C. E. SHADALL.

INTERNAL COMBUSTION ENGINE.

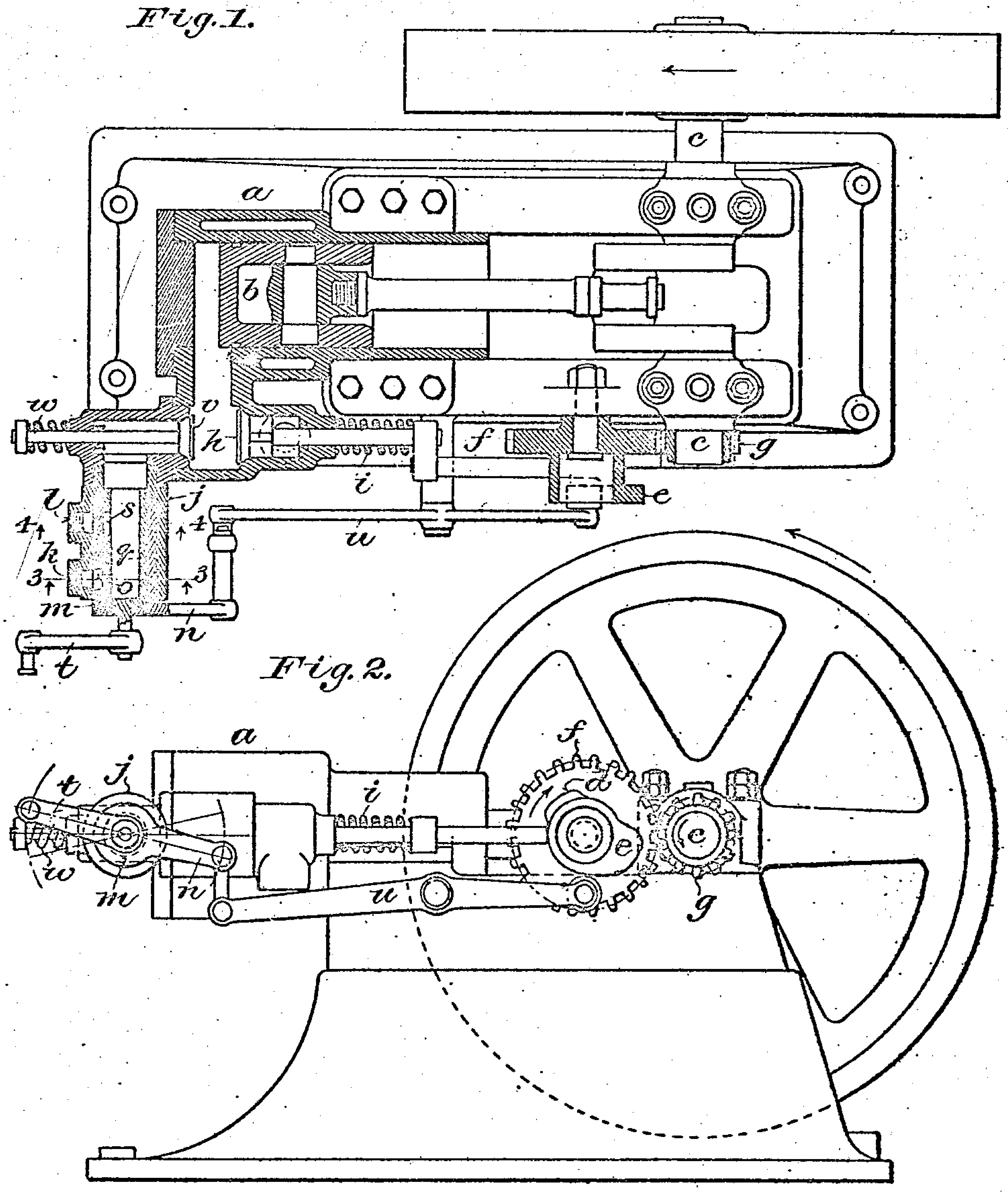
APPLICATION FILED AUG. 8, 1904.

899,136.

Patented Sept. 22, 1908.

2 SHEETS—SHEET 1.

Fig. 1.



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2 SHEETS—SHEET 2.

Fig. 9.

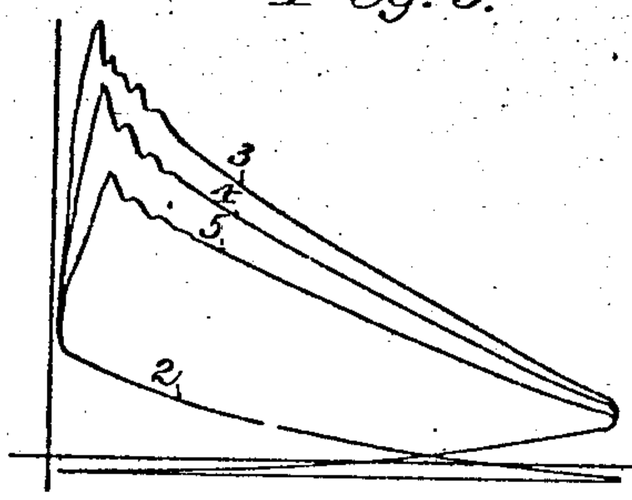


Fig. 10.

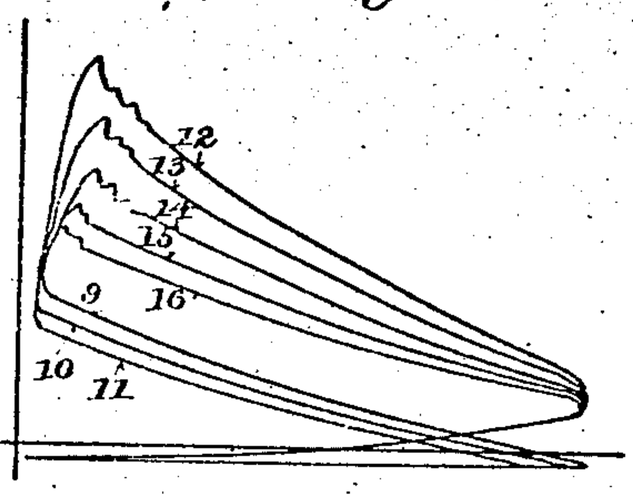


Fig. 3.

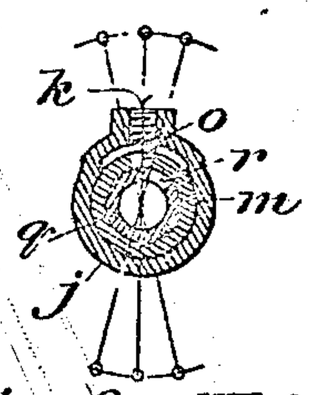


Fig. 4.

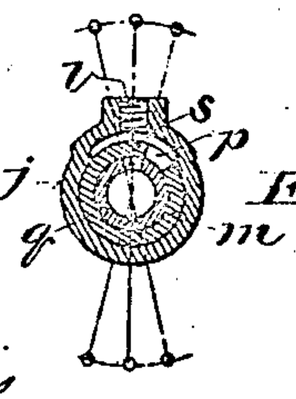


Fig. 5.

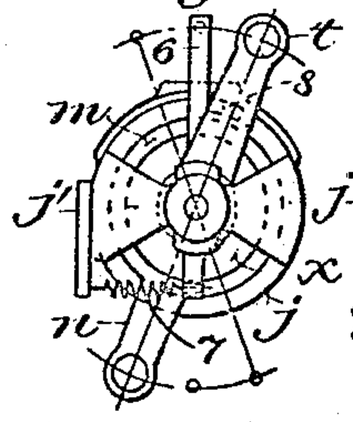


Fig. 6.

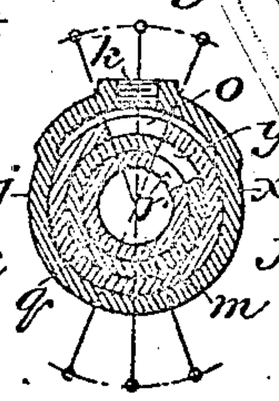


Fig. 7.

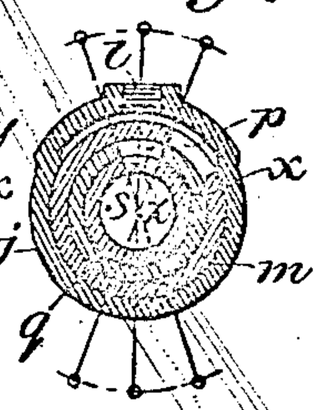
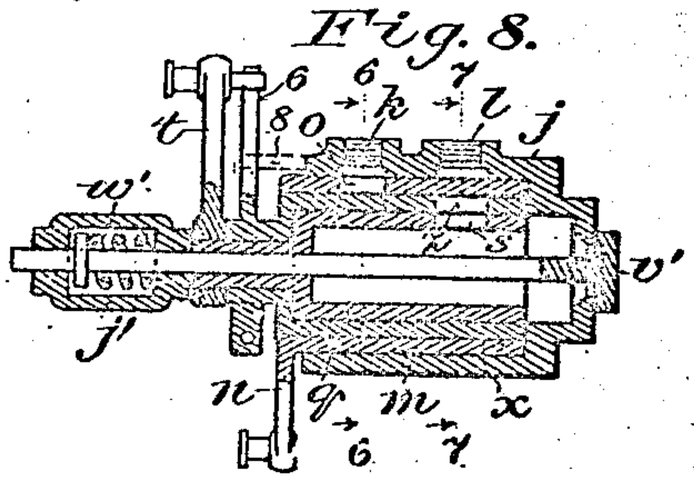


Fig. 8.



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UNITED STATES PATENT OFFICE.

CHARLES E. SHADALL, OF MILWAUKEE, WISCONSIN, ASSIGNOR, BY DIRECT AND MESNE ASSIGNMENTS, OF ONE-FOURTH TO FREDERICK L. HORNEFFER, OF MILWAUKEE, WISCONSIN, AND ONE-FOURTH TO FRANK H. DURBIN, OF WAUWATOSA, WISCONSIN.

INTERNAL-COMBUSTION ENGINE.

No. 899,136. Specification of Letters Patent. Patented Sept. 22, 1908.

Application filed August 8, 1904. Serial No. 219,877.

To all whom it may concern:

Be it known that I, CHARLES E. SHADALL, citizen of the United States, residing at Milwaukee, in the county of Milwaukee and State of Wisconsin, have invented certain new and useful Improvements in Internal-Combustion Engines, of which the following is a specification, reference being had to the accompanying drawing, forming a part thereof.

This invention relates to engines which are actuated by the expansive force of an exploded mixture of gas or oil vapor and air or inert gas.

The main objects of the invention are to regulate or vary the speed of the engine automatically or manually by gradually varying the relative proportions of explosive mixture and air or inert gas admitted into the cylinder, to obtain a high thermal efficiency by producing a high and approximately constant compression of the explosive mixture for varying speeds or loads, to avoid shock or jar by exploding varying volumes of the explosive mixture at regular intervals without intermission, and generally to improve the construction and operation of engines of this class.

It consists in certain novel features of construction and in the peculiar arrangement and combinations of parts hereinafter particularly described and pointed out in the claims.

In the accompanying drawing like characters designate the same parts in the several figures.

Figure 1 is a plan view and horizontal section of an engine embodying the invention; Fig. 2 is a side elevation of the same; Figs. 3 and 4 are sections of the valve mechanism on the lines 3 3 and 4 4 respectively of Fig. 1; Figs. 5, 6, 7 and 8 are an end view, cross sections on the lines 6 6 and 7 7 of Fig. 8, and a longitudinal section of a modification of the valve mechanism; Fig. 9 is an indicator diagram illustrating the operation of the engine provided with valve mechanism as shown in Figs. 1, 3 and 4; and Fig. 10 is a similar diagram illustrating the operation of the engine provided with valve mechanism as shown in Figs. 5 to 8 inclusive.

For the purpose of illustrating and explaining the invention, a four cycle explosive engine is shown, in which *a* is the cylinder, *b* the piston and *c* the crank shaft.

d and *e* are cams formed with or attached to a gear *f*, meshing with a smaller gear *g* on the crank shaft, the ratio of the gear *f* to the gear *g* being as 2 to 1, so that the cams will be turned one revolution to every two revolutions of the crank shaft.

h is the exhaust valve, seated by a spring *i* and arranged to be opened by the cam *d*.

j is a cylindrical valve chamber communicating at one end with a passage which leads into one end of the cylinder *a*. It has an air supply connection *k* and an explosive mixture supply connection *l*.

m is a hollow cylindrical valve provided at the outer end with a crank arm *n* and having two ports *o* and *p*, in constant communication with the air and explosive mixture supply connections *k* and *l*, which are extended as shown in Figs. 3 and 4, inside of the valve case, to communicate with the ports *o* and *p* within the limits of their movement.

q is a hollow regulating cylinder fitted to turn in the valve *m* and provided with two ports *r* and *s*, which are arranged to register one at a time with the ports *o* and *p* in the valve. This cylinder communicates at its inner end with the passage leading into the engine cylinder *a*, and is provided at its outer end, which is closed, with a crank arm *t*, which may be connected with a governor or pressure regulator of the usual kind suitable for the purpose of automatically regulating the engine, or it may be adjusted manually. The valve arm *n* is connected by a link with a lever *u*, which carries a roller or has a projection in the path of the cam *e*; or the valve *m* may be operated synchronously with the movement of the piston *b* by any other suitable connection.

v is an inwardly opening check valve, normally seated by a spring *w* in the passage leading from the regulating valve mechanism into the cylinder *a*.

With the form of valve mechanism above described the engine operates as follows: For the greatest load or highest speed, the regulating cylinder *q* is turned to the extreme right, as shown in Figs. 3 and 4, in which the valve *m* is shown in the position it has at the beginning of the suction stroke of the piston. In this position both the ports *o* and *p* are

closed by the cylinder *q*. As the piston *a* moves towards the crank shaft the valve *m* is turned to the left, carrying its port *p* immediately over and into register with the port *s*, thereby admitting an explosive mixture of gas or oil vapor and air into the regulating cylinder, thence through the connecting passage by the check valve *v* into the cylinder *a* behind the piston, the check valve being opened by the partial vacuum produced in the cylinder by the suction stroke of the piston.

In the above mentioned movement of the valve *m* its air port *o* is carried away from the corresponding port *r* in the regulating cylinder *q*, so that no air will be admitted into the engine cylinder under the conditions stated, but said cylinder will be filled with explosive mixture at or a little below atmospheric pressure. Upon the return stroke of the piston the check valve *v* being closed by the spring *w*, the charge is highly compressed and exploded at the proper time in the usual way by any suitable means, such as an electric spark. The explosion thus produced forces the piston back towards the crank shaft, imparting a powerful impulse thereto, in the usual manner in this class of engines. During the next return stroke of the piston the exhaust valve *h* is opened by the cam *d* and the spent charge is expelled from the cylinder. During the next stroke of the piston towards the crank shaft, a fresh charge is drawn into the cylinder and the cycle of operations above described follows.

To maintain an approximately constant speed in case of a decrease of load or to decrease the speed in case of a constant load, the regulating cylinder *q* is turned by its governor connection, or by other means, manually or otherwise, to the left. This carries the port *r* into position to permit the opening of the air port *o* more or less at the beginning of the suction stroke of the piston and at the same time carries the port *s* into position to close the mixture port *p* during a corresponding part of the suction stroke of the piston. Under these conditions the movement of the valve *m* to the left during the suction stroke of the piston operates to first admit air into the cylinder *a* and then the explosive mixture. The volume of the explosive mixture being thus cut down, the force of the explosion is correspondingly decreased, thereby tending either to maintain a constant speed under decreased load, or to diminish the speed under a constant load. By turning the regulating cylinder *m* from its extreme position at the right to its extreme position at the left, the admission of explosive mixture is gradually reduced, while the admission of air is correspondingly increased, beginning with a charge composed entirely of the mixture, and ending with a charge composed entirely of air. The total volume of the charge being the same, or constant under varying conditions, whatever the relative proportions of the mixture and air may be, the compression of the charge will remain constant or be the same under such varying conditions, so that high compression may be produced with a small quantity of explosive mixture, as well as with a large quantity thereof, and a maximum thermal efficiency obtained under the varying conditions with charges comprising small as well as larger quantities of explosive mixture.

As the explosive mixture will in practice rarely if ever be entirely cut off by the regulating valve mechanism, the engine will be supplied at regular intervals with more or less of the mixture according to the load or speed of the engine, and consequently there will be explosions at regular intervals or without intermission, as in the ordinary method of operating and regulating engines of this class. The explosions thus taking place at regular intervals without intermission, and their force being gradually diminished or increased to vary the speed of the engine or to maintain a constant speed with a varying load, the shocks and jars incident to the method of regulation by intermitting explosions of substantially constant force, are avoided, and the engine is made to run smoothly and quietly.

The operation of the engine as above explained is illustrated by the diagram in Fig. 9, in which 2 designates the compression line and 3, 4 and 5 expansion lines indicating charges of various proportions of the mixture and air, according to the adjustment of the regulating cylinder *q*.

Referring to Figs. 5 to 8 inclusive, a throttling cylinder *x* is fitted and adapted to turn between the valve *m* and the regulating cylinder *q*. It is formed with ports *y* and *z*, corresponding and normally registering with the ports *r* and *s* of the regulating cylinder. It is provided at its outer end with an arm 6, normally held by a spring 7 against a stop 8 on the valve case. This arm is arranged as shown in Fig. 8, in the path of the crank pin or a projection of the arm *t*. The check valve *v'* is in this case located over a port at the inner end of the valve chamber *j*, and its stem passes axially through the regulating cylinder *q* and is guided at its outer end in a bonnet *j'* attached to the outer end of the valve case and furnishing a bearing for the inner end of the spring *w'*. The engine with this form of valve mechanism operates as follows: When the regulating cylinder is in its extreme position at the right as shown in Figs. 6 and 7, and the throttling cylinder is in its normal position with the arm 6 resting against the stop 8, a full charge of explosive mixture will be admitted into the cylinder *a* during the suction stroke of the piston, the air port remaining closed. To decrease the speed of the engine with a constant load or to

maintain its speed with a decreased load, the cylinder *q* is turned to the left automatically by the governor or pressure regulator, or manually, as hereinbefore explained. This operates to partially close the ports *r* and *s* without changing the relation of the ports *y* and *z* in the throttling cylinder *x* to the ports *o* and *p* in the valve *m*. As the valve is turned to the left during the suction stroke of the piston, explosive mixture is admitted as before to the cylinder, but it is throttled in its passage through the restricted port *s*, and the volume of the charge is reduced. This results in lower compression and in explosions of less force. As the regulating cylinder is turned to the left the force of the explosions is diminished in a greater degree than the compression of the charges. The operation of this form of the regulating mechanism to the extent above explained, is illustrated in the indicator diagram shown in Fig. 10, by the compression lines 9, 10, 11, and the corresponding expansion lines 12, 13 and 14. When the crank pin or projection of the arm *t* engages the arm 6 in the continued movement of the arm *t* to the left, the cylinder *x* will be turned with the cylinder *q*, in the further movement of the latter to the left, and from this point on the movement of the two cylinders *q* and *x* together, operates as in the case of the valve and regulating mechanism shown in Figs. 1, 3 and 4, to vary the proportions of explosive mixture and air in the charges without change in the total volume of the charges and without variation in the degree of compression, substantially as hereinbefore explained. This latter operation of the modified valve and regulating mechanism is illustrated by the diagram Fig. 9, and also by the compression line 11 and the expansion lines 15 and 16 of the diagram Fig. 10.

Various changes in details of construction and arrangement of parts other than those shown and pointed out, may be made without departing from the principle and scope of the invention.

I claim:

1. In an internal combustion engine the combination with a cylinder and piston, of a cylindrical valve chamber having separate air and explosive mixture supply connections, a hollow oscillating valve fitted in said chamber and having ports in constant communication with said connections, a hollow regulating cylinder adapted to turn within said valve and having ports arranged to register one at a time with the valve ports, and means for adjusting said regulating cylinder to vary the relative volumes of air and mixture admitted to the engine cylinder which communicates with the interior of said regulating cylinder, substantially as described.

2. In an internal combustion engine the combination with a cylinder and piston, of a valve chamber having separate air and explosive mixture supply connections, a hollow cylindrical valve fitted to turn in said chamber and having ports communicating with said connections, a connection with the piston for rocking said valve, a regulating cylinder adapted to turn within said valve and having ports arranged to register one at a time with the valve ports and to admit air in advance of the mixture into the engine cylinder, and means for turning said regulating cylinder to vary the relative volumes of air and mixture, substantially as described.

3. In an internal combustion engine the combination with a cylinder and piston of a valve chamber having separate air and explosive mixture supply connections, a hollow cylindrical valve fitted to turn in said chamber and having ports communicating with said connections, a connection for rocking said valve synchronously with the movement of the piston, a hollow regulating cylinder communicating with the engine cylinder and having ports arranged to register one at a time with the ports in said valve, means for adjusting said regulating cylinder to vary the proportions of air and mixture admitted into the engine cylinder, and an inwardly opening check valve in the passage between the regulating cylinder and the engine cylinder, substantially as described.

4. In an internal combustion engine the combination with the cylinder and piston, of a cylindrical valve chamber having separate air and explosive mixture supply connections, a cylindrical valve fitted in said chamber and having ports in constant communication with said connections, a connection for rocking said valve, a throttling cylinder fitted in said valve and having ports arranged to register one at a time with the ports in said valve, a regulating cylinder fitted in said throttling cylinder and having ports corresponding with the ports therein, and means for turning said regulating cylinder to vary the time of closing the air port and of opening the mixture port, said regulating cylinder being capable of a limited movement with relation to the throttling cylinder for partially closing the ports therein, substantially as described.

In witness whereof, I hereto affix my signature in presence of two witnesses.

CHARLES E. SHADALL.

Witnesses:

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A. F. WEST.