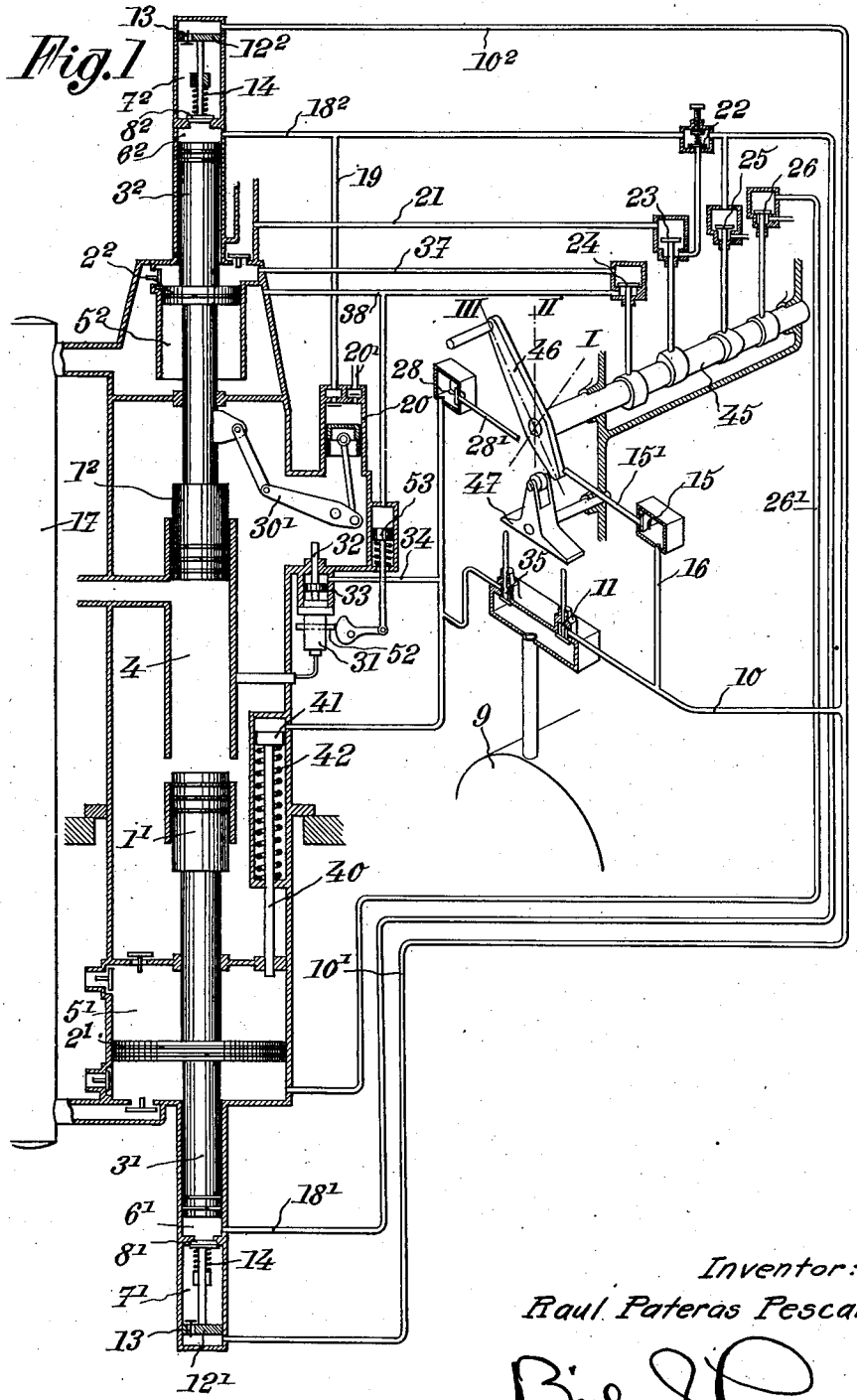
Aug. 8, 1939. R. PATERAS PESCARA 2,168,828

STARTING MEANS FOR FREE PISTON MOTOR COMPRESSORS

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Fig. 1



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Fig. 2

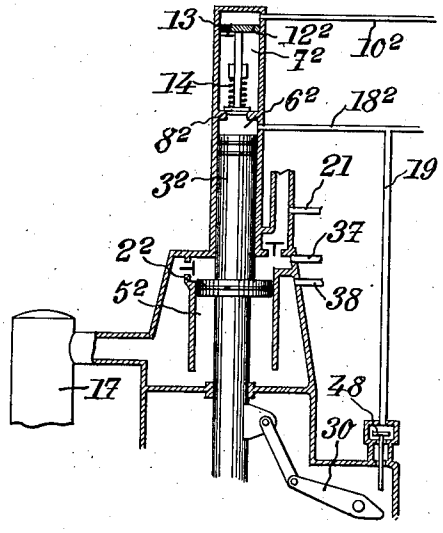
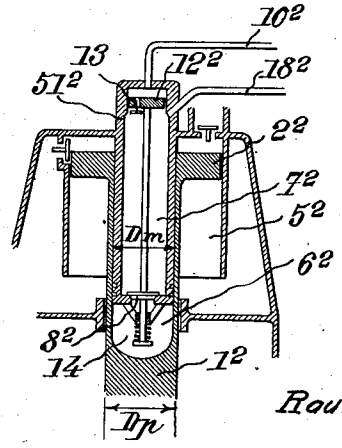


Fig. 3



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UNITED STATES PATENT OFFICE

2,168,828

STARTING MEANS FOR FREE PISTON MOTOR COMPRESSORS

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In Belgium July 15, 1935

21 Claims. (Cl. 230—56)

This invention relates to internal-combustion motor-compressor units of the free and opposed piston type and more particularly to starting and stabilizing means applicable to said devices; and it relates still more particularly to improvements in certain starting and stabilizing means disclosed in my co-pending application Ser. No. 707,595, which means consisted, namely, in pneumatic energy storing means or accumulators whose mean effective pressure was higher during the starting up and transition period lasting until said motor-compressor has reached its normal operating regime, than the mean pressure under which said energy storing means co-operate with the stabilizing means in normal operation.

My above-mentioned co-pending application related mainly to engines of the type in question provided with energy storing means or accumulators operating under substantially constant pressure during at least part of the stroke of the reciprocating piston assemblies.

The main purpose of my invention is to make said means also applicable to motor-compressors of the type in question provided with energy storing means in which the pressure is more or less variable during all or part of the stroke of the reciprocating piston assemblies, while their construction and operation are simplified.

The principal object of my invention is to provide, in an internal-combustion motor-compressor unit of the free and opposed piston type, energy storing stabilizing means adapted to propel the motive pistons during the initial starting up period, and adapted, during the subsequent warming up period, and until the motor-compressor unit has reached its normal operating regime, to function under mean effective pressures substantially higher than those required in said stabilizing means in normal operation, and means for progressively reducing said mean effective pressures in said stabilizing means, as the pressure in the compressed gas storage reservoir increases, said pressure-reducing means being adapted to reduce the amount of air in said stabilizing means gradually as the total energy available for the return stroke exceeds allowable limits.

Another object is to provide, in a motor-compressor of the type described, means for reducing the mean pressure in said stabilizing means during the warming up period, by connecting same to the suction of one of the pressure stages or of the auxiliary starting compressor.

A further object is to provide, in a motor-compressor of the type described, means for reducing the mean pressure in said stabilizing means during the warming up period adapted to release air from said stabilizing means whenever the return stroke of the pistons exceeds the normal inner dead center.

A still further object is to provide, in a motor compressor of the type described, energy-storing stabilizing means, and means for compensating the leakage of compressed fluid from said stabilizing means, by placing the same, at each stroke, in communication with a source of fluid under pressure, for example with the high-pressure delivery either directly or through the medium of a pressure reducing valve.

A still further object is to provide, in a motor compressor of the type described, means for permanently applying the suction pressure of pressure stages higher than the first to the inactive or rear faces of the compressor pistons in said stages, for the purpose of effecting, after the shut down of the unit, the return of the pistons to their outer dead centers.

A still further object is to provide, in a motor compressor of the type described, pneumatic means for instantly and automatically returning the motive pistons to their outer dead centers, after the shut down of the unit.

Other objects and advantages of my invention will appear to one skilled in the art from the following description with reference to the accompanying drawings, which description and drawings are, of course, given by way of illustration, and should not be construed as limiting the scope of the invention.

In these drawings:

Fig. 1 illustrates diagrammatically a two-stage free piston motor-compressor unit embodying my invention.

Figs. 2 and 3 illustrate two variants of the same.

In one of the preferred embodiments of my invention concerning more particularly a two-stage free-piston motor-compressor unit, as illustrated in Fig. 1, two oppositely reciprocating motive pistons 1^1 and 1^2 are rigidly connected to compressor-pistons 2^1 and 2^2, and to auxiliary cushioning pistons 3^1 and 3^2, thus forming two oppositely reciprocating piston assemblies co-acting with three groups of co-axial cylinders, namely a single motor cylinder 4, two compressor cylinders 5^1 and 5^2 and two pneumatic energy storing cylinders or accumulators 6^1 and 6^2. In the case of motor-compressors comprising several compression stages as illustrated in Fig. 1, which refers more particularly to the vertical type, I prefer to dispose said compression stages

unsymmetrically with respect to the motor cylinder; for example, with the low-pressure stage 5^1 at the lower end of the device, and the high-pressure stage 5^2 at the upper end thereof. 6^1 and 6^2 are pneumatic accumulators consisting of cylinders rigidly connected to, or cast integral with, said motor and compressor cylinders; said accumulators being adapted not only to ensure the stability of the motor-compressor in normal operation by supplying the energy required for the return stroke of the piston assemblies, but also to start up the unit, and then to ensure its stability during the transition period until it reaches its operating regime. Said accumulators 6^1 and 6^2 are shown disposed at the extreme lower and upper ends of the machine, but may also be located otherwise.

The starting up of the motor-compressor is effected by introducing compressed air or gas in said accumulators 6^1 and 6^2. To this end two air chambers 7^1 and 7^2 of suitable known capacity are provided which are adapted to communicate respectively with said accumulators through the medium of valves 8^1 and 8^2. Said air chambers 7^1 and 7^2 are connected respectively by pipes 10^1 and 10^2 with an auxiliary starting air reservoir 9 in which air is stored under a pressure higher than that required by the accumulators 6^1 and 6^2 to ensure the stability of the unit in normal operation. In pipe 10, leading into the starting air reservoir 9, is inserted at least one valve 11 which, when open, causes air chamber 7^1 and 7^2 to be filled with compressed air. The opening of valves 8^1 and 8^2, for the purpose of admitting compressed air in said accumulators 6^1 and 6^2 may be effected through the medium of pistons such as 12^1 and 12^2 provided with non-return valves 13; and the closing of valves 8^1 and 8^2 is effected by springs 14.

When the air chambers 7^1 and 7^2 are filled with compressed air, as the result of the opening of valve 11, valves 8^1 and 8^2 may be opened, for the purpose of starting up the unit, by reducing the air pressure acting on the outer faces of pistons 12^1 and 12^2, for example by opening valve 15 inserted in an off-take from pipe 10. Before starting up the unit, it is assumed that the reciprocating piston assemblies have been moved apart to their outer dead center.

When the motor-compressor has started, all the energy for the return stroke is supplied, during a certain number of strokes, by the expansion of the air in the accumulators 6^1 and 6^2, the pressure of the air and the capacity of said cylinders being judiciously chosen to that end; said air pressure being, as mentioned above, higher than that required to ensure the stability of the unit in normal operation.

As the intermediate-pressure air reservoir 17 interconnecting the low and high pressure compressor stages 5^1 and 5^2 gradually fills with air, the expansive-energy of the air cushions in the clearance spaces of said compressor stages increases; hence the energy supplied by the accumulators 6^1 and 6^2 must progressively decrease, in order that the sum of the amounts of energy available from both sources for the return stroke remain within certain limits upon which depends the correct operation of the unit.

To this effect, the pressure in accumulators 6^1 and 6^2 may be reduced:

Either, as shown in Fig. 1, by connecting said accumulators, through the medium of pipes such as 18^1, 18^2 and 19, for example with the suction of an auxiliary compressor 20 which supplies reservoir 9 with starting air under pressure, through the delivery line 20^1 which connects with said reservoir 9, although not so, shown in the figure;

Or else, as shown in Fig. 2, by progressively releasing the pressure in said accumulators 6^1 and 6^2 through the medium of a suitable device such as a valve 48 inserted in the pipe 19, which valve is adapted to open under the action of a mechanism 30 connected by a suitable linkage with one of the reciprocating piston assemblies, in such a manner that, if the motive pistons should, under the impulse of too great an amount of return energy, be driven too close together, valve 48 opens and reduces the return energy available for the next stroke, by lowering the pressure in the accumulators 6^1 and 6^2.

When the machine has reached its normal operating regime, the feed pressure of the accumulators 6^1 and 6^2 must remain constant, and for this purpose, they may be placed in communication with a source of compressed air, for example, with the delivery of the high-pressure stage, through the medium of pipes 18^1, 18^2 and 21, said communication being established, for example, by the opening of a valve 23, care being taken, however, to interpose between said valve 23 and the accumulators 6^1 and 6^2 at least one non-return valve 22 adapted to isolate said accumulators when they are still under a pressure higher than the delivery pressure of the motor-compressor.

By means of the above described control devices, or of any similar arrangement, it is possible to ensure, in normal operation, a constant ratio between the feed pressure of the energy accumulators and the delivery pressure of the unit.

Under certain circumstances depending on the particular design characteristics of different motor compressor units of the type described, it may be advisable to have a more or less rapid pressure rise within the accumulators 6^1 and 6^2. If the pressure desired in said accumulators at the end of the working stroke is not very high, air chambers 7^1 and 7^2 may readily be used as supplementary storage capacities; and for this purpose, springs 14 acting to close valves 8^1 and 8^2 may be set so that said valves will remain open during the operation of the motor-compressor. If, on the contrary, it is desired to dispose of a very high pressure in the accumulators at the end of the working stroke, springs 14 are set so as to keep valves 8^1 and 8^2 closed.

In the first case, the construction outlined in Fig. 3 may be adopted, since it presents the advantage of reducing the bulk of the unit.

According to this arrangement the accumulator chamber 6^2 is enclosed within the motive piston 1^2, and said accumulator chamber is closed by fixed hollow piston member 51^2 constituting a sort of cylinder head therefor. Air chamber 7^2 is formed inside of said hollow piston member 51^2 and is used, as described hereabove, for starting purposes, and its volume is added to that of accumulator chamber 6^2 to function as energy storing means, by the opening of valve 8^2, said valve remaining open in normal operation. Pipe connection 18^2 may then open directly into chamber 7^2.

It is understood, of course, that the auxiliary starting air compressor 20 must be proportioned, with respect to the accumulators 6^1 and 6^2, so as not to interfere with the operation of said accumulators. To this end, the motion of said

compressor 20 may advantageously be synchronized with that of the main motive pistons, for example by means of kinematic linkages such as 30^1, the suction and delivery phases of said auxiliary compressor being suitably timed.

The same linkages may also be adapted to operate other accessories, such as the fuel injection pump 31, for example by disposing said linkages so as to exert a sudden thrust on the plunger 32 of the fuel pump, when the motive pistons are at or near their inner dead center.

The motor-compressor may be shut down by stopping the fuel injection, for example, by providing said fuel pump plunger 32 with a piston 33 upon which is applied a force such as the pressure of the starting air, through the medium of a pipe 34 and a valve 35.

When the unit is shut down, and, at all events, before the next starting up period, it must be prepared for the same by bringing the motive pistons back to their outer dead centers.

According to my invention, this may be done in a very simple manner, without having to empty the intermediate reservoirs, firstly as shown in Figs. 1 and 3, by causing the suction pressure to act on the rear face of the high-pressure pistons such as 2^2. In the case, in which energy accumulators are located in the interior of the motive pistons, as illustrated in Fig. 3, the diameter D_m of the motive pistons is chosen such as not to differ substantially. The capacities limited by the rear faces of said pistons are also interconnected during the setting of the motive pistons for the next starting period, for example through the medium of pipe connections such as 37 and 38, and by the opening of a valve 34.

Simultaneously, the capacity of the low-pressure compressor may advantageously be emptied, for example by the opening of a valve 26, connected with said compressor by a pipe connection 26^1, and, in the same manner, the pressure in the accumulators 6^1 and 6^2 is also released, for example by opening up a valve 25.

At least one of the piston assemblies may be displaced by suitable means, for no important pneumatic forces now interfere with the outward of said pistons.

For example, as indicated in Fig. 1, recourse may be had to a rod 40 operated by a piston 41 against the action of a spring 42. Said rod 40 may be operated by means of compressed air, for example starting air obtained from reservoir 9 which acts upon piston 41, said compressed air being advantageously fed thereto through the same circuit as 34, which controls the piston 33 of the injection pump. Said circuit may afterwards be discharged by the opening of a valve 28. Under the thrust of the compressed air, the rod 40 forces piston 2^2 back to its outer dead center. As soon as this has been done, the valve 28 is opened and the rod 40 returned to its initial position under the action of the spring 42.

The regulation of motor-compressor units of the type described is generally effected automatically, in the known manner consisting in proportioning the amount of fuel injected to the demand for compressed air. To this effect, the quantitative regulation control device associated with the fuel pump, such, for example, as a sliding rod 52, of the type shown in my prior Patent No. 2,038,442, for instance, is operated by a device acted upon by the variations in the delivery pressure, such, for example, as a piston 53 subjected on one face to the delivery air pressure, and on the other to the thrust of a spring or the action of a manometric cell. Said elements are set so that, up to a given pressure close to the normal operating pressure the amount of fuel injected increases with the pressure; whereas beyond said given pressure, the fuel feed on the contrary decreases as the delivery pressure increases.

In motor-compressor units of the type described above which comprise no braking forces or air delivery during the starting up period, it is safer to regulate the fuel injection as a function of the variation in the lower stage pressure, for example as shown in Fig. 1, by causing said pressure to act on a piston such as 53 operating for example, through the medium of a cam on the rod 52 adapted to effect the quantitative regulation of the fuel injection. In this manner the injection of overdoses of fuel when the resistance on the compressor end is reduced is avoided. In normal operation, the high and low stage pressures vary proportionally.

The action of the high and low stage pressures may also be combined to regulate the fuel injection.

The operation of all the valves mentioned hereabove may advantageously be effected by a single control device, which in its different positions controls the starting up operations, the transitory or "warming up" period, the normal operation, and the shut down.

For example, as shown in Fig. 1, valves 23, 24, 25 and 26 may be operated by means of cams suitably distributed on a common shaft 45, the angular displacement of which is effected by means of a crank 46.

Valves 15 and 28 may be disposed opposite one another, and their operating rods 15^1 and 28^1 may be set so as to be operated by an extension of the crank arm 46, in such a manner that, for each of the characteristic positions of said crank, one of said valves will be open and the other closed.

The valves 11 and 35 may be operated through the medium of the same oscillating member 47, the latter being subjected to angular displacements by the extension of crank arm 46.

Said crank arm 46 might, for example, occupy for the shut down the position I, and when moved to position II which is an intermediate position, the following operations are effected:

1. Oscillating member 47 is tilted and opens valve 11, admitting starting air into the air chambers 7^1 and 7^2;

2. The valve 15 is opened and releases the pressure on the outer faces of pistons 12^1 and 12^2, which in turn starts up the unit by opening up valves 8^1 and 8^2.

When moved to the position II, the valve 23 is still closed; but in passing from positions II to III, which is that of normal operation, valve 23 is opened and connects the accumulators 6^1 and 6^2 with the delivery of the high-pressure stage; and said valve 23 remains open continuously in normal operation.

In the above manœuvre, the valves 24, 25 and 26 are closed by the rotation of shaft 45.

In normal operation, crank arm 46 remains in position III. To shut down the unit, said crank arm is swung back into position I, which move has the following effect.

1. By the tilting of the oscillating member 47, the valve 35 is opened, which stops the fuel injector by the action of the starting air on piston

33, and rod 40 is driven outwards by the air pressure acting on piston 41, thus setting the pistons on their outer dead centers;

2. The valve 24 is opened, thus releasing the pressure in the high-pressure compressor; the valves 25 and 26 are also opened, the first for the release of the pressure in the accumulators 6^1 and 6^2, and the second for releasing the pressure in the low-pressure compressor;

3. The valve 23 is closed, cutting off the communication between the delivery of the high-pressure compressor and the accumulators 6^1 and 6^2.

At the end of the course of crank arm 46 (position I) the valve 28 is opened by crank arm 46, the rod 40 is released and returned to its initial position by the spring 42, and the plunger 32 of the fuel injection pump 31 is also released. The unit is then ready to be started up again.

I wish it to be understood that I do not desire to be limited to the exact details of construction shown and described, for obvious modifications thereto will occur to a person skilled in the art.

What I claim is:

1. In a free piston internal combustion engine compressor, having at least one accumulator which serves for stabilizing the engine, means for blowing compressed air into said accumulator to start the engine, and means mechanically connected to and actuated by said free piston for gradually lowering the mean pressure in this accumulator to the normal pressure during the transition period to normal operation.

2. In an internal combustion engine compressor according to claim 1, said last means including an auxiliary compressor for gradually withdrawing a part of the starting air from the accumulator and a driving linkage connecting said compressor and said free piston.

3. In an internal combustion engine compressor according to claim 1, said last means including a compressor for withdrawing a portion of the starting air from the accumulator and for delivering the withdrawn starting air into a container for the starting air, and a driving linkage connecting said compressor and said free piston.

4. In a free piston internal combustion engine compressor having at least one accumulator which serves for stabilizing the engine, means for blowing compressed air into said accumulator to start the engine, means actuated by said free piston for gradually lowering the mean pressure in this accumulator to the normal pressure during the transition period to normal operation, said last means including a valve for releasing a part of the starting air from the accumulator and means for automatically opening said valve, said opening means being operated by said free piston when the latter passes beyond its normal inner dead-point position under the influence of too great a return energy.

5. In a free piston internal combustion engine compressor having at least one accumulator chamber which serves for stabilizing the engine, means for blowing compressed air into said accumulator to start the engine, the accumulator comprising two partial chambers, means to introduce compressed air into the outer partial chamber, and a valve connecting said chambers, whereby by the opening of said valve starting is effected.

6. In an internal combustion engine compressor according to claim 5, means to open said valve comprising a piston connected to the valve and located in the outer partial chamber, and a return stroke valve opening into the said outer partial chamber, whereby the pressure prevailing in the outer partial chamber opens the first valve after a release of the pressure has occurred on the outside of the said piston.

7. In an internal combustion engine compressor according to claim 5, a spring urging the valve to closed position, said spring being of such strength that the valve remains open as soon as starting has been effected.

8. In an internal combustion engine compressor according to claim 5, a hollow stationary piston projecting into the interior of the hollow free piston, the interior of the stationary piston forming the outer partial chamber of the accumulator, and the interior of said free piston forming the inner partial chamber of the accumulator.

9. In a free piston internal combustion engine compressor having at least one accumulator which serves for stabilizing the engine, means for blowing compressed air into said accumulator to start the engine, means actuated by said free piston for gradually lowering the mean pressure in this accumulator to the normal pressure during the transition period to normal operation, a high pressure pipe, a connecting pipe between the interior of the accumulator which serves for the stabilization and the high pressure pipe, a valve controllable from the outside in said connecting pipe, and a return stroke valve which shuts off the interior of the accumulator from the high pressure pipe as long as there prevails in the additional compressor cylinder a pressure which is greater than the pressure in the high pressure pipe.

10. In a free piston internal combustion engine compressor having at least one accumulator which serves for stabilizing the engine, means for blowing compressed air into said accumulator to start the engine, means actuated by said free piston for gradually lowering the mean pressure in this accumulator to the normal pressure during the transition period to normal operation, means controlled by the stopping of the injection of fuel to shut down the compressor for bringing the free pistons to their outer dead points.

11. In a free piston internal combustion engine compressor having at least one accumulator which serves for stabilizing the engine, means for blowing compressed air into said accumulator to start the engine, means actuated by said free piston for gradually lowering the mean pressure in this accumulator to the normal pressure during the transition period to normal operation, a piston, a rod connected to said piston and engageable with said free piston, means to conduct starting air to one side of said piston, and a valve in said conducting means, whereby upon opening said valve the rod brings the free piston into its outer dead-point position.

12. In a free piston internal combustion engine compressor having at least one accumulator which serves for stabilizing the engine, means for blowing compressed air into said accumulator to start the engine, means actuated by said free piston for gradually lowering the mean pressure in this accumulator to the normal pressure during the transition period to normal operation, a piston, a ramrod connected to said piston and engageable with said free piston, means to conduct starting air to one side of said piston, and a valve in said conducting means, whereby upon opening said valve the ramrod brings the free piston into

its outer dead-point position, and a spring normally resisting movement of said piston.

13. In a multi-stage internal combustion engine compressor with opposed free pistons and having an engine cylinder and compressor cylinders asymmetrically arranged at the two sides of the engine cylinder, means to subject the rear side of the compressor piston of the high pressure stage to the substantially constant inlet pressure of this stage.

14. In an internal combustion engine compressor according to claim 13, a chamber on the rear side of the high pressure compressor piston, a connecting pipe between said chamber and the interior of the high pressure compression cylinder, a valve in said connecting pipe, and means to open said valve when the free piston is brought into the outer dead-point position to prepare for starting.

15. In a free piston internal combustion engine compressor having at least one accumulator which serves for stabilizing the engine, means for blowing compressed air into said accumulator to start the engine, means actuated by said free piston for gradually lowering the mean pressure in this accumulator to the normal pressure during the transition period to normal operation, a single controlling member, and means connected to said member to control all the valves which serve for the transition to normal operation and for the starting of the engine.

16. In a free piston internal combustion engine compressor having at least one accumulator which serves for stabilizing the engine, means for blowing compressed air into said accumulator to start the engine, means actuated by said free piston for gradually lowering the mean pressure in this accumulator to the normal pressure during the transition period to normal operation, a single controlling member, and means connected to said member to control all the valves which serve for the transition to normal operation and for the starting of the engine, said member comprising a shaft, a controlling lever fixed on the shaft, a plurality of cams on said shaft, and means controlled by said cams to operate a plurality of valves.

17. In a free piston internal combustion engine compressor having at least one accumulator which serves for stabilizing the engine, means for blowing compressed air into said accumulator to start the engine, means actuated by said free piston for gradually lowering the mean pressure in this accumulator to the normal pressure during the transition period to normal operation, a single controlling member, and means connected to said member to control all the valves which serve for the transition to normal operation and for the starting of the engine, said member comprising a shaft, a controlling lever fixed on the shaft, a plurality of cams on said shaft, and means controlled by said cams to operate a plurality of valves, said controlling lever having an extension cooperating alternately on the one hand with the valve rods of two opposed valves and, on the other hand, with a rocking lever for operating two further valves alternatively.

18. In a multi-stage free piston internal combustion engine compressor having at least one accumulator which serves for stabilizing the engine, means for blowing compressed air into said accumulator to start the engine, means actuated by said free piston for gradually lowering the means pressure in this accumulator to the normal pressure during the transition period to normal operation, said engine having a fuel injection pump, a controlling member for the fuel injection pump, means to subject said controlling member to the pressure of the compressed gas, a spring acting on said controlling member in opposite direction to the compressed gas, said parts being so constructed that until a gas pressure is reached substantially corresponding to that of normal operation the fuel injection increases with increasing pressure, while, when this pressure is exceeded, the injection of fuel decreases with further increase of the gas pressure.

19. In a free piston internal combustion engine compressor having at least one pneumatic accumulator which serves for stabilizing the engine, means for releasing a part of the air under pressure contained in said accumulator, said means being actuated by said free piston when the latter passes beyond its normal dead-point position under the influence of too great a return energy.

20. In an internal combustion engine compressor with at least one free piston, having at least one accumulator which serves for stabilizing the engine, the accumulator comprising two coaxial partial chambers, means to introduce compressed air into the outer partial chamber, and a valve connecting said chambers, whereby by the opening of said valve starting is effected.

21. In a multi-stage internal combustion engine compressor according to claim 13, two pneumatic accumulators symmetrically arranged at the two ends of the engine cylinder.

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