

April 17, 1928.

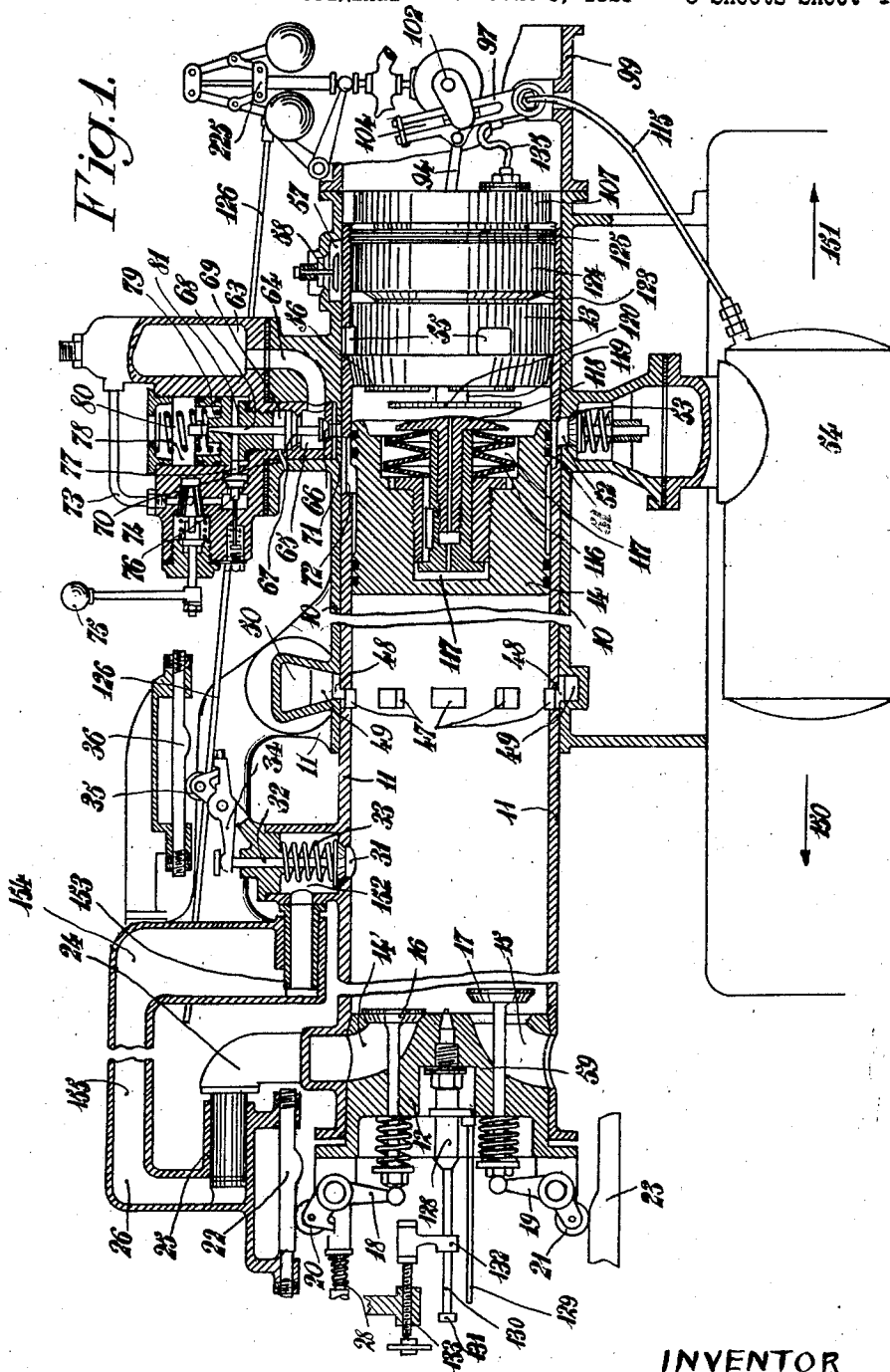
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R. P. PESCARA

MOTOR COMPRESSOR APPARATUS

Original Filed June 5, 1925

3 Sheets-Sheet 1



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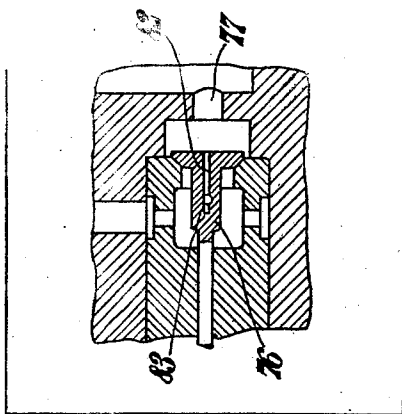
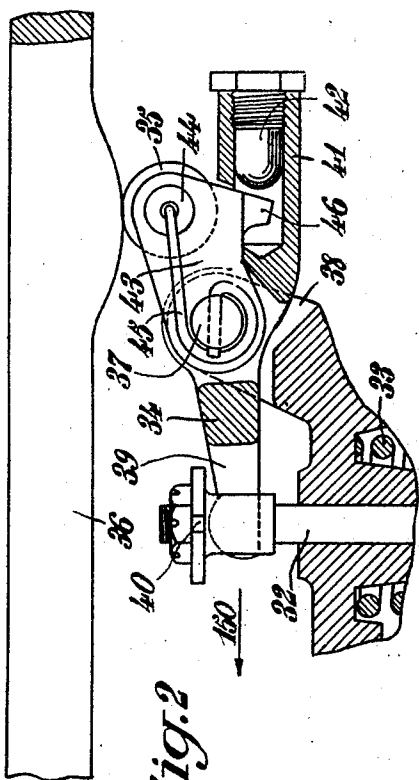
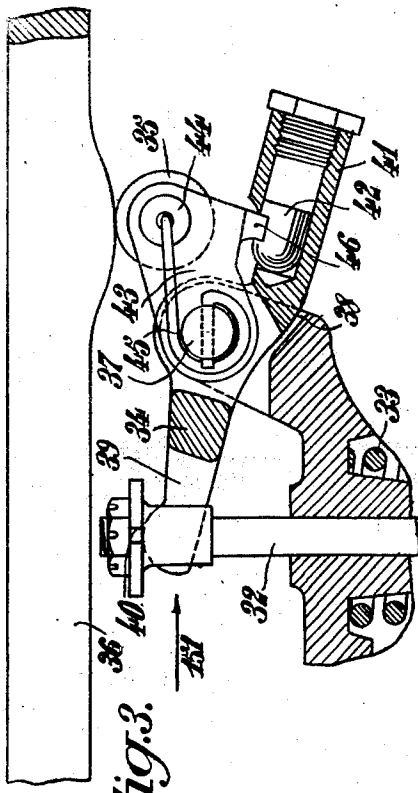
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Fig. 4.



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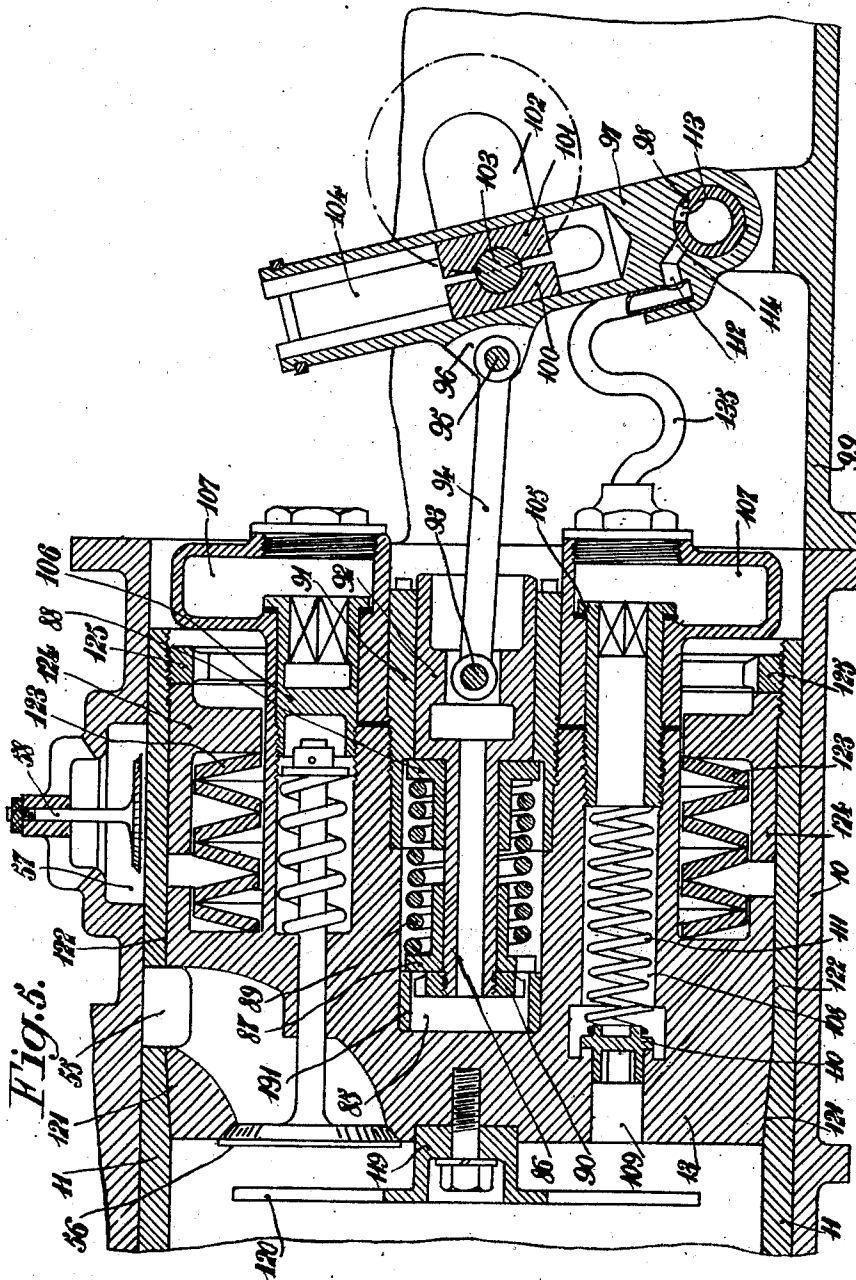
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Original Filed June 5, 1925 3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE.

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MOTOR-COMPRESSOR APPARATUS.

Original application filed June 5, 1925, Serial No. 35,249, and in France June 11, 1924. Divided and this application filed January 8, 1927. Serial No. 159,853.

This is a division from my application Serial No. 35,249 filed on the 5th June, 1925.

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 thermo-dynamic 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, combustion taking place under constant pressure.

The present invention consists essentially in carrying out the following operations inside a cylindrical space, whose volumetric capacity 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 pressure, carrying the expansion down to a pressure eventually equal to 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 movement 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 air at a low pressure for scavenging the cylinder.

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 pure air.

6. 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.

7. Compressing the air remaining in the cylinder until the desired pressure is ob-

tained, and injecting 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.

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, 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 valve 16-17, whose movements are controlled by the bent rocking levers 18-19, which are pivoted on the cylinder head 12 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 end portion of the oscillating cylinder 11 to be placed in communication with a storage reservoir 154 by means of the pipings 14', 24, 25, 26 and 155, the piping 26 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 another application for patent filed by me on the 5th June, 1925, Serial No. 35,250, or may be similar to the lever 34, hereinafter described and shown in detail in Figs. 2 and 3. This 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-actuated 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 head 12 is provided with a device for injecting fuel under pressure. This device 128, which has been shown only diagrammatically, has nothing novel as regards its construction and operation. It is fed with oil under pressure through 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, towards the right (arrow 151) a fixed stop 132 whose position can be regulated by means of the screw 133.

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 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 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 substantially 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 rig-

idly 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 10 of the apparatus.

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

A crank shaft 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 125 acting through the rod 126 on the supply of combustible oil.

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 annular spring 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 or pieces of mechanism 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 spring 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 rings 116 and 123 will act as shock absorbers and prevent damage to the machine.

The apparatus described above operates in the following way:

The reservoir 63 being filled with compressed air as at 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 through an opening in the head 12 closed by a suitable plug (not shown). Through this same opening a little gasoline is 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 80 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 pressure is sufficient to ignite the gasoline charged compressed air.

From this instant on, the compressor motor 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 eventually 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 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 as 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.

5 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 10 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 open- 15 ings 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 20 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) be- 25 yond 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 combustion 30 chamber.

Moreover, during the stroke of the piston 14 (in the direction 150) between the dead point and the exhaust ports 47, the valves 16 open and allow a current of air to pass. 35 The exact moment for the opening of said valves 16 is determined experimentally so that the air current to which they give passage may sustain the movement of exhaust of the burnt gases mixed with the scavenging 40 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 45 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 air therein enclosed. At this moment the 50 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 air is driven into the storage reservoir 154 through the tube 153 having a 55 sliding fit with respect to said reservoir. The reservoir 154 is fixed and carries the fixed cam 36. The whole structure comprising the cam 36, the reservoir 154, the tubes 155 and 26, the cams 22 and 23, and 60 the fixed stop 132, 133 is a fixed structure rigidly connected (in the manner shown) to some fixed base such as the frame 10 of the machine.

It should further be noticed that the storage reservoir 154 communicates by a tube

155 with the tube 26. Therefore, this same air, is injected through the passage 14' during the next return stroke.

When the piston 14 passes before the opening 31, the valve 32 falls back on to 70 its seat owing to the setting of the cam 36. The air remaining in the cylinder space is then strongly compressed. Oil injection takes place at the end of the stroke. The injection needle 130 is raised at the end of 75 the stroke when its head 131 comes into contact with the fixed adjustable stop 132. The injection device, which is of any commercial type, causes the atomization and projection of the combustible oil into the 80 cylinder 11, where combustion takes place due to the heat of compression.

It should be noted that on arriving at the end of its stroke the cylinder 11 is braked 85 strongly by the work of compressing the air. 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 90 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 op- 95 eration.

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 100 cylinder 11 and the piston 14 it has to be considered what would happen in case something arose to disturb the operation of the 105 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 110 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 115 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 120 expansion of the buffer should be equal, or very nearly so, to the work of storage and compression preliminary to the combustion.

If any accidental cause should arise to 125 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.

Supporting, for example, a sudden and 130

accidental increase in the force generated by the combustion 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 air. The combustion thus produced will be still more powerful than its predecessor, etc.

If the effects of a sudden and accidental decrease in the force generated by the combustion 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 air for combustion to too great a pressure.

It is seen therefore that the consequences of a diminution in the force of the combustion 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 combustion 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 combustion.

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 strong combustion.

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.

I claim—

1. In an apparatus comprising a frame, a cylinder, and a free piston reciprocating in said cylinder, said cylinder being mechanically free to reciprocate with respect to said frame, means for injecting into said cylinder a combustible oil under pressure, said means consisting in an injection needle valve mounted on the cylinder head, a stop on said needle and a fixed abutment cooperating with said stop.

2. In an apparatus comprising a frame, a cylinder, and a free piston reciprocating in said cylinder, said cylinder being mechanically free to reciprocate with respect to said frame, means for injecting into said cylinder a combustible oil under pressure, said means consisting in an injection needle valve mounted on the cylinder head, a stop on said needle, a fixed abutment cooperating with said stop, and means for adjusting the position of said abutment.

3. In an apparatus comprising a cylinder and a free piston reciprocating in said cylinder, one end portion of the cylinder serving as a combustion chamber, the combination of means for permitting the escape of burned gases after they have expanded down to a pressure approximately that of the surrounding atmosphere, means for admitting 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 burned

gases, means cooperating with the piston and cylinder for compressing and discharging out of the cylinder a part of the pure air it contains, the air thus discharged being evacuated into a storing reservoir at a low pressure, the contents of the reservoir being utilized to produce the aforesaid scavenging at a low pressure, the air remaining in the cylinder being compressed by the piston, and means for injecting into the combustion chamber and burning oil under pressure, and other means cooperating with the piston and the other end portion of the cylinder for storing energy developed by the moving piston.

4. In an apparatus comprising a cylinder and a free piston reciprocating in said cylinder, one end portion of the cylinder serving as a combustion chamber, the combination of means for permitting the escape of burned gases after they have expanded down to a pressure approximately that of the surrounding atmosphere, means for admitting 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 burned gases, means cooperating with the piston and cylinder for compressing and discharging out of the cylinder a part of the pure air it contains, the air thus discharged being evacuated into a storing reservoir at a low pressure, the contents of the reservoir being utilized to produce the aforesaid scavenging at a low pressure, the air remaining in the cylinder being compressed by the piston, and means for injecting into the combustion chamber and burning oil under pressure, and other means cooperating with the piston and the other end portion of the cylinder for admitting, compressing and discharging air.

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