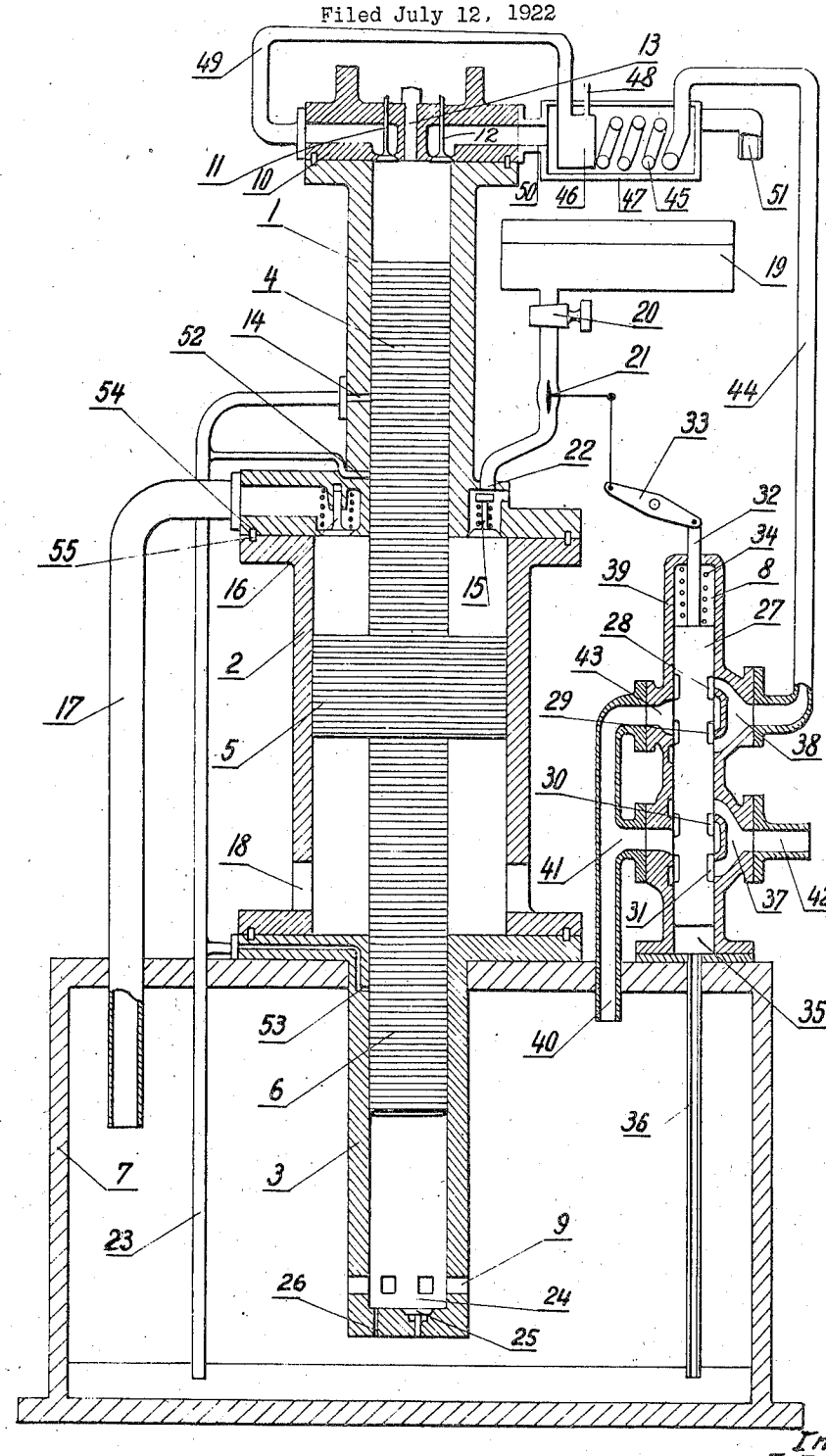
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J. BABIN

METHOD AND APPARATUS FOR COMPRESSING GAS

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JULES BABIN, OF PARIS, FRANCE.

METHOD AND APPARATUS FOR COMPRESSING GAS.

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To all whom it may concern:

Be it known that I, JULES BABIN, citizen of the French Republic, residing 25 Bld. Malesherbes, Paris, France, have invented certain new and useful Methods and Apparatus for Compressing Gas, of which the following is a specification.

My invention relates to a method and apparatus for compressing gas.

The motor-compressor group according to my invention is constituted by the combination with a reservoir containing gas under pressure, of an internal combustion motor operating upon previous and separate compression, of what is termed the atmospheric type, and a single-acting pump, the pistons of motor and pump being rigidly connected together and in all cases independent of all mechanical transmission devices. Such pistons are generally called free flying pistons. The end of the motor cylinder situated farthest from the combustion chamber is in permanent communication with the compressed gas reservoir constituting an artificial atmosphere.

When the power piston is impelled by the explosion, the volume of compressed gas situated forwardly of said piston within the cylinder is conducted into the reservoir wherein the pressure increases. At the same time the pump draws in a charge of gas to be compressed. When the piston is brought to the starting point by the pressure of the compressed gas in the reservoir, this gas partially expands and produces the effective work, that is the compression of the charge of gas in the pump and the delivery of the gas into said reservoir. Compressed gas for outside use is taken as desired from the same reservoir, which also supplies a carburetting apparatus or a gas generator wherein is produced the explosive mixture under pressure which is required for the motor.

The said operating method based upon retarded effect or "reaction" will provide for high efficiency and regular working in a motor-compressor with free cylinder, such as appears difficult to obtain by utilizing the direct action of the explosion. The effect of prejudicial spaces upon the efficiency of an air compressor is already known, and this effect is much reduced by bringing the piston as far as the end of the cylinder. On the other hand it may be affirmed that it is impossible to obtain in an internal combustion engine working under industrial conditions the perfect and constant uniformity of the power of the explosions. Should therefore an attempt be made to employ immediately the impulse action of the explosions for compressing the gas, for example with a motor and a pump both of the double-acting type, it would be essential to maintain a considerable gas cushion at the end of the stroke in order to obviate the danger of violent shocks of the pistons against the cylinder heads, and this would tend to decrease the efficiency. In the device according to my invention the stopping point of the free flying pistons at the end of the compression stroke will no longer depend, as will be set forth hereunder, upon the power of the explosions, but upon elements which are susceptible of a much more exact determination.

The following description together with the accompanying drawing, disclose an embodiment of said invention, as applied to a motor compressor group, especially intended for the compression of air.

The apparatus is essentially composed of three cylinders in coaxial disposition, comprising a power cylinder 1, a compressor cylinder 2 and a counter-pressure cylinder 3. Each of said cylinders has movable therein a piston which is free from all mechanical connection 4, 5, 6; said pistons are coaxial and are rigidly connected together. The device is completed by an air reservoir of large capacity 7 adapted to support the assemblage formed by the three cylinders and a regulating device 8. The counter-pressure cylinder 3 extends within the reservoir 7 and is connected therewith by the large apertures 9. The cross-section of the cylinder 3 is somewhat smaller than that of the cylinder 1; the effective cross-section of the cylinder 2 is generally greater than the section of cylinder 3 and is calculated with respect to the latter according to the pressure to be obtained, as will be set forth hereunder.

Above the power cylinder 1 is disposed a cylinder head 10 provided with an operated valve 11 for admission of the compressed explosive mixture, an operated valve 12 for the exhaust of burnt gas, and an electric spark plug 13. Such valves as 11 and 12 are described in Patent No. 1,537,450. The two valves 11 and 12 are actuated by suitable means, not shown, such for instance as

those described in my aforesaid patent. The wall of the cylinder 1 is provided at a suitable height with one or more water injection orifices 14. The compressor 2 is provided with a plurality of automatic suction valves 15; the compressed air is delivered into the reservoir 7 through the automatic valve 16 by means of the pipe 17. The compressor is provided at the bottom with large apertures 18 in direct connection with the atmosphere. A tank 19 contains cold water whose flow is controlled by the cock 20 and valve 21; the water is supplied through the orifices 22 above each of the valves 15. A pipe 23 is used to take up the water accumulating at the bottom of the reservoir 7 and to inject it through the orifices 14 into the cylinder 1. At the bottom of the cylinder 3 is provided a dashpot 24 having opening towards the interior thereof a valve 25. An orifice of small section 26 connects the bottom of the cylinder 3 with the reservoir 7.

The regulating device is essentially composed of a main body 7 having a cylindrical bore wherein is movable the piston 27 provided with four grooves 28, 29, 30, 31; the piston rod 32 controls the valve 21 through the medium of a transmission device 33. A spring 34 surrounds said rod and presses constantly upon the piston 27. The said regulating device comprises the following distinct parts. A lower cylinder 35 closed at the bottom and connected by the pipe 36 with the reservoir 7, two chambers with valves 37, 38, and an upper cylinder 39 connected at the top with the atmosphere.

A pipe 40 connects the upper part of the reservoir 7 with the chambers 37, 38. The compressed air for outside use enters the chamber 37 through the neck 41 and leaves said chamber through the neck 42. The compressed air for the use of the motor passes through the neck 43 into the chamber 38 whence it issues through the pipe 44 ending in the worm tube 45 and the carburating apparatus 46, both of which are disposed within a temperature-exchanging receptacle 47. The carburant is delivered by a pump, not shown, into the carburating apparatus, entering the same through the orifice 48. The pipe 49 conducts the explosive mixture to the admission valve 11.

The pipe 50 receives the burnt gas and the injection water discharged through the valve 12, and conducts the same into the receptacle 47 of the temperature exchanging device which is provided with the outlet orifice 51. The pistons 4, 5, 6 are not provided with elastic packing members, they may if desired be provided with circular grooves. Lubrication is afforded and tight working obtained by the use of water joints consisting of circular grooves 52, 53 formed in the walls of the cylinders and constantly covered by the pistons; said joints are supplied by water under pressure from the reservoir 7.

The said arrangement will admit the use of pistons of wood, which are made waterproof by suitable means, plain or reinforced by metal, or of any suitable material which by reason of its lightness is adapted for high speeds of stroke which will tend to increase the output of air from the apparatus, and to reduce the duration of the recoil stresses upon the body of the cylinder and reservoir.

It is found necessary to dispose the three cylinders exactly in the coaxial position by reason of the very precise adjustment of the pistons required by the elimination of packing members, as well as the rigidity and great length of the single element formed by the three pistons. To this effect, said cylinders are provided with very wide flanges having no insertion fitting in order to afford a perfectly smooth surface upon the whole of the flange. A circular groove 54 is formed in each flange in the surfaces in contact, said grooves being disposed upon a common diameter which is as large as possible. A ring 55 is fitted upon the inner and outer diameters of said groove, and it engages the two grooves placed opposite each other but without coming into contact with the bottom of said grooves. In all cases where said flanges form a joint, a tight fit is secured by the flat configuration of the surfaces, these being if necessary treated with a viscous liquid, but without interposition of a solid substance of appreciable thickness. Should it be desired to utilize the ring 55 to complete the tightness of the joint, said ring is disposed within the row of bolts, and it is made of a metal whose coefficient of expansion is greater than that of the flanges.

The operation of said apparatus is as follows:

The reservoir 7 is supposed to be filled with air by any adequate means at the suitable pressure; the pistons 4, 5 are in contact with the respective piston heads, and all the valves are closed. Compressed air enters the reservoir 7 through the regulating device 8 whose spring 34 is regulated in such manner as to equilibrate a pressure at 35 which is somewhat smaller than the operating pressure of the compressor when the piston 27 is at the bottom of the stroke. The compressed air becomes mixed with the carburant and proceeds to the valve 11; the latter will open, as shown in Patent No. 1,537,450 and the mixture at the pressure of the reservoir 7 will enter the cylinder 1. Inasmuch as the cross-section of said cylinder is somewhat greater than the section of cylinder 3, the three pistons 4, 5, 6 will be driven downwardly at a comparatively slow rate. When the proper amount of mixture

has entered the cylinder 1, the valve 11 is closed, as shown in Patent No. 1,537,450, a spark occurs at 13, and the pistons are impelled by the explosion. In this downward motion, the piston 5 draws a supply of air into the cylinder 2 and the piston 6 forces the compressed air from the cylinder 3 into the reservoir 7 through the orifices 9.

Towards the end of the same downward stroke, the valve 12 will open, as shown in Patent No. 1,537,450 and the burnt gas begins to escape into the atmosphere if its residual pressure is sufficient. At about the same time, the piston 4 will uncover the orifices 14, and the water under pressure from the reservoir 7 will suddenly enter the cylinder, cooling the residual gases and the walls, until the piston 4 rises sufficiently to close the apertures 14. During this downward stroke, the speed of the pistons is increased until the pressure of the burnt gas becomes reduced to the pressure of the reservoir. After this time, the speed of the pistons diminishes, and the stroke is completed with the concourse of the vis viva of said pistons.

When the pistons stop, the pressure of the air of the reservoir 7 upon the piston 6 will drive upwardly the combination 6, 5, 4. The piston 4 discharges the residual burnt gas and the injected water through the valve 12 into the receptacle 47. The piston 5 compresses the air contained in the cylinder 2, and then discharges the same through the valve 16 and the pipe 17 into the reservoir 7. During this upward stroke, the effort of resistance of the gas of the pump 2 is in the first place less than the motive effort of the air of the reservoir, and the speed of the pistons will increase until the two products of area and pressure become equal, for cylinders 2 and 3. After this point, the effort of resistance of the compressed air in the pump 2 will exceed the motive effort of the air of the reservoir; the speed decreases, and the stroke continues and is completed with the concourse of the vis viva of the pistons, which latter force should be entirely exhausted at the precise point at which the pistons 4, 5 enter into contact with the respective cylinder heads, if the apparatus has been properly adjusted. This result will be obtained if during each return stroke the sum of the elementary work of the motors is equal to the sum of the elementary work of resistance.

In view of the practical impossibility as above stated of obtaining explosions having a perfectly uniform power and therefore of obtaining piston strokes of constant length, it is necessary that the stopping point of the pistons at the end of the return stroke shall be independent of the length of this stroke. It will be readily observed that the method of operation of the apparatus will produce this result.

Let us suppose that the problem has been solved and that the apparatus is well adjusted. In this event the pistons will return at each stroke almost in contact with the cylinder heads, and the return stroke is in all cases equal to the forward stroke. The total work of compression and delivery of the charge of air by the pump 2 will in the case here considered be substantially proportional to the volume of air drawn in, and consequently this work is also proportional to the length of the suction (or forward) stroke. Furthermore, since the capacity of the reservoir 7 is here supposed to be quite considerable with respect to the volume of the cylinder 3, the motive effort set up by the piston 6 is substantially constant during the whole of the return stroke; or in other words, the work of the piston 6 is proportional to said stroke.

With these considerations in view, it is to be concluded that if the equality between the values of the resistance work of the compressor piston 5 and the motive work of the piston 6 has been established for a return stroke of given length, this equality will still prevail for strokes of all lengths. It only remains to determine the means for establishing this equality for a stroke of any suitable length.

If one considers the total work required to compress the unit volume of a gas in isothermic conditions and to deliver the same at constant pressure into a reservoir, it is recognized that the values of the work corresponding to different pressures in the reservoir will have the ratio of the logarithms of these pressures, whence it results that the total work of compression will increase less rapidly than the pressure in the reservoir. Since on the other hand, in said apparatus the motive work of the piston 6 increases at the same rate as the pressure in the reservoir, it follows that in order to absorb the whole amount of this work, the pump 2 must have a larger cross-section with respect to that of the cylinders 3 if the pressure in the reservoir 7 is to be high, than if said pressure is to be low. In practice, the ratio of the cross-sections of the two cylinders, 2 and 3 which is near unity for pressures but little above atmospheric pressure, will be about two for a compression at three atmospheres, three for seven atmospheres, four for seven atmospheres, etc.

Inversely, with a motor-compressor group having two cylinders 2 and 3 of given cross-sections, the equality between the motive work and the resistance work of compression will only be established for an exactly specified reservoir pressure, which may be termed the operating pressure. A higher pressure

would occasion shocks of the piston against the cylinder heads, and with a lower pressure the pistons would be stopped too soon with a consequent reduction of compression efficiency.

In short, in order that a motor-compressor group constructed according to the said principles shall have a perfectly stable operation and the maximum efficiency the following conditions are to be observed.

(*a*) Each apparatus is to be constructed in view of the maximum pressure of the requisite external output, that is with the adequate ratio of sections of cylinders 2 and 3.

(*b*) When starting, the exact value of the reservoir pressure corresponding to this ratio should be sought by various trials.

(*c*) During the running, the operating pressure thus determined is to be maintained perfectly constant. This latter function is fulfilled by the regulating device 8 above described, which is operated as follows:

When the piston-valve 27 is in the inoperative position at the bottom of the stroke, it closes the passages of the chamber 37, and the output of air to the exterior is null. On the other hand, the grooves 28, 29 will leave the passages of the walls of the chamber 38 entirely open, so that the admission of compressed air to the motor is now free. When the piston-valve 27 which rises by the effect of an increase of pressure upon the lower surface shall have attained the mean position as indicated in the figure, the passages of the chamber 37 have now opened to the maximum, and the passages of the chamber 38 which had been hitherto widely open, will begin to diminish in section. In the upper position of the piston valve, the passages of the chamber 37 are always fully open, but those of the chambers 38 are entirely closed.

In consequence, firstly, the output of compressed air to the exterior can only commence if the operating pressure in the reservoir is established; secondly, this output is limited to the maximum output of the compressor; thirdly when the consumption is below the said maximum output, the regulating device throttles the supply conduit of the motor, thereby reducing the speed of the piston 4 during the admission period, increasing the duration of said period, and thus reducing the number of explosions per unit of time; fourthly if the outside consumption of compressed air becomes null, the motor will stop, but is automatically started again as soon as the consumption is resumed.

Furthermore, during approximately the upper half of its stroke, the piston-valve acts upon the power transmission device 33 which closes the valve 21 controlling the admission of cold water to the compressor in the same proportion as said regulating device reduces the number of explosions. By preserving the permanent form of the curve of compression temperatures at all speeds, said device aids in finally providing a constant value of the resistance work of the pump. At the same time, the said means will provide for the constant value of the temperature and weight of the charges of fuel mixture admitted into the explosion chamber. The water drawn into the pump then proceeds as above mentioned into the power cylinder and thence into the heat exchanging device 46, 47 and determines the temperature of their walls and hence that of the mixture. If care is taken to provide a constant volume for the explosion chamber and the greatest possible uniformity of composition of the gas, by adequate means, the constancy of temperature of the mixture will have the final effect of giving to the successive explosions a regularity of power which suffices to enable the utilization of practically, the whole length of the cylinders, without apprehension of shocks of the piston 5 when at the bottom of the stroke.

As an additional safeguard, the apparatus employs at 24 a dash-pot which comes into action when the piston 6 descends sufficiently to close the orifices 9 and to prevent all shocks in the accidental case of too powerful explosions. In order that the proportionality between the work and the stroke of piston 6, the utility whereof has been pointed out, shall not suffer in case the dash pot should operate, the bottom is provided with an orifice 26 whose section is such that the mean pressure of the expansion of the air contained in the chamber 24 below the piston 6 shall be less than its mean pressure of compression and substantially equal to the reservoir pressure.

What I claim is:

1. A method for compressing gases by means of a free flying piston travelling in a cylinder consisting in introducing a charge of a compressed explosible mixture into the cylinder, igniting said charge when the piston has travelled over a part of its stroke, utilizing the working of the piston produced by the introduction of the said charge and by the explosion, to reduce the volume of a supply of compressed gas whose pressure is kept constant, using the same working of the piston for the suction of a given charge of the gas to be compressed, using the expansion of the said supply of compressed gas for producing the working of the piston in an opposite direction, using the said opposite working of the piston for compressing and then forcing at a constant pressure, the charge of gas to be compressed, using said opposite working of the piston for expelling the exhaust gases, and equalizing the quantity of motive power produced by the expansion of the compressed gas and the

quantity of resisting power invested in the compression of the gas and its forcing at a constant pressure, so that the free flying piston will reach its starting point with a speed equal to zero.

2. A gas compressor comprising in combination an explosion cylinder, a free flying piston in the said cylinder, means for introducing a compressed explosible mixture into the said cylinder, means for igniting the said mixture, means for expelling the exhaust gases from the said cylinder, a compressor cylinder, a free flying piston in the said compressor cylinder, means for introducing a charge of gas to be compressed into the said cylinder, means for expelling the compressed gas from the said cylinder, a compressed gas reservoir, a pressure regulator upon the said gas reservoir, a counter-pressure cylinder in permanent communication with the said reservoir, a free flying piston in the said counter pressure cylinder, means for rigidly connecting the explosion, compressor, and counter pressure pistons, the cross section of the compressor piston being at least equal to that of the counter-pressure piston and the relation of the said sections being such as the free flying pistons will reach their starting points with a speed equal to zero.

3. An air compressor comprising in combination an explosion cylinder, a free flying piston in the said cylinder, igniting means in the said cylinder, means for expelling the exhaust gases from the said cylinder, a compressor cylinder, a free flying piston in the said compressor cylinder, means for introducing a charge of air to be compressed into said compressor cylinder, a compressed air reservoir, a pressure regulator upon the said reservoir, means for connecting the pressure regulator to the explosion cylinder, a carbureter traversed by the said connecting means, an automatic valve controlling the entrance of the combustible mixture into the explosion cylinder, means for connecting the compressor cylinder with the air reservoir, an automatic valve controlling the forcing of the compressed air out of the compressor cylinder, a counter-pressure cylinder in permanent communication with the said reservoir, a free flying piston in the said counter-pressure cylinder, means for rigidly connecting the explosion, compressor and counter-pressure pistons, the cross-section of the compressor piston being at least equal to that of the counter-pressure piston, and the relation of the said sections being such as the free flying pistons will reach their starting points with a speed equal to zero.

4. A gas compressor comprising in combination an explosion cylinder, a free flying piston in the said cylinder, means for introducing a compressed explosible mixture into the said cylinder, means for igniting the said mixture, means for expelling the exhaust gases from the said cylinder, a compressor cylinder, a free flying piston in the said compressor cylinder, a water reservoir, means for connecting the water reservoir with the said compressor cylinder, an automatic suction valve controlling the entrance of the water into the compressor cylinder, means for introducing a charge of gas to be compressed into the said compressor cylinder, a compressed gas reservoir, a pressure regulator upon the said gas reservoir, a piston in the said regulator, means for connecting the compressor cylinder with the gas reservoir, an automatic valve controlling the forcing of the compressed gas out of the compressor, a counter pressure cylinder in permanent communication with the said gas reservoir, a free flying piston in the said counter pressure cylinder, a pipe connecting the part of the gas reservoir which contains water with the explosion cylinder around the explosion piston, a pipe connecting the part of the gas reservoir which contains water with the regulator under the piston of said regulator, and means for rigidly connecting the explosion, compressor and counter-pressure pistons, the cross section of the compressor piston being at least equal to that of the counter-pressure piston and the relation of the said sections being such as the free flying pistons will reach their starting points with a speed equal to zero.

5. A gas compressor comprising in combination an explosion cylinder, a free flying piston in the said cylinder, means for introducing a compressed explosible mixture into the said cylinder, means for igniting the said mixture, means for expelling the exhaust gases from the said cylinder, a compressor cylinder, a free flying piston in the said compressor cylinder, a water reservoir, a pipe for connecting the water reservoir with the compressor cylinder, an automatic suction valve controlling the entrance of the water into the compressor cylinder, means for introducing a charge of gas to be compressed into the said compressor cylinder, a compressed gas reservoir, a pressure regulator upon the said gas reservoir, a piston in the said regulator, a valve in the pipe connecting the water reservoir with the compressor cylinder, means for connecting the said valve to the piston of the regulator, means for connecting the compressor cylinder with the gas reservoir, an automatic valve controlling the forcing of the compressed gas out of the compressor, a counter pressure cylinder in permanent communication with the said gas reservoir, a free flying piston in the said counter pressure cylinder, a pipe connecting the part of the gas reservoir which contains water with the regulator under the piston of said regulator, and

means for rigidly connecting the explosion, compressor and counter-pressure pistons, the cross-section of the compressor piston being at least equal to that of the counter pressure piston, and the relation of said sections being such as the free flying pistons will reach their starting points with a speed equal to zero.

6. A gas compressor comprising in combination an explosion cylinder, a free flying piston in the said cylinder, igniting means in said cylinder, means for expelling the exhaust gases from the said cylinder, a compressor cylinder, a free flying piston in the said compressor cylinder, a water reservoir, a pipe for connecting the water reservoir with the compressor cylinder, means for introducing a charge of gas to be compressed into the said compressor cylinder, a compressed gas reservoir, a pressure regulator upon the said gas reservoir, means for connecting the pressure regulator to the explosion cylinder, a piston in the said regulator whereof one face is submitted to the reservoir pressure and the opposite face to the pressure of the atmosphere added to that of an adjustable spring, a valve in the pipe connecting the water reservoir with the compressor cylinder, means for connecting the said valve to the piston of the regulator, grooves in the piston of the regulator, corresponding ports in the fixed part of the regulator so that when the piston is moved by reason of an increase of pressure in the reservoir it will first gradually open the orifice for outside delivery of compressed air from zero to the maximum, and then while leaving said orifice open to the maximum degree, will gradually close the admission of explosive mixture to the motor, at the same time gradually closing the valve controlling the entrance of water into the compressor cylinder, a counter pressure cylinder in permanent communication with the said reservoir, a free flying piston in the said counter pressure cylinder, means for rigidly connecting the explosion, compressor, and counter pressure pistons, the cross section of the compressor piston being at least equal to that of the counter pressure piston and the relation of the said sections being such as the free flying pistons will reach their starting points with a speed equal to zero.

In witness whereof I have hereunto set my hand.

JULES BABIN.