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PISTON AND COMPRESSOR STRUCTURE

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2 Sheets-Sheet 1

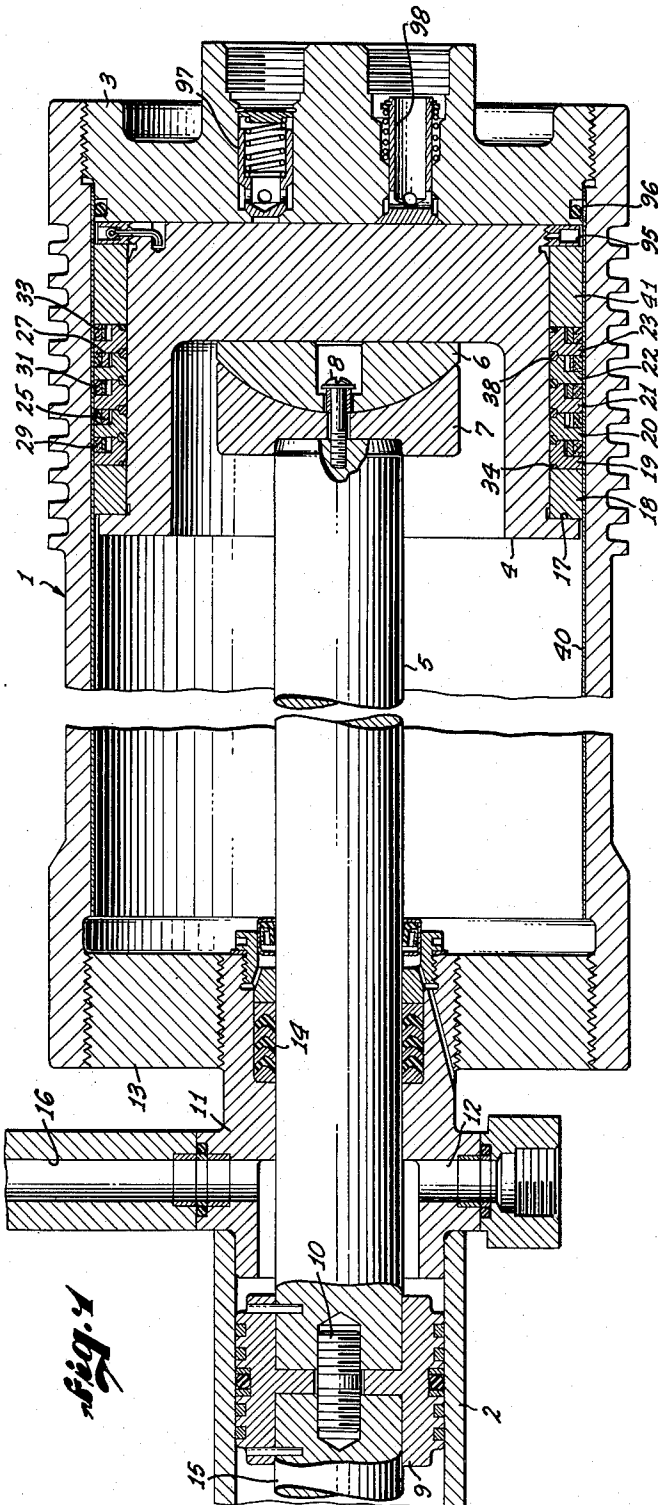


fig. 1

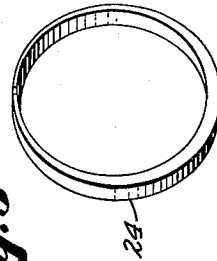
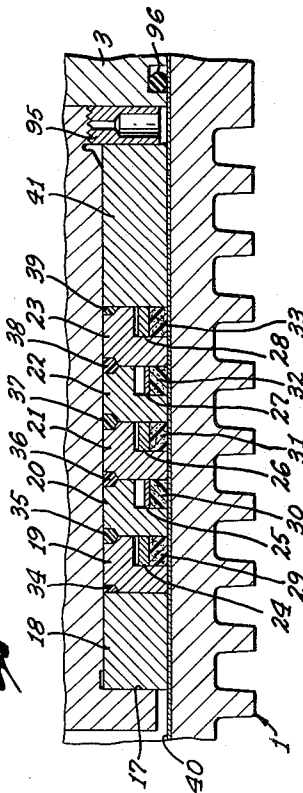


fig. 2



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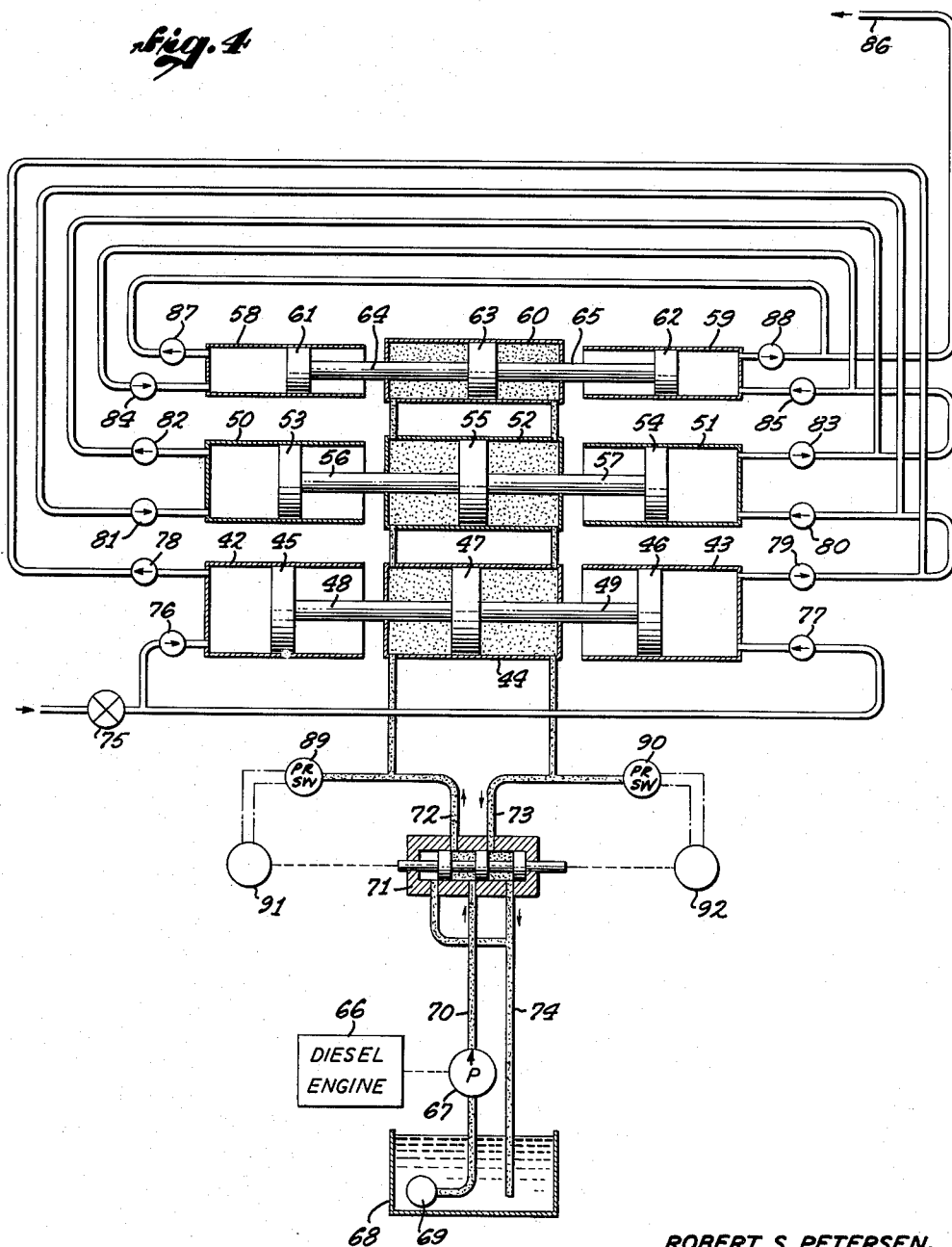
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PISTON AND COMPRESSOR STRUCTURE

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Fig. 4



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2,991,003 PISTON AND COMPRESSOR STRUCTURE

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This invention relates to compressors and more particularly to an improved gas compressor having a novel piston and cylinder assembly, and a control system in which a plurality of piston and cylinder assemblies may be operated with a high degree of efficiency in a multiple stage gas compressor.

In compressors in which gas is compressed at relatively high pressures, it is essential that the moving parts of the compressor system be sealed to minimize the escape of gas. As the pressure of the gas on which the compressor operates is increased, the problem is magnified with the result that in many compressors the degree of compression that can be achieved is limited by the effectiveness of the seals. In conventional piston and cylinder compressors, it is well known to mount one or more piston rings on the piston which engages the cylinder wall to reduce the flow of gas past the piston. In general, if known types of piston sealing rings are constructed of a soft enough material to provide an effective seal, the piston rings rapidly become worn and lose their efficiency. On the other hand, if the piston rings are constructed of relatively hard material to withstand wear, they generally do not provide a good seal.

In multiple stage piston and cylinder compressors where several stages are operated together synchronously, the efficiency of the over-all system is limited because the stroke of each of the pistons is a fixed distance, and with a given source of power the pumping efficiency varies as a function of the pressure of the gas upon which the compressor is operating.

Accordingly, it is an object of the present invention to provide a piston and cylinder assembly including a new and improved seal between the piston and the cylinder.

It is another object of the present invention to provide a new and improved piston sealing ring having superior qualities of sealing efficiency and durability.

It is a further object of the present invention to provide a new and improved multiple stage compressor.

It is still another object of the invention to provide an improved multiple stage compressor including superior piston and cylinder seals along with a novel compressor control system.

It is an additional object of the invention to provide an improved multiple stage compressor system including a novel compressor control system.

Also among the objects of this invention is to provide improvements over the prior art devices heretofore intended to accomplish similar purposes.

It is additionally among the objects of this invention to provide in a new and improved piston construction, new and improved, efficient and highly effective piston ring construction.

Another further object of the invention is the provision of a new and improved piston ring construction in a piston of the character described having maximum ability to withstand high pressures and achieving an optimum sealing and wiping action.

Another object of the invention resides in the provision of new and improved materials and structure thereof for obtaining optimum efficiency at minimum cost associated with ease of production and assembly or disassembly for renewal or replacement.

Yet another object of the invention is the provision of

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a new and improved unique combination of materials adapted to obtain a self-lubricating piston action with optimum wiping characteristics and sealing properties in the combination illustrated, described and claimed.

Yet another object of the invention is the provision of new and improved ring for retaining and installing or disassembling a piston of the desired character described without modification of the basic piston structure but merely by the substitution, elimination or addition of piston ring members for varying the effective piston ring area without altering the over-all structure of the piston.

Yet another object of the invention is the provision in a piston of the character described of new and improved means for removably inserting or replacing any desired number of such piston ring members as herein described.

Yet a further object of the invention is the provision of new and improved ring members per se in a piston of the character described, or its like, which is continuous, self-lubricating and simple to replace or repair.

Another further object of the invention is the provision of new and improved ring expander means for use in connection with a piston ring of the preferred character described.

A further specific object of the invention is the provision of replaceable piston construction and seat members therefor which are capable of ready adjustment for establishing a desired degree of tension against the cylinder wall.

Another object of the invention is the provision of new and improved piston means, including new and improved piston ring means adapted to scour and seat with utmost accuracy and effectiveness against the corresponding cylinder wall.

Other objects and purposes will appear from the following description considered in the light of the accompanying drawings and claims.

In the drawings:

FIGURE 1 is a sectional view of a portion of a stage of a compressor including an illustrative embodiment of the improved piston and cylinder sealing feature of the invention;

FIGURE 2 is an enlarged sectional view of a portion of the piston and cylinder arrangement of FIGURE 1; FIGURE 3 is a perspective view of an expandable ring for use in the apparatus of FIGURES 1 and 2; and

FIGURE 4 is a circuit diagram of a multiple stage compressor including a control system in accordance with the invention.

By way of illustration but not of limitation, as a preferred embodiment of the invention, there is shown in the drawings a cylinder and piston arrangement including a gas cylinder 1 and an hydraulic cylinder 2. The gas cylinder 1 is enclosed at the right-hand end as by a cylinder head 3 which is preferably threaded into the gas cylinder 1, wherein there is mounted, for reciprocation, a gas cylinder piston 4, linked to a piston rod 5, preferably by means of a universal joint type or other preferred connection comprising the members 6 and 7, which are fastener to the piston rod 5 as by means of a cap screw 8.

Within the hydraulic cylinder 2 there is also mounted an hydraulic piston 9 to which the piston rod 5 is connected as by means of a threaded stud, or the like 10. The end of the hydraulic cylinder 2 adjacent the gas cylinder 1 is sealed by means of cap assembly 11 which preferably includes a supply line 12 through which hydraulic fluid is introduced into the hydraulic cylinder 2 for movement of the hydraulic piston 9. The gas cylinder 1 is attached to the cap assembly 11 by means of a threaded cap ring 13. The piston rod 5 is slidably supported in the cap assembly 11, and an hydraulic fluid seal 14 surrounding the piston rod 5 inhibits the flow of

hydraulic fluid along the surface of the piston rod 5.

The apparatus of FIGURE 1 illustrates an hydraulic fluid piston 9 which is adapted to drive a pair of gas cylinders. Accordingly, an additional gas cylinder and piston arrangement may be connected to the left-hand end of the piston 9, therein shown as by means of a connecting rod 15, only a portion of which is shown. In addition, the cap assembly 11 includes a supply line 16 which is connected to the hydraulic cylinder at a successive compression stage whereby a plurality of compression stages may be operated from an initial or single source of hydraulic fluid.

In order to seal the piston 4 within the gas cylinder 1 so that leakage of gas around the piston 4 is minimized, the circumference of the piston 4 includes an annular seat 17 for receiving a piston ring assembly. Such assembly is shown in detail in FIGURE 2, and includes any number of carbon-metal, or the like, bearing rings 18. Adjacent the bearing ring or rings 18 are a series of brass, or the like, sealing rings 19—23, each of which is L-shaped in cross section. Nested in said L-shaped rings 19—23 there are supported spring steel expander rings 24—28 normally biasing specially constructed piston rings 29—33 radially outwardly against the cylinder wall.

The construction of a preferred expander ring is shown in FIGURE 3, in which the same is tapered towards its opposed ends to equalize the expansion stress. Each of the specially constructed piston rings 29—33 comprises a continuous ring of tetrafluoroethylene resin (Teflon) or its like, impregnated with glass fibers, or their like. This resin is remarkably well adapted to provide an effective seal under the encountered temperatures with the inner surfaces of the gas cylinder so as to prevent the flow of gas past the piston.

Due to the fact that, unreinforced, the resin is subject to excessive wear in use, it is necessary to incorporate therein a selected quantity of glass fibers. And the combination thereof has been found to resist wear and fortify the resin without diminishing the extraordinary gas-sealing characteristics of the resultant piston ring. Thus, it has been found that an amount of glass fibers equal to approximately 25% of the piston ring by volume increases the useful life of the rings approximately five-hundred-fold. Even greater amounts of glass fibers can also be used to advantage, as will appear.

In order to minimize the flow of gases around and under the L-shaped rings 19—23, the seals 34—39 are included, and since these seals are not subject to wear, they may compromise substantially pure tetrafluoroethylene, or its like.

Because the piston rings 29—33 engage and wear against the inner wall, a hard layer 40 on the inner surface of the cylinder is needed. Such is advantageously formed by a plating of chromium having an appropriate thickness, e.g., approximately .003 inch, which is treated for required hardness and strength.

The fiberglass filler for the Teflon piston rings tend to be abrasive, and cut into or polish the cylinder wall against which they move. This abrasive polishing quality, which would normally be impractical in cylinder walls of ordinary ferrous construction, is used to advantage by means of the hardened surface coating provided by the preferred chromium plate on the inner surface of the subject cylinder wall. Thereby, the abrasive polishing action provides a smooth and accurate surface against which the glass-filled Teflon forms a virtually perfect seal.

The L-shaped rings 19—23, the expander rings 24—28, and the piston rings 29—33 are held in place on the piston 4 by means of any number of second bearing rings 41, which are similar to the above-mentioned bearing ring 18. A retainer ring 95 is threaded into the piston 4 to lock the piston rings 29—33 and associated parts in place.

The Teflon rings are unbroken so as to avoid the undesired split-ring leakage in piston rings of conventional

construction. The use of the retainer ring structure permits the replaceable insertion of the unbroken Teflon annuli as and for piston rings, because the L-shaped brass retainer rings and the springy expander rings retained therein are all individually and collectively removable and replaceable.

A silicone or other seal is included between the gas cylinder 1 and the cylinder head 3 to eliminate any seepage of gas which might otherwise occur past the cylinder head 3.

Said cylinder head 3 includes an intake check valve 97, which opens to allow gas to enter the cylinder 1 as the piston 4 travels to the left, and an outlet check valve 98, through which the gas passes from the gas cylinder 1 when the piston 4 travels to the right, and vice versa in the opposed piston and cylinder on the corresponding left side of the apparatus.

In operation, hydraulic fluid, under pressure, is introduced into the conduit 12 which pushes the hydraulic piston 9 the left along with any other pistons in successive stages which are similarly connected by means of conduit 16. As the hydraulic piston travels to the left the gas piston 4 follows, the valve 97 opens, and gas is taken into the cylinder 1 between the piston 4 and the cylinder head 3. At a predetermined pressure point in the cycle, the hydraulic fluid is shut off from the conduit 12 and introduced to the opposite side of the piston 9 through a conduit (not shown) which may be similar to the conduit of the cap assembly 11.

The introduction of hydraulic fluid under pressure on the left-hand side of the piston 9 causes the piston 4 to travel to the right in a compression stroke in which the gas passes from the cylinder 1 through the valve 98.

In a particular embodiment, another gas cylinder and piston arrangement may be connected to the left-hand end of the hydraulic piston 4 via the connecting rod 15. Of course, the cycle of operation in the gas cylinder and piston connected to the left-hand end of the hydraulic piston 9 will be opposite with respect to the gas cylinder 1 and piston 4. That is, as the piston 4 advances to the left for a gas intake stroke, the left-hand piston will be advancing to the left for a compression stroke and while the gas piston 4 is advancing to the right on a compression stroke, the left-hand gas piston will be traveling in a gas intake stroke.

In FIGURE 4 there is illustrated a multiple stage gas compressor including three compression stages, each of which is preferably constructed in a manner similar to the new and improved piston and cylinder assembly shown in FIGURES 1—3. Thus, the multiple stage compressor of FIGURE 4 includes a first stage having a left-hand gas cylinder 42, a right-hand gas cylinder 43, and an hydraulic cylinder 44. A gas piston 45, and a gas piston 46 in the gas cylinders 42 and 43 are each connected to an hydraulic piston 47 by means of the piston rods 48 and 49. In a similar fashion, the second stage includes the gas cylinders 50 and 51, an hydraulic cylinder 52, the pistons 53, 54 and 55, and the connecting rods 56 and 57. Likewise, the third stage includes the gas cylinders 58 and 59, the hydraulic cylinder 60, the pistons 61, 62 and 63, and the connecting rods 64 and 65.

In operation, referring particularly to the apparatus of FIGURE 4, the hydraulic cylinder pistons 47, 55 and 63 are adapted to be moved back and forth by alternately connecting a source of hydraulic fluid under pressure to opposite sides of the hydraulic pistons. One suitable method for supplying hydraulic fluid under pressure is shown in which a diesel engine 66 drives a pump 67. The pump intake extends into a reservoir 68, which contains a quantity of hydraulic fluid. Any conventional filter 69 may be included in the intake line. The pump 67 supplies hydraulic fluid under pressure to a fluid conduit 70 which is connected to a suitable valve 71.

Preferably, this is a four-way valve, in which the arrows 75 on the drawing diagrammatically illustrate the path of

hydraulic fluid flow therethrough in one of the respective positions of the same. Thus, when the valve is in one position, the hydraulic supply conduit 70 is connected to a left-hand hydraulic cylinder supply line 72, and a right-hand hydraulic cylinder supply line 73 is connected to a return conduit 74 which discharges into the reservoir 68. In another position of the valve 71, the supply lines 72 and 73 are cross-coupled to the conduits 70 and 74, so that fluid is passed from the supply conduit 70 to the right-hand supply line 73, while the left-hand supply line 72 is connected to the discharge conduit 74 for releasing fluid into the reservoir 68. By switching the valve from one position to the other, the hydraulic pistons 47, 55 and 63 are correspondingly urged first in one and then in the opposite direction, and thereby also the gas cylinder pistons 45, 46, 53, 54, 61 and 62 are reciprocated.

A gas to be compressed, or to be further compressed, such as helium, is introduced to the multiple stage compressor of FIGURE 4 via an inlet valve 75, which is connected via the check valves 76 and 77 to the first stage gas cylinders 42 and 43. As the pistons 45, 47 and 46 move towards the left, the check valve 77 opens to allow gas to enter the right-hand gas cylinder 43, while the check valve 76 remains closed. On the other hand, when the pistons 45, 46 and 47 move to the right, the check valve 76 opens to allow gas to enter the left-hand gas cylinder 42 while the check valve 77 remains closed.

As indicated in FIGURE 4, successive stages of the compressor include gas cylinders of smaller diameter, as desired, and in accordance with sound engineering requirements. By connecting the gas cylinders 42 and 43 of the first stage to the gas cylinders of the second stage, the gas is expelled from the first stage into the smaller gas cylinder chambers of the second stage, thereby effecting a compression of the gas. For this purpose the gas cylinders 42 and 43 of the first stage are connected via the check valves 78 and 79 to the intake check valves 80 and 81 of the second stage gas cylinders 50 and 51. In a similar manner the outlet check valves 82 and 83 of the second stage gas cylinders 50 and 51 are connected to the inlet check valves 84 and 85 of the third stage gas cylinders 58 and 59.

In operation, as the pistons move to the right, gas is forced into the left-hand gas cylinders 42, 50 and 58 from the inlet valve 75 in the case of the first stage, and from the preceding stage in the case of the second and third stages. When the pistons move to the left, gas is taken into the gas cylinders 43, 51 and 59 in the case of the first stage from the inlet valve 75 and the case of the second and third stages from the preceding stage. The third stage gas cylinders 58 and 59 are connected to the outlet line 86 via the check valves 87 and 88. Suitable safety valves and the like devices can obviously be added, as well as cooling apparatus within the skill of the art for securing against excess pressures and conveying away the heat of compression of the gases.

By virtue of a new and improved control system, the multiple stage compressor of FIGURE 4 is adapted to handle the compression of gases over a wide range of inlet pressures while at the same time operating with a high efficiency. It will be appreciated that the length of the stroke of each of the pistons depends upon the pressure of the gas against which the piston is working, and the capacity of the pump 67 to deliver hydraulic fluid at a high enough pressure to move the piston against the pressure of the gas. Of course, as the piston moves, the pressure of the gas increases due to the compression of gas resulting from the transfer of the gas into successively smaller chambers. Thus, when the inlet pressure of the gas is relatively low, it may be expected that the pump 67 will be capable of forcing hydraulic fluid into the hydraulic cylinders 44, 52 and 60, to cause the pistons to travel through a relatively long stroke. However, where the inlet pressure is relatively high, the stroke is automatically shortened as needed to correspond to the

capacity of the pump 67 to deliver hydraulic fluid under pressure and to insure that the maximum efficiency of the pump will be realized.

It has been found that the pressure of the hydraulic fluid is the optimum measurement of the efficiency of operation of the pump. Accordingly, there is provided in the multiple stage pump of FIGURE 4 a pressure sensitive switch 89 connected to the left-hand hydraulic cylinder supply line 72, and another pressure sensitive switch 90 connected to the right-hand hydraulic cylinder supply line 73. These pressure switches 89 and 90 are pre-set and adapted to sense the condition where the fluid in the hydraulic cylinders approaches a predetermined level. Whenever the hydraulic pressure reaches such predetermined level, an appropriate one of the switches 89 and 90 is actuated. By linking the pressure switches 89 and 90 to the valve 71, the valve 71 is actuated to reverse the flow of hydraulic fluid into the hydraulic cylinders 42, 54 and 60, so that the travel of the pistons is reversed. The pressure sensitive switches 89 and 90 may be hydraulically or mechanically linked to the valve 71, or as in the embodiment of FIGURE 4, a pair of solenoids 91 and 92 may be electrically energized by the pressure switches 89 and 90 to switch the valve 71. By means of the control system described above, the overall operation of the compressor is controlled as a function of the hydraulic pressure so that maximum efficiency is achieved beyond any prior art apparatus.

An additional feature of the multiple stage compressor of FIGURE 4 is the connection of the hydraulic cylinders 44, 52 and 60 in parallel so that hydraulic fluid is supplied to each of the hydraulic cylinders from a single source. Due to the common connection of the supply lines 72 and 73, the hydraulic pressure in each of the hydraulic cylinder 42, 54 and 60 is inherently equalized, and since the hydraulic pistons 47, 55 and 63 are not mechanically linked together, the length of the stroke in each stage of the compressor automatically adjusts itself to the most efficient mode of operation in accordance with the pressure of the gas being compressed in each individual compressor stage and the capacity of the hydraulic fluid pump 67 to deliver hydraulic fluid under pressure.

This invention features the provision of new and improved piston ring construction either alone or in association with new and improved expander rings, retainer rings, and hardened complementary cylinder walls. It also features a new and improved unbroken piston annulus of novel and valuable properties in combination with the described, preferred structure, or its like. In addition, the invention features the provision of a multi-stage compressor structure having new and improved hydraulically actuated and pressure-controlled operation to overcome the erratic and inefficient low-inlet pressure capacity of prior art compressors. Moreover, the instant apparatus, by its pressure-controlled switching operation, assures the necessary piston displacement in the first compression stages, giving optimum efficiency and rated capacity, irrespective of inlet or outlet pressures for the apparatus. Among other features is the provision of a construction promoting full use of all compression stages for a subject gas within the limits of available power.

While I have herein shown and described what I believe to be the preferred embodiment of this invention, it is understood that modifications may be made in the combination, subcombination and methods thereof within the skill of the art and in the light of the instant disclosure without departing from the spirit of the invention within the scope of the claims.

I claim:

1. In a gas compressor the combination of a plurality of pump stages, each of which includes a pair of gas cylinders and pistons, and a fluid operated driving cylinder and piston, and piston rods connecting the gas cylinder pistons and the driving cylinder pistons; a source of

driving fluid under pressure; means connecting the source of driving fluid to the driving cylinders of each of the stages in parallel; valve means for selectively applying driving fluid to opposite sides of each of the driving cylinder pistons to cause reciprocating motion of the driving cylinder pistons within the driving cylinders; valve means to admit gas to the first stage gas cylinders; and means interconnecting gas cylinders on one side of the driving cylinders to gas cylinders of a succeeding stage on the opposite side of the driving cylinders to provide a progressive flow through successive stages thereof.

2. In a gas compressor, the combination of a plurality of pump stages, each of which includes a pair of gas cylinders and pistons, a hydraulic cylinder and piston, and piston rods connecting the gas cylinder pistons and the hydraulic cylinder pistons; a source of hydraulic fluid under pressure; means connecting the source of hydraulic fluid to the hydraulic cylinders of each of the stages in parallel; valve means for selectively applying hydraulic fluid to opposite sides of each of the hydraulic cylinder pistons to cause reciprocating motion of the hydraulic pistons within the hydraulic cylinders; valve means to admit gas to first stage gas cylinders and means interconnecting the gas cylinders to provide a progressive flow through successive stages thereof, the gas cylinders of each pump stage being on opposite sides of their respective hydraulic cylinders and gas cylinders being connected to discharge into gas cylinders of a succeeding stage which are on the opposite side of the hydraulic cylinder of the succeeding stage.

3. In a gas compressor the combination of a plurality of pump stages, each of which includes a pair of gas cylinders and pistons, a hydraulic cylinder and piston, and piston rods connecting the gas cylinder pistons and the hydraulic cylinder piston; a source of hydraulic fluid under pressure; means connecting the source of hydraulic fluid to the hydraulic cylinders of each of the stages in parallel; valve means for selectively applying hydraulic fluid to opposite sides of each of the hydraulic cylinder pistons to cause reciprocating motion of the hydraulic pistons within the hydraulic cylinders; means interconnecting the gas cylinders of each of said stages for compressing gases as the hydraulic cylinder pistons are reciprocated, and a pressure sensing device connected to the hydraulic cylinders and the valve means for actuating the valve means to reverse the travel of the hydraulic cylinder pistons whenever the fluid within the hydraulic cylinders achieves a predetermined pressure.

4. In a gas compressor, the combination of a plu-

ality of stages; each of said stages including a pair of gas cylinders and cooperating pistons, an intermediate hydraulic cylinder and piston, and a piston rod connecting the gas pistons and hydraulic piston whereby the pistons travel together in unison; said gas cylinders being oppositely disposed about the hydraulic cylinders so that in each stage the gas piston of one gas cylinder moves in a compression stroke while the gas piston in the other gas cylinder moves in an intake stroke; means connecting the gas cylinders of each stage to the gas cylinders of a successive stage so that gas may be transferred from each gas cylinder during a compression stroke to a gas cylinder of a succeeding stage during an intake stroke; a source of hydraulic fluid under pressure; a first hydraulic fluid supply line connected to the hydraulic cylinders to each of the stages on one side of each of the hydraulic pistons; a second hydraulic fluid supply line connected to the hydraulic cylinders of each of the stages on the other side of the pistons; a valve connected to the first and second hydraulic fluid supply lines and the source of hydraulic fluid under pressure; said valve being adapted to alternately pass hydraulic fluid to the first and second fluid supply lines whereby the hydraulic pistons are reciprocated in the hydraulic cylinders; and a pressure sensing device linked to the hydraulic cylinder supply lines for sensing a condition when the pressure within the hydraulic cylinders rises to a predetermined level; and means linked between the pressure sensing device and the valve for actuating the valve to change the flow of hydraulic fluid from one of the hydraulic fluid supply lines to the other of the hydraulic fluid supply lines whereby the direction of travel of the hydraulic piston is reversed whenever the pressure of the hydraulic fluid rises to said predetermined level.

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