

[54] RECIPROCATING MACHINE

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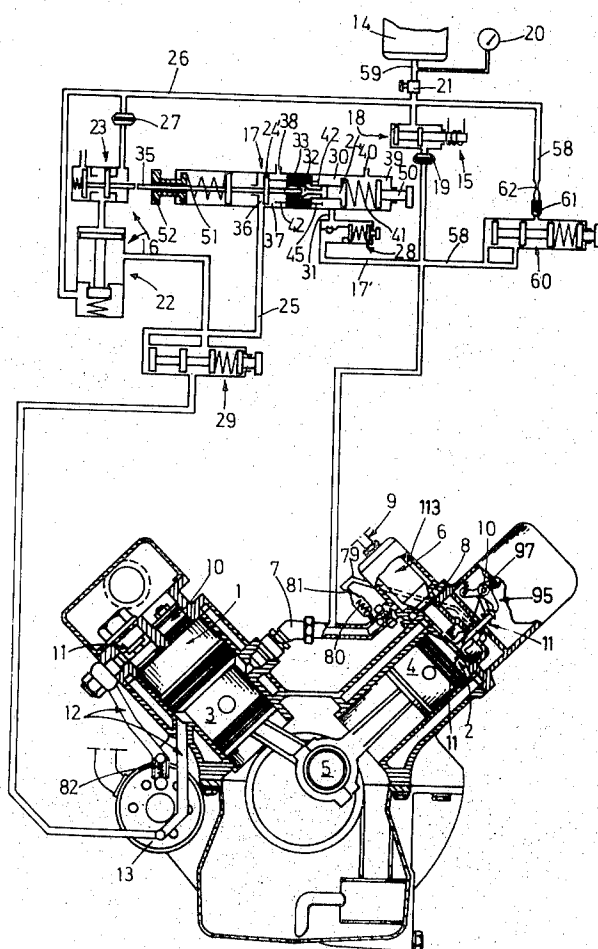
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ABSTRACT

This invention relates to a combustion reciprocating machine of the kind in which combustion takes place outside of the chamber in which the pressurized fluid is expanded, on the one hand, to provide an efficient and fast operating starting device, which cannot be implemented in a satisfactory manner, particularly as regards the starting time, in this type of reciprocating machine by a battery and an electric starter such as those used for running in conventional internal combustion engines and, on the other hand, to provide a device to pressurise the fluid and a regulator permitting to ensure in the said enclosure wherein combustion takes place an adequate flow of pressurised fluid at a satisfactory pressure, whatever may be the working conditions of the reciprocating machine and this in such a manner that the latter shall have a satisfactory operating flexibility and be able to provide immediately a reasonable output, no matter what the working condition may be.

29 Claims, 8 Drawing Figures

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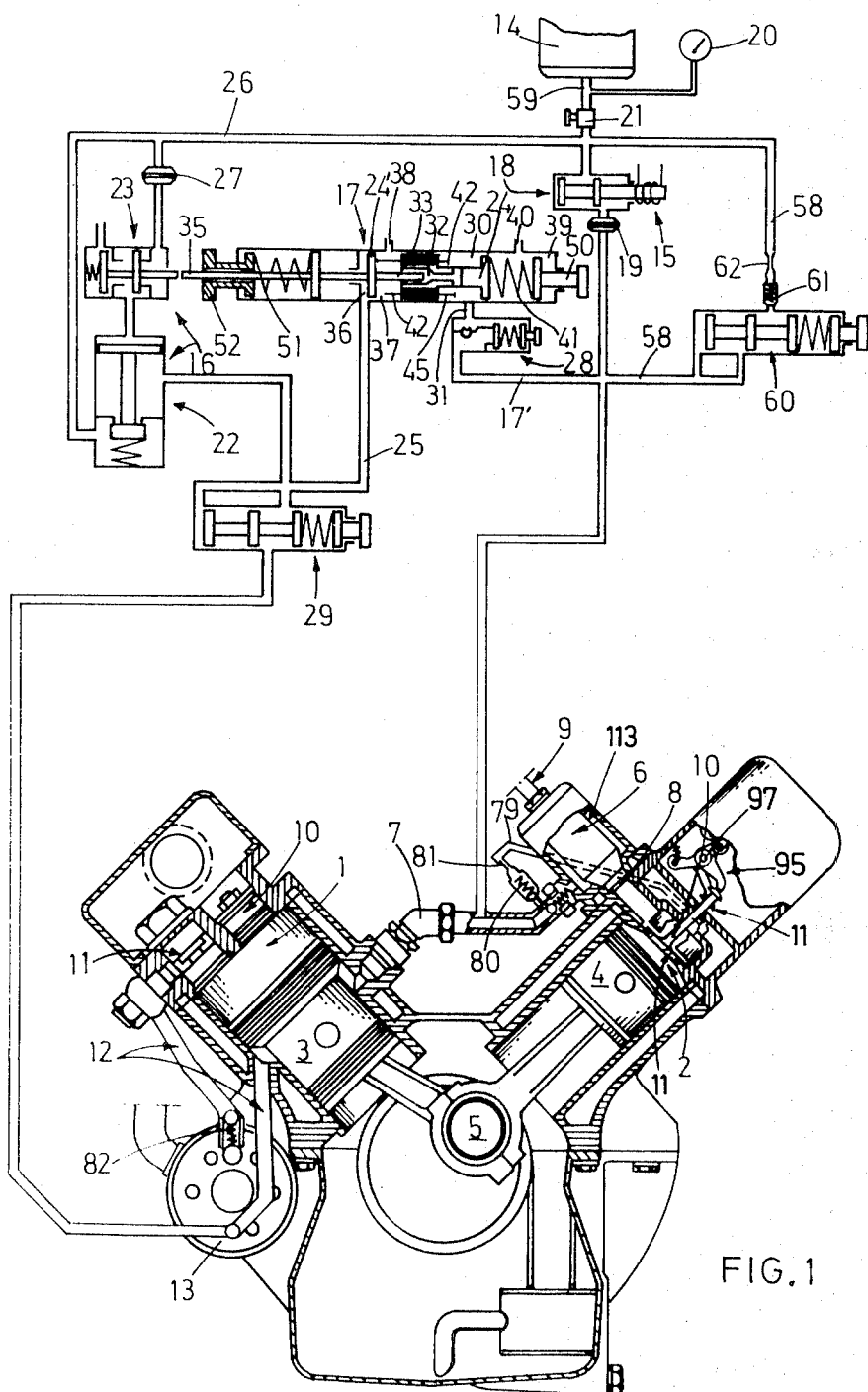
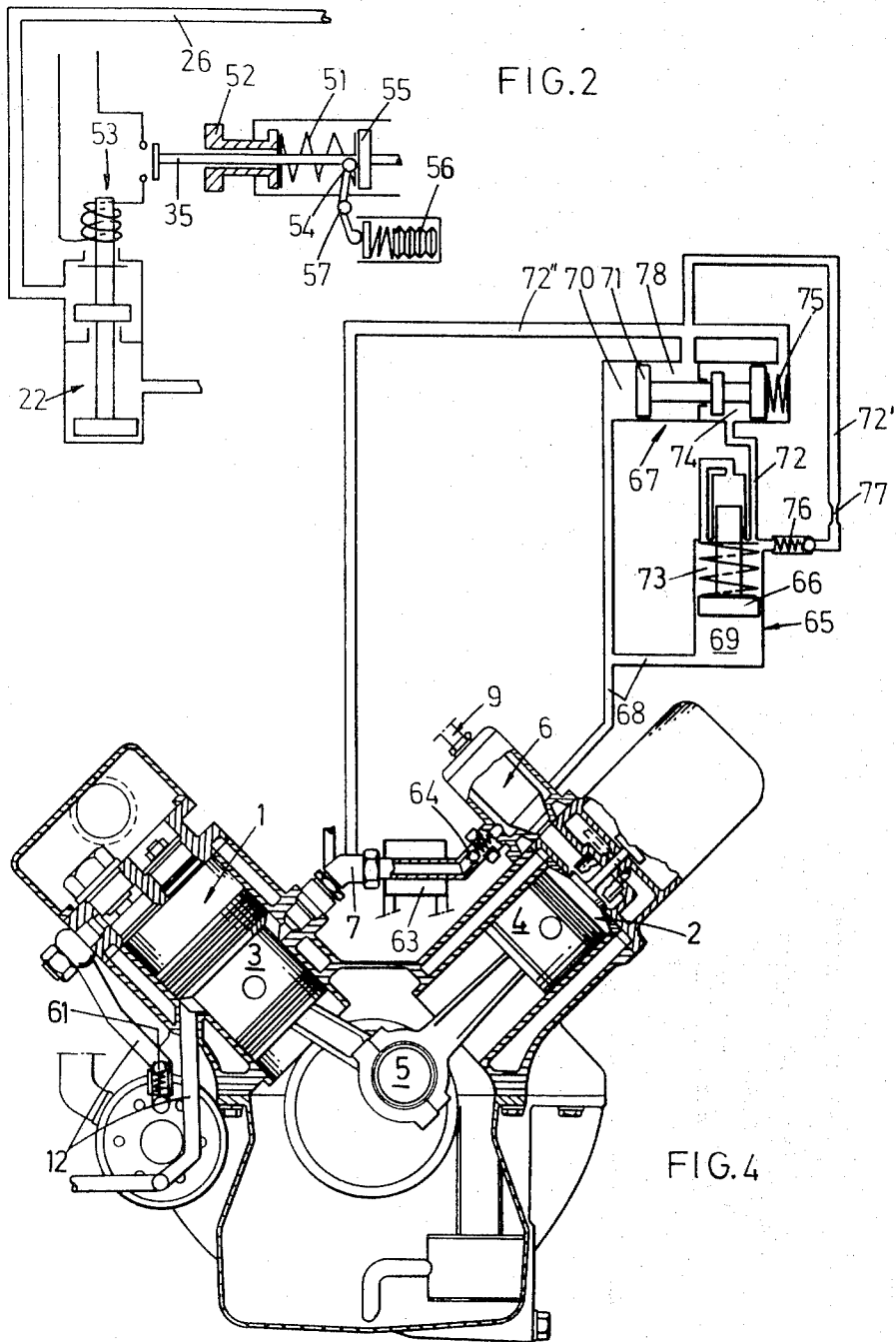


FIG.1



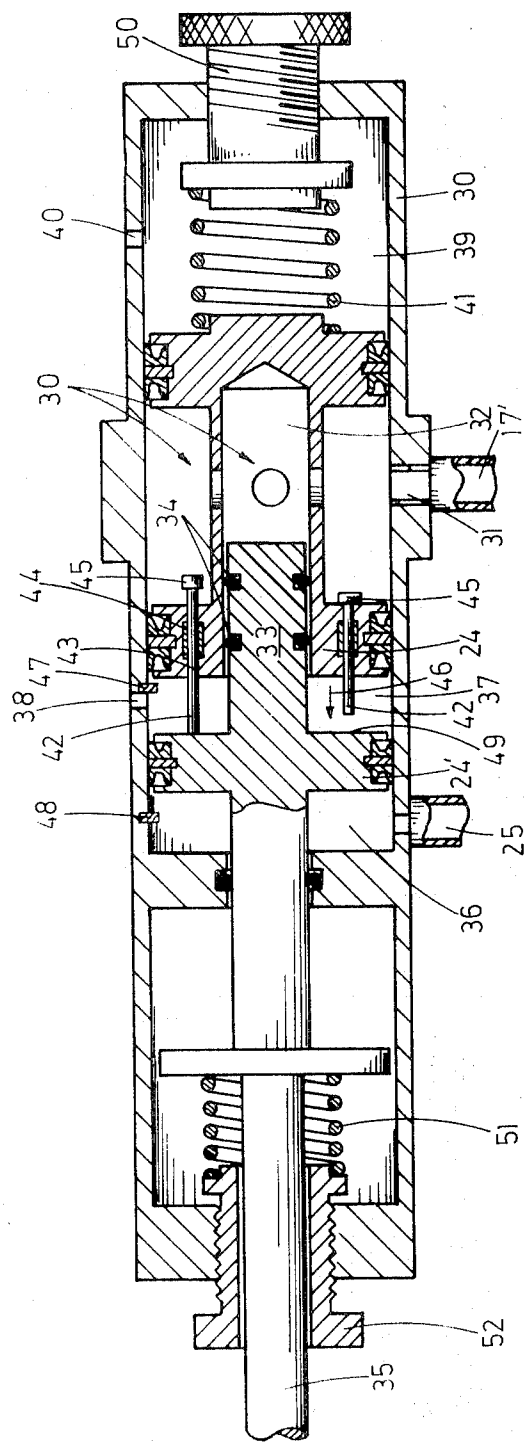
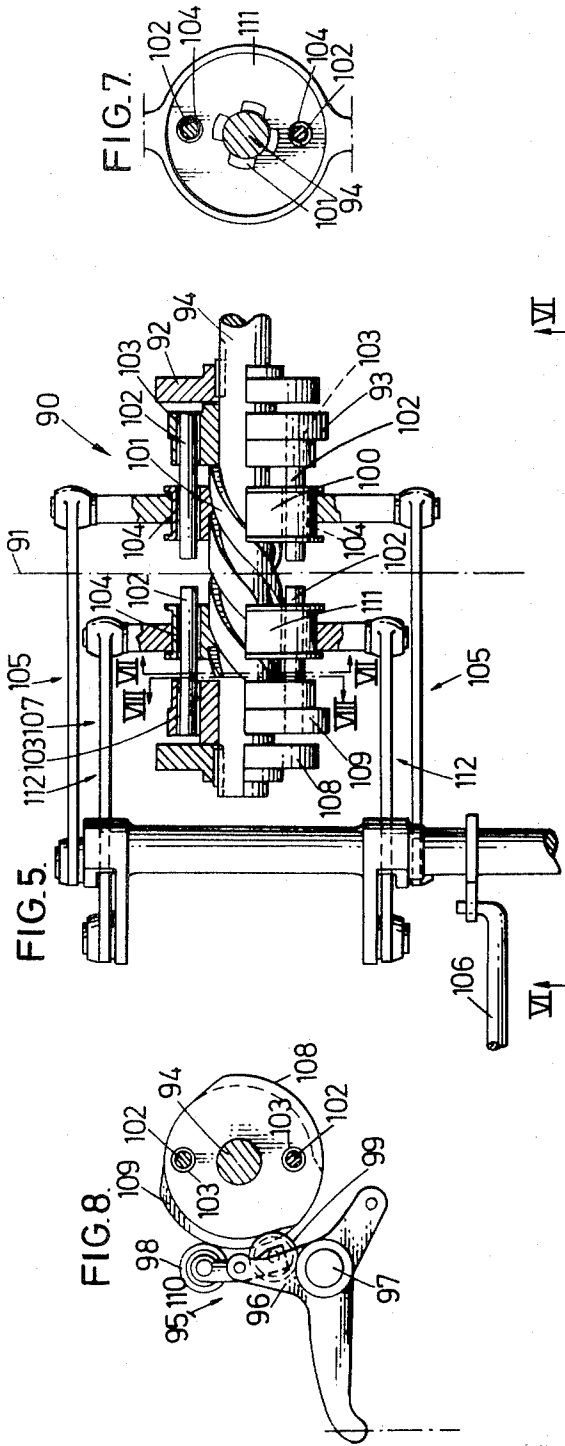


FIG. 3



RECIPROCATING MACHINE

The present invention has for its object a reciprocating machine comprising at least one chamber wherein is fitted a piston to compress a fluid, at least one chamber wherein is provided a piston driven by the expansion of the said fluid, these two pistons being mounted on one and the same shaft fitted in order to provide an alternating motion to each of the pistons in their respective chamber, an enclosure, provided inbetween the two chambers and connected to the latter by connection pipes, in which the compressed fluid is delivered and from which is withdrawn the fluid to be expanded, means for raising the temperature of the fluid in the enclosure and means for authorizing the admission and the exhaust of the fluid in each one of the chambers.

The invention aims essentially in a combustion motor of the kind in which combustion takes place outside of the chamber in which the pressurized fluid is expanded, on the one hand, to provide an efficient and fast operating starting device, which cannot be implemented in a satisfactory manner, particularly as regards the starting time, in this type of reciprocating machine by a battery and an electric starter such as those used for running in conventional internal combustion engines and, on the other hand, to provide a device to pressurise the fluid and a regulator permitting to ensure in the said enclosure wherein combustion takes place an adequate flow of pressurised fluid at a satisfactory pressure, whatever may be the working conditions of the reciprocating machine and this in such a manner that the latter shall have a satisfactory operating flexibility and be able to provide immediately a reasonable output, no matter what the working condition may be.

For that purpose, according to the invention, the piston used for pressurising the fluid in the said chamber is double acting in order to provide a two stage compressor, connection pipes being provided to interconnect the two compressor stages as well as the second stage thereof to the said enclosure, the said reciprocating machine comprising a reserve of fluid compressed to a pressure exceeding that which may be reached during the running of the reciprocating machine by the fluid comprised in the pipe connection of the reciprocating machine connecting the second stage of the compressor to the said enclosure, means to connect this reserve of pressurised fluid to the pipe connection connecting the second stage of the compressor to the enclosure, means to connect this reserve of pressurised fluid to the pipe connection connecting the first stage of the compressor to the second stage of the latter as well as means to connect simultaneously with the said reserve of fluid and with the pipe connections connecting respectively the second stage to the enclosure, the first and second compressor stages, the latter means being controlled by the pressurised fluid admitted into these two pipe connections in order to allow or cut off the flow of the pressurised fluid originating from the said reserve into the pipe connection connecting the first stage of the compressor to the second stage of the latter.

According to a mode of embodiment of the invention, the means connecting the reserve of pressurised fluid to the pipe connection connecting the second stage of the compressor to the said enclosure comprise a normally closed, electromagnetically controlled, uni-

directional valve coupled with the electric starter of the reciprocating machine, so that the valve shall be open for a set time during the running in of the motor and shall allow fluid to flow from the reserve to the connection pipe.

According to an advantageous embodiment of the invention, the means assuring the communication of the reserve of compressed fluid with the pipe connection connecting the first stage of the compressor to the second stage of the latter comprise a distributor wherein are mounted differential pistons subject to the pressure ruling in the pipe connection connecting the first stage of the compressor to the second stage thereof and to the pressure ruling in the pipe connection connecting the second compressor stage to the said enclosure, this distributor being fitted to admit or cut off the flow of the fluid originating from the said fluid reserve to the pipe connection connecting the first to the second compressor stage when the pressures ruling in the said two pipe connections vary one with reference to the other.

According to a particularly advantageous mode of embodiment of the invention, the distributor is connected to an adjustable sequential operation valve mounted downstream of the distributor, with reference to the pipe connection connecting the second compressor stage to the said enclosure in order to prevent the differential pistons from moving continuously inside the distributor in order to admit and stop the flow of fluid from the reserve into the pipe connection connecting the two compressor stages when the pressures ruling inside the said two pipe connections are close to their state of equilibrium determined by the characteristics of the compressor, such sequential operation valve being inserted between the distributor chamber connected to the pipe connection which connects the second compressor stage to the said enclosure and to such pipe connection.

Other details and features of the invention will become apparent from the description of the drawings attached to the present specification and which represent, by way of non-limitative examples, two particular forms of embodiment of the object of the invention.

FIG. 1 is a diagrammatic sectional view of a combustion reciprocating machine of the said kind provided with the starting, compression and regulating devices according to the invention.

FIG. 2 is a diagrammatic partial view illustrating a modified form of the regulating device shown in FIG. 1.

FIG. 3 is an elevational sectional view of the said distributor drawn to a larger scale than the FIG. 1.

FIG. 4 is a diagrammatic view similar to that of FIG. 1 partially broken away, showing a regulating device to be associated with the starting, compression and regulating devices illustrated in FIG. 1 when it is foreseen to heat the fluid in the pipe connection connecting the second compressor stage to the said enclosure, by the expanded fluid escaping from the chamber in which expansion of the fluid takes place.

FIG. 5 is a partly broken elevational view of a device allowing to simultaneously vary the admission time and the exhaust time in the motor chamber where the fluid is expanded.

FIG. 6 is a detailed view along line VI—VI of FIG. 5, showing the rod system controlling the sliding means of said device.

FIGS. 7 and 8 are cross-sectional views along lines VII—VII and VIII—VIII of FIG. 5.

In the different figures, the same numerical references designate similar or identical elements.

The reciprocating machine according to the invention and shown in the drawings, comprises two chambers 1 and 2 in each of which is fitted a piston provided with an alternating motion. The two pistons 3 and 4 are mounted on one and the same shaft 5, the piston 3 being used to compress a fluid, while the piston 4 is driven by the expansion of such fluid, an enclosure or combustion chamber 6 being provided between the two chambers 1 and 2 to which it is connected by pipe connections 7 and 8 so that the pressurized fluid shall flow into the chamber 6 and that the fluid to be expanded shall be withdrawn from the latter, means 9 being provided to raise the temperature of the fluid in the chamber 6 as well as means 10 and 11 to authorise the admission and the escape respectively of the fluid for each of the chambers. In order to fulfil the aims of the invention, namely to provide the reciprocating machine with a start as fast as that of conventional motors and to provide such reciprocating machine with a regulator affording it a large operating flexibility and an adequate reserve of power for all running speeds, the piston 3 being double acting in order to provide, with the chamber 1, a two stage compressor, a pipe connection 12 being provided to interconnect, through a cooler 13, the two compressor stages, while the second compressor stage is connected to the combustion chamber 6 by the pipe connection 7, the reciprocating machine comprising a reserve 14 of fluid compressed to a higher pressure than that which may be reached during the running of the reciprocating machine by the fluid inside the pipe 7, means 15 to connect such reserve 14 and the pipe 7 connecting the second compressor stage to the chamber 6, means 16 to connect the fluid reserve 14 and the pipe 12 connecting the first to the second compressor stage as well as means 17 communicating simultaneously with the pipe connections 7 and 12 connecting the second compressor stage to the chamber 6 and the first to the second compressor stage respectively, such means 17 being controlled by the pressurised fluid inside such pipe connections 7 and 12 in order to allow or to cut off the flow, in the pipe 12, of pressurised fluid originating from reserve 14.

The means 15 which are fitted to connect the fluid reserve 14 and the pipe 7 connecting the second compressor stage to the combustion chamber 6 have for their object to permit, on starting the reciprocating machine, the passage of pressurised fluid from the reserve 14 to the chamber 6 in order to supply it with a fluid at a pressure adequate to authorise the immediate operation of the means 9 provided to raise the temperature of the fluid in the chamber 6 and thus ensure an adequate power of the reciprocating machine to allow it to start up an equipment, such as that of a motor car on which it would be mounted, without it being necessary for that purpose to have recourse to an extended use of the starter driving the reciprocating machine in order that the two stage compressor shall raise the pressure of the fluid in the chamber 6 up to the pressure needed for cutting in the said means 9. These means 15 comprise a normally closed electromagnetically controlled unidirectional valve 18, coupled to an electric device, not shown, for starting up the reciprocating machine so that the valve 18 shall remain open for a preset

time on running in the reciprocating machine and allow the flow of pressurised fluid from the reserve 14 to the combustion chamber 6 via the pipe connection 7. Such means 15 also comprise a pressure reducer 19 which reduces the pressure of the fluid to a pressure practically equal to that which it is possible to attain during the running of the reciprocating machine by the fluid contained in the pipe connection 7 connecting the second compressor stage to the combustion chamber 6, a gauge 20 being advantageously provided to permit checking the pressure of the fluid in the reserve 14 as well as a stop valve 21 allowing to cut off the said reserve 14 from the reciprocating machine, particularly in the case of an extended stoppage of the latter, in order to prevent any leakage of pressurised fluid contained in the reserve 14 through the pipe connections and the reciprocating machine.

The means 16 which, on account of the action of a distributor 17 by virtue of the pressurised fluid inside the pipe connections 7 and 12, connect the reserve 14 and the pipe connection 12 connecting the two compressor stages and are also used to assure a supply of pressurised fluid originating from the reserve 14 in the circuit between the first and second compressor stage in order to achieve a practically constant equilibrium between the pressure of the fluid inside the pipe connection 12 and the pressure of the fluid inside the pipe 7 so that the same flow of fluid shall be available in the chamber 6 at an adequate pressure on changes of the running speed of the reciprocating machine when variations of its working conditions occur, as such equilibrium is only achieved by the two stage compressor on its own after a certain lapse of time, which would of course impair the flexibility of the said reciprocating machine.

These means 16 connecting the reserve 14 with the pipe connection 12 comprise a unidirectional valve 22 controlled through a microvalve 23 by the distributor 17, the differential pistons 24 and 24' of which are subjected to the pressure ruling in the pipe 12 and the pipe 7 through the ducts 17' and 25. The unidirectional valve 22 is connected to the reserve 14, downstream of the closing valve 21 at a location between the valve 21 and the valve 18. This valve 22 is fitted to permit the flow of the fluid originating from the reserve to the pipe connection 12 when the pressure of the fluid rises in the pipe connections 7 and 17' and when the equilibrium between the pressures ruling in the pipe connections 7 and 12, determined by the compressor characteristics, is broken. The purpose of the microvalve 23 is to reduce the force needed at the distributor 17 to control valve 22 as it is, on the one hand, connected to the pipe connection 26 connecting such valve 22 to the reserve 14, a pressure reducing valve 27 being provided on this branch and, on the other hand, connected to the valve 22, the pistons of which are fitted in such a manner that the low pressure fluid, acting on the opening of the microvalve 23, as controlled by the distributor 17, may overcome the pressure of the reserve fluid and ensure the opening of the valve 22 and thus permit the fluid to pass from the reserve 14 to the pipe connection 12. In order to prevent the differential pistons 24 and 24' of the distributor 17 continuously moving within the latter to permit and stop the flow of the fluid originating from the reserve to the pipe connection 12 when the pressures ruling in the pipe connections 7 and 12 are within the said equilibrium range, the distributor 17

is associated with an adjustable sequential valve 28 mounted inbetween the pipe connection 7 and the chamber of the distributor 17, described below, communicating with such pipe connection 7. A safety valve 29 is advantageously provided between the pipe connection 12 and the distributor 17 and the valve 22, the said valve 29 being fitted to close when a pressure higher than a preset pressure practically equal to the normal working pressure provided between the first and second compressor stage is present in the pipe connection 12 of the compressor, such valve 29 operating to cut off the compressor from the fluid reserve 14, particularly in the case of seizure of the distributor 22 in such a position that it would be possible for the pressurized fluid originating from the reserve 14 to enter the pipe connection 12 and to raise the pressure in the latter to a value which might prove dangerous for the compressor.

The distributor 17 comprises a cylinder 30 wherein are assembled the said differential pistons 24 and 24' able to move one with reference to the other, the piston 24' being subjected, through the pipe connection 25 to the action of the fluid within the pipe connection 12, while the piston 24 is subjected to the action of the fluid within the pipe connection 7 through the pipe connection 17'. The piston 24 is provided, on the one hand, with a peripheral recess providing a leak-proof chamber 30 in communication, through an opening 31 with the pipe connections 17' and 7 and, on the other hand, with an axial recess 32 communicating with the chamber 30 and wherein is housed an element 33 of the piston 24' having a cross-section corresponding to that of the recess 32 and provided with tightness members 34, the piston 24' being provided opposite to the element 33 with a central stem 35 providing the control stem of the distributor for operating the microvalve 23. The two pistons 24 and 24' are further fitted in order to determine in the cylinder 30 four chambers isolated in a leak-proof manner from one another and laid out in the following manner: a first chamber 36 into which opens the pipe connection 25 communicating with the pipe connection 12, a second chamber 37 determined by the pistons 24 and 24' and vented to atmosphere through an opening 38 of the cylinder, a third chamber 30 being provided by the said peripheral recess and lastly a fourth chamber 39 vented to atmosphere through an opening 40 provided in the cylinder 30. A spring 41 is provided in the chamber 39 in order to cooperate with the piston 24 while studs 42 are provided in the portion 43 of the piston 24. These studs 42 are of decreasing lengths and their axes are parallel to those of the pistons 24 and 24'. They are uniformly laid out around such axis inside channels 43 permitting them to slide in a leak-proof manner with the help of tightness members 44. Each of these studs 42 comprises a peripheral stop 45 positioned inside the chamber 30 and limiting their movement in the direction of the arrow 46 and extend across the chamber 37 so as to be able to rest on piston 24'. Spring 41 is selected in such a manner that it forces piston 24 against its stop 47 for the minimum set pressure allowed in the chamber 36 and that its maximum compression shall correspond to the maximum determined pressure allowed in such chamber 36, the stroke of the spring 41 being substantially equal to the difference in length between the longest and the shortest of the studs 42, a

stop 48 being also provided to limit the stroke of the piston 24'.

As the pressure ruling in the first stage of a compressor is generally substantially equal to the square root of the pressure of the second stage, the ratio between these two pressures is not constant and it was therefore necessary to provide the said regulating system with a distributor provided with differential pistons of variable area, such variations of area being assured by the expedient of the studs 42 of unequal lengths. Thus, when the pressure rises in the chamber 30, the pressure applied to the piston 24' acting on element 33 of the latter increases pro rata of the number of studs in contacting relationship with the face 49 of the piston 24', the latter moving in the direction of the arrow 46, and the stem 35 actuates the microvalve 23 controlling the admission of fluid originating from the reserve to the pipe connection 12. The pressure then rises inside the chamber 36 and the piston 24' returns to its equilibrium position which breaks the flow of the fluid originating from the reserve. At the said minimum pressure the spring 41 is fully expanded and the studs are fitted so that in such position of the spring all the studs 42 rest on the face 49 of the piston 24'. When the pressure rises in the chamber 30, the pressure differential applied to the pistons 24 and 24' compresses the spring 41 and they spread apart from one another. This movement of the piston 24 results in drawing by means of the stops 45 the shortest studs so that they no longer rest on the piston 24' and that the pressure they support is transmitted to the piston 24 which, consequently, increases the area of the latter.

The strain of the spring 41 is adjustable by means of a control screw 50 cooperating with the cylinder 30. A spring 51 is also provided to cooperate with the piston 24', the strain of this spring being likewise adjustable by means of a control screw 52.

Valve 22 might also be controlled as shown in FIG. 2 immediately from the distributor 17 by means of an electromagnet 53. In order to keep up the adjustment of the distributor 17 independently of the atmospheric pressure, so as not to permit the reserve 14 to supply fluid to the pipe connection 12 when the atmospheric pressure drops, a pushrod 54 might also be provided supported on component 55 of the piston 24' and controlled by an aneroid case 56, such push rod being pivotally mounted in 57 so as to raise its pressure, because of the action of the aneroid case on component 55 of the piston 24' when the atmospheric pressure drops.

According to the invention and in order that the reserve 14 may be recharged with pressurised fluid, the pipe connection 7 connecting the second compressor stage with the chamber 6 is connected by a duct 58 to the duct 59 connecting the reserve 14 to the valve 18, upstream of the latter with reference to the said reserve so as to refurnish the latter. A valve 60 is provided in the duct 58 and is normally closed so as to prevent, on starting the reciprocating machine, and with a low pressure of the fluid in the reserve, that part of the fluid compressed by the compressor shall be used to charge up the reserve 14 and thus endanger the starting of the reciprocating machine, the same applying during changes in the speed of the latter when, in order to retain all the output of the reciprocating machine, the whole of the fluid supplied by the second compressor stage is needed. The valve 60 is fitted to open at a preset pressure ruling in the pipe connection 7, such preset

pressure being slightly below the pressure ruling in such pipe 7 during the running of the reciprocating machine in order to allow pressurised fluid originating from the pipe connection 7 to flow to the reserve 14. A non-return check valve 61 is advantageously provided between the valve 60 and the reserve 14 and is fitted so that, even when such valve 60 is in the open position, the pressurised fluid may not enter such reserve 14 unless the pressure ruling inside the latter is less than that inside the pipe connection 7, and this always in order that a maximum pressure shall be available in the pipe connection 7 so that the reciprocating machine shall retain its full power during changes in speed or working conditions. Always with this object in view, a throttle 62 may also be provided in the pipe connection 58 in order to throttle the flow of the pressurised fluid to the reserve 14 when the valve 60 and the non-return check valve 61 permit such flow.

According to the invention and as shown in FIG. 4, a heat exchanger 63 may be mounted in the pipe connection 7 connecting the second compressor stage to the chamber 6 in order to preheat the fluid flowing from the said compressor to the chamber 6, such heat exchanger 63 being connected to the exhaust of the chamber 2 wherein the expansion of the fluid takes place. In that case, a device to balance the pressure ruling in the pipe connection 7 and that ruling in the chamber 6 is particularly interesting, because in the course of accelerations of the reciprocating machine, the pressure rises in the chamber 6 and the compressor is obliged to raise sharply the pressure in such pipe 7 in order to keep the reciprocating machine running, which is difficult because of the heat exchanger 63 and of the important volume of fluid contained in the pipe run of the latter. According to the invention, this balancing device comprises a non-return valve 64 in order to prevent a back flow of the fluid contained in the chamber 6 towards the pipe connection 7, a cylinder 65 in which is fitted a piston 66, a valve 67, a duct 68 connecting the chamber 6 with the chambers 69 and 70 determined within the cylinder 65 and the valve 67 by the piston 66 and the plunger 71 of the valve and ducts 72, 72' and 72'' connecting the pipe connection 7, between the heat exchanger 63 and the second compression stage to the chamber 73 of the cylinder 65 and the chambers 74 and 75 of the valve 67. When the pressure rises sharply in the chamber 6, the pressurised fluid closes the non-return valve 64 and influences the plunger 71 of the valve 67 and the piston 66 compressing the fluid located in the chamber 73 of cylinder 65, in the duct 72 and the chamber 74 of the valve 67. Considering the difference in pressure then present in the chambers 70 and 75 of the valve, the latter, which is normally closed, opens and allows the fluid compressed by the piston 66 to flow from the chamber 74 of the valve 67 to the pipe connection 7 through the duct 72'', this assisting the compressor to raise the pressure in the pipe connection 7 on a sharp increase of pressure in the enclosure 6, a non-return valve 76 and a throttle 77 being advantageously provided in the duct 72' in order to allow pressurised fluid to enter chamber 73 of the cylinder 65 only when the pressure inside the latter is below the pressure ruling in the chamber 78 of valve 67.

The reciprocating machine according to the invention comprises advantageously, as shown in FIG. 1, a by-pass 79, provided in the pipe connection 7 connect-

ing the second compressor stage to the chamber 6, upstream of the latter, and having for its object to direct the pressurised fluid originating from the compressor to the means 10 allowing the admission of the fluid to the chamber 2 in order to cool such means 10 swept by the fluid at high temperature originating from the chamber 6. A non-return valve 80 and a throttle 81 are provided in this by-pass 79 in order to restrict the flow of fluid in this by-pass to the means 10 so that in the pipe connection 7, a maximum quantity of fluid will be available to supply the chamber 6 on variations of the speed of the reciprocating machine. The pipe connection 7 also comprises a non-return valve 82 mounted in the pipe connection 12 in order to prevent any back-flow of fluid between the second and the first compressor stages.

According to the invention, the admission time of said fluid in motor chamber 2 can advantageously be varied by acting on admission valve 10. By reducing the admission time, the pressure in combustion chamber 6 and upstream said chamber is increased in order to reach a higher combustion pressure at idling and at partial working conditions, which results, on the one hand, in increasing the motor efficiency and, on the other hand, in limiting the intervention of the motor regulating device hereinbefore described. Although said pressure increase in chamber 6 results in an efficiency lowering of the compressor, this lowering must not particularly be taken into account because said efficiency lowering will not substantially affect the above-mentioned pressure. On the contrary, by increasing the admission time, the pressure in combustion chamber 6 is reduced so as to maintain this pressure in reasonable limits which are fixed, on the one hand, by the resistance of the motor pieces and the temperature which can be reached by the latter and, on the other hand, by the compressor efficiency, so as to not too much reduce the latter.

This is the reason why it has been provided on the motor means 90 intended to vary for a given rotation speed of the motor the admission time in chamber 2 in terms of the resisting torque. Said means 90 are formed (see portion of FIG. 5 on the right of broken line 91) by two cams 92 and 93 mounted on a shaft 94 rotated by the motor and controlling the admission valve through a moving equipment 95 of Caprotti type (FIG. 8). Said moving equipment 95 comprises a rocking lever 96 pivoting around a fixed shaft 97 and the ends of which each support a follower 98 or 99 cooperating with one of the cams 92 or 93, cam 92 being locked on shaft 94 while cam 93 is free rotating on the latter, a sliding means 100 being provided on shaft 94 to control the angular movement of cam 93 with respect to the cam 92. Shaft 94 has a threaded portion 101 forming an endless screw with very elongated pitch, which cooperates with the sliding means 100 and, when the latter longitudinally moves in parallel to the axis of shaft 94, causes the rotation of cam 93 around the latter, by means of two rods 102 which are parallel to the axis of shaft 94 and are diametrically opposed, said rods being fixed to cam 93 by means of their threaded end 103 and being able to freely slide in apertures 104 provided in the sliding means 100. Movements of said sliding means 100 are controlled by a rod system 105 connected to the motor accelerator (not shown) through a control rod 106.

According to this invention, the exhaust time of the fluid of motor chamber 2 can also be varied by acting on exhaust valve 11. By varying the exhaust time, either the control device of the exhaust valve is alleviated when the back-pressure in chamber 2 is lower than the pressure in combustion chamber 6, or the pinging is prevented which can exist in said device, particularly at the level of the rocker-arm when the back-pressure in chamber 2 is higher than the pressure in chamber 6. To produce said variation of exhaust time, means 107 are provided on the motor, which are intended to vary for a given speed of the motor the exhaust time in chamber 2 in terms of the resisting torque. Said means 107 are formed (see portion of FIG. 5 on the left of broken line 91) by two cams 108 and 109 which are mounted on a shaft 94 driven by the motor, the moving equipment 110, sliding means 111 and shaft 94 cooperating with said cams 108 and 109 being arranged in a similar manner as analogous elements hereinbefore described and forming part of means 90. Just as the sliding means 100, the sliding means 101 is controlled by a rod system 112 connected to the motor accelerator through rod 106.

Also according to the invention, the admission time and the exhaust time in chamber 2 can be caused to simultaneously vary for a given rotation speed of the motor, in terms of the resisting torque, in order to combine previously mentioned advantages resulting on the one hand, from the variation of the admission time and on the other hand from the variation of the exhaust time. In said case, as shown in FIG. 5 to be considered as a whole, cams 92 and 93 and cams 108 and 109, as well as all the elements cooperating therewith are mounted on a common shaft 94 having a threaded portion 101 with which the sliding means 100 and 111 cooperate, said means being simultaneously activated by rod systems 105 and 112, from the motor accelerator, through control rod 106. The rod systems 105 and 112 are arranged so that the said variations are such that when the admission time is increased, the exhaust time is reduced and vice versa. It results from a consideration of rod systems 105 and 112 (FIGS. 5 and 6) that the variation of exhaust time is lower than the variation of admission time. However, according to the motor characteristics, it can be quite well conceived to have either substantially equal variations of admission and exhaust times, or a variation of exhaust time which is higher than that of admission time.

The chamber 6 wherein the temperature increase of compressed fluid is obtained advantageously comprises a safety valve 113 which is regulated so as to open at a determined pressure, the latter being higher than the normal working pressure of the motor and lower than the breaking pressure of the combustion chamber 6. Said valve 113 is either open to atmosphere or connected to the motor exhaust pipe.

It is to be understood that the invention is not at all limited to the forms of embodiment described and that many changes may be introduced therein within the scope of the appended claims.

Thus, the reciprocating machine, according to the invention, may operate in a closed circuit and provide a so-called "hot air" reciprocating machine. In that case, the exhaust of the chamber 2 is connected to the entry of the first compressor stage, a cooler being then mounted between the said exhaust and the compressor.

I claim:

1. Reciprocating machine comprising at least one chamber wherein is fitted a piston to compress a fluid, at least one chamber wherein is provided a piston driven by the expansion of the said fluid, these two pistons being mounted on one and the same shaft fitted in order to provide an alternating motion to each of the pistons in their respective chamber, an enclosure, provided in between the two chambers and connected to the latter by connection pipes, in which the compressed fluid is delivered and from which is withdrawn the fluid to be expanded, means for raising the temperature of the fluid in the enclosure and means for authorizing the admission and the exhaust of the fluid in each one of the chambers, the reciprocating machine being characterised in that the piston used for pressurising the fluid in the said chamber is double acting in order to provide a two stage compressor, connection pipes being provided to interconnect the two compressor stages as well as the second stage thereof to the said enclosure, the said reciprocating machine comprising a reserve of fluid compressed to a pressure exceeding that which may be reached during the running of the reciprocating machine by the fluid comprised in the pipe connection of the reciprocating machine connecting the second stage of the compressor to the said enclosure, means to connect this reserve of pressurized fluid to the pipe connection connecting the second stage of the compressor to the enclosure, means to connect this reserve of pressurized fluid to the pipe connection connecting the first stage of the compressor to the second stage of the latter as well as means to connect simultaneously with the said reserve of fluid and with the pipe connections connecting respectively the second stage to the enclosure, the first and second compressor stages, the latter means being controlled by the pressurised fluid admitted into these two pipe connections in order to allow or cut off the flow of the pressurized fluid originating from the said reserve into the pipe connection connecting the first stage of the compressor to the second stage of the latter.

2. A reciprocating machine as claimed in claim 1, characterised in that the means connecting the reserve of pressurised fluid to the pipe connection connecting the second stage of the compressor to the said enclosure comprise a normally closed, electromagnetically controlled, unidirectional valve coupled with the electric starter of the reciprocating machine, so that the valve shall be open for a set time during the running in of the motor and shall allow fluid to flow from the reserve to the connection pipe.

3. A reciprocating machine as claimed in claim 2, characterised in that the said means comprise a pressure reducer mounted downstream of the said unidirectional valve and having for its object to reduce the pressure of the fluid, originating from the reserve of fluid, to a pressure equal to that which it is possible to attain during the running of the reciprocating machine by the fluid contained in the pipe connection connecting the second compressor stage to the said enclosure.

4. A reciprocating machine as claimed in claim 2, characterised in that a gauge and a stop valve are provided between the said reserve of pressurised fluid and the said unidirectional valve.

5. A reciprocating machine as claimed in claim 1, characterised in that the means assuring the communication of the reserve of compressed fluid with the pipe

connection connecting the first stage of the compressor to the second stage of the latter comprise a distributor wherein are mounted differential pistons subject to the pressure ruling in the pipe connection connecting the first stage of the compressor to the second stage thereof and to the pressure ruling in the pipe connection connecting the second compressor stage to the said enclosure, this distributor being fitted to admit or cut off the flow of the fluid originating from the said fluid reserve to the pipe connection connecting the first to the second compressor stage when the pressures ruling in the said two pipe connections vary one with reference to the other.

6. A reciprocating machine as claimed in claim 5, characterised in that means are provided to cooperate with the piston of the said distributor subject to the pressure ruling in the pipe connection connecting the first to the second compressor stage in order to permit modifying the ratio existing between a set pressure ruling in such pipe connection and the corresponding pressure ruling in the pipe connection connecting the second compressor stage to the said enclosure, particularly in order to allow for the wear of the compressor.

7. A reciprocating machine as claimed in claim 6, characterised in that the means cooperating with the said piston comprise a spring the adjustable strain of which may be changed by means of a screw.

8. A reciprocating machine as claimed in claim 6, characterised in that the said means comprise a push rod resting on an element cooperating with the piston of the distributor subject to the pressure ruling in the pipe connection connecting the first to the second compressor stage and controlled by an aneroid case, the push rod being fitted to increase its pressure, because of the action of the aneroid case on the said piston by means of the said element when the atmospheric pressure drops.

9. A reciprocating machine as claimed in claim 5, characterised in that the means connecting the reserve of pressurised fluid to the pipe connection connecting the first and second compressor stages comprise a unidirectional valve, controlled by the said distributor and connected to the reserve of pressurised fluid, downstream of the closing valve and upstream of the unidirectional valve and of the pipe connection connecting the first to the second stage of the compressor, such valve being fitted to permit the flow of the fluid originating from the reserve to the latter pipe connection when the equilibrium between the pressures ruling in the said two pipe connections, determined by the compressor characteristics is broken by a rise of the pressure ruling in the pipe connection connecting the second compressor stage to the enclosure.

10. A reciprocating machine as claimed in claim 9, characterized in that a microvalve is inserted between the distributor and the said unidirectional valve in order to reduce the strain of the latter when controlling the said unidirectional valve, the microvalve being connected to the pipe connection connecting the unidirectional valve to the reserve of pressurised fluid, a pressure reducing valve being provided on this branch and connected to the unidirectional valve, the pistons of the latter being fitted in such a manner that the low pressure fluid, acting on the opening of the microvalve, by the action of the distributor may overcome the pressure of the reserve fluid and ensure the opening of the unidirectional

rectional valve in order to permit the flow of the reserve fluid from the reserve to the pipe connection connecting the first to the second compressor stage.

11. A reciprocating machine as claimed in claim 5, characterised in that the distributor is associated with an adjustable sequential valve mounted downstream of the distributor with reference to the pipe connection connecting the second compressor stage to the said enclosure in order to prevent the differential pistons continuously moving within the distributor to permit and stop the flow of the fluid originating from reserve to the pipe connection connecting the two compressor stages, when the pressures ruling in the said two pipe connections are within their equilibrium range determined by the compressor characteristics, such sequential valve being mounted inbetween the distributor chamber connected to the pipe connecting which connects the second compressor stage to the said enclosure and such pipe connection.

12. A reciprocating machine as claimed in claim 5, characterised in that in the pipe connection connecting the two stages of the compressor, there is provided between the said unidirectional valve and the compressor, a second unidirectional valve fitted to cut off the flow of the fluid between the latter and the compressor when the pressure ruling between such two unidirectional valves as well as between such second unidirectional valve and the compressor exceeds a set pressure.

13. A reciprocating machine as claimed in claim 5, characterised in that the said distributor comprises a cylinder wherein are assembled two pistons able to move one with reference to the other, a first piston being subjected to the action of the fluid within the pipe connection connecting the first to the second compressor stage, while the second piston is subjected to the action of the fluid within the pipe connection connecting the second compressor stage to the said enclosure, the second piston being provided on the one hand with a peripheral recess providing a leak-proof chamber in communication through an opening provided in the cylinder with the pipe connection connecting the second compressor stage to the said enclosure and, on the other hand, with an axial recess communicating with the said chamber and wherein is housed an element of the first piston having a cross-section corresponding to that of the recess and provided with tightness means, the first piston being provided opposite the said element with a central stem providing the control stem of the distributor permitting or preventing the flow of the fluid from the reserve to the pipe connection connecting the first to the second compressor stage, the two pistons being further fitted in order to determine in the said cylinder four chambers isolated in a leak-proof manner from one another and laid out in the following manner, a first chamber comprised inbetween the actual first piston and the cylinder walls and partly surrounding the said control stem, this first chamber communicating, through an opening provided in the cylinder, with the pipe connection connecting the first to the second compressor stage, a second chamber comprised inbetween the first and the second piston and partially surrounding the said first piston element, such second chamber being connected to atmosphere through an opening provided in the cylinder, a third chamber provided by the peripheral recess produced in the second piston and communicating with

the pipe connection connecting the second stage of the compressor to the enclosure, a fourth chamber communicating with atmosphere through an opening provided in the cylinder, wherein is fitted a spring supported by the second piston, the portion of the second piston comprised between the said second and third chambers being provided with studs of decreasing lengths and their axes running parallel to that of the piston around which the studs are uniformly laid out inside channels wherein the studs are able to slide in a leak-proof manner, each of these studs comprising a peripheral stop positioned inside the third chamber and extending through the second chamber so as to be able to rest on the first piston, stops being provided for the first and the second piston in the first and the second chamber respectively, the said spring being selected in such a manner that it forces the second piston against its stop for the minimum set pressure allowed in the first chamber and shall experience maximum compression for the maximum determined pressure allowed in such first chamber, the stroke of the spring being substantially equal to the difference in lengths of the longest and the shortest of the said studs.

14. A reciprocating machine as claimed in claim 13, characterised in that the strain of the said spring is adjustable, an adjustable tension spring being also provided to cooperate with the first piston.

15. A reciprocating machine as claimed in claim 1, characterised in that the pipe connection connecting the second compressor stage and the said enclosure communicates with a duct connecting the reserve of pressurised fluid to a electromagnetically controlled unidirectional valve, upstream of the latter with reference to the fluid reserve in order to refill the latter with pressurised fluid.

16. A reciprocating machine as claimed in claim 15, characterised in that a unidirectional valve is provided in the duct connecting the said pipe connection and the duct connecting the reserve and the said valve, such valve normally closed being fitted to open at a set pressure ruling inside the pipe connection connecting the second compressor stage and the enclosure, such set pressure being slightly below the pressure ruling in the latter pipe connection during normal running of the reciprocating machine, in order to permit the flow of the pressurised fluid originating from the said pipe connection to the fluid reserve, a non return check-valve being provided between the valve and the reserve and fitted in such a manner that even when the valve is open, pressurised fluid originating from the pipe connection is only able to enter the said reserve when the pressure of the fluid contained in the latter is below the pressure ruling in the pipe connection connecting the second compressor stage to the enclosure.

17. A reciprocating machine as claimed in claim 16, characterised in that a throttle is provided in the said duct in order to throttle the flow of the fluid to the reserve when the valve and the nonreturn check valve permit such flow.

18. A reciprocating machine as claimed in claim 1, characterised in that a by-pass is provided in the pipe connection connecting the compressor to the enclosure upstream of the latter, directing fluid originating from the compressor to the means allowing the admission of the fluid to the chamber wherein the expansion of the fluid takes place in order to cool the said means.

19. A reciprocating machine as claimed in claim 1, characterised in that a heat exchanger is provided in the pipe connection connecting the compressor to the said enclosure, this heat exchanger, used for preheating the fluid flowing from the compressor to the enclosure, being connected to the exhaust of the chamber wherein the expansion of the fluid takes place.

20. A reciprocating machine as claimed in claim 19, characterised in that it comprises means allowing to balance, during variations of the speed of the reciprocating machine, the pressures ruling in the said enclosure and in the pipe connection connecting the second compressor stage to the said enclosure.

21. A reciprocating machine as claimed in claim 20, characterised in that the means permitting to balance the said pressures comprise a cylinder in which is fitted a double acting piston determining two chambers in the said cylinder, a valve provided with a double acting plunger determining four chambers inside the valve along the axis of the plunger, a duct assuring the communication of the said enclosure with a first chamber of the cylinder and a first terminal chamber of the valve, ducts being provided to assure the communication of the second end chamber of the valve with the duct connecting the second compressor stage to the enclosure upstream of the heat exchanger, the second cylinder chamber with the internal chamber of the valve nearest the second end chamber of the valve and the second chamber of cylinder with the internal chamber of the valve nearest the first end chamber of the said valve, such normally closed valve being fitted so as to open when the pressure rises sharply in the enclosure in order to connect the two internal chambers of the valve.

22. A reciprocating machine as claimed in claim 21, characterised in that a non-return check valve and a throttle are provided in the duct connecting the second chamber of the cylinder and the internal chamber of the valve nearest the first terminal chamber of the latter in order to adjust the flow of the fluid from the valve to the cylinder.

23. A reciprocating machine as claimed in claim 1, characterised in that it is mounted in a closed circuit so as to provide a so-called "hot-air" reciprocating machine, the exhaust of the chamber wherein the fluid expands being connected to the entry of the first compressor stage, a cooler being mounted in the duct connecting the said exhaust to the compressor.

24. A reciprocating machine as claimed in claim 1, characterised in that the enclosure in which the temperature of compressed fluid is increased comprises a safety valve which is regulated so as to open at a determined pressure higher than the normal working pressure of the motor and lower than the breaking pressure of the enclosure, said valve being either open to atmosphere or connected to motor exhaust pipe.

25. A reciprocating machine as claimed in claim 1, characterised in that it comprises means to vary for a given rotation speed of the motor the admission time in the chamber where the fluid is expanded, in terms of the resisting torque.

26. A reciprocating machine as claimed in claim 1, characterised in that it comprises means to vary for a given rotation speed of the motor, the exhaust time in the chamber where the fluid is expanded in terms of the resisting torque.

27. A reciprocating machine as claimed in claim 26, characterised in that it comprises means to simultaneously vary the admission time and the exhaust time in the chamber where the fluid is expanded for a given rotation speed of the motor in terms of the resisting torque, said means being arranged so that when the admission time is increased, the exhaust time is reduced and vice versa.

28. A reciprocating machine as claimed in claim 25, characterised in that said means allowing to vary either the admission time or the exhaust time in the chamber where the fluid is expanded are formed by two cams mounted on a shaft rotated by the motor and actuating through a moving equipment of Caprotti type, the admission and exhaust valves, said moving equipment comprising a rocker-lever pivoting around a fixed axis and the ends of which each support a follower cooperating with one of said cams, one of said cams being locked on said shaft while the other cam is free mounted on the latter, a sliding means being provided on the shaft to control the angular movement of the moving cam with respect to the cam locked on the shaft, the latter having a threaded portion forming an endless screw with very elongated pitch cooperating

with the sliding means and causing when the latter longitudinally moves in parallel to the shaft axis, the rotation of the moving cam around the latter, by means of at least one rod parallel to the axis of said shaft, said rod being fixed to the moving cam and being able to freely slide in an aperture provided in the sliding means, movements of the latter being controlled by a rod system connected to the motor accelerator.

29. A reciprocating machine as claimed in claim 27, characterised in that said means allowing to simultaneously vary the admission time and exhaust time comprise two sets of two cams mounted on said shaft which is driven by the motor, each set controlling through a moving equipment one of the admission or exhaust valves, each set of cams comprising a cam locked on said shaft and a cam freely mounted on the latter, the moving cam of each of cam sets being controlled by a sliding means, said sliding means cooperating, to cause the rotation of moving cams, with said threaded shaft portion forming an endless screw with very elongated pitch, both sliding means being simultaneously controlled by a rod system connected to the motor accelerator.

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