June 23, 1959 G. V. B. HALL ET AL 2,891,718

OPPOSED FREE PISTON RECIPROCATING GAS COMPRESSOR

Filed Nov. 6, 1956

Fig. 1

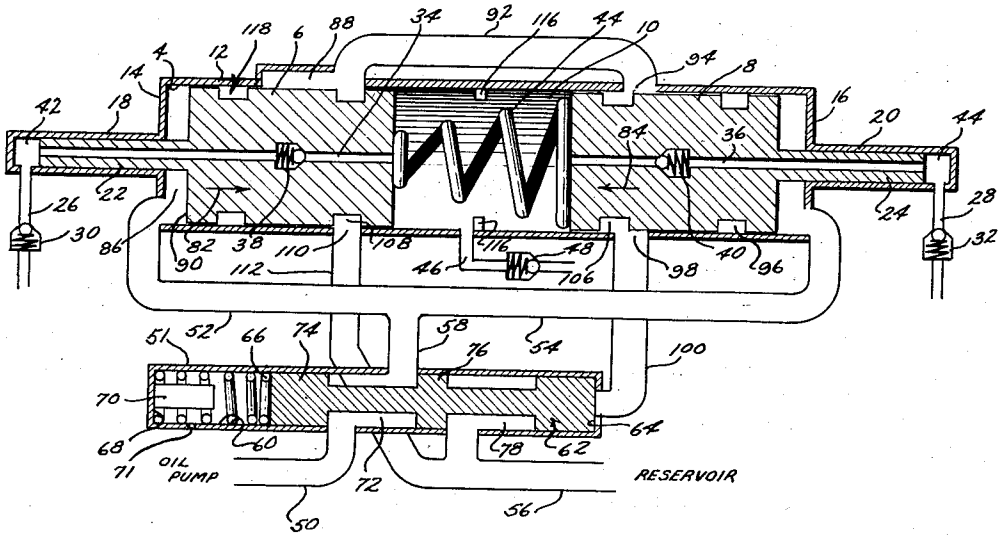
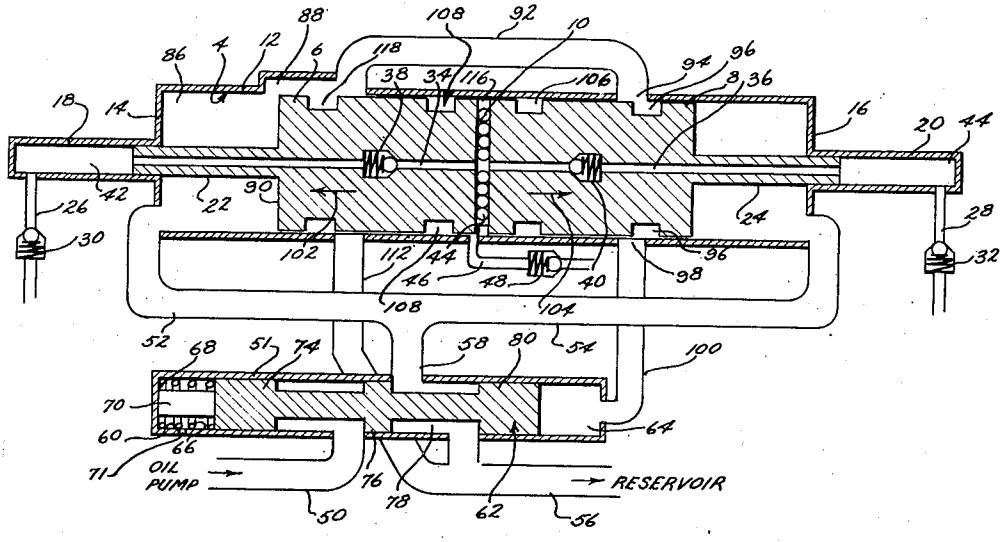


Fig. 2



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United States Patent Office 2,891,718
Patented June 23, 1959

2,891,718

OPPOSED FREE PISTON RECIPROCATING GAS COMPRESSOR

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Application November 6, 1956, Serial No. 620,722

10 Claims. (Cl. 230—53)

The present invention relates to improvements in gas compressors and more specifically to a hydraulically operated free piston reciprocating gas compressor. The present invention contemplates the provision of a cylindrical compression chamber containing a pair of opposed free operating compression pistons forced together in a compression stroke by working pressurized hydraulic fluid and forced apart in the return stroke by a compression spring. The pistons are provided with an internal coaxially bored compressed gas delivery passageway terminating in a cylindrical coaxial extension on the outer end of each of the pistons with the extension projecting slidably into a coaxial compression chamber extension communicating with a gas delivery conduit provided with a non-return valve.

Automatic reciprocation of the free opposed pistons is obtained by self-actuation with the flow of pressurized actuating fluid controlled by a spool valve movable in a valve chamber to alternately communicate the ends of the compression chamber with the compressed working fluid and with the reservoir. The valve spool reciprocates within the valve chamber by action of the compressed working fluid which is conducted to the valve chamber through first, second and third valve operating ports that are placed in communication by being exposed by movement of the first piston and by being aligned with a valve operating passageway through the second piston. The valve spool is moved to its return position by an operating spring and by being vented through first, second, third and fourth valve operating ports and first and second valve relieving passageways to vent the valve to the reservoir.

It is accordingly an objective of the present invention to provide an improved, opposed free piston gas compressor operated by pressurized hydraulic fluid, constructed, operated and controlled in the manner above described.

A broader aspect of the invention is to provide a gas compressor which will eliminate oscillatory vibration by utilizing opposed simultaneous operating free pistons.

Another object of the invention is to provide an improved gas compressor utilizing opposed free pistons which are internally ported, and connected for self-actuated reversal of the piston stroke.

Another object of the invention is to provide an improved gas compressor utilizing opposed free pistons, which is adaptable to either a single stage or to a two stage gas compressor.

Another object of the invention is to provide an opposed free piston hydraulically operated gas compressor wherein full compression strokes of the opposed pistons are assured.

An object of the invention is to provide a hydraulically operated gas compressor which employs a reciprocating piston wherein the control of the piston is through self-actuation obtained by a simplified control valve operated by the hydraulic fluid for actuating the compressor.

Other objects and advantages will become more apparent from the teaching of the priciples of the invention in the disclosure of the preferred embodiments thereof in the specification and drawings, in which:

Figure 1 is a vertical sectional view partially in diagrammatic form illustrating the construction of the compressor and the control valve; and

Figure 2 is another view of the compressor and control valve similar to Figure 1, but with the opposed pistons in their closed discharge position and the control valve moved to a position to permit the pistons to return in their intake stroke.

While the features of the invention are best disclosed with the description of the preferred embodiment described and shown herein, it will be understood that the various elements and features of the invention, while finding particular utility in the combination shown, may be utilized and their advantages exploited in other arrangements, as will be recognized by those skilled in the art.

As illustrated in Figures 1 and 2, the compressor includes a chamber **4**, which is preferably cylindrical in shape so as to contain a pair of opposed free cylindrical compressing pistons **6** and **8**. The pistons are shown at the end of their intake stroke in Figure 1 after having drawn a gas such as air into the chamber 4 in the space **10** between them, and shown in Figure 2 as they appear at the end of their first stage compression stroke.

The cylindrical chamber **4** is formed of a cylindrical wall **12** having end walls **14** and **16**. At each end of the chamber **4**, projecting outwardly coaxially from the chamber are a first and second compression chamber extension **18** and **20**, each of which is of smaller diameter than the main chamber. The pistons **6** and **8** each have a piston extension **22** and **24**, which are slidably engaged in the cylinder extensions **18** and **20**.

The hollow ends of the compression chamber extensions **18** and **20** communicate with compressed gas delivery conduits **26** and **28**. Each of these conduits is provided with a non-return valve **30** and **32**, which are of the conventional type of check valve having a spring loaded ball which seats to prevent the return of gas, but which is unseated by the delivery of a flow of gas of higher pressure than the downstream pressure in the conduit.

When the first and second pistons **6** and **8** move together to compress the gas in the volume **10**, the gas is forced out through the gas delivery passageways **34** and **36** extending in the form of coaxial bores through the center of each of the pistons and terminating in the piston extensions **22** and **24**. Each of the gas delivery passageways is also provided with a non-return valve **38** and **40**, which is in the form of a spring compressed ball check valve similar to that shown in the gas delivery conduit at **30** and **32**. These check valves will permit the passage of gas when the pistons are moved toward each other to reduce the size of the chamber **10** between them.

Although the size of the chambers **42** and **44** at the end of the piston extensions within the cylinder extensions becomes larger, the diameters of these chambers are so much smaller than the diameter of the chamber **4** that the total available volume for the gas will be reduced and the compressed gas will be forced equally out through the two gas delivery conduits **26** and **28**. When the pistons **6** and **8** again separate or move apart in their intake stroke, the chambers **42** and **44** of the compression chamber extensions **18** and **20** will be reduced in volume, and the check valves **38** and **40** will prevent the escape of gas thereby causing a secondary delivery of compressed gas out through the conduits **26** and **28**.

The compression pistons 6 and 8 are forced apart in their intake stroke by a spirally shaped coil compression spring 44. The spiral shape of this spring permits it to be condensed to a fully compacted spiral when the pistons are together as is illustrated in Figure 2.

When the pistons move apart in their intake stroke, gas is drawn in through the air or gas intake conduit 46. This intake conduit is provided with a non-return valve 48, which is in the form of a spring loaded ball check valve, and the check valve will seat to prevent the escape of air or gas within the chamber 10 when the pistons 6 and 8 move together in their discharge stroke.

The motive power for operating the pistons is obtained from a pressurized fluid, such as a hydraulic fluid in the form of oil or the like. While not being restricted to operation by one type of fluid, for convenience of description the material will be interchangeably referred to as oil or hydraulic or operating fluid. Operating fluid is admitted from a fluid or oil pump delivering into the conduit 50. The fluid passes through the control valve 51, which is operated in a manner to be later described, and splits to the fluid operating conduits 52 and 54 leading to the first and second ends of the compression chamber 4. The conduits 52 and 54, leading to the ends of the chamber 4 become return conduits to permit the breakdown of pressure at the ends of the pistons 6 and 8, and to permit the return of fluid to the reservoir through the conduit 56 when the pistons are moved to their return position, as illustrated in Figure 1.

The conduits 52 and 54 connect to the control valve 51 through the base of the T-connection 58.

The control valve comprises a control valve chamber 60, which is preferably cylindrical in form and which contains the valve spool 62. The valve spool 62 is shown at the right end of the chamber 60 in Figure 1, wherein the right end 64 of the valve chamber is relieved, and the spool is shown in its left position in the valve chamber in Figure 2 wherein the spool is actuated by fluid pressure in the end 64 of the valve chamber.

The valve spool 62 is urged to its relieved position, in Figure 1, by the spool operating spring 66 which is compressed between the left hand end of the spool 62 and the base 68 of the valve chamber. A boss 70 may be provided in the chamber for holding the spring and to serve as a stop to limit the motion of spool 62 (Fig. 2). The dead volume at the left end of the chamber 60 is suitably vented at 71 either directly to the atmosphere or to the reservoir.

When in the relieved position, as shown in Figure 1, the valve spool 62 permits communication between the fluid pressure conduit 50 and the conduits 52 and 54 leading to the compression chamber 4. This fluid communication is possible through a passageway 72 in the spool shown in the form of an annular groove extending completely around the spool. At the ends of the annular groove the full diameter of the valve spool forms a land 74 to prevent the oil from leaking into the compartment housing the spring 66, and another land 76 to direct the flow of the pressurized fluid up into the conduit 58.

When the valve spool is in its operated position, as shown in Figure 2, communication is permitted between the passageway 56 leading to the reservoir, and the passageways 52 and 54 leading to the ends of the compression chamber 4. This communication is afforded by the valve by the passageway 78 shown in the form of an annular groove around the valve spool leaving the full diameter land 80 on the spool to isolate the fluid in the end 64 of the valve chamber 60 from the fluid in communication with the reservoir conduit 56.

When the valve spool 62 is in the position of Figure 1, the pistons 6 and 8 will move together in the directions indicated by the arrows 82 and 84. As the pistons move together they reach the closed compressed position of Figure 2, and at this point the valve spool 62 is

moved to the position of Figure 2. To cause the valve spool 62 to move from the relief position of Figure 1 to the operated position of Figure 2, pressurized operating fluid from the left end 86 of the compression chamber is permitted to flow down into the end 64 of the chamber 60. The fluid flows through the first valve operating port 88, which is uncovered by the rear end 90 of the piston 6. The operating fluid then flows through a connecting passageway 92 to the second valve operating port 94 which also extends through the cylindrical wall 12 of the compression chamber. At this point the port 94 is aligned with the valve operating passageway 96 that extends through the second piston 8, and which is shown in the form of an annular groove extending around the piston. This passageway 96 communicates with a third valve operating port 98 that connects to the valve operating conduit 100 to feed pressurized fluid down into the end 64 of the chamber to act against the end of the valve spool 62 forcing it against the action of its spring 66 and moving it to the position shown in Figure 2. This causes the reservoir conduit 56 to be placed in communication with the conduits 52 and 54 leading to the ends of the compression chamber 4. The pressure of the compressed fluid therein will then break down and the fluid will begin to flow back to the reservoir whereupon the coil compression spring 44 will spread the pistons 6 and 8 causing an intake of air or gas through the intake 46 and also forcing the smaller remaining portion of compressed air or gas out of the chambers 42 and 44. When the pistons have been pushed back to the end of their intake stroke, moving in the direction of the arrows 102 and 104, as shown in Figure 2, the valve spool 62 is automatically returned to its relieved position of Figure 1.

When the second piston 8 reaches its return position, its valve relieving passageway 106 will permit communication between the valve operating ports 94 and 98. The valve relieving passageway 106 is shown in the form of an annular groove. This permits escape of the oil or actuating fluid from the valve chamber up through the conduit 100 to pass through conduit 92, through the valve operating port 88 and through the second valve relieving passageway 108, which extends through the first piston 6. This second valve relieving passageway 108 is shown in the form of an annular groove around the piston. The passageway 108 permits communication between the valve operating port 88 and the valve relieving port 110. This port extends through the wall 12 of the compression chamber 4 and connects to a conduit 112 connecting to the reservoir conduit 56. This permits the actuating fluid to flow back to the reservoir and the valve spool 62 will return to the relieved position whereupon the actuating fluid from the oil pump will again be communicated to the ends of the compression chamber 4.

It will be noted that the first piston 6 is provided with an additional unusable annular groove 118, this groove making the piston 6 identical to the piston 8 for ease of manufacture and interchangeability in assembly or repair.

Although the operation of the compressor and control valve will be clear from the description of the individual elements and their relationship to the entity as a whole, a review of the description will be helpful in understanding the operation and appreciating the objectives and advantages of the invention.

With the valve spool 62 shown in the relieved position in Figure 1, pressurized operating fluid is fed through the conduit 50, through the passageway 72 past the valve spool, through passageway 58 and to the passageways 52 and 54 leading to the ends of the compression chamber 4. This forces the pistons 6 and 8 toward each other reducing the area of the chamber 10 between them and forcing the gas out through the passageways 34 and 36 through the center of the pistons. The gas will leave the compressor through the delivery conduits 26 and 28.

When the pistons reach the full extent of their compressed travel, and only when both pistons are completely to the center of the chamber 4, the valve spool 62 will change from the relieved to the operated position of Figure 2. It is to be noted that stop members 116 are provided in the chamber 4 between the pistons so that if one piston reaches the center of the chamber first, it will be stopped until the other piston reaches the center. At this point the rear face 90 of the first piston 6 uncovers the first valve operating port 88, permitting pressurized fluid to flow through the passageway 92 and through the second valve operating port 94. The fluid then flows through the annular passageway 96 around the second piston 8, through the third valve operating port 98, down through the conduit 100 and to the end 64 of the valve chamber 60. This forces the valve spool 62 to the left to cause a communication between the conduits 52 and 54 and the reservoir conduit 56, which permits the fluid to drain from the ends of the compression chamber back to the reservoir. The spring 44 between the pistons 6 and 8 returns the piston in their intake stroke and air will be drawn in through the intake conduit 46. This also forces the compressed air out of the chambers 42 and 44 with the escape of air back through the pistons being prevented by the check valves 38 and 40.

When the pistons 6 and 8 reach their return position, fluid escapes from the valve chamber 60 up through conduit 100, valve operating port 98, valve relieving passageway 102, valve operating port 94, passageway 92, valve operating port 88, valve relieving passageway 108, and valve relieving port 110. The fluid flows down through the conduit 112 and back to the reservoir conduit 56 thus permitting the valve spool 62 to move to its relieved position whereupon the cycle of operation of the compressor is again repeated.

Thus it will be seen that we have provided an opposed free piston compressor which meets the objectives and advantages hereinbefore set forth. The pistons operate simultaneously and eliminate the usual oscillatory vibration that accompanies the operation of a compressor. The pistons are internally ported and, therefore, self-actuated for automatic reversal of the piston stroke. A full stroke of both pistons is insured since the operating valve will not change positions until both pistons are properly at the end of their stroke.

As will be apparent to those skilled in the art, in certain circumstances it may be desirable to use only a single piston instead of the two opposed pistons. This, of course, could be accomplished by providing a cylinder and valve mechanism for one piston only.

It will be recognized that the compressor is well adapted to multiple stage gas compression as well as being advantageous for use in a single stage gas compressor. The control valve and operating mechanism are of rugged construction and adapted to a long operation without the necessity of frequent or accurate adjustment and with fluid operation the parts are capable of a long wearing life.

We have, in the drawings and specification presented a detailed disclosure of the preferred embodiments of our invention, but it is to be understood that we do not intend to limit the invention to the specific form disclosed, but intend to cover all modifications, changes and alternative constructions and methods falling within the scope of the principles taught by our invention.

We claim as our invention:

1. A compressor and control system for compressing a gas comprising a compression chamber, a pair of opposed pistons reciprocable in said chamber, smaller gas delivery extension chambers projecting from the ends of the compression chamber, extensions for each of the pistons slidably projecting into said chamber extensions, gas delivery conduits leading from the ends of said chamber extensions, gas delivery passageways leading through the center of each of said pistons and extending into the piston extensions, a gas intake conduit leading into the chamber between said pistons, a non-return valve in said gas conduit, biasing means positioned between the pistons for spreading the pistons in an intake stroke, working fluid conduits leading to the ends of the chamber to move the pistons in a delivery stroke, a working fluid control valve chamber having a port connected to the working fluid conduits, a spool valve within the valve chamber and having passageways therethrough to communicate with the working fluid port and direct a source of working fluid to the working fluid conduit or to vent the working fluid from the conduit, a port in the compression chamber adapted to be exposed when a first piston is in its full delivery position, a second port in the compression chamber in communication with the first through a valve operating conduit, a third valve operating port in the compression chamber, a valve operating passageway through the second piston, said valve operating passageway through the second piston being aligned with the second and third valve operating ports when the second piston is in a fully discharged position, and a second valve operating conduit communicating between the third port and one end of the valve plunger to move the spool valve to supply pressurized working fluid to the ends of the pistons whereby the spool valve is moved only when both pistons are at the end of their delivery stroke.

2. A gas compressor comprising a compression chamber in which gas is compressed, a free floating working piston movable in the chamber in an intake stroke and a compression stroke and having a compression side and a working side, gas valve means communicating with the chamber on the compression side of the piston for controlling the intake and discharge of gas from the chamber, a fluid control valve chamber, a working fluid conduit connected to the valve chamber and to the compression chamber on the working side of the piston, said valve chamber having a first port connected to said working fluid conduit, a second port for connecting to a source of pressurized fluid, and a third open port for venting fluid, a valve spool slidable in said chamber between a venting position and a fluid delivery position, said first and second ports being in communication in said delivery position, and said first and third ports being in communication in said venting position, a valve control port in said compression chamber positioned to be uncovered by the piston at the end of its intake stroke, means for delivering pressurized fluid to the control port while it is uncovered by said piston, a valve operating line connected between said control port and said valve chamber to move the valve spool to said delivery position with a flow of pressurized fluid from said control port, means for moving said piston in said intake stroke when the working fluid is vented through said conduit and valve, and means for returning said valve spool to venting position when said control port is covered and the fluid pressure delivery to said valve spool is terminated.

3. A gas compressor comprising a compression chamber in which gas is compressed, a pair of opposed freely movable pistons in said chamber adapted for movement toward and away from each other in an intake and a discharge stroke, gas valve means communicating with said chamber to control the intake and discharge of gas from the chamber, fluid valve means communicating with the chamber for controlling the intake and discharge of working fluid from the other end of the pistons, said fluid moving the pistons in their discharge stroke, means for moving the pistons in their intake stroke, and control means intermittently changing the position of said fluid valve means for reciprocating the pistons and compressing the gas as they move in opposing directions in the chamber.

4. A gas compressor comprising a compression chamber in which gas is compressed, a pair of opposed freely movable pistons in said chamber adapted for movement toward and away from each other in an intake and a discharge stroke, gas ports in the chamber for the intake and discharge of gas at one side of each of the pistons, fluid ports in the chamber for the intake and discharge of

working fluid at one side of each of the pistons, said working fluid moving the pistons in their discharge stroke, means for moving the pistons in their intake stroke, gas valve means communicating with said gas ports controlling the intake and discharge from the chamber, fluid valve means communicating with said fluid ports controlling the intake and discharge of working fluid from the other end of the pistons, said fluid valve means being fluid operated, and valve operating ports in the chamber positioned to be covered or opened by movement of the pistons and connected to the fluid valve means whereby movement of the pistons changes the positions of the fluid valve means.

5. A gas compressor comprising a compression chamber in which gas is compressed, a pair of opposed freely movable pistons in said chamber adapted for movement toward and away from each other in an intake and a discharge stroke, gas ports in the chamber for the intake of gas when the pistons move away from each other and for the discharge of gas as they move toward each other, fluid ports at the ends of the chamber to admit and discharge working fluid to operate the pistons, a spring means positioned to urge the pistons apart in their intake stroke and to force working fluid out of said ports, gas valve means communicating with the gas ports, fluid valve means communicating with the fluid ports, and control means for intermittently changing the position of said fluid valve, means for moving the pistons together to compress gas and permitting the pistons to move in opposing directions to discharge working fluid and draw in gas.

6. A gas compressor comprising a compression chamber in which gas is compressed, a pair of opposed freely movable pistons in said chamber adapted for movement toward and away from each other in an intake and a discharge stroke, gas ports in the chamber for the intake and discharge of gas at one side of each of the pistons, fluid ports in the chamber for the intake and discharge of working fluid at one side of each of the pistons, said working fluid moving the pistons in their discharge stroke, means for moving the pistons in their intake stroke, gas valve means communicating with said gas ports controlling the intake and discharge from the chamber, fluid valve means communicating with said fluid ports controlling the intake and discharge of working fluid from the other end of the pistons, and valve positioning means operatively connected to the pistons whereby as the pistons reach one end of their stroke the fluid valve means is changed in position to move the pistons to the other end of their stroke so that the pistons are self actuating.

7. A gas compressor comprising a compression chamber in which gas is compressed, a pair of opposed freely movable pistons in said chamber adapted for movement toward and away from each other in an intake and a discharge stroke, gas ports in the chamber for the intake of gas when the pistons move away from each other and for the discharge of gas as they move toward each other, fluid ports at the ends of the chamber to admit and discharge working fluid to operate the pistons, a spring means positioned to move the pistons away from each other for moving the pistons apart in their intake stroke and to force working fluid out of said ports, gas valve means communicating with the gas ports for permitting the discharge and intake of gas, and a single fluid valve with conduits communicating with the fluid ports at opposite ends of the chamber to simultaneously admit working fluid to the ends of both pistons.

8. A gas compressor comprising a compression chamber in which gas is compressed, a pair of opposed freely movable pistons in said chamber adapted for movement toward and away from each other in an intake and a discharge stroke, gas ports in the chamber for the intake of gas when the pistons move away from each other and for the discharge of gas as they move toward each other, fluid ports at the ends of the chamber to admit and discharge working fluid to operate the pistons, a spring means positioned to move the pistons away from each other for moving the pistons apart in their intake stroke and to force working fluid out of said ports, gas valve means communicating with the gas ports, a fluid control valve chamber having fluid passageways connecting to the fluid ports in the ends of the chamber, a valve spool movable therein and having fluid passageways to be aligned with the passageways of the valve chamber, and valve operating passageways communicating with the compression chamber to change the position of the valve spool in one stroke of the piston whereby the fluid control valve is actuated by the piston.

9. A gas compressor comprising a compression chamber in which gas is compressed, smaller extension gas delivery chambers at the ends of the chamber, a pair of opposed freely movable pistons in said chamber adapted for movement toward and away from each other in an intake and a discharge stroke, extensions on each of said pistons slidably extending into the extension gas delivery chambers, passageways through each of the pistons communicating between the space between the pistons and the gas delivery chambers, a spring means positioned to urge the pistons away from each other for moving the pistons apart in their intake stroke and forcing fluid from the spaces between the ends of the chamber and the pistons, and a fluid control valve communicating with the chamber at the ends of the pistons to admit working fluid to the ends of the chamber for simultaneously forcing the pistons together.

10. A gas compressor comprising a compression chamber in which gas is compressed, a pair of opposed freely movable pistons in said chamber adapted for movement toward and away from each other in an intake and a discharge stroke, gas valve means communicating with said chamber to control the intake and discharge of gas from the chamber, fluid valve means communicating with the chamber on the other side of the piston for controlling the intake and discharge of working fluid from the other end of the pistons, said working fluid moving the pistons in their discharge stroke, means for moving the pistons in their intake stroke, and a control means connected to the fluid valve means and operated by both of the pistons and operative to terminate the supply of operating fluid only after both pistons have completed their discharge stroke.

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