May 24, 1927.

1,629,927

R. P. PESCARA

MOTOR COMPRESSOR UNIT

Filed June 5, 1925

3 Sheets-Sheet 1

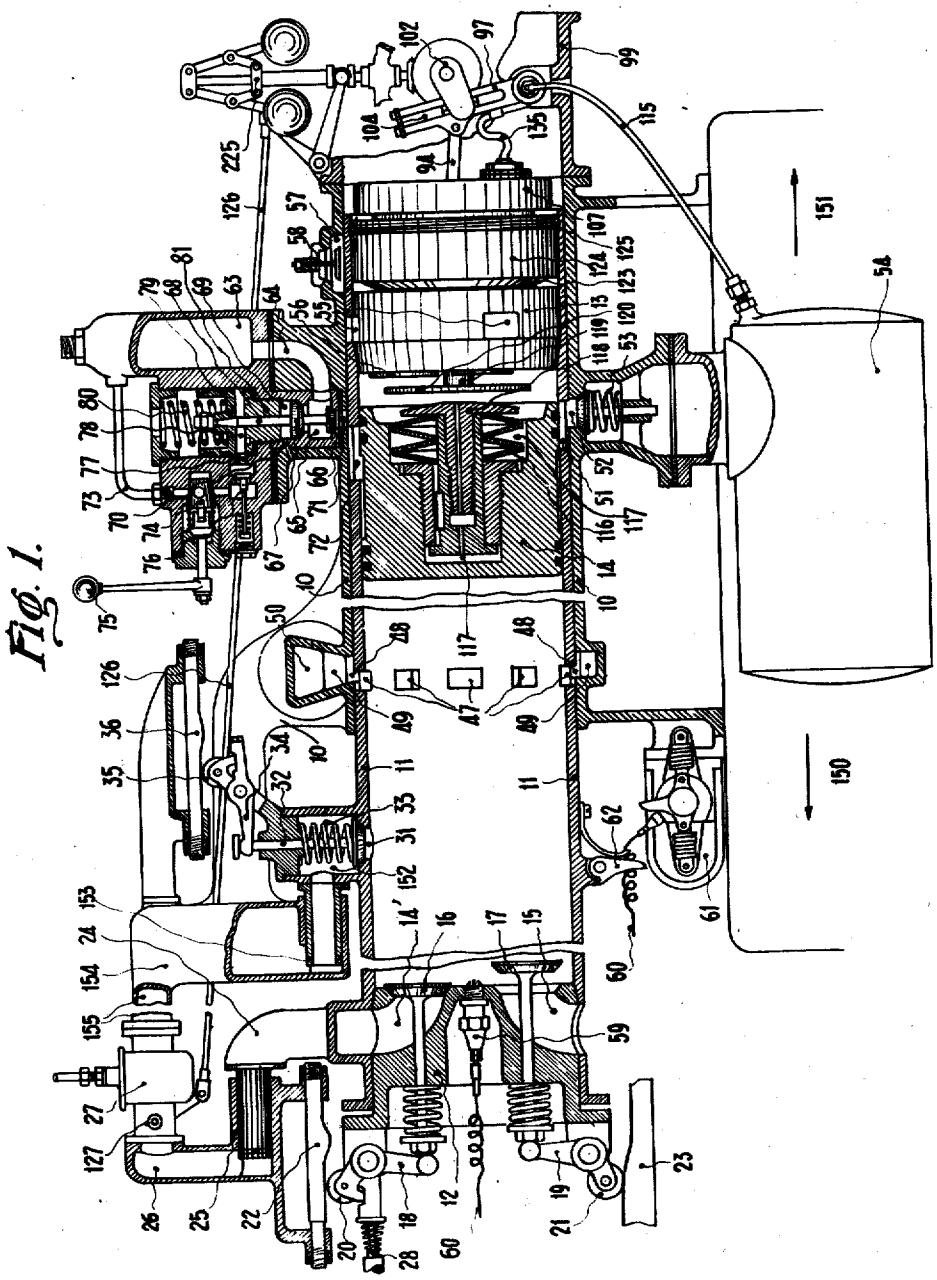


Fig. 1.

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Fig. 4.

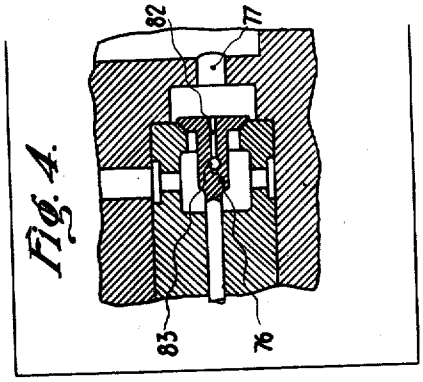



Fig. 2.

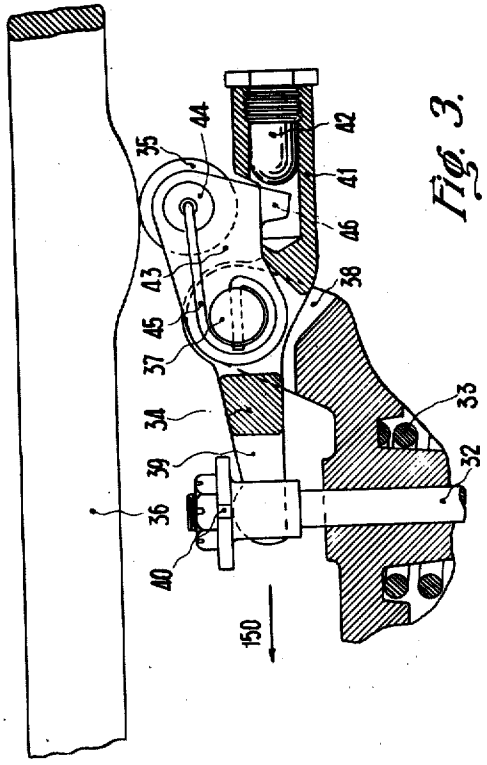
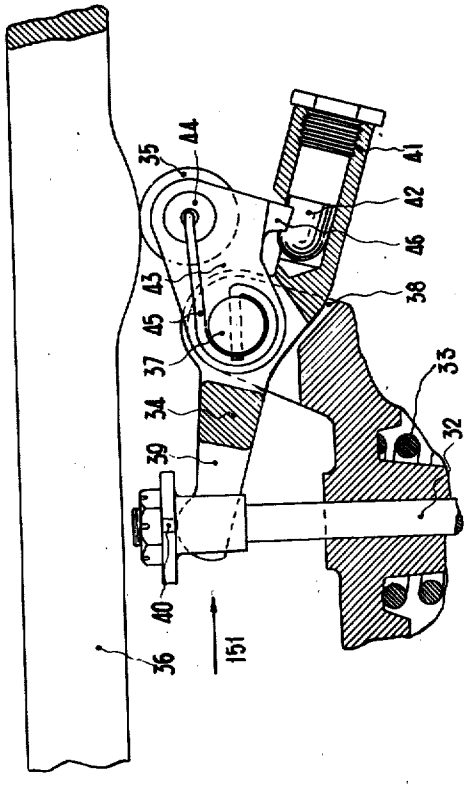



Fig. 3.




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Fig. 6.

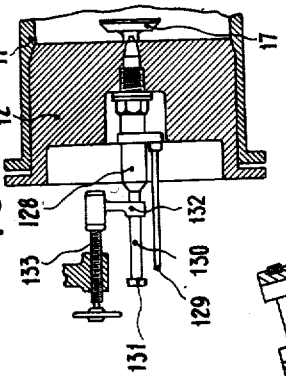



Fig. 5.




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# UNITED STATES PATENT OFFICE.

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## MOTOR-COMPRESSOR UNIT.

Application filed June 5, 1925, Serial No. 35,249, and in France June 11, 1924.

This invention relates to machines which are at the same time producers and transformers of energy, for example, motor compressor units.

The main object of the invention is to increase the efficiency of the cycles at present employed in industry for the thermodynamic evolution of the gaseous masses intended for combustion or arising from combustion, in internal combustion engines, and forms, in a sense, an improvement and refinement in the so-called two stroke cycle, whether combustion takes place under constant volume or under constant pressure.

The present invention consists essentially in carrying out the following operations inside a cylindrical space, whose volume is made to vary by the alternating movements of a gas-tight piston arranged therein, said cylindrical space having a very great ratio between the length and the bore:

1. Expanding the burnt gases arising from the combustion of a combustible agent effected under constant volume or constant pressure, the expansion being carried down to a pressure approximating that of the surrounding atmosphere.

2. Causing the machine to suck in from the atmosphere a certain amount of pure air, which enters in the proximity of the combustion chamber and is drawn along in the wake of the burnt gases, cooling the walls as it follows the movements of the piston.

3. Utilizing the speed acquired by this mass of air and by the mass of burnt gases to cause the expulsion of a portion thereof when the movement of the piston slackens.

4. Injecting at a low pressure, a sufficient quantity of carburetted air, in case combustion is effected under constant volume, taking great care to make this injection in such a way that, on the one hand the burnt gases remaining at this moment in the cylinder are always separated from the carburetted air by a layer of pure air and, on the other hand, that the mass of carburetted air injected may never reach the burnt gases exhaust ports.

5. Terminating the expulsion of the burnt gases by means of the return stroke of the piston, driving them against the pure air while completing the filling up with carburetted air, in the case of combustion under constant volume, or with pure air, in the case of combustion under constant pressure.

6. Compressing and forcing at low pressure a portion of the combined pure air and carburetted air, into the low pressure reservoir used for feeding the motor during the period of injection of carburetted air (combustion under constant volume).

Or compressing and forcing at low pressure a portion of the pure air into the low pressure reservoir used for feeding the motor during the latter part of the period of the scavenging with pure air, if the combustion is effected under constant pressure.

7. Compressing substantially adiabatically the carburetted gases remaining in the cylinder to such pressure as may be deemed desirable and at which they will be ignited. If desired this compression is carried up to the point where self ignition of the mixture is obtained, in the case where combustion is effected under constant volume.

Or compressing substantially adiabatically the air remaining in the cylinder until the desired pressure is obtained, in the case of combustion under constant pressure, and injecting the atomized combustible under pressure.

The invention thus generally described comprises a large number of applications to which the protection of the present patent will be naturally extended, as also to any apparatus of any kind utilizing its principle, and to their separate parts.

The invention will be easily understood by reference to the following description and also to the annexed drawings, which, however, are only given by way of example.

Fig. 1 of said drawings is a longitudinal section of a motor compressor unit constructed in accordance with the invention.

Figs. 2 and 3 are large scale sections showing the working of the device for opening the storage valves.

Fig. 4 is a large scale section showing part of the starting device of the apparatus.

Fig. 5 is a large scale section of the cylinder head closing the cylinder on the compressor side.

Fig. 6 shows the cylinder in longitudinal section along a plane perpendicular to the plane on Fig. 1 and shows the installation of

an oil injection device taking the place of the sparking plug.

According to the invention, and more especially in accordance with the constructions to which the drawings refer, supposing it is desired to construct a motor compressor unit, this can be done as follows or in some similar manner. In a fixed horizontal frame 10, a portion of whose interior is bored out, is arranged a cylinder 11 having an easy sliding fit in the frame 10. The cylinder 11 is closed at one end by a cylinder head 12 rigidly connected thereto, and at the other end by a head 13, mounted as will be explained later on. A gas-tight piston 14 can reciprocate in the cylinder 11.

The combination of the piston 14 and the cylinder 11 forms then an oscillating system such that the piston 14 can reciprocate in the interior of the cylinder 11 while the cylinder 11 itself can reciprocate in the frame 10.

The cylinder head 12 has two passages 14'—15 to which correspond the valves 16—17, whose movements are controlled by the bent rocking levers 18—19, which are pivoted on the cylinder 11 and carry the rollers 20—21 co-operating with the fixed cams 22—23.

The passage 15 communicates freely with the atmosphere. The passage 14' terminates in a tube 24, outside the cylinder and bent at a right angle. This tube 24 slides inside a fixed casing 25 in which it fits forming a gas-tight joint. The arrangement thus allows the interior of the oscillating cylinder 11 to be placed in communication with a carburetter 27 by means of the pipings 14' 24—25 and 26, this last one being fixed.

The rocking lever 19 is of the ordinary type. The rocking lever 18 on the contrary may be of a type already described in detail in another application for patent filed of even date herewith, Serial Number 35,250. This type of rocking lever controls the opening and closing of the valve 16 when the cylinder 11 moves in the direction of the arrow 151. On the contrary, the valve 16 always remains closed and, so to speak, integral with the cylinder 11 when this latter moves in the direction of the arrow 150.

The cylinder 11 also has one or more openings like those at 31, guarded by valves like 32, opening from within outwards, and kept closed by sufficiently strong springs such as 33.

The valve 32 is controlled by a rocking lever 34 carrying a roller 35 co-operating with a fixed cam 36. The drawing in Fig. 1 does not allow the arrangement of the rocking lever 34 to be clearly seen, on account of the smallness of the scale. The rocking lever 34 has therefore been shown in Figs. 2 and 3, on a large scale, which allows the following explanations to be easily understood.

The rocking lever 34 is formed essentially of a forged piece pivoted about the axis 37 in lugs 38 cast on the cylinder. This piece carries a fork 39 which acts on the head 40 of the valve 32 and a cylindrical extension 41 in the interior of which there moves a small piston 42 having the form of a projectile.

On the same axis 37 is mounted a pawl 43 which carries the axis 44 of the roller 35. The pawl 43 is constantly pressed against the cam by the spiral spring 45 and a projection 46 of said pawl can enter the interior of the cylindrical cavity 41.

It will be understood from a comparison of Figs. 2 and 3, that according to the position of the piston 42 in the cylindrical cavity 41 and consequently of the projection 46, the rocking lever can be locked to its pawl, or can, on the other hand, remain independent thereof. In the first case (Fig. 3) the roller 35 on passing over the raised portion of the cam controls the valve. In the second case (Fig. 2), on the contrary, the valve is not raised when the roller 35 passes over the raised portion of the cam. The operation of this device will be explained later on.

The cylinder 11 carries (Fig. 1) a further series of ports 47 capable of registering with corresponding openings 48 arranged in the fixed frame 10. All the openings 48 lead into a peripheral passage 49 which opens at 50 into the exhaust tube placed perpendicularly to the plane of Fig. 1.

Another set of ports 51 are arranged in the cylinder 11. These can register with the openings 52 in the fixed frame 10. Said openings 52 are guarded by spring held valves 53 and serve to place the interior of the cylinder 11 in communication with the compressed air reservoir 54.

The cylinder head 13 (Fig. 5) is provided with one or more passages as 55 whose opening into the interior of the cylinder is guarded by automatic suction valves 56. These valves are arranged so that they can open towards the interior of the cylinder 11 when acted upon by a difference between the pressure existing in the passage 55 and the cylinder 11. In order to allow the atmospheric air to enter through the passages 55, the frame 10 is provided with openings as 57, which can register with the exterior mouths of the said passages 55. The openings 57 are guarded by safety valves 58 whose object will be explained later on.

The ignition of the charge is effected by a spark plug 59 (Fig. 1) connected by a wire 60 to a trip magneto 61, actuated by a pawl 62, which is pivoted to the cylinder 11 and moving therewith.

In addition to these essential devices the apparatus is further provided with various accessory mechanisms which will now be described.

*Starting device.*—The object of this mechanism is to automatically start the piston and the cylinder and to cause them to correctly make their first stroke. It comprises the following parts:

A reservoir 63, of a predetermined capacity contains compressed air at a sufficient pressure which can, according to circumstances, be the same as, or different from, the pressure of the air in the reservoir 54. It communicates by the passage 64 with a chamber 65, closed at its lower end by the valve 66 and at its upper end by the valve 67. These two valves 66 and 67 are of the same diameter and are rigidly mounted on the same spindle 68.

The valve 67 is arranged in a cylindrical recess 69 communicating with the atmosphere by a passage 70. In the cylindrical recess 69 it acts as a gas-tight piston, that is to say, that when open or closed, it forms an obstacle to communication between the chamber 65 and the atmosphere. It will be understood that the two valves 66 and 67 mounted on the same spindle 68 act as a balanced valve when the pressure existing in the cylinder 11 is the atmosphere pressure and that their lifting movement requires no effort, whatever may be the pressure existing in the reservoir 63 and, consequently, in the chamber 65.

The valve 66 guards the orifice 71 arranged in the fixed frame 10, which orifice 71 can communicate in certain positions of the cylinder 11 with the slit 72 arranged in this latter.

The reservoir 63 is also provided with a conduit 73 closed by a cock 74 whose plug can be actuated by means of a lever 75. On the other side of the cock 74 is a small automatic valve 76 closing the orifice of the passage 77.

This orifice 77 thus allows of communication between the reservoir 63 (through the tube 73, cock 74 and valve 76) and a cylinder 78, whose axis coincides with that of the spindle 68 of the valves 66 and 67.

In the cylinder 78 there can move a gas-tight piston 79 rigidly connected to the spindle 68 and pressed downwards by a calibrated spring 80.

It will be noticed that the recess 69 is separated from the cylinder 78 by a screw plug 81 and that there can be no communication between them.

A portion of the valve 76 has been shown on a large scale in Fig. 4. It will be seen that the valve 76 has a micrometric hole 82, which moreover opens into another micrometric hole 83 drilled perpendicular to the first and passing right through the valve 76.

The operation of the whole device will be explained later on.

*Auxiliary rotative device* (*Figs. 1 and 5*).—Although, in principle, the apparatus shown in Fig. 1 does not need any kinematic connection or any transformation of movement, it has been recognized that it might be useful in certain cases to have available a shaft revolving at a speed proportional to the number of reciprocations per second of the piston and cylinder. It is to be clearly understood that this shaft is not in any way intended to transmit energy to the exterior of the apparatus, but to allow of the linking up of certain apparatus found in commerce and in a rotative form. Such, for example, are, centrifugal governors, revolution counters which, in the present case, may be utilized for measuring the number of reciprocations, oil or water pumps, diagram recorders, etc.

To sum up, it is a question then of a device which is not essential to the working of the motor compressor unit, which should only consume an exceedingly small amount of power in comparison with the power used in compressing the air, but which may be convenient for studying the operation of the machine and for applying to it certain indispensable measuring and regulating apparatus. In the case of the motor compressor unit shown in Fig. 1 of the drawings, care has been taken to so construct the auxiliary rotative element that the oscillatory movements of the cylinder 11 shall be in no way hampered by the connection between it and the revolving shaft. It is desirable that this shaft should have a fairly uniform speed of rotation, but on the other hand, the oscillations of the cylinder, supposing it to be perfectly free would take place according to a kinematic law which it is too difficult to combine with any simple mechanism.

A mixed solution has therefore been adopted and a kinematic coupling device employed such that, supposing the shaft turns uniformly, the movement of the cylinder would closely approach the theoretical movement it would have if it were perfectly free. This theoretical movement is characterized by considerable accelerations at the beginning and end of the strokes and above all by a great difference in duration between the two successive strokes which form one complete oscillation.

The coupling device is therefore necessarily of the so-called "quick return" type, of which various forms are ordinarily employed in machine tools such as planing machines, shaping machines and the like, but it presents in this case the peculiarity that, conversely to what happens in machine tools, it is here the shaft which is driven instead of being the driving member.

On the other hand, as the movements caused by the device do not correspond exactly to the theoretical movement of a free cylinder, a certain freedom must be left to the cylinder in its connection with

the device, so as to prevent the transmission of any considerable amount of power to the exterior of the apparatus, which would have the effect of considerably diminishing the mechanical efficiency of the machine.

Fig. 5 is a section on a large scale of the cylinder head 13 and of the kinematic connections of the cylinder 11 and with the aid of which the following explanations will be easily understood.

In the cylinder head 13 is provided a cylindrical cavity 85 in which is arranged an axis 86 carrying two stops 87 and 88 between which a spring 89 is compressed by means of a nut 90. The whole is enclosed in the cavity 85 by means of a threaded tube 91 forming an abutment for the stop 88, whereas another tube 191 forms an abutment for the stop 87. The axis 86 is rigidly connected to a cylindrical piece 92 which has an easy sliding fit inside the sleeve 91. This piece 92 has a transverse axis 93 on which is pivoted the foot of connecting rod 94.

The connecting rod 94 is also pivoted at its other end 95 to the lugs 96 which are connected to a lever 97. The latter is itself pivoted around a fixed hollow axis 98 mounted in a casing integral with the general frame of the apparatus 10.

Besides this, said lever 97 is in form generally tubular and a piston, composed of two pieces 100—101, slides therein.

A crank 102, rigidly connected to the shaft to which the uniform rotary movement is required to be given, has its crank pin 103 held between the two halves 100—101 of the piston and it is capable of passing through the lever 97 in which slots such as 104 have been made for this purpose.

The crankshaft 102 actuates a centrifugal governor 225 acting through the rod 126 on the throttle valve 127 of the carburetter 27.

*Stabilization device.*—It is also necessary to redress perturbations which may occur in the movement of the apparatus and this is the object of the following stabilization device, whose operation will be explained later and which is shown in Fig. 5.

On the bottom of the cylinder head 13 there is fixed by means of several tubular screw bolts such as 105—106, a small reservoir of compressed air 107. This reservoir 107 communicates, on the one hand, through the inside of the bolt 105 and the passages 108 and 109 with the interior of the cylinder 11. This communication can be intercepted by means of an automatic valve 110 held on its seat by a spring 111.

On the other hand the reservoir 107 is provided with a flexible tube 135 fixed to the lever 97 and communicating with a passage 112 arranged inside of the said lever 97. The hollow axis 98 is provided with an orifice 113 which is capable of registering with the orifice 114 of the passage 112 when the lever 97 oscillates round its axis 98.

Finally, it will be seen in Fig. 1 that the hollow axis 98 communicates through its interior, by means of a tube 115, with the reservoir of compressed air 54.

*Safety device.*—It has been necessary to foresee also the case of a collision between the piston and the cylinder, on the side of the cylinder head 13.

Fig. 1 shows, to prevent this, several Belleville rings 116 arranged in a recess 117 provided for this purpose in the piston 14. These rings bear, on the one hand, on a piece 118 acting as a buffer and, on the other hand, on the body of the piston 14 by means of a special mounting easy to understand, and shown on Fig. 1.

Opposite the buffer 118 is fixed on the cylinder head 13, (Figs. 1 and 5) an abutment 119 carrying a hollowed out plate 120 whose object is to prevent, in the case of breakage of one of the valves 56, the possibility of any fragments of pieces of mechanisms falling into the interior of the cylinder 11.

On the other hand, the cylinder head 13 (Fig. 5) is adjusted to the cylinder 11 by a conical part 121, which ensures the tightness of the joint, and by a cylindrical part 122. Behind the cylinder head 13 are arranged several other Belleville rings 123, by means of which and the cover 124, the cylinder head 13 abuts against the cylinder 11 by means of the threaded ring 125.

It will be easily understood that in case of a collision between the buffer 118 of the piston 14 and the abutment 119 of the cylinder head 13, the Belleville rings 116 and 123 will act as shock absorbers and prevent damage to the machine.

*Oil injection device.*—In case it is desired to realize a combustion cycle instead of an explosion cycle, the spark plug 59 can be replaced by an injection device for fuel under pressure. This device 128 which has been shown diagrammatically in Fig. 6 has nothing novel as regards its operation. It is fed with oil under pressure by a flexible tube 129.

The injection nozzle 130 ends in a head 131 which meets, at the end of the stroke of the cylinder 11, a fixed stop 132 whose position can be regulated by means of the screw 133.

The apparatus described above operates in the following way:

The reservoir 63 being filled with compressed air at a suitable pressure, the piston 14 is so positioned that its edge, on the side towards the cylinder head 13, is flush with the ports 72 of the cylinder 11. This can

be done with the aid of a marked rod introduced into the cylinder 11 by the opening for the spark plug 59. Through this same opening a little gasoline in injected into the cylinder 11.

The piston 14 being positioned, the cylinder 11 is brought into a position marked beforehand, so that the openings 71 and 72 are in communication.

The lever 75 is then actuated so that the cock 74 brings the tube 73 into communication with the cylinder 78. The compressed air of the reservoir 63 raises the valve 76 and acts then on the piston 79 which is driven upwardly. The valve 66 gives passage to the compressed air from the reservoir 63, which fills the space included between the piston 14 and the cylinder head 13.

The piston 14 is then driven in the direction of the arrow 150 and the cylinder 11 in the direction of the arrow 151. The compressed air injected between these two parts expands. The pressure falls rapidly to the atmospheric pressure. The spring 80 tends then to bring back the piston 79 to its original position, driving before it the air filling the cylinder 78. This air can only be expelled through the micrometric openings 82 and 83 because the valve 76 has, at this moment, fallen back on its seat. The valve 66 then falls back slowly also on to its seat and so closes the communication between the reservoir 63 and the cylinder 11.

It will be understood that the device gives the following main results:

1. The opening of the orifices 71 is accomplished very rapidly and at a speed almost independent from the manner in which the lever 75 is actuated.

2. The time during which the injection of compressed air takes place is also independent from the manner in which the lever is acted on. This time depends solely on the calibration of the spring 79 and the size and shape of the micrometric orifices 82 and 83.

3. Finally, it will be understood that it is easy to regulate once for all the starting apparatus for a certain initial pressure in the reservoir 63, so as to start the piston 14 and the cylinder 11 with the necessary and appropriate force, which force is always the same.

The piston 14 and the cylinder 11, having been started as just explained, compress between them the air in the cylinder space enclosed between the piston 14 and the cylinder head 12. In the proximity of the dead point, the pawl 62 acts on the magneto 61. A spark flashes in the spark plug 59, igniting the gasoline charged compressed air.

From this instant on the motor compressor unit is in its normal working condition and we shall now study what takes place successively in each stroke, and on each side of the piston, during a complete reciprocation.

*Forward stroke.*

*Motor side.*—The explosion forces the piston 14 in the direction of the arrow 151 and the cylinder 11 in the direction 150. The expansion of the burnt gases goes on until the moment when the piston 14 reaches the exhaust ports 47, the pressure in the cylinder then being approximately equal to that of the surrounding atmosphere.

The ports 47 and 48 begin to coincide at the moment when the piston passes over them and at the same time the cam 23, acting on the valve 17, opens the orifice of the passage 15.

The movement of the piston 14 continues, but with a tendency to slacken, so that the burnt gases following it begin to escape through the openings 47 by reason of the speed they have acquired behind the piston. At the same time an indraught of air is caused through the passages 15, which scavenges the burnt gases still remaining in the cylinder. This pure air acquires also a certain speed which results in causing it to continue its scavenging movement, during the whole of the movement of the piston in the direction 151, between the openings 47 and the dead point.

During this forward stroke, the valve 32 is not lifted because at the moment of explosion the cylinder suddenly starts in the direction of the arrow 150, the result being that the piston 42 is made to slide into the position shown in Fig. 2. Therefore, when the roller 35 passes over the raised portion of the cam 36 the projection 46 cannot actuate the rocking lever 34. On the other hand, the spring 33 is sufficiently strong to prevent any movement of the valve 32 due to the effect of the expanding gases.

However, on arriving at the end of the stroke, the acceleration of the cylinder is reversed, and the piston 42 tends by its inertia, to continue its motion in the direction of the arrow 150 since, at that moment, the roller 35 has already passed the raised portion of the cam, and the pawl 43, therefore, is raised by the spring 45, and the piston 42 can pass under the projection 46 and finally occupies the position shown in Fig. 3.

The valve 16 has also remained on its seat, its mechanism being similar to that of the valve 32.

*Compressor side.*—The movement of the piston 14 and cylinder 11 has a result, the compression at first and afterwards the discharging, through the orifices 51 and 52, to the reservoir 54, of the air which filled the cylinder 11 at the beginning of the stroke. This air has not been able to escape through the exhaust orifices 47, because these only begin to coincide with the openings 48 when

the face of the piston towards the head 13 has already passed the openings 47.

It is advantageous to so calculate the apparatus that the damping of the reciprocal movement of the cylinder 11 and the piston 14 takes place during the discharge of the compressed air. That is to say, the movement of these parts ceases when their kinetic energy has produced the necessary work of discharge. The advantages of this arrangement will be explained in connection with the operation of the stabilization device.

It will be noticed that in case of breakage of a valve such as 56, a large portion of the air contained in the cylinder 11 would be driven out at the beginning of the stroke, through the passage 55 then communicating through the openings 57 with the atmosphere. Under these circumstances a very violent collision might take place between the piston 14 and the cylinder head 13. Although considerably deadened by the collision device above described, it might still be feared that such a violent encounter might cause serious damage to the machine.

The object of the safety valves 58 is precisely that of avoiding any escape of air by the passages 55 and the openings 57 which they close directly any air current, however insignificant, comes to pass. Under these circumstances the breakage of an intake valve no longer gives rise to a serious accident.

*Return stroke.*

*Compressor side.*—The cylinder 11 is forced back in the direction of the arrow 151 and the piston in that of the arrow 150 by the buffer of compressed air which is at the pressure of the reservoir 54 and has remained imprisoned between the piston 14 and the cylinder head 13 at the moment the movement has stopped.

When this buffer expands, its energy transforms itself into kinetic energy for the piston and cylinder. When the expansion has been carried to a point slightly below the atmospheric pressure, the automatic valves 56 open and permit the atmospheric air to fill the cylinder 11, because at this moment, owing to the movement of the cylinder 11 in the direction 151, the passages 55 communicate with the atmosphere through the openings 57.

Just as in the forward stroke, there can be no communication with the exhaust passage 50 because the ports 47 cease to register with the openings 48 as soon as the face of the piston opposite the head 13 reaches the ports 47.

*Motor side.*—The piston begins by driving before it the burnt gases which have followed it in its movement (in the direction 151) beyond the openings 47.

These burnt gases are forced to escape through the ports 47 because they encounter, opposite these ports, the current of pure air coming from the bottom of the explosion chamber.

Moreover, during the stroke of the piston 14 (in the direction 150) between the dead point and the exhaust ports 47, the valve 16 opens and allow a richly carburetted current of air to pass. The exact moment for the opening of said valve 16 is determined experimentally so that, on the one hand, the gaseous current to which it gives passage may sustain the movement of exhaust of the burnt gases mixed with the scavenging air and that, on the other hand, said gases may remain isolated from said ports 47 by a sufficient layer of pure air, up to the moment of the closing of the ports 47.

The movement of the piston 14 and of the cylinder 11 continuing, the ports 47 close immediately the piston passes them. The valves 16 then also close in turn.

There is then produced in the cylinder space included between the piston 14 and the cylinder head 12 a slight compression of the gaseous mixture therein enclosed. At this moment the storage valve 32 lifts, being actuated by the cam 36, the piston 42 being held by the projection 46 in the position of Fig. 3. A portion of the gaseous mixture is driven into the storage reservoir 154 through the tube 153, having a sliding fit with respect to said reservoir. The reservoir 154 is carried by a portion of the fixed frame 10, or some other relatively fixed structure. The carburetor 27, tube 26, and cams 36, 22 and 23 are all similarly supported.

It should further be noticed that the storage reservoir 154 communicates by a tube 155 with the carburetor 27. Therefore, this same gas, sufficiently enriched with combustible will be used in the injection of highly carburetted air, which injection takes place through the passage 14′ during the next return stroke.

The storing, as carried out in this apparatus, causes therefore no loss of combustible.

When the piston 14 passes before the opening 31, the valve 32 falls back on to its seat owing to the setting of the cam 36. The carburetted gases remaining in the cylinder space are then strongly compressed up to their ignition, which may be produced either by the spark plug 59 and the magneto 61 actuated by the pawl 62 in the proximity of the dead point, or by a compression carried far enough to cause self ignition.

It should be noted that on arriving at the end of its stroke the cylinder 11 is braked strongly by the work of compressing the gaseous mixture. The inertia of the piston 42 tends to cause it to continue moving in the direction of the arrow 151, and, as the roller 35 is bearing on the rectilinear portion

of the cam 36, said piston is able to pass under the projection 46 and to take up the position shown in Fig. 2.

The devices for auxiliary rotation and security against shocks have been sufficiently explained previously and it would be superfluous to dwell now on their mode of operation.

*Operation of the stabilization device.*— The foregoing explanations have disclosed the normal operation of the motor compressor unit. In practice, in view of the complete liberty left to the movements of the cylinder 11 and the piston 14, it has to be considered what would happen in case something arose to disturb the operation of the apparatus.

It must first be remarked that, in the forward stroke (direction of the arrow 150 for the cylinder and 151 for the piston 14) the movements of the piston and cylinder have been so calculated that the work of expansion of the burnt gases, at first transformed partially into kinetic energy of the oscillating parts, is found again in the end under three forms: work of compression, work of discharge into the reservoir 54, work stored up in the buffer.

A similar balance for the return stroke (direction 151 for the cylinder 11 and 150 for the piston 14) shows that the work of expansion of the buffer should be equal, or very nearly so, to the work of storage and compression preliminary to the explosion of the gases intended for combustion.

If any accidental cause should arise to upset these balances the piston 14 and the cylinder 11 will perform abnormal strokes, whose amplitude and frequency will be different from those provided for in the calculation of the apparatus.

Supposing, for example, a sudden and accidental enrichment of the explosive mixture, the following phenomena will take place.

First forward stroke: The piston receiving a greater impulse than that provided for will compress the buffer at the end of its stroke with a pressure higher than the compression pressure, that is to say, higher than that in the reservoir 54.

First return stroke: The piston will be returned towards the cylinder head 12 by a too powerful buffer; at the end of its stroke it will impart an exaggerated compression to the explosive mixture. The explosion thus produced will be still more violent than its predecessor, etc.

If the effects of a sudden and accidental impoverishment of the explosive mixture are studied, the following conclusions will be arrived at.

First forward stroke: The piston 13 will not have received sufficient energy to discharge from the cylinder 11 into the reservoir 54 the expected quantity of compressed air. At the end of its stroke there will remain therefore an air buffer which will have, it is true, the pressure in the reservoir 54, but whose volume will be greater than the volume expected.

First return stroke: The piston 14 is returned by the buffer towards the cylinder head 12, receiving during this stroke an exaggerated impulse owing to the volume of air in the buffer having been increased while its pressure has remained equal to that in the reservoir 54. At the end of its stroke the piston will compress the explosive mixture to too great a pressure.

It is seen therefore that the consequences of a diminution in the force of the explosion are, by the end of an oscillation, exactly the same as those due to an increase in such force.

The above given explanations have shown that the operation of the apparatus, as so far described, is unstable. In other words, and to sum up, if any disturbing cause should arise to upset the normal operation of the oscillating system, even if this cause should immediately disappear, said oscillating system would not tend of its own accord to return to its equilibrium, but on the contrary would tend to depart from it more and more.

The stabilization device which has been described is intended to remedy this drawback. It will now be explained how it works, supposing a sudden and accidental increase in the force of the explosion should take place. The case of a diminution in such force need not be considered, as it results, in the following oscillation, in an increase of the preliminary compression and, finally, in an increase in the force of the explosion.

Suppose that the piston has been driven in the direction of the arrow 151 and the cylinder in that of the arrow 150 by the expansion of burnt gases arising from an abnormally rich charge.

The piston 14 and the cylinder 11 will, to a certain extent pass beyond the position corresponding to their theoretical dead points. Consequently, the buffer compressed between them will be, as already explained, at a greater pressure than that in the reservoir 54.

But when the pressure of the compressed air exceeds the normal compression pressure, the valve 110 (Fig. 5) lifts, and puts the dead space of the cylinder 11 into communication with the auxiliary reservoir 107. This latter is absolutely isolated at this moment from the exterior, as the lever 97 occupies the position shown in Figure 5, and the orifice 114 is not opposite the orifice 113.

Under these circumstances, the oscillating parts absorb the excess of kinetic energy,

not through the work of compression of the buffer comprised in the cylinder 11, but through a work of compression acting both on the air in said cylinder and on that in the auxiliary reservoir 107.

When the movement of the oscillating system stops and reverses, the non-return valve 110 closes the passage 109 and the only buffer which, on expansion, can act on the piston and cylinder is that remaining in the cylinder 11 between the piston 14 and the cylinder head 12, at the moment when the valve 110 has fallen back on its seat.

The piston 14 and the cylinder 11 perform therefore their return stroke under the impulse of a buffer of lesser mass than the normal buffer, but whose pressure is, on the other hand, superior to the normal. It is easy to imagine that the expansion of such a buffer may be equivalent to that of the theoretical buffer and that, consequently, the operations of the return stroke can be correctly performed.

As a matter of fact, a detailed calculation shows that, as a general rule, the deadening of the abnormal oscillation and the return to the theoretical operation are not achieved in one single stroke, but, if the capacity of the auxiliary reservoir 107 has been suitably chosen, as a function of the normal volume of the dead space, stability of operation of the apparatus is obtained; any disturbance in the normal operation of the apparatus is corrected in a small number of oscillations.

It should be noted that during the return stroke of the piston 14 and the cylinder 11, the lever 97 swings in the direction of the arrow 151 under the influence of the connecting rod 94. At a given moment, the openings 114 are in registry with the ports 113. Communication is thus established between the auxiliary reservoir 107 and the reservoir 54 by means of the passages 135, 112 and 115. In this way the pressure of the air contained in the reservoir 107 is automatically brought back to the compression pressure which is also, it must not be forgotten, that of the normal buffer. The device is thus ready to work again normally, from the following oscillation onwards.

*Operation of the device for injecting combustible oil.*—The apparatus so far described can also be operated according to the combustion cycle, described at the beginning of the present specification, by making three slight variations in its arrangement. Thus the cylinder head 12 should be provided with the fittings shown in Figure 6 and previously described, in place of the spark plug 59. The carburetter 27 will be removed and a direct communication will be established between the reservoir 154 and the tube 26.

Oil injection takes place at the end of the compression stroke of the piston and cylinder, the cylinder 11 moving as already described in the direction of the arrow 151 and the piston in that of the arrow 150. The injection needle 130 is raised at the end of the stroke when its head 131 comes into contact with the fixed adjustable stop 132. The injection device, which may be of any commercial type, causes the atomization and projection of the combustible oil into the cylinder 11 where combustion takes place.

It is unnecessary to describe the working of the rest of the motor compressor unit in this case, all its parts, with the exception of the omitted carburetter 27, operating under similar conditions to those described above for the explosion cycle.

I claim:

1. In an apparatus comprising a cylinder and a piston reciprocating in said cylinder the combination of means for permitting expansion of burnt gases down to a pressure approximately that of the surrounding atmosphere; means for sucking in from the atmosphere a certain quantity of pure air which enters the cylinder in the proximity of the combustion chamber and is drawn along in the wake of the burnt gases; means for injecting at a low pressure, in the wake of the pure air previously introduced, a suitable quantity of carburetted air, in such a way that on the one hand the burnt gases remaining at this moment in the machine are separated from the carburetted air by a cushion of pure air, and on the other hand that the carburetted air can never reach the exhaust ports of the machine; means for simultaneously expelling the burnt gases from the cylinder, which expulsion is produced both by the speed acquired by the burnt gases, as they follow the movement of the piston and also by the return motion of this latter which terminates said expulsion; means for compressing, at a low pressure, and discharging from the cylinder a part of the fresh gas previously admitted, a storing reservoir into which said fresh gas is discharged at a low pressure, whose contents, suitably carburetted, are used to produce the injection of carburetted air at the aforesaid low pressure; means for compressing the gases remaining in the cylinder and means for electrically igniting the compressed mixture.

2. In an apparatus comprising a cylinder and a piston reciprocating in said cylinder the combination of means for permitting expansion of burnt gases down to a pressure approximately that of the surrounding atmosphere; means for sucking in from the atmosphere a certain quantity of pure air which enters the cylinder in the proximity of the combustion chamber and is drawn along in the wake of the burnt gases; means for injecting at a low pressure, in the wake of the pure air previously introduced, a suitable quantity of carburetted air, in such

a way that on the one hand the burnt gases remaining at this moment in the machine are separated from the carburetted air by a cushion of pure air, and on the other hand that the carburetted air can never reach the exhaust ports of the machine; means for simultaneously expelling the burnt gases from the cylinder, which expulsion is produced both by the speed acquired by the burnt gases, as they follow the movement of the piston and also by the return motion of this latter which terminates said expulsion; means for compressing at a low pressure, and discharging from the cylinder a part of the fresh gas previously admitted, a storing reservoir into which said fresh gas is discharged at a low pressure, whose contents, suitably carburetted, are used to produce the injection of carburetted air at the aforesaid low pressure; means for compressing the gases remaining in the cylinder, to such a pressure that self ignition of the charge is produced.

3. In an apparatus comprising a cylinder and a piston reciprocating in said cylinder, producing motive energy on one and the same side of the piston, by the combination of means for permitting expansion of burnt gases down to a pressure approximately that of the surrounding atmosphere; means for sucking in from the atmosphere a certain quantity of pure air which enters the cylinder in the proximity of the combustion chamber and is drawn along in the wake of the burnt gases; means for injecting at a low pressure, in the wake of the pure air previously introduced, a suitable quantity of carburetted air, in such a way that on the one hand the burnt gases remaining at this moment in the machine are separated from the carburetted air by a cushion of pure air, and on the other hand that the carburetted air can never reach the exhaust ports of the machine; means for simultaneously expelling the burnt gases from the cylinder, which expulsion is produced both by the speed acquired by the burnt gases as they follow the movement of the piston and also by the return motion of this latter which terminates said expulsion; means for compressing, at a low pressure, and discharging from the cylinder a part of the fresh gas previously admitted, a storing reservoir into which said fresh gas is discharged at a low pressure, whose contents, suitably carburetted, are used to produce the injection of carburetted air at the aforesaid low pressure; means for compressing the gases remaining in the cylinder and means for electrically igniting the compressed mixture; and means for admitting, compressing and discharging air on the non-motive side of the piston.

4. In an apparatus comprising a cylinder and a piston reciprocating in said cylinder, producing motive energy on one and the same side of the piston by the combination of means for permitting expansion of burnt gases down to a pressure approximately that of the surrounding atmosphere; means for sucking in from the atmosphere a certain quantity of pure air which enters the cylinder in the proximity of the combustion chamber and is drawn along in the wake of the burnt gases; means for injecting at a low pressure, in the wake of the pure air previously introduced, a suitable quantity of carburetted air, in such a way that on the one hand the burnt gases remaining at this moment in the machine are separated from the carburetted air by a cushion of pure air, and on the other hand that the carburetted air can never reach the exhaust ports of the machine; means for simultaneously expelling the burnt gases from the cylinder, which explosion is produced both by the speed acquired by the burnt gases, as they follow the movement of the piston, and also by the return motion of this latter which terminates said expulsion; means for compressing at a low pressure and discharging from the cylinder a part of the fresh gas previously admitted, a storing reservoir into which said fresh gas is discharged at a low pressure, whose contents, suitably carburetted, are used to produce the injection of carburetted air at the aforesaid low pressure; means for compressing the gases remaining in the cylinder to such a pressure that self ignition of the charge is produced; and means for admitting, compressing and discharging air on the non-motive side of the piston.

5. In an apparatus comprising a frame, a cylinder and a piston reciprocating in said cylinder said cylinder being mechanically free to reciprocate with respect to said frame, a distributing device for the ports of said cylinder, said device comprising a valve for one of said ports, a rocking lever pivoted to the cylinder, a fixed cam, a pawl pivoted to said lever and cooperating with said cam, a locking member for locking said pawl to said lever, said locking member being free to slide by inertia in said rocking lever in a direction parallel to that of the cylinder.

6. In an apparatus comprising a frame, a cylinder and a piston reciprocating in the cylinder, said cylinder being free to reciprocate in the frame, a port in the cylinder, a valve in the port, and means for operating the valve comprising a rocking lever pivoted on the cylinder, a fixed cam, a pawl pivoted on the lever, a spring for holding one end of the pawl in engagement with the cam, a passage in the lever, and a member free to slide in this passage in a direction substantially parallel to the movements of the cylinder, a portion of the pawl moving into and out of this passage as the pawl follows the

contour of the cam, whereby the pawl is free to move independently of the lever when the sliding member is at one end of the passage and out of the path of movement of the pawl, but the pawl and lever are locked against independent movement when the member is at the other end of the passage.

7. In an apparatus comprising a frame, a cylinder and a piston reciprocating in the cylinder, said cylinder being free to reciprocate in the frame, a port in the cylinder, a valve in the port, and means for operating the valve comprising a rocking lever pivoted on the cylinder, a fixed cam, a pawl pivoted on the lever, a spring for holding one end of the pawl in engagement with the cam, and a member thrown by its own inertia from one position to another by the movements of the cylinder, this member being in the path of movement of the pawl in one position to lock the pawl and lever against independent movement.

8. In a motor compressor unit, comprising a cylinder and a piston reciprocating in said cylinder a starting device comprising means for injecting from a reservoir compressed air behind the motor piston on the compression side, said device comprising a cock, a piston loaded by a spring, a balanced valve connected to said piston and controlling a port in the cylinder, said cock admitting air from said reservoir under said piston, and a non-return valve between said cock and said piston and vents in said valve.

9. A motor compressor unit comprising a cylinder and a piston reciprocating in said cylinder, a reservoir for air under pressure, one end portion of the cylinder being provided with a valved air inlet, and a valved air outlet to said reservoir, the piston in its travel to this end of the cylinder being adapted to compress air and force same into the reservoir, the end of the cylinder beyond the outlet to the reservoir confining air which serves as a gaseous buffer, the piston being returned by the expansion of this gaseous buffer, and means for limiting the maximum energy stored in this gaseous buffer.

10. A motor compressor unit comprising a cylinder and a piston reciprocating in said cylinder, a reservoir for air under pressure, one end portion of the cylinder being provided with a valved air inlet, and a valved air outlet to said reservoir, the piston in its travel to this end of the cylinder being adapted to compress air and force same into the reservoir, the end of the cylinder beyond the outlet to the reservoir confining air which serves as a gaseous buffer, the piston being returned by the expansion of this gaseous buffer, and auxiliary connections between the reservoir and this gaseous buffer.

11. A motor compressor unit comprising a cylinder, a piston reciprocating in said cylinder, and a main reservoir for compressed air, a device for controlling the rate of the reciprocations of the piston, said device consisting of an auxiliary reservoir for compressed air, connections between said auxiliary reservoir and the cylinder end on the compressor side, comprising automatic non-return valves, and means for re-establishing in said auxiliary reservoir, at each stroke, the pressure existing in the main reservoir of the compressor.

12. A motor compressor unit, comprising a cylinder and a piston reciprocating in said cylinder, a safety device adapted to prevent damage to the machine in case of an accidental collision between the piston and the bottom of the cylinder, said device consisting in an elastic buffer mounted on the piston, an abutment on the head of the cylinder and an elastic connection between said head and said cylinder.

13. In a motor compressor unit comprising a cylinder and a piston reciprocating in said cylinder, air inlets for the compressor, valves for said air inlets on the compressor side, and non-return valves between said first-named valves and the atmosphere.

14. In an apparatus comprising a frame, a cylinder, a piston reciprocating in said cylinder, said cylinder being mechanically free to reciprocate with respect to said frame, an auxiliary shaft, a "quick-return" device connected to said shaft and to said cylinder and an elastic connection between said device and said cylinder.

15. In an apparatus comprising a frame, a cylinder, a piston reciprocating in said cylinder, said cylinder being mechanically free to reciprocate with respect to said frame; ports in said cylinder, tubes connected to said ports, and communicating chambers on said frame, each of said tubes having a sliding air-tight fit in one of said chambers, so as to form a fluid circulating passage from said movable cylinder to and through said fixed chambers and thence back to the cylinder.

16. In an apparatus comprising a cylinder and a piston reciprocating in said cylinder, a carburetter, inlet and outlet connections from said carburetter to one end portion of the cylinder, an air inlet in this end portion of the cylinder, valves in these connections, and automatic means for operating the valves whereby during the expansion stroke of the piston carburetted air is admitted to the cylinder under low pressure, and pure air is drawn in, the mixture is compressed on the succeeding compression stroke of the piston, and a portion of this compressed mixture is returned to the carburetter for injection during the next expansion stroke.

17. In an apparatus comprising a cylinder and a piston reciprocating in said cylinder, a carburetter, a storage chamber com-

municating with the carburetter, passages from the cylinder to the storage chamber, and from the carburetter to the cylinder, valves in these passages, and automatic means for operating the valves.

18. In an apparatus comprising a cylinder, a frame, and a piston reciprocating in said cylinder, the cylinder being mounted to reciprocate in the frame, a carburetter mounted on the frame, fluid passages leading from one end portion of the cylinder to the carburetter and from the carburetter back to this end of the cylinder, and automatic valves in the passages, the passages being extensible to permit the movement of the cylinder.

19. In an apparatus comprising a cylinder, a frame, and a piston reciprocating in said cylinder, the cylinder being mounted to reciprocate in the frame, a carburetter mounted on the frame, a storage chamber mounted on the frame and connected with the carburetter, a passage from the cylinder to the storage chamber, a passage from the carburetter to the cylinder, valves in these passages, and means for controlling the valves operated by the movements of the cylinder.

20. In an apparatus comprising a cylinder, a frame, and a piston reciprocating in said cylinder, the cylinder being mounted to reciprocate in the frame, a carburetter mounted on the frame, a storage chamber mounted on the frame and connected with the carburetter, a passage from the cylinder to the storage chamber, a passage from the carburetter to the cylinder, valves in these passages, fixed cams carried by the frame, and means including rockers mounted on the cylinder and engaging the cams for controlling the valves.

21. In a motor compressor unit comprising a frame, a closed cylinder, and a piston reciprocating in said cylinder, said cylinder being mechanically free to reciprocate with respect to said frame; means for producing an expansive force on one side of said piston within said cylinder, means for simultaneously compressing air on the other side of said piston and means for discharging said compressed air at such a pressure that the reciprocal deadening of the relative movements between the cylinder and the piston is equal to the work of compression and discharge of the air, less the work of restoring the piston and cylinder to their initial position.

22. In a motor compressor unit comprising a frame, a closed cylinder and a piston reciprocating in said cylinder, said cylinder being mechanically free to reciprocate with respect to said frame, means for producing an expansive force on one side of said piston within said cylinder, means for simultaneously compressing air on the other side of said piston, means for discharging a portion of said compressed air at such a pressure that the reciprocal deadening of the relative movements between the cylinder and the piston is equal to the work of compression and discharge of the air, and means for imprisoning the remaining portion of said compressed air between the piston and the corresponding cylinder end, at the same pressure so that its expansion may restore the piston and cylinder to their initial position.

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municating with the carburetter, passages from the cylinder to the storage chamber, and from the carburetter to the cylinder, valves in these passages, and automatic means for operating the valves.

18. In an apparatus comprising a cylinder, a frame, and a piston reciprocating in said cylinder, the cylinder being mounted to reciprocate in the frame, a carburetter mounted on the frame, fluid passages leading from one end portion of the cylinder to the carburetter and from the carburetter back to this end of the cylinder, and automatic valves in the passages, the passages being extensible to permit the movement of the cylinder.

19. In an apparatus comprising a cylinder, a frame, and a piston reciprocating in said cylinder, the cylinder being mounted to reciprocate in the frame, a carburetter mounted on the frame, a storage chamber mounted on the frame and connected with the carburetter, a passage from the cylinder to the storage chamber, a passage from the carburetter to the cylinder, valves in these passages, and means for controlling the valves operated by the movements of the cylinder.

20. In an apparatus comprising a cylinder, a frame, and a piston reciprocating in said cylinder, the cylinder being mounted to reciprocate in the frame, a carburetter mounted on the frame, a storage chamber mounted on the frame and connected with the carburetter, a passage from the cylinder to the storage chamber, a passage from the carburetter to the cylinder, valves in these passages, fixed cams carried by the frame, and means including rockers mounted on the cylinder and engaging the cams for controlling the valves.

21. In a motor compressor unit comprising a frame, a closed cylinder, and a piston reciprocating in said cylinder, said cylinder being mechanically free to reciprocate with respect to said frame; means for producing an expansive force on one side of said piston within said cylinder, means for simultaneously compressing air on the other side of said piston and means for discharging said compressed air at such a pressure that the reciprocal deadening of the relative movements between the cylinder and the piston is equal to the work of compression and discharge of the air, less the work of restoring the piston and cylinder to their initial position.

22. In a motor compressor unit comprising a frame, a closed cylinder and a piston reciprocating in said cylinder, said cylinder being mechanically free to reciprocate with respect to said frame, means for producing an expansive force on one side of said piston within said cylinder, means for simultaneously compressing air on the other side of said piston, means for discharging a portion of said compressed air at such a pressure that the reciprocal deadening of the relative movements between the cylinder and the piston is equal to the work of compression and discharge of the air, and means for imprisoning the remaining portion of said compressed air between the piston and the corresponding cylinder end, at the same pressure so that its expansion may restore the piston and cylinder to their initial position.

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## Certificate of Correction.

**Patent No. 1,629,927.** Granted May 24, 1927, to

RAUL PATERAS PESCARA.

**It is hereby certified that error appears in the printed specification of the above-numbered patent requiring correction as follows: Page 9, line 85, for the word "explosion" read *expulsion;* and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.**

**Signed and sealed this 28th day of June, A. D. 1927.**

[SEAL.]

M. J. MOORE,
*Acting Commissioner of Patents.*

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