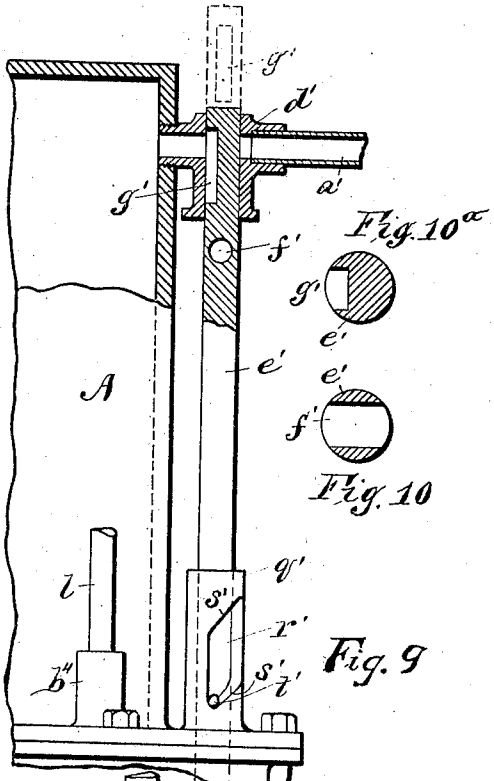

Fig. 9

Fig. 10

Fig. 10a

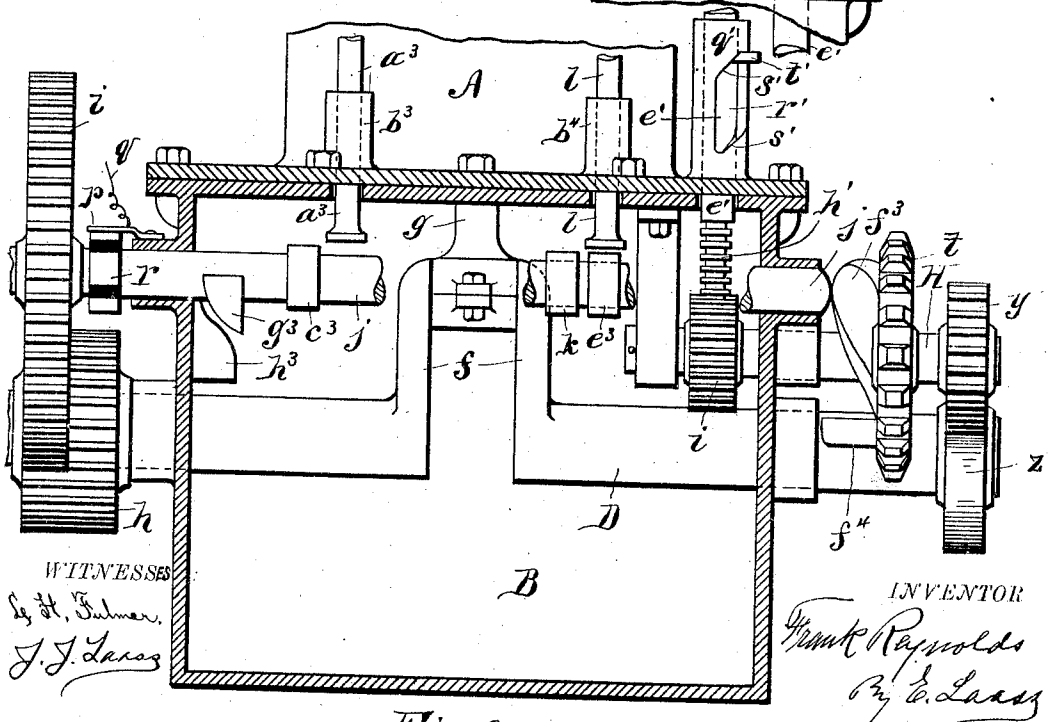

Fig. 8

WITNESSES

L. H. Fulmer.

J. J. Lacey

INVENTOR

Frank Reynolds

By E. Lacey

ATTORNEY.

UNITED STATES PATENT OFFICE.

FRANK REYNOLDS, OF SYRACUSE, NEW YORK.

STARTING DEVICE FOR EXPLOSIVE-ENGINES.

1,016,522. Specification of Letters Patent. Patented Feb. 6, 1912.

Application filed November 9, 1904. Serial No. 231,971.

To all whom it may concern:

Be it known that I, FRANK REYNOLDS, of Syracuse, in the county of Onondaga, in the State of New York, have invented new and useful Improvements in Starting Devices for Explosive-Engines, of which the following, taken in connection with the accompanying drawings, is a full, clear, and exact description.

This invention pertains to explosive-engines and relates more particularly to that type of engine having a reciprocating piston, and it resides in a novel device for easily and conveniently starting the engine and which may be applied to an engine having one or more cylinders, and it is designed for both "two-cycle" and "four-cycle" engines having either upright cylinders or horizontally opposed cylinders.

The main object of the present invention is to produce a starting-device which may be readily combined with any well known engine of the aforesaid types, and which shall be simple and compact in construction, very efficient in its operation and at the same time can be easily and conveniently operated.

To this end the invention consists in the novel arrangement and construction of the component parts of the starting-device as hereinafter fully described and set forth in the claims.

In the accompanying drawings Figure 1, is partly a plan view and partly a longitudinal section of a so-called "opposed-cylinder" explosive-engine equipped with my improved starting device, Fig. 2 is a horizontal section taken on the dotted line —X—X— in Fig. 1, Fig. 3 is an enlarged detail front view of the cam-mechanism and the rack-and-pinion mechanism which control the action of the valve-operating means of the starting device, Fig. 4 is a vertical section on the line —Y—Y— in Fig. 3, Fig. 5 is an end view of a single-cylinder engine equipped with my invention, Fig. 6 is partly a side-view and partly a longitudinal section of the latter engine, Fig. 7 is a vertical section on line —Z—Z— in Fig. 6, Fig. 8 is an enlarged longitudinal section through the crank-case of the single cylinder engine, Fig. 9 is an enlarged detail view showing the rod provided with the inlet-port and relief-passage and the means of oscillating the rod, Figs. 10 and 10^a are further enlarged transverse sections of the rod taken through the said port and passage respectively, Fig. 11 is a detail side view of the mutilated gears by which the crank-shaft is turned to move the piston, Fig. 12 is an enlarged detail side view of one of said gears having a portion broken away, showing the yielding tooth thereof; and Fig. 13 shows a modification of the means for oscillating the aforesaid rod.

Referring to Figs. 1, 2, 3 and 4 of the drawings illustrating the opposed-cylinder engine, —A—A— represent the cylinders which are disposed horizontally and out of line and are united by a divided case —B— which may be supported in any suitable and well known manner. Each of said cylinders is provided with an exterior chamber —C— which may be formed integral therewith and is preferably disposed at one side of the cylinder. These chambers communicate with the cylinders by means of passages —*a*—*a*— and are provided with inlet-ports —*b*—*b*— for admitting the explosive mixture supplied by pipes —*c*—*c*— leading from the usual carbureter (not necessary to be shown), which ports are provided with the usual valves —*d*—*d*—. These valves are opened by suction produced by the inward thrusts of the pistons in the well known manner and are closed automatically by the usual spiral springs —*e*—*e*—. —D— denotes the main shaft provided with the well known cranks —*f*—*f*— to which are connected the usual rods —*g*—*g*— of the reciprocating pistons —E—E— disposed in the cylinders —A—A—, and —G— denotes the usual balance-wheel secured to the said crank-shaft. The shaft —D— is journaled in the case —B— in the well known manner and secured thereto adjacent to the case are pinions —*h*—*h*— which mesh with gears —*i*—*i*— secured to shafts —*j*—*j*— suitably journaled on the case and protruding at the exterior thereof. To these shafts —*j*—*j*— are secured cams —*k*—*k*— which are arranged to alternately actuate rods —*l*—*l*— respectively to open valves —*m*—*m*— of the exhaust-ports —*n*—*n*— disposed in the aforesaid chambers —C—C—, which valves are closed automatically by means of spiral springs —*o*—*o*— surrounding the rods and moving the rods in opposition to the cams in the well known manner. —*p*—*p*— denote the usual electric-contacts which are secured to any suitable parts of the engine and to which are attached the primary circuit wires —*q*—*q*—, which contacts bear on the usual timers —*r*—*r*— secured to the shafts —*j*—*j*— in the well known manner.

—*s*—*s*— denote the usual electric spark-plugs which are fastened in the cylinders, in the present case they are secured to the chambers —C—C— which communicate with said cylinders, to which plugs are fastened the usual secondary-circuit wires —i^4—i^4—.

The described parts are common to all explosive-engines and for that reason a further description of the same is unnecessary. I will therefore proceed to describe my improved starting-device as applied to the two-cylinder engine shown.

—H— is a supplemental shaft which is suitably journaled on the crank-case —B— and is oscillated for the purpose hereinafter explained. To said shaft —H— is secured a sprocket wheel —*t*— which is connected by the usual chain —*u*— to a sprocket-wheel —*v*— secured to another shaft —*w*— which may be supported in any suitable manner. To the latter shaft is secured a hand-lever —*x*— which may be arranged in any convenient position to be operated by the person in charge of the engine. This lever serves to oscillate the shaft —*w*— whereby like movement is imparted to the aforesaid shaft —H—. To the shaft —H— is secured a small mutilated gear —*y*— which is arranged to mesh with a larger mutilated gear —*z*— secured to the crank-shaft —D—. The said lever is so limited in its movement as to cause the mutilated portion of the gear —*y*— to be presented to the other gear —*z*— when the lever is in its normal position thereby permitting free and uninterrupted rotation of the shaft —D— during the running of the engine. When the engine is at rest and it is desired to start the same, the lever is actuated whereby the small gear is caused to engage the larger one.

The engagement of the rotated gear —*y*— with the gear —*z*— imparts motion to the crank-shaft —D—, whereby the pistons are moved. These gears are of such relative sizes and deprived of a sufficient number of teeth as to cause them to become automatically disengaged when one of the pistons has reached substantially its outermost position, so as to leave the same in said position, said piston being the one which was next to have been in the power-stroke or cycle when the engine came to rest. It will be understood that the movement of the pistons is regulated by the position the gear —*z*— assumes, in relation to the gear —*y*—, when the engine stops running.

It is obvious that the explosive-mixture is to be admitted into the cylinder whose piston has been positioned. This is determined by a novel arrangement of valves and mechanism for controlling the same as will be hereinafter fully described. By the aforesaid automatic disengagement of the gears —*z*— and —*y*—, the latter is permitted to be rotated in reverse direction when the hand-lever —*x*— is moved to its normal position.

The initial engaging tooth of the small mutilated gear is formed separate from the gear and is set in a socket —1— in which is disposed a spiral spring —2— bearing on the tooth, this spring allows the tooth to yield slightly to prevent the same from riding on a tooth of the large gear, thereby insuring a mesh of the two gears.

—I— represents a reservoir in which is stored explosive-mixture under compression. This compression may be effected by any suitable and well known means. (Not necessary to be shown.) From said reservoir extends a pipe —a^1— which is connected by a suitable valve —b^1—, to branch-pipes —c^1—c^1— which lead to the respective cylinders —A—A—. This valve is operated by the aforesaid shaft —H—, as will be hereinafter more fully described. In each of the branch-pipes —c^1— adjacent to the cylinders is provided a coupling or case —d^1— and through these couplings extend rods —e^1—e^1— which are permitted to be reciprocated longitudinally and to be oscillated for the purpose shortly explained. Each of these rods is provided with a port —f^1— which is arranged to register with the pipe —c^1— to afford communication of the latter with the adjacent cylinder. This port is normally at right angles to the pipe and constitutes an inlet-valve for supplying the cylinder with the mixture. Each rod is also provided with a longitudinal channel or groove —g^1— which is disposed quarter-way around the rod in relation to the aforesaid port and is in front of the same, as clearly shown in Fig. 1. This channel constitutes a relief-passage or valve and normally faces the cylinder and communicates therewith. The latter valve serves to permit the escape of any previously admitted mixture which may have remained in the cylinder when the engine came to rest, and thereby relieves the piston from pressure and resultant resistance thereto incident to moving the piston to the beginning of its power stroke in the manner aforesaid. This relief-passage is normally within the coupling to prevent escape of mixture from the cylinder during the running of the engine and of sufficient length to extend outside of the coupling or case —d^1— while in communication with the cylinder to effect the escape of the mixture when the rod —e^1— is shifted outwardly. When the rod has moved sufficiently to cut off this communication, it is given a quarter turn to cause the aforesaid port —f^1— to register with the pipe —*c*— thus admitting the explosive mixture into

the cylinder from the chamber —I—. The rod —e^1— is immediately shifted in inward direction to close the port —f^1— and thus the admitted mixture is entrapped in the cylinder. During the latter movement of the rod the relief-passage is maintained out of communicaiton with the cylinder to prevent escape of the entrapped mixture, and just previous to the completion of this movement said rod is rotated to carry the port and relief-passage to their normal positions.

While I have shown the valves of only one cylinder, at the same time it will be understood that those of the other cylinder are identical both in construction and operation except in a reverse condition and therefore do not require illustration.

—h^1— denotes an annularly toothed rack which is disposed horizontally and suitably supported on the engine, and is actuated by a pinion —i— secured to the aforesaid shaft —H— as clearly shown in Fig. 2. The rack is formed at one end with a sleeve —j^1— provided with a longitudinal slot —k^1— having a notch —l^1— in one edge adjacent to the outer end, in which sleeve slides a rod —m^1— provided at its inner end with a transverse pin —n^1— movable in the slot and adapted to engage the notch —l^1—. To the outer end of the rod —m'— is rigidly attached one end of an arm —o^1—, the opposite end of which arm is disposed loosely between two collars —p^1—p^1— rigidly secured to one of the rods —e^1—. This rod —e^1— is supported longitudinally movable at one end in the aforesaid coupling or case —d^1— and at its opposite end in a sleeve —q^1— rigidly fastened to the crank-case —B— of the engine. This latter sleeve is provided with a longitudinal slot —r^1— having inclined or oblique ends as indicated at —s^1—s^1—. This rod —e^1— is provided with a transverse pin —t^1— sliding in the said slot —r^1— and adapted to engage the ends thereof. To the opposite end of the aforesaid rack —h^1— is rigidly connected a rod —u^1— to which is rigidly fastened a sleeve —v^1— provided with a longitudinal slot —w^1— having a notch —x^1— in one edge adjacent to its inner end similar to the other sleeve —j^1—. In the said sleeve —v^1— slides the other rod —e^1— provided at its inner end with a transverse pin —a^2— movable in the slot —w^1— and adapted to engage the notch —x^1—. This rod is supported longitudinally movable in the other coupling or case —d^1— and in a sleeve —b^2— rigidly attached to the adjacent cylinder —A—. This sleeve is provided with a longitudinal slot —c^2— having inclined or oblique ends as indicated at —d^2—d^2—, and to the rod is secured a transverse pin —e^2— sliding in said slot and adapted to engage the ends thereof. By moving the aforesaid hand-lever —x— from its normal position the shaft —H— is turned in one direction whereby the pinion —i^1— then causes the rack —h^1— to shift to the right.

In case the pin —n^1— is in engagement with the notch —l^1— of the slotted-sleeve —j^1—, the rod —m^1— is carried with the rack and sleeve, whereby the arm —o^1— is caused to move the rod —e^1— in like direction. This movement of the said rod causes the outer end relief-pasage —g^1— in the rod to extend outside of the coupling or case —d^1— which passage is in connection with the cylinder, thereby relieving the piston from pressure of any mixture that may have remained in the cylinder, and thus permitting the piston to be easily moved to the beginning of its power stroke in the manner aforesaid.

When the rod —e^1— has been moved a sufficient distance to close the communication betwen the passage and cylinder, the rod is automatically turned quarter-way around by the engagement of the pin —t^1— with the outer inclined or oblique ends —s^1— of the slot, whereby the port —f^1— is caused to register with the pipe —c^1— and thus the compressed explosive-mixture is admitted into the cylinder. By moving the said hand-lever —x— to its normal position the rack and connected rods are shifted in reverse direction, whereby the said port —f^1— is closed to entrap the mixture in the cylinder. During the movement of the rod —e^1— the pin —t^1— travels in the slot —r^1— whereby the relief-passage is prevented from communicating with the cylinder, and when the said pin engages the other inclined or oblique end of the slot the rod is automatically turned in reverse direction to move the port and passage into their normal positions. It will be understood that in case the said pin —n^1— is disengaged from the notch —l^1— the rack is permitted to move independent of the rod —m^1—. When this pin is disengaged, the pin —a^2— is in engagement with the notch —x^1— formed in the slot —w^1— of the sleeve —v^1—, thus by reciprocating the rack as described the other rod —e^1— is moved likewise and automatically oscillated to carry its inlet-port and relief-passage into and out of communication with the other cylinder —A—. It will be observed that the mechanisms just described automatically control the admission-valves of the cylinders, thereby determining the cylinder whose piston is at the beginning of the power-stroke or cycle. The said pins —n^1—a^2— are caused to engage and disengage their respective notches —l^1— x^1— by the oscillation of the rack —h^1— which movement is effected by means of a pinion —f^2— secured to the rod —u^1—, and a vertically disposed rack —g^2— engaging said pinion. This rack is secured to a ver-

tically reciprocating elongated plate —h^2— which is provided with a longitudinal slot —i^2— having reduced end-portions as indicated at —j^2—, and is supported by a sleeve or box —k^2— projecting rigidly from the crank-case —B— of the engine on which sleeve one of the aforesaid cam-shafts —j— is journaled. Said plate is guided in its movement by means of rods —l^2—l^2— projecting rigidly from the crank-case and extending through the end-portions —j^2—j^2— of the slot —i^2— as more clearly shown in Figs. 3 and 4 of the drawings. The plate is actuated by means of two pins —m^2—m^2— projecting rigidly from its outer face and arranged to be alternately engaged by the cam —k— secured to the shaft —j—. To the shaft —w— of the aforesaid hand-lever —x— is secured an arm —n^2— constituting an electric-circuit-maker and breaker.

—o^2—o^3— denote the flexible electric-contacts which are insulated apart and may be supported in any suitable and convenient manner, and to which are connected the primary electric-circuit wires —p^2—p^2— of the usual induction-coil (not necessary to be shown). The said arm —n^2— is arranged to press the contact —o^2— against the contact —o^3— when the lever is in its normal position. When the lever is moved forward the circuit is broken. Said movement of the lever operates the aforesaid sprocket-wheels —t— and —v— and chain —u— which actuate the mutilated gears —y—z— to advance the pistons to the beginning of their inward strokes, and also causes the rack —h^1— to actuate one of the rods —e^1— to move its relief-passage and inlet-port into communication with the cylinder in the manner aforesaid.

By the return movement of the hand-lever the arm —n^2— is caused to press the contact —o^2— against the other contact —o^3—, thereby closing the primary circuit and causing a sparking at the plug —s— in the cylinder in the well known manner. It will of course be understood that the circuit-closer is timed in its movement in relation to that of the rods —e^1—e^1— so as to effect the said sparking after the rods have been moved to close communication between the pipes —c^1—, and the adjacent cylinders. The pipe —a^1— leading from the reservoir —I— is preferably provided with a suitable valve —q^2— operative for shutting off the mixture to relieve the pipes from pressure when the engine is not in use, or to permit the removal or repair of the pipes when required, and prevent leakage at the ports —f^1—f^1—.

In Figs. 5, 6, 7, 8 and 9 of the drawings illustrating a single-cylinder engine, the cylinder —A— is disposed vertically and is supported on the crank-case —B— in which the crank-shaft —D— is journaled similar to the described two-cylinder engine. —d— represents the main intake-valve and —m— the exhaust valve. These valves are connected respectively to rods —a^3—l— disposed vertically and passing through guides —b^3—b^4— and extending into the crank-case. These valves are opened alternately by the usual cams —c^3—k— which are secured to the rotary shaft —j— and are arranged to engage the lower ends of respective rods —a^3—l—. These valves are closed automatically by spiral springs —c—o— in the well known manner. The rod —e^1— in this instance, which is provided with the interport —f^1— and relief-passage —g^1— is disposed vertically, and is actuated by the rack —h^1— and pinion —i^1— in the manner hereinbefore described. To the shaft —j— is secured a supplemental cam —e^3— which is adapted to engage the rod —l— for opening the valve —m— to effect the exhaust of the initial explosion. This shaft is adapted to be reciprocated and is provided with the gear —i— meshing with a pinion —h— secured to the crank-shaft —D—, and to permit this movement, I provide the pinion with a wide engaging face as clearly shown in Figs. 6 and 8. Said shaft is shifted manually in one direction by means of a cam —f^3— formed on or secured to the side of the sprocket-wheel —t— which is turned by the hand-lever —x—, which movement carries the main cams —c^3—k— out of operative position and simultaneously carries the supplemental cam —e^3— into said position as shown in Fig. 6, said sprocket-wheel being fastened to the shaft —H— which is provided with a mutilated gear —y— adapted to engage a larger gear —z— secured to the crank-shaft —D— as aforesaid. This movement of the lever —x— primarily causes the rod —e^1— to be moved outward to permit the old mixture to escape from the cylinder through the relief-passage or port —g^1—, and thence to be automatically turned quarter-way around by the engagement of the pin —t^1— with the outer inclined end of the slot —r^1— to admit the compressed mixture through the port —f^1— into the cylinder. When the lever —x— is returned to its normal position, the shaft —j— is caused to be retained in the position into which it has been shifted by the aforesaid cam —f^3—. This return movement of the lever imparts reverse longitudinal and rotary movement to the rod —e^1— and thereby closes the port —f^1— to entrap the mixture in the cylinder, and also actuates the circuit-maker and breaker —n^2— which is timed to effect the sparking at the plug in the cylinder and resultant ignition of the entrapped mixture subsequent to the closing of said port —f^1—. The ignition drives the piston inward in the well known manner, whereby the shaft —D—, through the pinion —h— and gear —i— imparts rotary

motion to the shaft —*j*—. To the latter shaft is secured a cam-lug —g^3— which is arranged to engage a similar lug —h^3— on the crank-case during its rotation, by which engagement the shaft is automatically shifted to its normal position to carry the cams —c^3— and —*k*— into operative position and simultaneously carry the supplemental cam out of said position. It will be understood of course that the supplemental cam is so arranged as to open the exhaust-valve before the cam-lug —g^3— on the shaft engages the other lug —h^3— on the crank-case.

When the engine is under motion, the main cams operate again in the usual manner. The sprocket-wheel —*t*— is provided with another cam —f^4— which is adapted to engage the end of the shaft —*j*— when the cam —f^3— has been moved out of contact with the shaft. This cam —f^4— is employed for imparting further movement to the shaft and to press the opposite end of said shaft firmly against the balance-wheel G when the piston has completed said movement. This engagement of the shaft with the balance-wheel serves as a brake for locking the crank-shaft to prevent the inward movement of the piston incident to the expansive-pressure of the initial charge of explosive-mixture admitted into the cylinder, and resultant escape of the unexploded-mixture through the exhaust valve. The movement of the hand-lever —*x*— to its normal position causes the cam —f^4— to release the balance-wheel from its engagement with the shaft —*j*—, whereby the cam-lugs —g^3—h^3— are allowed to shift the shaft to its normal position as aforesaid.

It will be understood that I do not limit myself to the aforesaid mechanism employed for oscillating the rod —e^1—, inasmuch as various other means may be used for this purpose. For example, two miter-gears —g^4—h^4— may be substituted for the rack —h^1— and pinion —i^1— secured to the rod —e^1— and supplemental shaft —H— respectively. This modification is illustrated in Fig. 13 of the drawings. It will be understood, that when these miter-gears are employed, the rod —e^1— receives only oscillatory movement and therefore is not provided with a relief-passage or valve for the escape of old mixture which might exist in the cylinder. In this instance the escape of the mixture is effected by the usual exhaust-valve —*m*— connected to the rod —*l*—, said valve being opened by one of the cams secured to the shaft —*j*— and actuating said rod. This shaft is rotated by the crank-shaft when the latter is turned to move the piston by the mechanism hereinbefore described. It will be further understood that this cam is so timed in its action as to allow the spring —*o*— to force the rod downward to close said exhaust-valve when the piston reaches substantially its outermost position.

I claim—

1. In an engine of the class described, the combination with the cylinder, piston and igniter, of a manually controlled starting-device comprising a reservoir for storing explosive-mixture under pressure and connected to the cylinder, a normally closed valve operative for admitting the explosive-mixture into the cylinder, a mechanism for moving the piston to a predetermined position and including means adapted to throw said mechanism out of connection with the engine to allow the piston to remain at rest in said position, means for opening said valve at will while the piston is at rest, and means controlled by the piston moving mechanism for effecting the ignition of the admitted mixture as set forth.

2. In an engine of the class described, the combination with the cylinder, piston and shaft, of a manually controlled starting-device comprising mechanism for turning the shaft to move the piston and including means adapted to automatically throw said mechanism out of operative connection with the shaft when the piston reaches a predetermined position allowing the piston to remain at rest, a reservoir for storing fluid under compression, a passage leading from said reservoir to the cylinder and provided with a normally closed valve, and means actuated by the shaft-turning mechanism for opening said valve when said mechanism is thrown out of connection with the shaft, whereby the fluid is admitted to the cylinder as set forth.

3. In an engine of the class described, the combination with the cylinder, its piston and exhaust means, of a manually controlled starting-device comprising a mechanism for moving the piston to a predetermined position, a reservoir for storing fluid under compression and connected to the cylinder, a normally closed valve operative for admitting the fluid into the cylinder, a brake, and means actuated by the aforesaid mechanism for applying said brake to the engine during the admission of the fluid as and for the purpose set forth.

4. In an explosive-engine, the combination with the cylinder, piston, igniter and exhaust-means, of a manually controlled starting-device comprising means for moving the piston to a predetermined position, a reservoir for storing explosive-mixture under compression, a pipe leading from said reservoir to the cylinder, a normally closed valve in said pipe, a mechanism operative for opening and closing said valve while the piston is in said position, a brake, means controlled by said valve-operating mechanism for applying the brake to the engine during the operation of said valve, and

means controlling the aforesaid igniter as set forth.

5. In an explosive-engine, the combination with the cylinder, piston, igniter and exhaust-means, of a manually operated starting-device comprising mechanism normally disconnected from the engine and operative for moving the piston outward to a predetermined position, a relief-valve opened by said mechanism during said movement of the piston, a reservoir for storing explosive-mixture under compression, a pipe leading from said reservoir to the cylinder, a valve controlling the discharge of mixture from the reservoir into the cylinder, means opening the latter valve subsequent to the positioning of the piston and closing of the relief-valve, and means controlling the igniter, as set forth.

6. In an explosive-engine, the combination with the cylinder, piston, electric-sparker therein and exhaust means, of a starting-device comprising a mechanism for moving the piston outward to a predetermined position, a reservoir for storing explosive-mixture under compression and connecting with the cylinder, a valve for admitting the mixture into the cylinder, mechanism for operating said valve, an electric-circuit-maker and breaker controlling the aforesaid electric sparker, manually operated means for actuating said mechanism and means for actuating the circuit-maker and breaker as set forth.

7. In an explosive-engine, the combination with the cylinder, its piston, electric sparker therein, and exhaust valve, of a starting-device comprising a mechanism for moving the piston outward to a predetermined position, a reservoir for storing explosive mixture under compression and connecting with the cylinder, a valve controlling the admission of mixture into the cylinder, mechanism for operating said admission valve, an electric circuit-maker and breaker controlling the igniter, cam-mechanism for opening the exhaust valve, and a manually operated lever for actuating said mechanisms and circuit-maker and breaker, as set forth.

8. In an explosive-engine, the combination with the cylinder, piston, and crank-shaft, electric sparker and exhaust means, of a manually controlled starting-device comprising mechanism operative for moving the piston to a predetermined position and adapted to free itself from the engine when the piston reaches said position, a reservoir for storing explosive-mixture under compression and connected to the cylinder, a normally closed valve disposed between the reservoir and cylinder, mechanism for opening and closing said valve, an electric circuit-maker and breaker controlling the aforesaid sparker, and a lever for actuating said mechanisms and circuit-maker and breaker, as set forth.

9. In an explosive-engine, the combination with the cylinder, piston, electric-sparker, intake-valve and exhaust-valve and main cams for automatically opening said valves, of a manually operated starting-device comprising mechanism for moving the piston to a predetermined position, a reservoir for storing explosive mixture under compression and connected to the cylinder, a valve controlling the discharge of mixture from the reservoir, mechanism for opening and closing said discharge-valve, a supplemental cam for operating the exhaust-valve, mechanism for moving the main cams out of operative position and simultaneously moving the supplemental cam in said position, an electric circuit-maker and breaker for controlling the aforesaid igniter and a lever for actuating said mechanisms and circuit-maker and breaker, as set forth.

10. In an explosive-engine, the combination with the cylinder, crank-shaft, piston, electric-sparker, intake-valve, exhaust-valve, an auxiliary shaft driven by the crank-shaft, main cams secured to the auxiliary shaft for opening the said valves, of a starting-device comprising mechanism for rotating the crank-shaft to move the piston to a predetermined position, a reservoir for storing explosive mixture under compression and connected to the cylinder, a discharge-valve between the reservoir and cylinder, mechanism for opening and closing the latter valve, a supplemental cam secured to the aforesaid auxiliary shaft for opening the exhaust-valve, mechanism for shifting the said shaft longitudinally to simultaneously move the main cams out of operative position and the supplemental cam into said position, means automatically moving said cam-shaft to its normal position, an electric circuit-maker and breaker controlling the sparker, and manually operated means for actuating said mechanisms and circuit-maker and breaker, as set forth.

11. In an explosive-engine, the combination with the cylinder, piston, crank-shaft, igniter and exhaust-means, of a starting-device comprising a suitably supported rotary-shaft operative for rotating the crank-shaft to move the piston to a predetermined position and normally disconnected from said crank shaft, manually operated means for rotating the rotary shaft, a reservoir for storing explosive mixture under compression and connected to the cylinder, a valve controlling the discharge of mixture from the reservoir, means actuated by the rotary shaft for opening and closing said discharge-valve, and a manually operated electric circuit-maker and breaker controlling the aforesaid igniter, as set forth.

12. In an explosive-engine, the combina-

tion with the cylinder, piston, crank-shaft, igniter, and exhaust means, of a starting-device comprising a suitably supported rotary shaft, operative for rotating the crank-shaft to move the piston to a predetermined position and comprising a pair of gears fastened to the respective shafts and normally out of mesh, a reservoir for storing explosive mixture under compression and connected to the cylinder, a normally closed valve for controlling the admission of the mixture into the cylinder, mechanism actuated by said rotary shaft for opening and closing said valve, an electric circuit-maker and breaker controlling the aforesaid igniter, and a manually operated lever for rotating the latter shaft and actuating the circuit-maker and breaker, as set forth.

13. In an explosive engine, the combination with the cylinder, piston, crank-shaft and exhaust-means, of a starting device comprising a suitable rotary shaft, a pair of mutilated gears for connecting said shafts and normally out of mesh, and operative for moving the piston outward to a predetermined position, a reservoir for storing fluid under compression and connected to the cylinder, a normally closed valve operative for admitting the fluid into the cylinder, a pinion fastened to said rotary shaft, a rack engaging said pinion and opening and closing said admission valve, and manually operated means for rotating the latter shaft, as set forth.

14. In an explosive-engine, the combination with the cylinder, piston, crank-shaft, electric sparker, and exhaust-means, of a starting-device comprising a suitably supported supplemental shaft, a pair of mutilated gears secured to the respective shafts and normally out of mesh and operative for moving the piston to a predetermined position, a chain and sprocket-mechanism for rotating said supplemental shaft, and actuated by a hand lever, a reservoir for storing explosive mixture under compression, a passage leading from the reservoir to the cylinder, a normally-closed valve in said passage for admitting the mixture into the cylinder and consisting of a reciprocating rod provided with an aperture arranged to register with the passage, a pinion secured to the supplemental shaft, a rack attached to the said rod and engaging the pinion and reciprocated thereby, and an electric circuit-maker and breaker actuated by the aforesaid lever and controlling the igniter, as set forth.

15. In an explosive-engine, the combination with the cylinder, piston, crank-shaft, electric-sparker, and exhaust-means, of a starting-device comprising a suitably supported supplemental shaft operative for rotating the crank-shaft to move the piston to a predetermined position and normally disconnected from said crank shaft, chain and sprocket-mechanism for rotating said supplemental shaft, a reservoir for storing explosive mixture under compression, a pipe leading from the reservoir to the cylinder, a coupling in the pipe adjacent to the cylinder, a rod extending through said coupling and provided with a normally closed inlet-port arranged to register with the pipe, a relief-passage extending lengthwise of the rod and arranged to communicate with the cylinder during the aforesaid movement of the piston, a rack on said rod and engaging a pinion on the supplemental shaft to reciprocate the rod for opening and closing said relief passage, means for oscillating the rod to open and close the inlet-port, a manually operated lever actuating said chain and sprocket-mechanism, and an electric circuit-maker and breaker actuated by said lever and controlling the aforesaid sparker, as set forth.

16. In an explosive-engine, the combination with the cylinder, piston, crank-shaft, igniter and exhaust-means, of a starting-device comprising a supplemental-shaft, means transmitting rotary movement from the latter shaft to the crank-shaft to move the piston to a predetermined position, manually operated means for rotating said supplemental shaft, a reservoir for storing explosive mixture under compression, a pipe leading from the reservoir to the cylinder, a coupling in said pipe adjacent to the cylinder, a longitudinally movable rod extending through the coupling and provided with a normally closed inlet-port arranged to register with the pipe and with a longitudinal relief-passage arranged to communicate with the cylinder, a suitably supported guide sleeve for the rod and provided with a longitudinal slot having inclined ends, a pin projecting from the rod and movable in the slot and adapted to engage the inclined ends thereof to oscillate the rod and thereby open and close the inlet port, a pinion secured to the aforesaid supplemental shaft, an annularly toothed rack engaging said pinion whereby the rod is reciprocated to open and close the relief-passage and permitted to oscillate, and a suitably actuated electric circuit-maker and breaker controlling the aforesaid igniter, as set forth.

17. In an explosive-engine, the combination with the cylinder, piston, crank-shaft, mixture intake-valve, exhaust-valve, igniter, and auxiliary shaft, geared to the crank-shaft and shiftable longitudinally, main cams secured to said auxiliary shaft and operative for opening said valves, of a starting-device comprising a suitably journaled supplemental shaft, a pair of mutilated gears secured to the crank-shaft and supplemental shaft respectively and operative for moving the piston to a predetermined

position, means for rotating said supplemental shaft, an auxiliarly cam secured to the auxiliary shaft for opening the exhaust-valve, a cam actuated by the supplemental shaft and shifting the cam-shaft in one direction to move the main cams out of operative position and simultaneously move the auxiliary cam into said position, another cam operative for automatically shifting the cam-shaft in the opposite direction to restore the main cams to their normal position, a reservoir for storing explosive mixture under compression and connected to the cylinder, a valve controlling the discharge of mixture from the reservoir, mechanism actuated by the aforesaid supplemental shaft for operating said valve, and a suitably actuated electric circuit-maker and breaker controlling the aforesaid igniter, as set forth.

18. In an explosive-engine, the combination with a plurality of cylinders, their pistons, igniters and suitably actuated exhaust-valves, of a starting-device comprising mechanism for moving the pistons to a predetermined position and including means for automatically throwing said mechanism out of connection with the engine, a reservoir for storing explosive-mixture under compression and connected to the said cylinders, normally closed valves operative for admitting the mixture into the respective cylinders, mechanisms for actuating said valves, automatic regulating means operative for determining the valve to be opened, and an electric circuit-maker and breaker actuated by the piston-positioning mechanism for controlling said igniters as set forth.

19. In an explosive-engine, the combination with a plurality of opposed cylinders, their pistons, crank-shaft, suitably actuated exhaust-valves and electric-sparkers in the cylinders, of a starting-device comprising a supplemental rotary shaft, means transmitting rotary movement from the latter shaft to the crank shaft for moving one of the pistons to a predetermined position, manually operated mechanism for rotating said supplemental shaft, a reservoir for storing explosive mixture under compression, pipes conducting the mixture from said reservoir to the cylinders, normally closed inlet-valves in the pipes adjacent to the respective cylinders, mechanism for independently actuating said valves and operated by the supplemental shaft, automatic regulating means causing the proper valve to be actuated, and a suitably actuated electric circuit maker and breaker controlling the aforesaid sparkers, as set forth.

20. In an explosive-engine, the combination with a plurality of opposed cylinders, their pistons, crank-shaft, electric-sparkers and suitably actuated exhaust-valves, of a starting-device comprising a supplemental rotary shaft, mutilated gears secured to the respective shafts and operative for moving the pistons so as to set a piston in a predetermined position, manually operated mechanism imparting oscillatory movement to said supplemental shaft, a reservoir for storing explosive mixture under compression and connected to said cylinders, normally closed valves adjacent to the respective cylinders for controlling the admission of mixture thereinto, mechanism actuated by said supplemental shaft for opening and closing said admission-valves, automatic means regulating the action of said mechanism whereby said valves are rendered independently operative to cause the proper cylinder to be charged with said mixture, and a suitably actuated electric circuit-maker and breaker controlling the said sparkers, as set forth.

21. In an explosive-engine, the combination with two opposed cylinders, their pistons, crank-shaft, electric-sparkers, and suitably actuated exhaust-valves, of a starting-device comprising a supplemental shaft, a pair of mutilated gears secured to the respective shafts and operative for moving the pistons to substantially their outermost positions, chain and sprocket-mechanism imparting oscillatory movement to said supplemental shaft, a manually operated lever for actuating said mechanism, a reservoir for storing explosive mixture under compression and connected to the cylinders, normally closed valves adjacent to the respective cylinders for controlling the admission of mixture thereinto, a rack connected to said valves for actuating the same, a pinion secured to the supplemental shaft and engaging said rack, means controlled by the engine and acting upon the rack and valve connections to render the valves independently operable to cause the proper cylinder to be charged, and an electric circuit-maker and breaker actuated by the aforesaid lever and controlling the said sparkers, as set forth.

22. In an explosive-engine, the combination with two opposed cylinders, their pistons, crank-shaft, electric-sparkers, exhaust-valves, and cam-shafts actuating said valves, of a starting-device comprising a suitably supported oscillatory supplemental shaft, mutilated gears secured to the respective shafts and operative for moving the pistons outward to predetermined positions, manually operated mechanism for oscillating said shaft, a reservoir for storing explosive mixture under compression and connected to said cylinders, normally closed valves for admitting the mixture into the respective cylinders, a rack connected to said valves, a pinion secured to the supplemental shaft and engaging said rack, and means operated by

the aforesaid cam-shafts for regulating the action of said rack to cause the same to open and close the proper admission-valves, and a suitably actuated electric circuit-maker and breaker controlling the aforesaid igniter, as set forth.

23. In an explosive-engine, the combination with two opposed cylinders, their pistons, crank-shaft, electric-sparkers, intake and exhaust-valves and cam-shafts actuating said valves, of a starting-device comprising a supplemental shaft connected by mutilated gears to the crank-shaft and operative for moving said pistons to predetermined positions, a reservoir for storing explosive mixture under compression, pipes conducting the mixture to said cylinders, a coupling in each pipe adjacent to the respective cylinders, longitudinally movable rods extending through said couplings and each provided with an inlet valve, consisting of a port arranged to register with the pipes and with a longitudinal relief passage arranged to communicate with the cylinder, guide-sleeves for said rods and provided with longitudinal slots having inclined ends, pins projecting from the rods and movable in the slots and adapted to engage the inclined ends thereof, to allow the rods to be reciprocated to open and close the relief-passages and oscillated to open and close the intake-ports, an annularly toothed rack provided at one end with a sleeve, a gear axially in line with and rigidly connected to the rack and provided with a sleeve extending in opposite direction to that of the rack sleeve, a rack engaging said gear, means operated by one of the aforesaid cam-shafts for actuating the latter rack to impart oscillatory movement to the annularly toothed rack, longitudinal slots provided in the sleeves of the rack and gear and each slot formed at one end with a notch, supplemental rods sliding in said sleeves and rigidly connected to the valve-rods and provided with pins traveling in said slots, said pins permitting free longitudinal movement of the gear and connected rack and adapted to engage the notches to impart reciprocatory movement to the valve rods, a pinion secured to the aforesaid supplemental shaft and imparting reciprocatory movement to the annularly toothed rack, mechanism oscillating the latter shaft, a hand-lever for operating said mechanism, and an electric circuit-maker and breaker actuated by the said lever and controlling the aforesaid sparkers, as set forth.

24. In an explosive engine, the combination with a cylinder, piston, crank shaft and automatic igniting devices, of a starting device comprising a suitably supported supplemental shaft, a pair of mutilated gears secured to the respective shafts and normally out of mesh, mechanism including a hand-lever for turning the supplemental shaft to move the piston to a predetermined position, and a separate ignition device controlled at will independently of the first named ignition device by the operation of the lever as set forth.

25. In an explosive-engine, the combination with the cylinder, piston and crank-shaft, of a starting-device comprising a supplemental shaft, a mutilated gear secured to the crank-shaft, a smaller mutilated gear secured to the supplemental shaft and arranged to mesh with the first mutilated gear, said smaller gear having a separately-formed spring-pressed initial tooth whereby the latter is allowed to yield to insure meshing with the teeth of the larger gear, as set forth and shown.

26. In an explosive-engine, the combination with the cylinder, piston and crank-shaft, of a starting-device comprising a reservoir for storing fluid under pressure and connected to the cylinder, a valve interposed between the cylinder and reservoir for admitting the fluid into said cylinder, a brake, a mechanism for applying said brake to the engine to retain the piston immovable during the admission of the fluid, mechanism for operating said valve, manually controlled means for actuating said mechanisms, and means for releasing said brake as set forth.

27. In an explosive-engine, the combination with a plurality of cylinders, pistons, and crank-shaft, of a starting-device comprising a reservoir for storing fluid under pressure and connected to the cylinders, normally closed valves operative for admitting the fluid into the respective cylinders, automatic means for determining the cylinder whose piston is on the power-stroke or cycle, whereby the corresponding valve is opened, a brake, and means for applying said brake to the engine while said valve is open and for releasing the brake as set forth.

28. In an explosive-engine, the combination with the cylinder, its piston and crank-shaft, of a starting-device comprising means for moving the piston to a predetermined position, a reservoir for storing fluid under pressure, a pipe connecting the reservoir to said cylinder, a valve in said pipe acting as a relief-valve during the movement of the piston to said position, and serving to admit the fluid into the cylinder as set forth.

FRANK REYNOLDS. [L. S.]

Witnesses:
J. J. LAASS,
L. H. FULMER.