

J. A. BABIN.

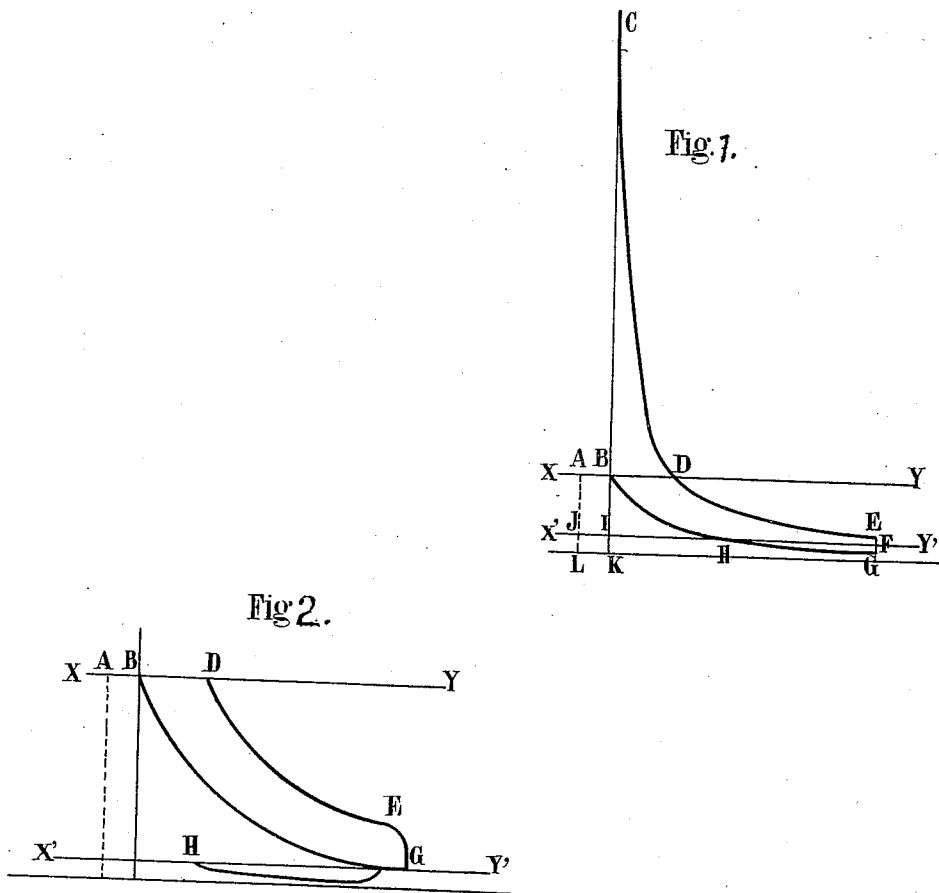
EXPLOSION CYCLE AND MOTOR OF ATMOSPHERIC TYPE.

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1,005,680.



WITNESSES:
J. M. Glynkeop,
G. B. Melton

INVENTOR
J. A. Babin
 BY
Amie Montefiore
 ATTORNEY.

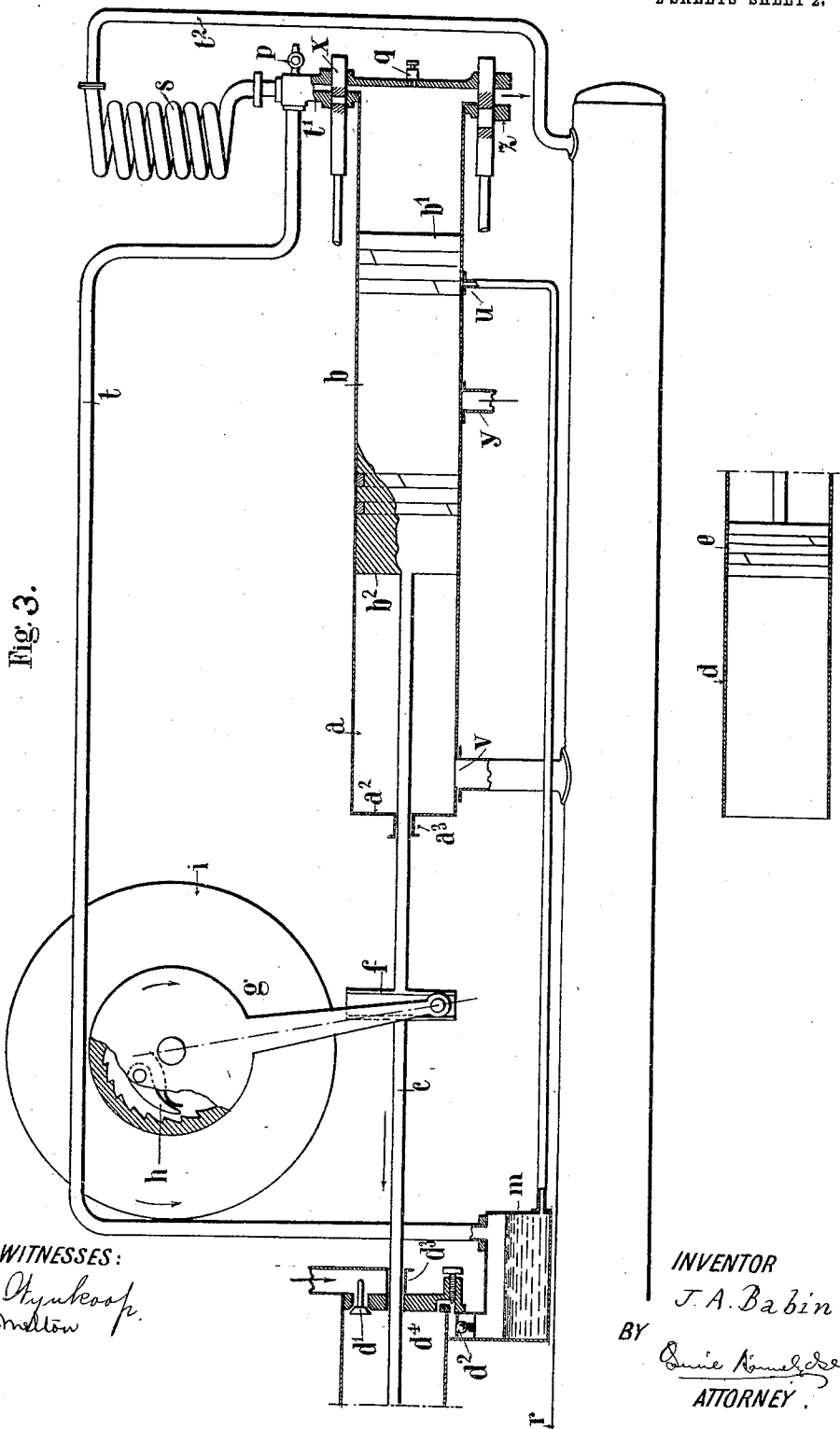


Fig. 3.

WITNESSES:
J. M. Dykewoos
Chas. B. Mellon

INVENTOR
J. A. Babin
BY *Quire Knecht*
ATTORNEY.

UNITED STATES PATENT OFFICE.

JULES ALFRED BABIN, OF VERSAILLES, FRANCE.

EXPLOSION CYCLE AND MOTOR OF ATMOSPHERIC TYPE.

1,005,680.

Specification of Letters Patent.

Patented Oct. 10, 1911.

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To all whom it may concern:

Be it known that I, JULES ALFRED BABIN, a citizen of the Republic of France, and resident of Versailles, France, have invented a new and useful Explosion Cycle and Motor of the Atmospheric Type, which invention is fully set forth in the following specification.

This invention relates to an internal combustion engine of the free expansion type which is arranged to work according to the cycle of operations hereinafter described, and has for its object to improve the efficiency of the cycle and the engine which operates thereunder.

The engine, according to this invention, is provided with a large tank containing compressed air, the pressure of which is maintained in accordance with the power required, said air being used for producing a so-called artificial atmosphere, as hereinafter described.

The pressure of the air is always equal to the pressure of the explosive mixture, a pump for compressing said mixture being provided and the piston thereof connected with the piston of the engine, the cylinders of the pump and the engine having approximately the same volume and the weight of the charges of mixture, which are compressed by the pump being made to increase with the pressure in the tank.

Since the engine of the present invention operates according to an improved cycle of operations, the invention will first be described with reference to the diagrammatic views, Figures 1 and 2, and will then be described as practically applied to one embodiment of the invention, shown in Fig. 3 in diagrammatic form.

In said drawings: Figs. 1 and 2 are diagrammatic representations of the forms of the cycle brought about by my invention, and Fig. 3 is a diagrammatic elevation of one form of motor which operates according to my invention.

Referring to said drawings, and particularly to Fig. 1, the operations forming the cycle above referred to are as follows: I. Introduction of the mixture into the explosion chamber (line A—B), at the pressure of the tank (line X—Y) by the slow movement of the pistons. II. Stoppage of the pistons, explosion at a constant volume (line B—C).

III. Adiabatic expansion of the gases (curve C—D—E), free and very rapid movement of the pistons, discharge of the compressed air filling the front end of the cylinder into the tank wherein the pressure of air is slightly raised in consequence. IV. Simultaneously with the three preceding stages there is sucked into the pump a full volume of pure air or fresh mixture (line J—F), at a pressure equal to or higher than that of the atmosphere (line X'—Y'). V. Cooling at a constant volume of the burned expanded gases inclosed in the cylinder (line E—G); this operation takes place at the end E of the stroke outward, and VI. Partial expansion of the compressed air of the tank (the pressure of which has been raised during the stroke outward by the discharge of the compressed air from the cylinder) producing simultaneously: (a) the return stroke of the pistons; (b) an amount of exterior work (the resistance of which may force the pistons to run with relatively slow and uniform speed); (c) in the engine cylinder (1) isothermal compression of the cold residue up to the pressure of the natural atmosphere (curve G—H); (2) the expulsion of the same into the atmosphere at the pressure of the latter (line H—J); (d) in the pump, expulsion at atmospheric pressure of part of the mixture first drawn in (line F—H), isothermal compression of the mixture retained (curve H—E), and discharge of the compressed mixture at the pressure of the tank, into that tank or into an intermediate container (line B—A).

The aforesaid operations and Fig. 1 relate to a motor working under reduced pressure and power. When the engine is required to develop the greatest possible power, Fig. 2 is to be referred to, the operations I, II, III and IV are the same, but the operations V and VI are replaced by operations V₁ and VI₁, which are equivalent from a thermodynamic point of view, and run as follows: V₁. Sudden fall of the residual pressure of the burned gases to atmospheric pressure by opening the cylinder to the atmosphere (line E—G); this operation takes place at the end E of the stroke outward. VI₁. Partial expansion of the compressed air in the tank producing simultaneously: (a) the return stroke of the pis-

tons; (*b*) an amount of exterior work; (*c*) concerning the engine cylinder, the expulsion of the residual burned gases into the atmosphere at the pressure of the latter (line G—J); (*d*) concerning the pump, (1) isothermal compression of the air or mixture (curve G—H—B), (2) and discharge of the compressed fresh gases, at the pressure of the tank, into that tank or into an intermediate container (line B—A).

More generally speaking, when the engine works under a pressure in the tank which is sufficiently high, the residual pressure of the burned gases at E, (see Figs. 1 and 2), is also high. In such cases, the cooling at a constant volume of the burned gases, according to operation V, can in practice be partially replaced by the discharge of those gases into the atmosphere forming operation V₁.

One form of motor according to this invention is shown in Fig. 3, and consists of a working cylinder and of a pump cylinder having very nearly the same volume, and arranged in tandem fashion. The explosion cylinder *a* is at one end in open communication through the orifices *v* with the tank *r* of a capacity four to five times greater than the cylinder and containing air at the working pressure. The fresh mixture enters behind the piston *b* through the slide valve *x*. The combustion gases escape into the atmosphere through the orifice *y* and the slide valve *z*. The pump *d* has, in the motor described, a cross-sectional area slightly smaller than that of the cylinder *a* and draws in the mixture through the valve *d'*, throughout the whole of the first stroke. The piston *e* of the pump is connected to the engine piston *b* by means of a rod *c* passing through the covers with stuffing boxes *a*³ and *d*³. The rod *c* transmits the driving effort to the fly-wheel *i* during the driving stroke from left to right by means of the link *f*, balance beam *g* and pawl *h*. Any other mechanical combination could be utilized. The compressed mixture is contained in the coil *s* communicating at one end with the discharge of the pump by means of the pipe *t* as well as with the inlet valve *x* by means of the pipe *t'*, and on the other hand is in open communication with the tank *r* by means of the pipe *t*². The contents of the coil are thus always at the pressure of the tank and its capacity is slightly larger than the volume of one compressed charge.

The whole apparatus works as follows: Assuming that the engine is to work in accordance with the cycle designed Fig. 2, firstly the tank has to be filled with air at a pressure predetermined by experience and corresponding to the maximum power of the engine. Then, let us suppose that the piston *e* is in contact with its cover, the

piston *b* in contact with its corresponding cover, the coil filled with a charge of mixture, and the valves all closed. If the slide valve *x* is opened, the mixture is admitted behind the piston *b* which is thus exposed to an equal pressure on both its faces *b'* and *b*². But as the useful surface of *b*² is reduced by the whole cross-sectional area of the rod *c*, the whole mechanism *b c e* is pushed without much speed toward the left. When the whole charge has passed into the cylinder, a suitable mechanism on the rod *c* closes the slide valve *x*, the movement of the piston ceases, and a suitable contact is made by the slide-valve, or in some other manner, and a spark at *q* produced. The explosion drives the pistons forward violently and forces into the tank *r* the compressed air filling the cylinder *a* through the orifices *v*, at the same time drawing, by means of the pump fresh mixture through the valve *d'*. If, owing to an excessive charge the piston *b* should have a tendency to move so far as to cover the orifice *v* the air imprisoned behind the cover *a*² will cushion the piston.

At the end of the stroke of the piston, the orifice *y* is uncovered and allows a portion of the combustion gases to escape so that the pressure in the cylinder at the side *b'* sinks to atmospheric pressure. The compressed air of the tank *r* pushes back the whole movable mechanism toward the right, acting by means of the pawl *h* on the fly-wheel *i* and compresses the mixture at the right hand side of *e*. As the piston *e* has in the motor described a smaller section than the piston *b* the pressure on the latter exceeds that acting on the former, so that the piston *e*, compressing the mixture, raises the valve *d*² and the said mixture passes into the coil *s*.

The difference of the cross-sectional areas of *b* and *e* must be just sufficient to enable the friction of the system to be overcome. In these conditions, a moderate braking will be sufficient to slacken the speed of the pistons and to disengage them from the fly-wheel so that they are led gently to the very end of the stroke and stopped suddenly simply by opening the slide valve *x*. Thus the forcing back of the whole of the mixture into the coil, and of the combustion gases into the atmosphere is effected without shock. The said braking can be effected by throttling the passage *z* for the combustion gases or the orifice of the valve *d*². It is also possible (this is the construction shown in the drawing) to make the orifice of valve *d*² at a small distance from the cover; when the piston covers it, the gases arrive at the valve only through a conduit *d*⁴ of adjustable cross-section. The pistons could also be slackened and stopped by advancing the admission period. The admission and the ignition be-

ing absolutely controlled by the slide valve x , it is only necessary, in order to give the explosion chamber the volume necessitated by the nature and the density of the charge, to shift the point of closing of the said slide valve, for instance by means of a trip gear operated by the pistons at variable points of their stroke.

It has been seen hereover that, toward the end of the outward stroke, part of the burned gases escaped to the atmosphere through the orifice y . But the piston b , when going backward, soon covers again the said orifice y ; then the discharge of burned gases is continued through the slide-valve z which is opened by means of a cam operated by the pistons. It is also possible to realize supplementary external work by means of the partial vacuum which water issuing through the orifice u , (when uncovered by the piston b), produces in the cylinder by sudden cooling of the residual burned gases; for that purpose, the slide-valve z should only be opened toward the end of the return stroke, that is to say, when the cold residue has been raised again, by compression in the closed cylinder, to the pressure of the atmosphere. The orifice y , which is not absolutely essential since its function could be performed by the slide-valve z , should be provided with closing means or with a stop-valve when the working pressure is only moderately high.

Any diffusion of gases from the coil into the tank r is avoided by terminating the charge introduced into the cylinder a , with a small quantity of pure air, in contact in the coil with the last portion of the mixture. An auxiliary air pump (not shown in the drawing), discharges directly into the general tank, and in so doing, replaces the air thus borrowed from that tank, and compensates for the general leakages. The aforesaid method of introducing air forms a protection against back-firing. The coil s could be replaced by any equivalent device.

The air and the gas could be compressed in separate pumps, and the gas alone stored in the coil, the air being sent to the tank r . The air and gas are, in this case, mixed together in suitable proportions on their way to the explosion chamber, or in the chamber itself, through any suitable pipes and valves. As an example, the two pumps may be placed side by side, their piston rods being connected to the cross-head f , and the sum of their sections being equal to the section of the mixture-pump d . It is also possible to compress in the pump d pure air and to supply it to the tank r . In that case, the compressed air, when conveyed from the tank r to the explosion chamber as the valve x is open, is caused to divide into two portions following two distinct paths by means of any suitable device. The first portion,

say one half, is led by a pipe directly to the valve x . The second portion of the compressed air is made to cross a suitable carbureting device. This device may be a carbureter in which a liquid and volatile hydrocarbon supplied by a pump or otherwise is vaporized at a low temperature. It may also be a lean-gas producer, containing red hot anthracite or other fuel through which the compressed air, together with a proper quantity of steam, is made to pass, according to the well-known process for producing lean gas. The gas so formed under the pressure of the tank then mixes with the compressed air coming direct from the tank r , before or when entering the explosion chamber. If, referring to Fig. 3, the carbureting apparatus should, for instance, take the place of pipe t' , and the coil s could be suppressed, or, if retained, specially applied to giving to the charges of air the constant temperature which is required for regular working of the engine, as will be explained hereunder. For this last said application, a coil might also be inserted between the carbureting apparatus in t' , and the valve x . The fuel might also be introduced into the compressed air by any other suitable means or device and at any other suitable period. In whatever manner and at whatever period the explosive mixture is prepared, the cycle hereover described is in no means altered.

No supplementary devices, such as safety-valves or auxiliary pumps, need be provided to insure a constant working pressure in the tank; for the engine is, in that respect, self-regulating, as long as the charges of mixture introduced in the explosion chamber (and supposed to be of constant composition in gas and air), are quite uniform in weight; which can be practically obtained if the three following conditions are fulfilled: the volume of the explosion chamber is maintained constant, the temperature of the mixture and of the walls of the explosion chamber are kept constant.

Supposing the engine operates in the conditions above set forth, the charges of mixture introduced in the motor cylinder will be perfectly uniform in weight and consequently in power, the strokes of the pistons will all be exactly of the same length, and the weight of the charges of air or mixture drawn in and compressed by the pump will be uniform. So, if the pressure in the tank happens accidentally to be too low, part of the output of the pump will not find space in the explosion chamber and will gather at each stroke in the tank, progressively raising the pressure in that tank. Finally, the volume of the tank being practically limited, the proper working pressure will soon be reached again. If, on the contrary, the engine is caused to work with a pressure in the tank which is excessive, considering the out-

put given at the same time to the pump, the weight of mixture entering the explosion chamber will exceed that delivered by the pump. So, at each stroke, a fraction of the compressed air previously stored in the tank will find room in the explosion chamber, and the pressure will soon fall to its proper amount in said tank. The volume of the explosion chamber will evidently remain constant as long as the valve x is made to close at the very same point of the beginning out stroke of the pistons, considering that the pistons stop suddenly and that the charge is fired, as soon as this valve x gets closed.

The constant temperature of the mixture and of the walls of the explosion chamber, which is the next necessary condition for a steady running of the engine, may be insured preferably by water-jackets surrounding the pump, receivers, pipes and cylinder, and by injections of water into the pump, and into the cylinder. As shown in the drawing, the water injected into the cylinder at u can be that, introduced by suction at d' with the air or mixture in the pump, forced out with the compressed gases, and then collected and cooled in the receiver m at the pressure of the tank; which arrangement does away with the necessity for a separate pump. The pressure in the tank, as well as the volume of the explosion chamber, have to be determined by experience, in order to obtain full strokes of the pistons, and must evidently vary with the nature and richness of the mixture. The volume of said chamber must also be adapted with the constant temperature given to its walls and to the mixture. It will seem preferable to use very rich mixtures, with a relatively low temperature at the moment of firing, in order to obtain high explosive pressures and very long expansions.

As has been said, the preceding description relates to the engine, when working in accordance with the cycle Fig. 2; in which case, the pump draws in and compresses full charges of mixture, the pressure of the air in the tank is maximum, and the engine develops at each stroke the greatest possible power. Let us now assume that the engine has not to develop its full power. Firstly, the pressure of the air in the tank must be diminished. Secondly, the output of the pump must be reduced in a proportion which experience will show: Reduced charges from the pump may be obtained, preferably by keeping the sucking-valve d' open during a more or less long portion of the beginning of the return stroke; so that a fraction of the charge of air or mixture first drawn in is expelled in the atmosphere, or in a special receiver of tubular form (not shown), where it shall be taken again at the next stroke. Thirdly, the volume of the

explosion chamber will have to be fitted anew, also by experience, and generally made larger as the pressure in the tank is chosen lower, (for, the mechanical and thermic efficiency diminish with the work the engine has to provide); this will be obtained very simply by making the slide-valve x shut later if the volume of the explosion chamber has to be made larger.

For the construction of diagram Fig. 1, which relates to the working under reduced pressure and power, the charges compressed by the pump have been supposed one half its volume, and consequently the pressure in the tank must be about one half the pressure of working under full power as designed by diagram Fig. 2. However different the diagrams Figs. 1 and 2 may appear at first sight, in fact they illustrate only one same cycle and one invention: Firstly, the two diagrams offer the same area of indicated positive work BCDEGHB, and consequently the theoretical efficiency of the engine remains the same, whatever be the pressure $X-Y$ in the tank. Next, referring to diagram Fig. 1, we see that the curve GHB corresponds, for its first portion GH, to the isothermal compression of the cooled burned gases, in the motor cylinder, from below, up to, atmospheric pressure $X'-Y'$; and, for its second portion HB, corresponds to the isothermal compression of the fresh mixture, in the pump, from atmospheric pressure, up to the pressure in the tank: These two succeeding operations may be considered as one same operation, the pump and cylinder having the same volume as a principle.

Referring now to Fig. 2, we find in the diagram the same curve GHB, but it corresponds in all its extent only to the compression of the mixture in the pump, there being no more any recompression of burned gases in the motor cylinder. For, the sudden cooling of those burned gases in the close cylinder, at the end of the outward stroke, should, if it was effected, only lower their pressure down to that of the atmosphere, their volume being, at ambient temperature and pressure, equal to the volume of said cylinder. Consequently, the total negative indicated work is exactly the same in diagram 1 and in diagram 2. Finally, from a thermodynamic point of view, as well as in practice, the two diagrams are identical, only differing by the position of the atmospheric line $X'Y'$, and the engine effectively works, in all cases, and with any pressure in the tank up to one maximum, according to one same cycle. Moreover, the charges drawn in by the pump might, if desired, (see here-over, description of the cycle, operation IV), be extracted from a receiver where the air or mixture should have been previously stored at a pressure higher than that of the atmos-

phere. By so doing, the power of the engine might be increased, and the total cycle would in no means be modified. Lastly, let us remark that the cycle described, and designed in diagrams 1 and 2, is exactly the cycle of the toothed-rack atmospheric engine of Otto and Langen, merely improved by the substitution of an artificial atmosphere under high pressure, to the natural atmosphere; which substitution leads to higher mean pressures of expansion, to more power from an engine having a cylinder of a given volume, and finally, to a very high thermic efficiency.

For starting the engine, it is preferable to fill the air tank at the desired pressure and to inject a charge of mixture, or the fuel alone, at the point p ; or the mixture may be drawn into the pump d by injecting compressed air into the cylinder a by means of the slide valve x kept open during one full out stroke, or by any other means.

When the engine works at full speed under a relatively low pressure in the tank r , if more power is needed to overcome greater external resistance, the pressure in the tank must be raised. This may be effected (in case the pump d only draws in pure air), by increasing the output of the pump, or even by making that pump d work at full admission as long as the proper pressure in the tank is not reached. For the same purpose, an auxiliary pump or a high pressure reserve air tank filled beforehand may also be utilized.

For governing the engine, that is to say, to keep its revolutions constant whatever be the external resistance, the number of explosions may be lowered in a given time. This may be effected by throttling or momentarily stopping either the discharge of the pump, or the admission to the cylinder or the exhaust, also by cutting out the ignition. These operations may take place together or separately, and be controlled by hand or by means of a governor. The speed may also be lowered by lowering the pressure in the tank and at the same time reducing the output of the pump or the richness of the mixture, or by reducing both.

The constructional form shown in Fig. 3 may be modified at will, namely, the pressure of the tank r could be exercised no longer on the piston b' , but on the piston e of the pump. Also, the reciprocating movement of the pistons, instead of being converted into rotary motion may be applied directly for pumping liquids, or compressing gases, etc. For the abovesaid applications the piston of the pump will be rigidly connected to the driving piston, the fluid will be sucked into the pump cylinder during the explosion stroke, and compressed during the return stroke; by so doing, the speed of the pistons during the return stroke will be no longer uniform, as when con-

trolled by a fly-wheel, but the cycle of operations in the cylinder as heretofore described, will in no way be altered.

Having thus fully described my invention, what I claim and desire to secure by Letters Patent of the United States, is:

1. An internal combustion engine, comprising in combination, an explosion cylinder having a piston, a pump cylinder also having a piston, said pistons being coupled together, an air-tank containing air under pressure, and having an open communication with said explosion cylinder in front of the piston therein, a charge coil, means openly connecting said coil and said air-tank, a conduit connecting said pump cylinder and said coil, a valve connection between said coil and said explosion cylinder behind said piston therein, and a valved outlet from said explosion cylinder.

2. An internal combustion engine, comprising in combination, an explosion cylinder having a piston, a pump cylinder having a piston, said pistons being coupled together, an air-tank containing air under pressure, a charge container adapted to be maintained at constant temperature, an open connection between said container and said air-tank, an intermittently opened connection between said container and said pump cylinder, and a correspondingly intermittently opened connection between said container and said explosion cylinder.

3. An internal combustion engine, comprising in combination, an explosion cylinder having a piston, a pump cylinder having a piston, said pistons being coupled together, an air-tank containing air under pressure, a charge container adapted to be maintained at constant temperature, an open connection between said container and said air-tank, an intermittently opened connection between said container and said pump cylinder, a correspondingly intermittently opened connection between said container and said explosion cylinder, and a slide-valve in said last-named connection and actuated by the piston of said explosion cylinder to create said intermittent opening, the opening of said slide-valve causing the explosion charge to move said piston forwardly to form an explosion chamber.

4. An internal combustion engine, comprising in combination, an explosion cylinder having a piston, a pump cylinder also having a piston, said pistons being coupled together, an air-tank containing air under pressure, and having an open communication with said explosion cylinder in front of the piston therein, a charge coil, means openly connecting said coil and said air-tank, a conduit connecting said pump cylinder and said coil, a valve connection between said coil and said explosion cylinder behind said piston therein, a valved outlet from said

explosion cylinder, and means for throttling said conduit between said pump and said coil and said outlet during the whole or portion of the period of discharge to reduce the speed of said pistons before the period of opening said valved connection between said coil and said explosion cylinder.

5. An internal combustion engine, comprising in combination, an explosion cylinder having a piston, a pump cylinder also having a piston, said pistons being coupled together, an air-tank containing air under pressure, and having an open communication with said explosion cylinder in front of the piston therein, a charge coil, means openly connecting said coil and said air-tank, a conduit connecting said pump cylinder and said coil, a valve connection between said coil and said explosion cylinder behind said piston therein, a valved outlet from said explosion cylinder, and a water-cooling reservoir connected between said pump cylinder and said explosion cylinder, whereby water may be injected into the latter after each explosion.

6. An internal combustion engine, comprising in combination, an explosion cylinder having a piston, a pump cylinder also having a piston, said pistons being coupled together, an air-tank containing air under pressure, and having an open communication with said explosion cylinder in front of the piston therein, a charge coil, means openly connecting said coil and said air-tank, a conduit connecting said pump cylinder and said coil, a valve connection between said coil and said explosion cylinder behind said piston therein, a valved outlet from said explosion cylinder, and means for reducing the pressure in said air-tank, whereby the air acting in front of said explosion-cylinder piston will vary the compressing power of said pump.

7. An internal combustion engine, comprising in combination, an explosion cylinder, a pump cylinder mounted on the axis of said explosion cylinder, pistons in said cylinders, a common piston rod connecting said pistons, an air-tank containing air under pressure, and having an open communication with said explosion cylinder in front of the piston therein, a charge coil, means openly connecting said coil and said air-tank, a conduit connecting said pump cylinder and said coil, a valve connection between said coil and said explosion cylinder behind said piston therein, and a valved outlet from said explosion cylinder.

8. An internal combustion engine, comprising in combination, an explosion cylinder having a piston, a pump cylinder having a volume slightly smaller than that of said explosion cylinder, said pump cylinder also having a piston, said pistons on the same

axis being coupled together, an air-tank containing air under pressure and having an open communication with said explosion cylinder in front of the piston therein, a suction-valve in said pump cylinder behind said piston therein, a conduit connecting said air-tank and said pump cylinder behind said piston therein, a valve connection between said conduit and said pump cylinder, a conduit connecting said air-tank and said explosion cylinder, an intermittently opened connection between last-named conduit and said explosion cylinder behind said piston therein, and a valved outlet from said explosion cylinder.

9. An internal combustion engine, comprising in combination, an explosion cylinder having a piston, a pump cylinder also having a piston, said pistons being coupled together, an air-tank containing air under pressure and having an open communication with said explosion cylinder in front of the piston therein, a gas receiver or producer, a conduit connecting said pump cylinder behind said piston therein with the atmosphere and with said gas receiver or producer, a suction-valve between said conduit and said pump cylinder, a charge coil, means openly connecting said coil and said air-tank, a conduit connecting said pump cylinder and said coil, a valve connection between said coil and said explosion cylinder behind said piston therein, and a valved outlet from said explosion cylinder.

10. An internal combustion engine, comprising in combination, an explosion cylinder, a pump cylinder mounted on the axis of said explosion cylinder, pistons in said cylinders, a common piston-rod connecting said pistons, an air-tank containing air under pressure and having an open communication with said explosion cylinder in front of the piston therein, a suction-valve in said pump cylinder behind said piston therein, a conduit connecting said air-tank and said pump cylinder behind said piston therein, an intermittently opened connection between said air-tank and said conduit, a carbureting device, means openly connecting said air-tank and said carbureting device, a valve connection between said carbureting device and said explosion cylinder behind said piston therein, and a valved outlet from said explosion cylinder.

11. An internal combustion engine, comprising in combination, an explosion cylinder having a piston, a pump cylinder having a piston, said pistons being coupled together, an air-tank containing air under pressure and having an open communication with said explosion cylinder in front of the piston therein, a suction-valve in said pump cylinder, a conduit between said pump cylinder and said air-tank, an intermittently

opened connection between said pump cylinder and said conduit, a charge container adapted to be maintained at constant temperature, an open connection between said container and said air-tank, an intermittently opened connection between said container and said explosion cylinder.

12. An internal combustion engine, comprising in combination, an explosion cylinder having a piston, a pump cylinder having a piston, said pistons being coupled together, an air-tank containing air under pressure and having an open communication with said explosion cylinder in front of the piston therein, a charge container adapted to be maintained at constant temperature, an open connection between said container and said air-tank, an intermittently opened connection between said container and said explosion cylinder, and a valve in said connection and actuated by the piston of said explosion cylinder to create said intermittent opening, the opening of said valve causing the explosion charge to move said piston forwardly to form an explosion chamber of any desired volume.

13. An internal combustion engine, comprising in combination, an explosion cylinder having a piston, a pump cylinder having a volume slightly smaller than that of said explosion cylinder, and having also a piston, said pistons being coupled together, an air-tank containing air under pressure, and having an open communication with said explosion cylinder in front of the piston therein, a suction-valve in said pump cylinder behind said piston therein, a conduit connecting said pump cylinder behind the piston therein and said air-tank, a charge container adapted to be maintained at constant temperature, an open connection between said container and said air-tank, a valve connection between said container and said explosion cylinder behind said piston therein, a valved outlet from said explosion cylinder, and means for increasing or reducing the output of the pump, whereby the pressure in said tank

will be modified and will vary the power of said engine.

14. An internal combustion engine, comprising in combination, an explosion cylinder having a piston, a pump cylinder also having a piston, said pistons being coupled together, an air-tank containing air under pressure, and having an open communication with said explosion cylinder in front of the piston therein, a charge container adapted to be maintained at constant temperature, an open connection between said container and said air-tank, a valve connection between said container and said explosion cylinder behind said piston therein, a valved outlet from said explosion cylinder, and a water-cooling reservoir, the top of which is intermittently connected with said pump cylinder and is in open communication with said air-tank, and the bottom of which is connected with said explosion cylinder, whereby water may be injected into the latter after each explosion.

15. An internal combustion engine, comprising in combination, an explosion cylinder having a piston, a pump cylinder also having a piston, said pistons being coupled together, an air-tank containing air under pressure and having an open communication with said explosion cylinder in front of the piston therein, a conduit connecting said pump cylinder and said air-tank, a valve connection between said conduit and said pump cylinder behind said piston therein, a valved outlet from said explosion cylinder, and means for throttling said conduit and said outlet during the whole or portion of the period of discharge of the pump, in order to reduce the speed of said pistons toward the end of their return stroke.

In testimony whereof I have signed this specification in the presence of two subscribing witnesses.

JULES ALFRED BABIN.

Witnesses:

EMILE LEDRET,
H. C. COXE.