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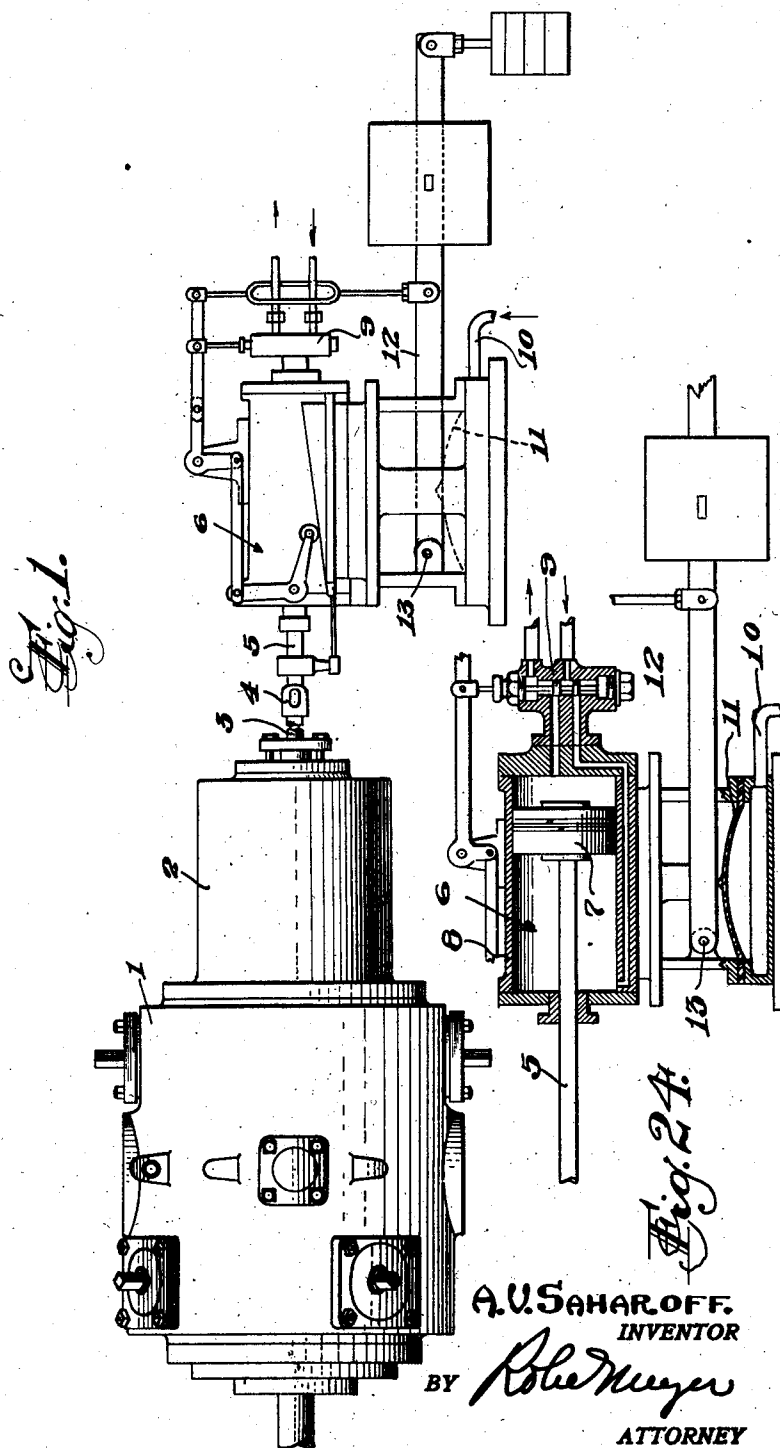
A. V. SAHAROFF

2,197,158

VARIABLE CAPACITY COMPRESSOR

Filed April 7, 1937

9 Sheets-Sheet 1



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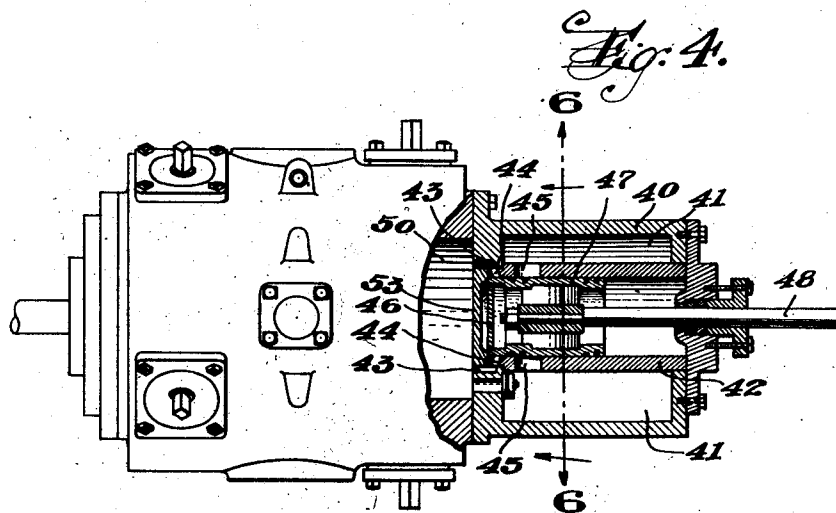
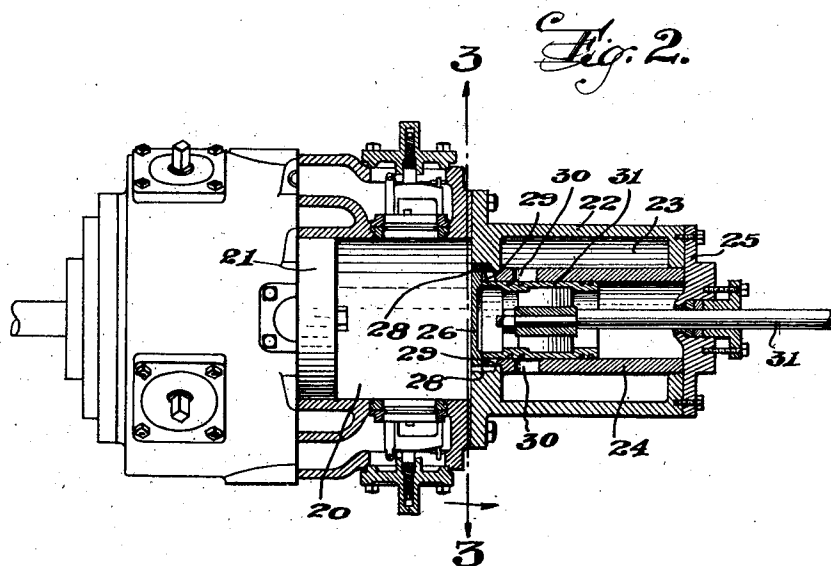
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VARIABLE CAPACITY COMPRESSOR

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9 Sheets-Sheet 2



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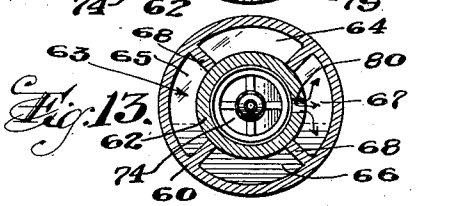
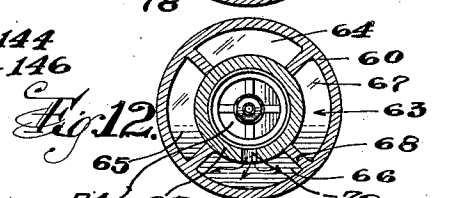
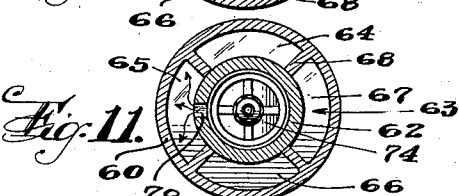
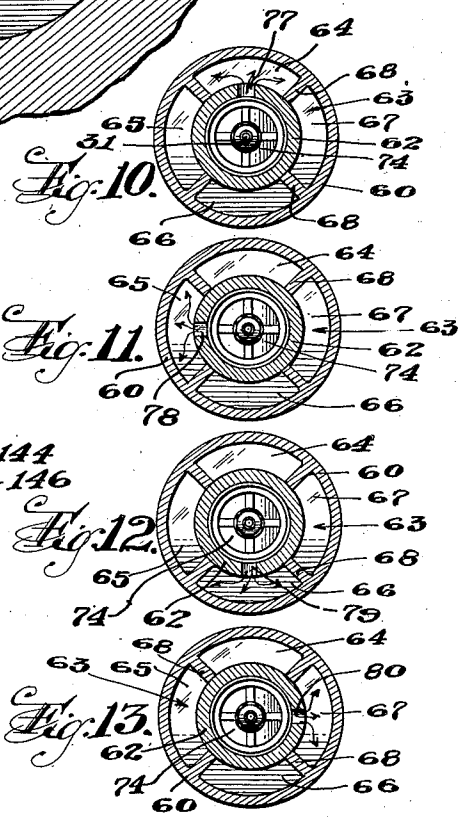
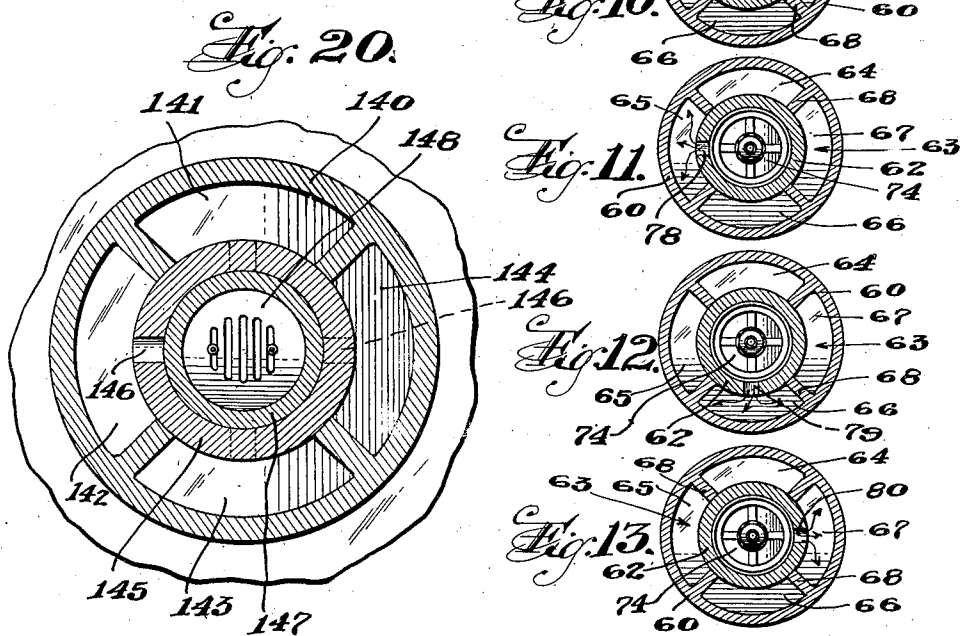
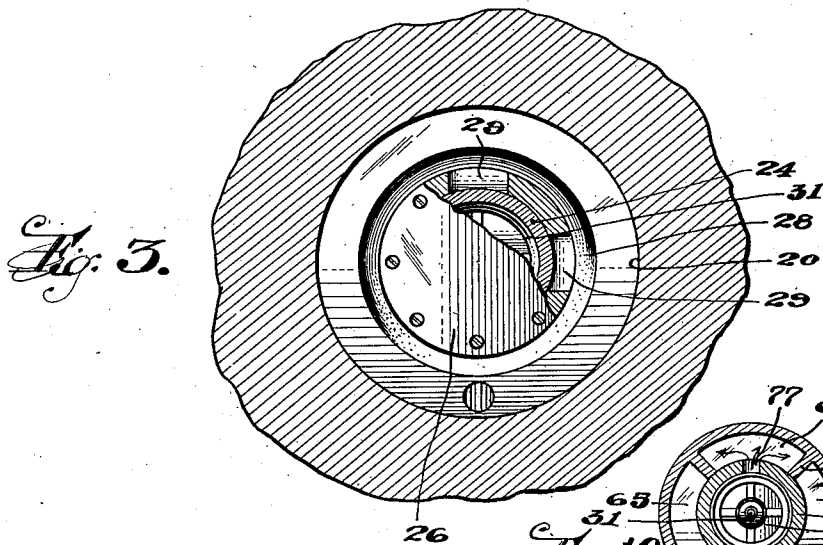
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VARIABLE CAPACITY COMPRESSOR

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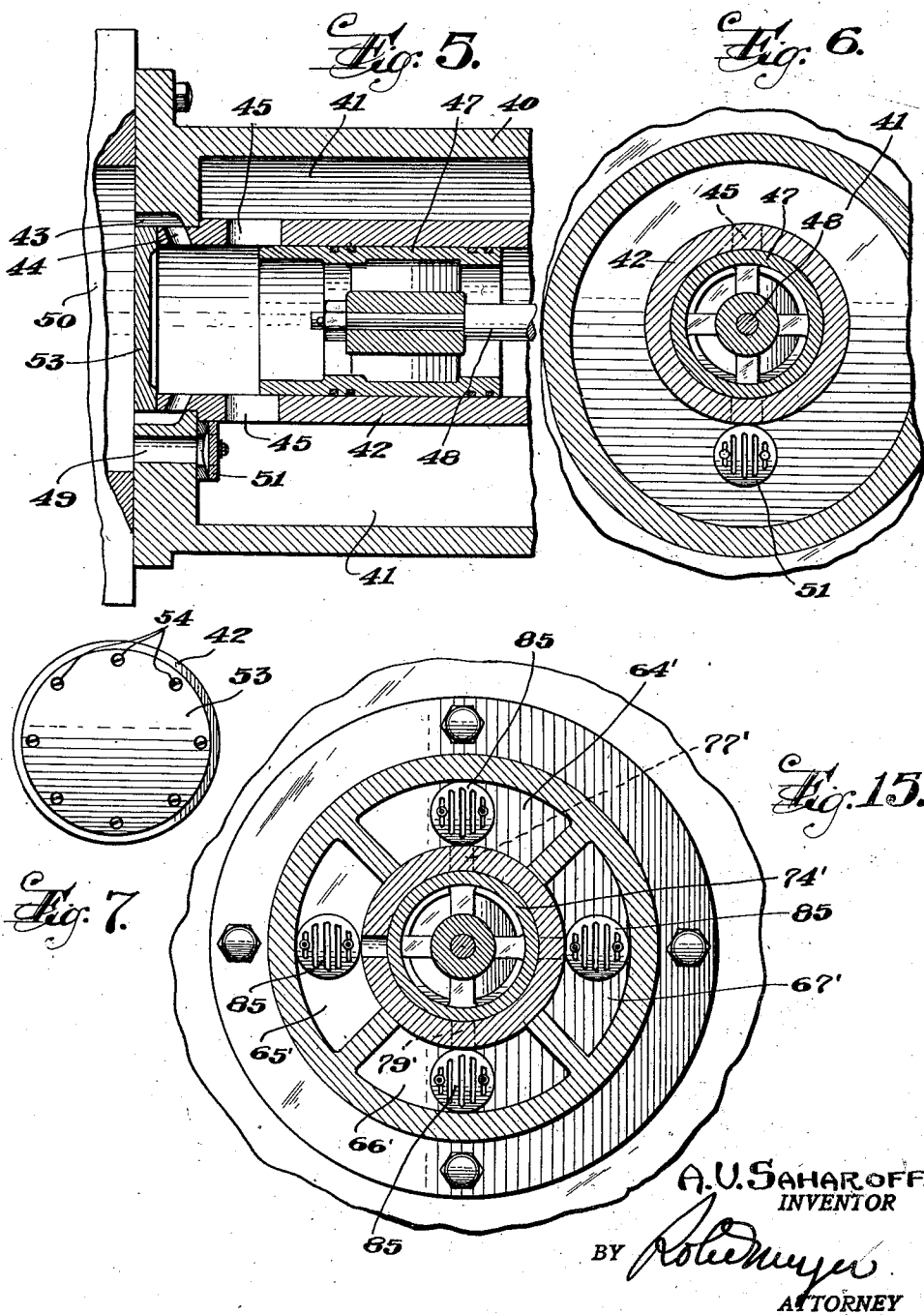
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VARIABLE CAPACITY COMPRESSOR

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Fig. 17.

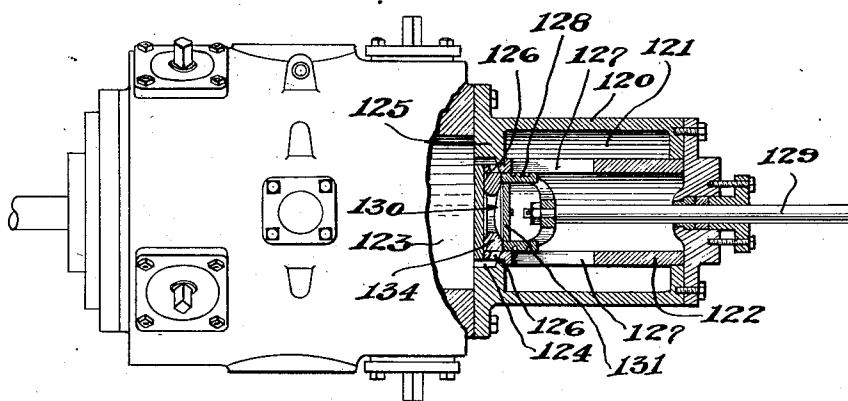
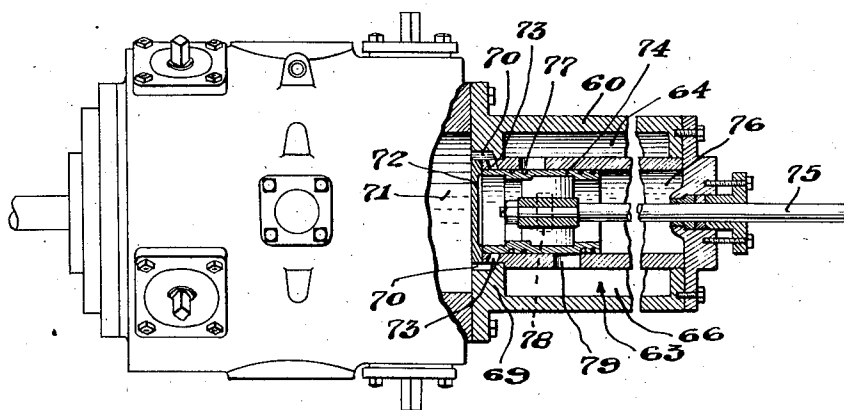


Fig. 8.



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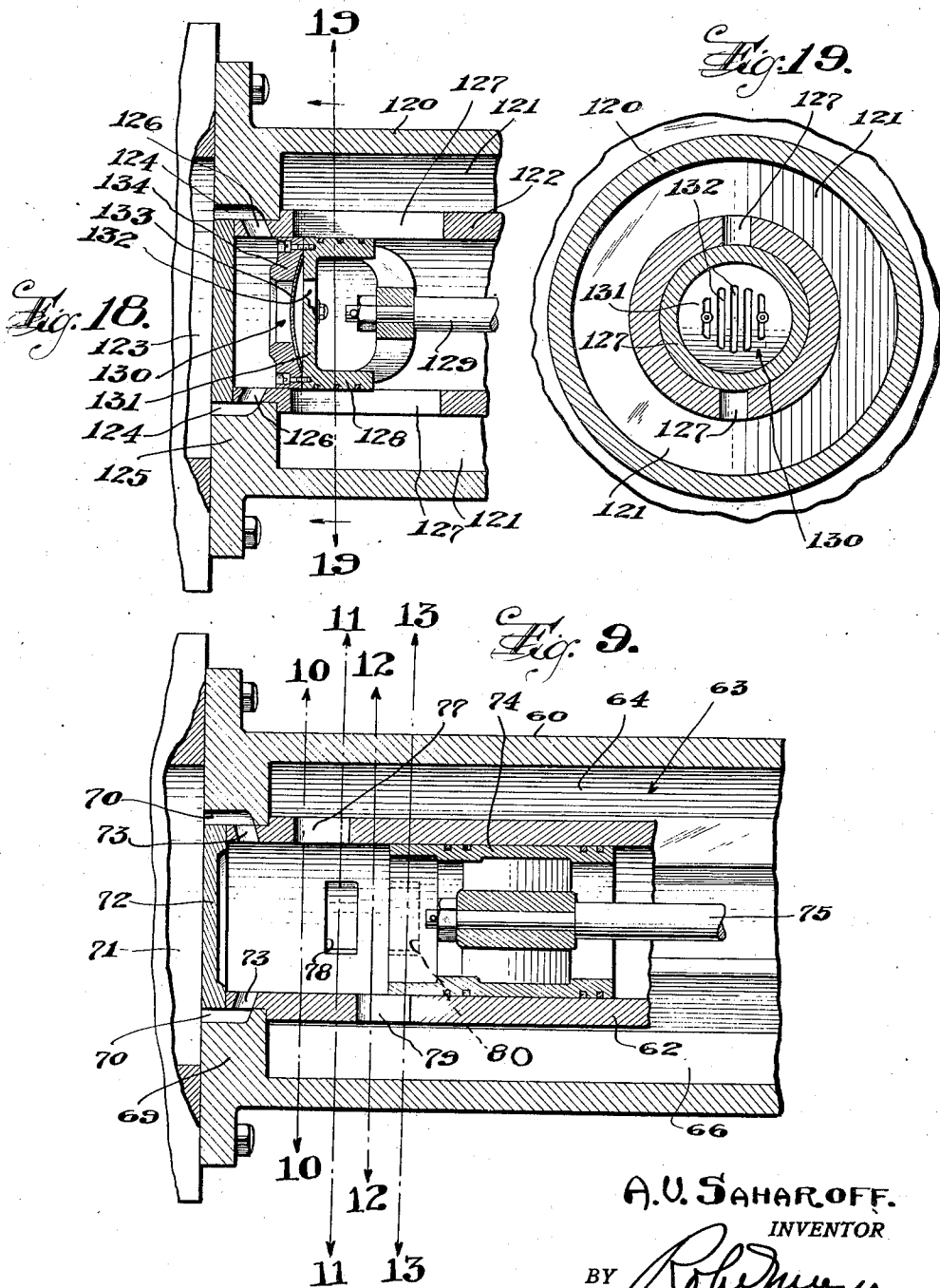
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VARIABLE CAPACITY COMPRESSOR.

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Fig. 14.

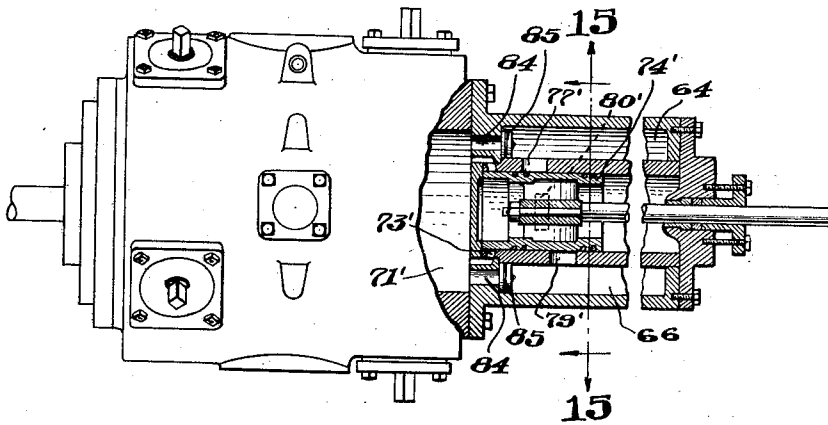
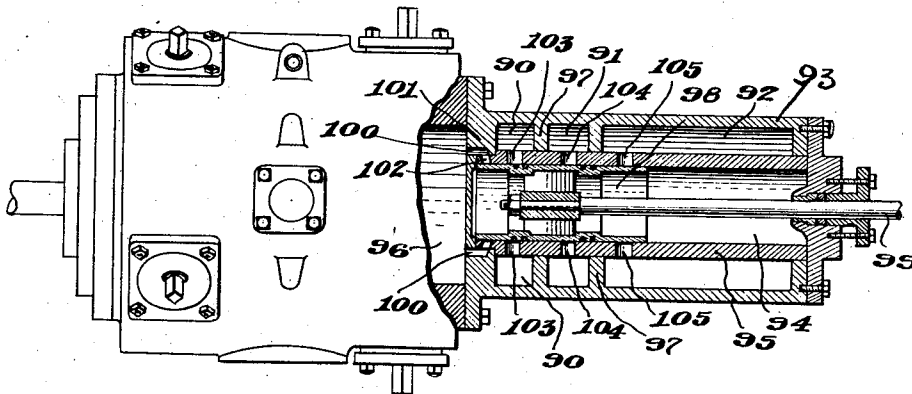


Fig. 16.



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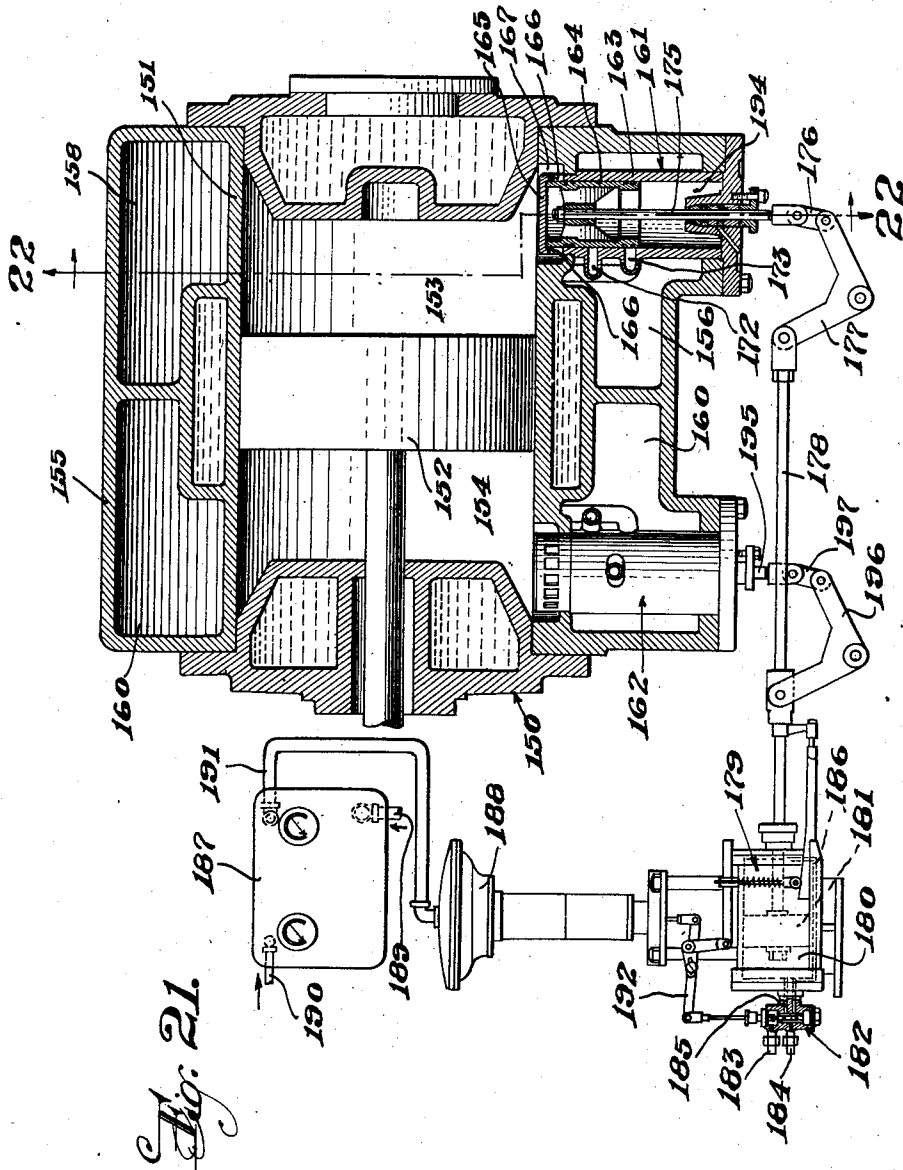
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VARIABLE CAPACITY COMPRESSOR

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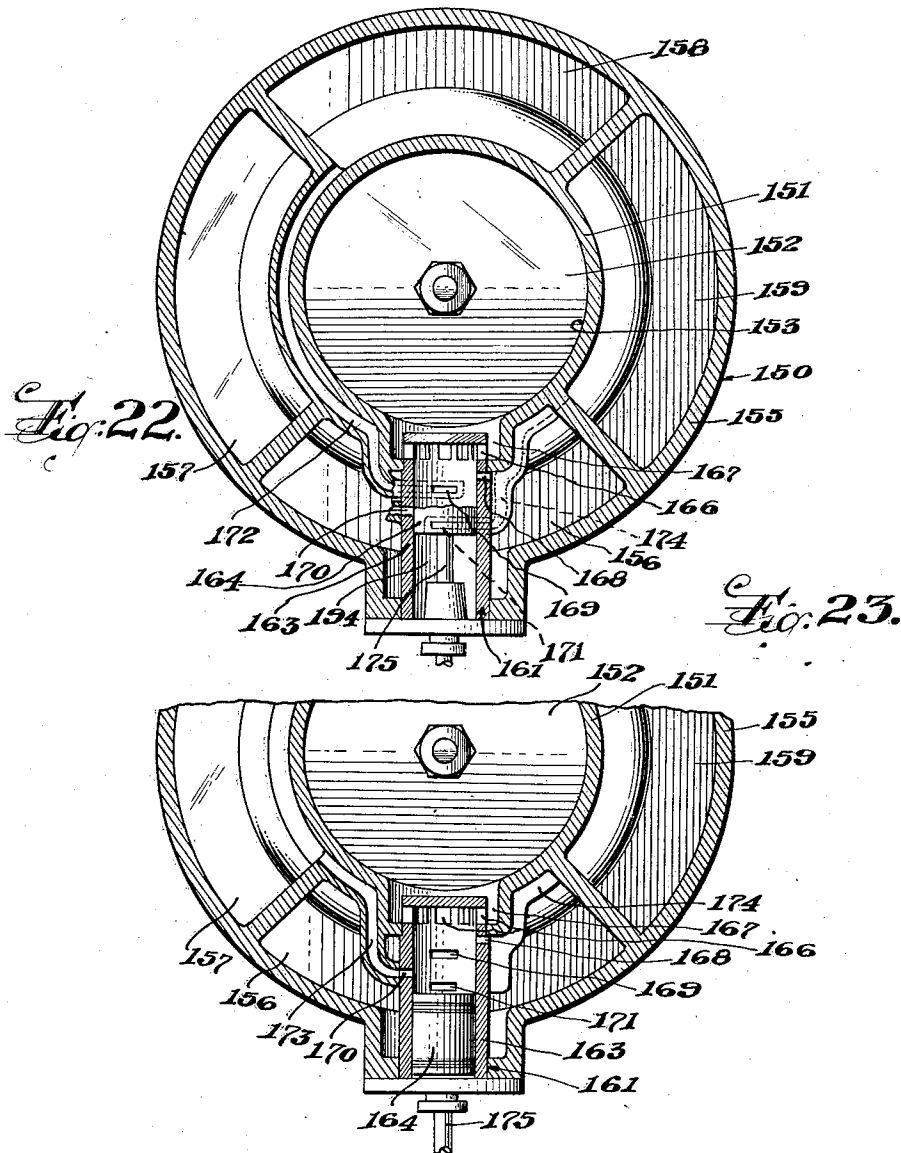
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VARIABLE CAPACITY COMPRESSOR

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2,197,158

VARIABLE CAPACITY COMPRESSOR

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Application April 7, 1937, Serial No. 135,468

11 Claims. (Cl. 230—21)

This invention relates to air or gas compressors and more particularly to a variable volume control mechanism for compressors.

5 An object of the present invention is to provide a volume control mechanism for a constant speed compressor responsive to pressure at some point in the system as, for example, the intake of the compressor, operating on one or more clearance pockets in such a manner as to vary the degree
10 of unloading effected by the clearance pockets gradually and uniformly and thus involving in effect an infinite number of steps in the loading and unloading process whereby the capacity of the compressor will be automatically adjusted to
15 maintain a constant pressure.

More specifically, an object of the present invention is to provide a volume control mechanism for compressors embodying a clearance chamber or chambers and a port or ports establishing communication between the compressor cylinder and the clearance chamber or chambers together with a movable valve controlling and limiting the amount of port opening or closing, thereby controlling and limiting the amount of air or gas
25 interchanged between the cylinder and the clearance chamber or clearance chambers which controls and limits the extent to which the final pressure is built in the clearance chamber, thereby controlling and limiting the amount of effective unloading or loading which the clear-
30 ance chamber can give to the compressor cylinder which permits use of a large clearance chamber with a large degree of unloading to be used for partial, controlled and limited degree of unloading of the compressor cylinder the same as
35 if the size of the clearance pocket itself was varied for different degrees of unloading.

In compressor installations wherein the volume control of the compressor must be arranged
40 to maintain a constant pressure at the discharge or in the intake pipe of the compressor, such as for example oil refinery installations wherein motor driven compressors are employed for pumping gases from stills, the approved type of
45 step by step volume control of the compressor, loading and unloading it in predetermined fractional proportions of its capacity, is not always satisfactory. Such variable volume control mechanisms are in some instances satisfactory
50 for the reason that if the governing mechanism is made sensitive enough to control the intake pressure within sufficiently narrow limits to meet the requirements, it must necessarily change from one step to the next step in such rapid suc-
55 cession as to bring about an objectionable condi-

tion of hunting, especially in those installations where the volume contained in the intake line to the compressor is limited.

An object of the present invention is to provide a variable volume control for overcoming the difficulty above set out, which control provides a clearance pocket or a limited number of clear-
5 ance pockets for controlling compressor capacity, and a valve arrangement for establishing and controlling communication between the clearance
10 pocket or the several clearance pockets and the compressor cylinder by gradually and slowly increasing or decreasing the size of the opening or openings between the compressor cylinder and the clearance pocket or pockets, whereby when
15 any particular clearance pocket is opened throttling occurs in the initial part of the opening action so as to limit the amount of gas taken into and discharged from the clearance pocket. As
20 the valve is gradually opened to a wider and wider position, the throttling is decreased in magnitude in proportion to the degree of opening of the valve and as the total unloading capacity of the particular clearance pocket becomes grad-
25 ually more fully available.

Another object of the present invention is to provide means for reducing to a minimum the economic loss imposed on the cycle of operation of the compressor by the throttling action of the clearance pocket controlling valve, in instances
30 where such losses are occasioned.

A further object of the present invention is to provide a variable volume control mechanism for air or gas compressors, whereby the valve controlling communication between the clearance
35 pocket or pockets and the compressor is directly connected by mechanical means to a pressure operated mechanism, operation of which in turn is controlled by pressure variances in any suitable pressure area such as the intake or discharge
40 of the compressor.

With these and other objects in view, as may appear from the accompanying specification, the invention consists of various features of construction and combination of parts, which will be first
45 described in connection with the accompanying drawings, showing a variable capacity compressor of the preferred form embodying the invention, and the features forming the invention will be specifically pointed out in the claims.
50

In the drawings:

Figure 1 is a side elevation of a compressor cylinder showing the variable volume control mechanism associated therewith.

Figure 2 is a longitudinal sectional view
55

through a part of a compressor cylinder showing one form of the improved variable volume control mechanism associated therewith, however, in this view and subsequent views, the motor which operates the control valve is not shown.

Figure 3 is a cross section taken on the line 3—3 of Figure 2 and having parts broken away.

Figure 4 is a view similar to Figure 2 showing a modified form of the control mechanism in longitudinal section.

Figure 5 is an enlarged detail sectional view of a part of the control mechanism of the type illustrated in Figure 4.

Figure 6 is a fragmentary cross section taken on the line 6—6 of Figure 4.

Figure 7 is a detail end view of the valve cylinder of the control mechanism.

Figure 8 is a side elevation of a compressor cylinder showing a further modified form of the variable volume control mechanism associated therewith and showing this latter mechanism in longitudinal section.

Figure 9 is an enlarged detail section of the control mechanism illustrated in Figure 8. The control mechanism illustrated in Figures 8 and 9 embodies a plurality of clearance pockets or chambers for controlling the capacity of the compressor, whereas the forms in Figures 1 to 7 inclusive embody a single clearance pocket or chamber.

Figures 10, 11, 12 and 13 are detail cross sections taken respectively on the lines 10—10, 11—11, 12—12, and 13—13 of Figure 9 and showing the sequence in the unloading of the compressor cylinder with the type of variable volume control mechanism shown in Figures 8 and 9.

Figure 14 is a view partly in side elevation and partly in longitudinal section of a further modified form of the compressor control mechanism.

Figure 15 is a cross section on the line 15—15 of Figure 14.

Figure 16 is a view partly in side elevation and partly in longitudinal section of a still further modified form of the variable volume control mechanism for the compressor showing a plurality of clearance pockets for controlling the capacity of the compressor which clearance pockets are arranged in longitudinal end to end relation to each other in contradistinction to the radial relation of the clearance pockets as shown in Figures 9 to 15 inclusive.

Figure 17 is a longitudinal sectional view through another modified form of the variable volume control mechanism illustrating such mechanism embodying a single clearance pocket and embodying means for reducing to a minimum the economic loss imposed on each cycle of operation of the compressor by the throttling action of the clearance pocket controlling valve.

Figure 18 is an enlarged fragmentary longitudinal section of the form shown in Figure 17.

Figure 19 is a cross section taken on the line 19—19 of Figure 18.

Figure 20 is a cross section of a modification of the form of control mechanism shown in Figures 18 to 19 inclusive and embodying a plurality of clearance pockets in contradistinction to a single clearance pocket.

Figure 21 is a longitudinal section through a compressor in which the clearance pockets are arranged circumferentially about the compressor cylinder in contradistinction to being located in the head of the compressor as shown in Figures 1 to 20 inclusive and showing clearance pockets in the head and crank ends of the compressor to-

gether with the mechanism, diagrammatically shown, for controlling the operation of the unloading valves.

Figure 22 is a cross section on the line 22—22 of Figure 21, showing communication between the valve cylinder and certain of the clearance pockets.

Figure 23 is a view similar to Figure 22 showing the communication between the valve cylinder and certain other clearance pockets.

Figure 24 is a detail view partly in section of the servo-motor employed in the variable volume control mechanism.

Referring more particularly to the drawings, Figure 1 of the drawings shows a side elevation of a compressor embodying a cylinder 1 and having a head 2 detachably connected thereto in which the clearance pocket or clearance pockets specifically shown in various subsequent figures, are located and in which the control valve which will also be specifically described hereafter is located. The control valve is operated by a shaft 3 which is directly connected in any suitable manner such as by a coupling 4 to the shaft 5 of the servo-motor 6. The servo-motor 6 is of approved type which can be purchased on the market and its specific construction forms no part of the present invention, except in the combination with the compressor, the control valve, etc. The servo-motor 6 includes the piston 7 which reciprocates within the cylinder 8 and has the piston rod 5 connected thereto which in turn reciprocates the valve rod 3. The piston 7 is reciprocated by pressure fluid from any suitable source, which may be a source entirely outside or independently of the pressure system in which the compressor is associated. The delivery of the pressure operating fluid to the cylinder 8 is controlled by the pilot valve 9 while the operation of the pilot valve 9 is in turn pressure controlled either by the suction or discharge pressure of the compressor or from any approved pressure area such as the pressure within the intake pipe to the compressor, the pressure at the discharge of the compressor or the pressure in a receiver (not shown) into which the compressor might discharge. The controlling pressure enters the servo-motor through the inlet pipe 10 and acts on the diaphragm 11 for rocking the lever 12 on its pivot 13 to control operation of the pilot valve 9 and consequently control movement of the piston 7 of the servo-motor. It is understood that the pilot valve 9 controls the delivery of the piston operating pressure fluid to the opposite ends of the cylinder 8 for moving the piston 7 either towards or away from the compressor cylinder 1 for controlling the loading and unloading of the compressor in accordance with variations of the pressure in the pressure area, which is connected to the servo-motor through the pipe 10 for operating the diaphragm 11.

It is understood that the servo-motor as shown in Figures 1 and 24 of the drawings is connected to the valve operating rod of all of the various forms of the variable volume control mechanism shown in Figures 1 to 20 inclusive of the drawings in the same manner as shown in Figure 1 of the drawings.

Referring particularly to the form of variable volume control mechanism for compressors illustrated in Figures 2 and 3 of the drawings, the compressor cylinder 20 in which the piston 21 reciprocates has the head 22 attached to the head end thereof in any suitable manner. The head 22 corresponds to the head 2 in Figure 1 of the

drawings and it has a substantially cylindrical shaped clearance pocket 23 formed therein which is defined by the outer wall of the head 22 and the valve cylinder 24. The valve cylinder 24 extends through the head 22 to the cover plate 25 thereof and it also extends through the inner end of the head, having its inner end 26 facing the interior of the compressor cylinder 20. The inner end 21 of the head 22 has opening therein through which the inner end of the valve cylinder 24 extends, and it also has a counter-bore 28 extending inwardly from the compressor cylinder 20 as clearly shown in Figures 2 and 3 of the drawings. The counter-bore 28 forms an annular ring-like opening which communicates with the interior of the compressor cylinder 20 and with the interior of the valve cylinder 24 through the radial inclined openings 29. The valve cylinder 24 is also provided with a plurality of radial openings or slots 30 opening from the interior of the valve cylinder into the clearance pocket or chamber 23.

A piston valve 31 is mounted for reciprocatory movement in the valve cylinder 24 and its piston rod 31, which corresponds to the piston rod 3 in Figure 1 of the drawings is connected to a servo-motor as shown in Figure 1, the general view.

When the pressure entering the pipe 10 of the servo-motor 6 is such as to require reduction in the volume of the capacity of the compressor, the servo-motor will be operated to move the valve 31 outwardly from the position shown in Figure 2 of the drawings. The operation of the servo-motor will be such that the valve 31 will be slowly moved outwardly, gradually uncovering the ports 29 and opening them to the interior of the valve cylinder 24, the interior of which cylinder will act as a clearance pocket. Upon the compressing and discharge movement of the piston 21 a predetermined portion of the fluid compressed in the head end of the cylinder will pass through the ports 29 into the interior of the valve cylinder 24, depending upon the degree of opening of the ports 29, this proportion of the capacity of the head end of the compressor increasing as the area of the opened parts of the ports 29 increase. When the valve 31 has been moved sufficiently to completely open the ports 29, then the full capacity of the valve cylinder 24 will be operative as a clearance pocket or chamber for reducing the output of the compressor an amount proportional to the capacity of the valve cylinder 24. On the suction or intake strokes of the piston 21 of the compressor, the air or gas which has passed into the interior of the valve cylinder 24 will be drawn back into the cylinder 20 of the compressor through the ports 29 and the annular or ring-like port 28.

As the pressure of the fluid in the controlling pressure area varies further, it will continue to operate the servo-motor 6 for moving the piston valve 31 farther out, and after a predetermined distance of movement of the piston valve 31 and after the full capacity of the valve cylinder 24 has been utilized as a clearance pocket, the movement of the piston valve 21 will gradually open the ports 30. The initial opening of the ports 30 as well as of the ports 29 provides a throttling action which limits the flow of the air or gas from the cylinder 20 into the clearance pocket formed by the valve cylinder 24 or into the clearance pocket 23. The throttling gradually decreases in magnitude in proportion to the degree of opening of the respective openings or ports, so that by the gradual movement of the piston valve

31 under the action of the servo-motor an indefinite number of steps in the unloading of the compressor cylinder are provided which unload the compressor cylinder from its full capacity to that fractional portion of its capacity, which may be the entire capacity, represented by the capacities of the clearance pocket or chamber within the valve cylinder 24 and the clearance pocket or chamber 23.

Upon a reverse variation of pressure in the controlling pressure area, the servo-motor 6 will be operated in a reverse direction which will slowly and gradually move the piston valve 31 inwardly closing the ports 30 and 29 in the same or substantially the same increment in which they are opened. The speed and degree of opening and closing of the ports 29 and 30 respectively depends of course upon the degree of variation of pressure in the controlling pressure area.

The controlling pressure area may be the pressure at the inlet of the compressor cylinder 20, may be the pressure at the discharge of the compressor or any other suitable pressure area such as a receiver (not shown) into which the compressor discharges.

The throttling of the openings 29 and 30 and consequently the throttling of the passage of the air or gas from the compressor cylinder 20 into the clearance pockets or chambers imposes an economic loss on the cycle of operation of the compressor, which economic loss is of course reduced proportionately to the number of steps or increments provided in the unloading of the compressor. However, in order to reduce such economic loss to an absolute minimum, the form of the invention disclosed in Figures 4 to 7 inclusive is provided.

In this modified form shown in Figures 4 to 7 of the drawings, the head 40 corresponds to the heads 22 and 2 and it has a clearance pocket 41 formed therein by the walls of the head 40 and the valve cylinder 42. Communication is had with the interior of the compressor cylinder through an annular or ring-like port 43 which corresponds to the annular or ring-like port 28, radial ports 44 in the cylinder 42, and from the valve cylinder 42 through the plurality of radial ports 45 to the clearance pocket 41.

The valve 41 has a valve rod 48 connected thereto which is connected in turn to a servo-motor such as the servo-motor 6 and the valve 41 is operated in exactly the same manner as the valve 31, such operation having been heretofore disclosed.

The clearance chamber 41 is shown in the drawings as eccentric of the valve cylinder 42, but the invention is not to be so limited. The clearance pocket 41 has an outlet port 49 communicating therewith and communicating with the interior of the compressor cylinder 50. This outlet port 29 is controlled by an automatic check valve 51 of any approved type but preferably of the "Feather" valve type such as disclosed in Letters Patent Number 1,916,685. This automatic check valve 51 is so positioned and operates in such manner as to allow full egress from the clearance pocket 41 into the compressor cylinder 50, but at the same time embodies partial ingress to the cylinder in proportion to the amount of the opening of the ports 45 by the valve 41. In other words the throttling of the air or gas as it passes from the compressor cylinder 50 to the clearance pocket or chamber 41 is always under control of the valve 41 and proportional to the amount of its opening. If the size of the check valve 51 is

sufficiently large, there will be practically no throttling of the air or gas when it passes from the clearance chamber to the cylinder and thus the economic loss which would be occasioned by the throttling of the opening or port 45 by the valve 47 will be eliminated.

The valve cylinder 42 is preferably formed of a cylinder normally open at both ends with its inner end closed by a closure plate 53. The closure plate 53 may be attached to the cylinder 42 in any manner such as by the bolts or tap screws 54. An end view of the valve cylinder is shown in Figure 7 of the drawings.

The present invention comprehends the provision of any predetermined number of clearance chambers or pockets for unloading the compressor which are successively brought into and out of unloading communication with the compressor cylinder, and in Figures 8 to 13 inclusive of the drawings is illustrated a further modification of the variable volume control for a compressor which embodies a plurality of clearance pockets or chambers.

In this form of the variable volume control mechanism, the clearance head 60, which corresponds to the clearance heads 2 and 40, has an annular space therein provided by the walls of the clearance head and the valve cylinder 62. This annular space 63, however, is divided into a plurality of radially disposed clearance chambers or pockets 64, 65, 66 and 67 by the partitions 68 as clearly shown in the cross sectional views 10 to 13 inclusive.

The inner end 69 of the head 60 is provided with a central bore through which the end of the valve cylinder 62 extends, and it is also provided with a counterbore 70 which provides an annular or ring-like port opening into the compressor cylinder 71 around the inner closed end 72 of the valve cylinder 62. The valve cylinder 62 is provided with a plurality of radial ports 73 corresponding to the radial ports 29 by means of which communication is established between the interior of the valve cylinder 62 and the interior of the compressor cylinder 71.

A piston valve 74 reciprocates in the valve cylinder 62 and its rod 75 is connected to a servo-motor such as the servo-motor 6 for moving the valve upon pressure variances in the control pressure area.

In this form of the invention five clearance pockets or chambers are provided which together with their various ports of communication in combination with the slow gradual movement of the piston valve 74 will provide substantially an infinite number of steps for the unloading and loading of the compressor and consequently provide high sensitive volume control of the compressor cylinder without any hunting or indecisive action on the part of the volume control mechanism.

Upon initial or small pressure variances in the control pressure area from the predetermined desired pressure, the servo-motor will act to move the piston valve 74 outwardly and gradually uncover the ports 73, opening the clearance chamber 76 formed in the interior of the valve cylinder 72 to the compressor cylinder 71 for unloading the compressor cylinder in increments of the capacity of the clearance pocket 76, such increments of capacity being proportional to the degree of opening of the ports 73.

As the pressure difference in the pressure control area further increases beyond the desired predetermined pressure the piston valve 74 is

continued in its outward movement by operation of the servo-motor and as it moves outwardly it gradually opens the port 77 which opens the clearance pocket 64 to the compressor cylinder 71 which increases the clearance capacity and consequently decreases the discharge volume of the compressor in proportion to the capacity of the clearance pocket 76 and the clearance pocket 64. The active clearance area of the clearance pocket or chamber 64 is of course gradually varied in increments of its capacity in proportion to the degree of opening of the port 77 until such time as the port 77 is completely open and the full clearance capacity of the chamber or pocket 64 is utilized. Further outward movement of the valve 74 under further increase in pressure difference from the predetermined desired pressure in the control area will gradually open the port or passage 78 which opens communication between the clearance pocket 65 through the valve cylinder 62 with the compressor cylinder 71. The clearance area of the clearance pocket or chamber 65 is gradually brought into effective operation in proportion to the degree of opening of the port 78 is as the pressure difference from the predetermined desired pressure in the pressure area further increases, the piston valve 74 continues slowly in its outward movement and gradually opens or uncovers the port 79 which opens the clearance pocket or chamber 66 to the compressor cylinder 71 in gradually increasing increments of its capacity in proportion to the degree of opening of the port 79. Further continued outward movement of the piston valve 74 gradually opens the port 80 which in turn opens the clearance pocket 67 to the compressor cylinder 71. When the port 80 is entirely open then all of the clearance pockets 76, 64, 65, 66 and 67 will be open to the compressor cylinder 71 and active to unload the compressor to zero capacity.

When the pressure difference in the control pressure area decreases the servo-motor will act to move the piston valve 74 inwardly and gradually cut off the various clearance pockets or chambers from communication with the compressor cylinder in a reverse order from that in which they are opened to the compressor cylinder. It will therefore be seen that with a plurality of clearance pockets or chambers communication of which with the compressor cylinder is gradually controlled, each in a large number of increments of its capacity, that an indefinite number of steps will be provided in the unloading and loading of the compressor cylinder providing practically perfect sensitive volume control of the compressor without any indecisive or hunting action on the part of the control mechanism.

In Figures 14 and 15 is illustrated a modification of the form of variable volume control shown in Figures 9 to 13 inclusive. This form is identical in construction and operation with the form just described and disclosed in Figures 9 to 13 inclusive except that the clearance pockets 64', 65', 66' and 67' all have ports or passages 84 communicating therewith and communicating with the compressor cylinder 71'. The ports 84 are controlled by check valves 85 of any approved type but preferably of the "Feather" valve type such as the valve 51 heretofore described in connection with Figures 4, 5 and 6 of the drawings. The automatic check valves 85 operate in the same manner as the automatic check valves 51, that is, they are provided to reduce any economic loss on the cycle of operation of the compressor

to an absolute minimum and they are so positioned, and the ports 84 are of such size as to allow full egress from the respective clearance pockets to the compressor cylinder 71' but at the same time they impose partial ingress to the cylinder in proportion to the amount of valve opening. In other words these valves 85 and the ports 84 will permit full discharge of the air or gas from the respective clearance pockets into the compressor cylinder 71' upon the suction operation of the compressor and will eliminate the economic loss in the return of the gas to the compressor cylinder which would otherwise be occasioned by the throttling of the various openings 73', 77', 78', 79' and 80' by the piston valve 74' during the operation of the apparatus.

In Figure 16 a form of variable volume control for a compressor is shown in which a plurality of clearance pockets 90, 91 and 92 are provided in the clearance head 93 and they cooperate with the clearance pocket or chamber formed within the valve cylinder 95 for controlling the degree of unloading of the compressor cylinder 96. These pockets, however, are each an annular or ring-like pocket and are spaced end to end in the head 93 being formed by suitable ring-like partitions 97 whereas the various pockets 64, 65, 66 and 67 are radial pockets.

A piston valve 98 reciprocates in the valve cylinder 95 and it is operated from a servo-motor such as the servo-motor 6 through the medium of the piston rod 99 in the same manner in which the piston valves of the various forms heretofore described operate. Communication between the compressor cylinder 96 and the interior of the valve cylinder 95 is had through an annular port 100 formed by a counterbore in the inner end 101 of the head 93 and the plurality of radial ports 102 which increase with the radial ports in the various other valve cylinders heretofore described. The various clearance pockets 90, 91 and 92 are opened to the compressor cylinder 96 through the valve cylinder 95 each through a plurality of radially disposed openings 103, 104 and 105 respectively. These series of radial openings are arranged in longitudinally spaced relation in the valve cylinder 95 so that the clearance pockets are successively opened to the compressor cylinder 96 as the valve 98 moves outwardly and are successively cut off in an inverse succession as the piston valve 98 is moved inwardly.

In Figure 16 of the drawings the clearance pocket 92 is shown as of greater capacity than the clearance pockets 90 and 91 and it may be understood that any one of these clearance pockets may be made with a larger area than the other or that all of them may be of the same size without departing from the spirit of the present invention. Also while in the various forms heretofore disclosed, such as those including a plurality of clearance pockets, said pockets have been shown as of the same size, it is to be understood that such clearance pockets may be of unequal size and/or capacity without departing from the spirit of the present invention.

In Figures 17 to 19 inclusive of the drawings the clearance head 120 is provided with a single substantially cylindrical clearance pocket 121 defined by the walls of the head 120 and the valve cylinder 122. The interior of the valve cylinder has communication with the interior of the compressor cylinder 123 through the usual annular or ring-like port 124 formed in the inner end 125

of the head 120. The valve cylinder 122 is provided with a plurality of radial ports 126 which are the same as the various other radial ports 29, 73, etc. The valve cylinder 122 is provided with a plurality of slots or long ports 127 which establish communication between the clearance chamber or pocket 121 and the compressor cylinder 123 and such communication is controlled by the piston valve 128. The piston valve 128 is operated from a servo-motor such as the servo-motor 6 through the medium of the valve rod 129. The valve piston 128, however, differs from the valve pistons in the various types heretofore described in that its inner end is formed of an automatic check valve 130. This check valve 130 may be of any approved type but preferably of the "Feather" valve type as above referred to. The head 131 of the piston valve 128 forms the valve seat which is ported in the usual manner as shown at 132. The ports 132 are controlled by the flexible valve strips 133 and are confined and limited in their movement by the guard 134 which is attached to the head 131 in any suitable manner. The automatic check valve structure 130 is arranged so that it will be closed on pressure fluid passing inwardly through the ports 126 into the cylinder and prevent any passage of fluid under pressure from the compressor cylinder 123 into the clearance chamber or pocket 121 except at such times as the piston valve 128 is moved rearwardly under the action of the servo-motor to partially open the ports 127. However, upon the suction operation of the compressor the flexible valve strips 133 unseat and permit free flow of the fluid under pressure from the clearance pocket back into the compressor cylinder 123. The valve structure 130 is provided to decrease to a minimum economic loss in the cycle of operation of the compressor which would be occasioned by the throttling action of the piston valve 128 and the openings 127 when the latter openings are only partially opened. The degree or proportion of unloading of the compressor cylinder 123 is controlled by the degree of or the amount that the openings 127 are opened forwardly of the piston valve 128 and full active unloading operation of the clearance pocket or chamber 121 is permitted only when the openings 127 are entirely opened. At all other times the unloading action of the clearance chamber or pocket 121 is in direct proportion to the degree of the opening of the ports 127 to the cylinder 123. Thus by the gradual movement of the piston valve 128 outwardly the compressor cylinder 123 may be unloaded in an indefinite number of steps or increments between the complete loaded condition and the active incorporation of the entire unloading capacity or area of the clearance chamber or pocket 121. The compressor cylinder 123 is loaded in an inverse manner by the inward movement of the piston valve 128.

In Figure 20 a cross section through a clearance head 140 is shown which clearance head is divided into a plurality of radial clearance pockets 141, 142, 143 and 144. These clearance pockets have communication with the interior of the valve cylinder 145 through openings 146 which correspond to the various openings 77, 78, 79 and 80 in Figure 9 of the drawings.

In this modified form shown in Figure 20, however, the piston valve 147 has an automatic check valve 148 in its inner end exactly in the same manner as the automatic check valve 130, is associated with the piston valve 128. The auto-

matic check valve 148 operates in exactly the same manner and for the same purpose as the automatic check valve 130.

In all of the various forms heretofore described the various clearance pockets have been illustrated and described as being formed in a clearance head at the end of the compressor and all controlled by a single piston valve. However, in Figures 21 to 23 inclusive a modification of the invention is shown wherein the clearance pockets are formed in the shell of the compressor cylinder and a series of pockets are provided for the head end of the cylinder and a second series of clearance pockets are provided for the crank end of the cylinder. The two series of clearance pockets are each controlled by independent piston valves.

Referring more specifically to the modification of the invention shown in Figures 21 to 23 inclusive, the compressor 150 embodies the compressor cylinder 151 in which the piston 152 reciprocates. The piston 152 compresses both at the head end 153 and the crank end 154 of the cylinder 151. The shell 155 of the compressor cylinder has a set of clearance pockets 156, 157, 158, and 159 formed therein about the head end of the cylinder and a second set of clearance pockets similar in shape and size, as well as in arrangement, about the crank end of the compressor cylinder. The opening of the clearance pockets 156 to 159 inclusive are controlled by a control valve structure 161 while the clearance pockets 160 about the crank end of the cylinder are controlled by a control valve structure 162.

The valve structure 161 is similar to and substantially the same as the various control valve structures heretofore described in connection with the various forms of the invention illustrated in Figures 1 to 20 inclusive. That is, it comprises a valve cylinder 163 in which a piston valve 164 reciprocates. The valve cylinder 163 has its inner end 165 closed and it is further provided with a plurality of radial openings or ports 166 which establish communication between the interior of the valve cylinder 163 and the interior of the head end 153 of the compressor cylinder 151 through the medium of an annular ring-like port 167.

The cylinder 163 is provided with a plurality of longitudinally spaced ports 168, 169, 170 and 171. The port 168 opens into the clearance pocket 156. The port 169 opens into a passageway 172 which in turn opens into the clearance pocket 158 while the port 170 opens into a passageway 173 which in turn opens into the clearance pocket 157. The port 171 opens into a passageway 174 which in turn opens into the clearance chamber 159. Thus by provision of the various ports 168, 169, 170 and 171 together with the passages 172, 173 and 174 the various clearance pockets may be opened to communication with the head end 153 of the compressor cylinder 151 for unloading the head end of the compressor cylinder in various proportions of its capacity, such unloading being controlled by the movement of the piston valve 164. While in the drawings, a particular construction or arrangement of passages 172, 173 and 174 is illustrated, it is to be understood that these passages may be formed or arranged in any suitable manner without departing from the spirit of the invention, so long as the various clearance pockets may be successively brought into communication with the crank end of the compressor cylinder as the piston valve 164 moves outwardly.

The piston valve 164 has a piston rod 175 connected thereto which is in turn connected by an articulate connection 176 to a bellcrank 177. The bellcrank 177 is connected to the piston rod 178 of the servo-motor 179 so that the piston valve 164 will be operated by the servo-motor 179. The servo-motor 179 is similar in its general construction to the servo-motor 6, that is it includes a cylinder 180 in which a piston 181 reciprocates. The reciprocation of the piston 181 operates the piston rod 178 and its speed of reciprocation as well as its direction of movement is controlled by a pilot valve 182. The servo-motor 179 as well as the pilot valve 172 may be purchased upon the open market. The pressure fluid for operating or moving the piston 181 enters the pilot valve from any suitable supply source which may be and usually is a source of pressure fluid independently of the pressure fluid circuit in which the compressor 150 is connected, through the inlet pipe 183. That is, in other words, the pressure fluid which operates the piston valve 164 is derived from a pressure source (not shown) outside of and independently of the pressure fluid circuit of the compressor. The pressure fluid for operating the piston 181 exhausts through the outlet pipe 184. The inlet of the pressure fluid into the cylinder 180 is controlled by the pilot valve 182 for moving the piston in either direction, suitable ports 185 and 186 being provided, which deliver the pressure fluid to the left hand end of the cylinder 180 and to the right hand end of the cylinder respectively.

The pilot valve is operated or its operation is controlled, rather, from a suitable pressure area in the pressure fluid circuit of the compressor, as for instance from the intake pipe (not shown) of the compressor 150 or as desired from the discharge pipe (not shown) of the compressor through a pressure control mechanism 187 commercially known as a "masonellan" control mechanism manufactured and sold by the Mason Neilan Company, and through a "masonellan" diaphragm regulator structure 188. The control mechanism 187 is connected by means of the pipe 189 to the pressure area which it is desired to control and in which pressure differences from the desired predetermined pressure will operate to load or unload the compressor 150. It receives its pressure fluid for operating the diaphragm regulator 188 through the inlet pipe 190. The pressure control mechanism 187 operation of which is controlled by the pressure fluid entering the pipe 189, delivers an operating pressure fluid through the pipe 191 to the diaphragm regulator 188. The pressure fluid delivered to the diaphragm regulator 188 operates this mechanism and operates the pilot valve 182 through the leverage connection 192. Thus the piston valve 164 is moved in and out for loading or unloading the head end of the compressor 153 in an infinite number of steps and an infinite number of increments of its capacity in accordance with the variations in pressure in the controlling pressure area (not shown) which is connected to the pipe 189.

The piston valve 164 moves outwardly, slowly and gradually in the same manner as the piston valves 31, 47, 74, etc., heretofore described and gradually opens the various ports 166, 168, 169, 170 and 171, providing the identical throttling action of these ports and consequently provides the utilization of the fractional capacity of the various clearance pockets comprising first the space or clearance chamber 194 within the valve 75

cylinder 163 and the clearance pockets or chambers 156, 157, 158 and 159. Thus the compressor may be unloaded and loaded in an infinite number of steps ranging from zero capacity to full capacity by the opening of the various valve ports in increasing increments controlled by the operation of the servo-motor 179.

The valve structure 162, while shown only in side elevation is identical in construction with the valve structure 161 and it is connected by means of the valve or piston rod 195 to the bellcrank 196 through a suitable articulated connection 197. The bellcrank 196 is in turn connected to the piston rod 178 for operating the valve structure 162 by the servo-motor in the same manner in which the valve structure 161 is operated.

The bellcranks 196 may be arranged to operate the valve structures 161 and 162 in unison or by slight variances in the angles of the bellcranks, the valve structures 161 and 162 may be operated slightly out of synchronism, that is, they may be operated so that the corresponding clearance pockets in the head and crank ends of the cylinder instead of being opened simultaneously to the respective ends of the compressor cylinder 151 will be opened in succession.

From the foregoing description taken in connection with the drawings it will be apparent that a variable volume control mechanism for compressors has been provided by means of which a compressor may be unloaded and loaded in an infinite number of steps from 100 per cent capacity to zero capacity by means of the opening of the control valves slowly in increasing increments, permitting the utilization of fractional portions of the capacities of the predetermined number of clearance pockets in proportion to the degree of opening of the communicating ports between the clearance pockets and the compressor cylinder. Also that a variable volume control mechanism for compressor has been provided in which the control valves are mechanically moved in lieu of being pressure moved as has heretofore been the normal practice and further that the operation of the variable volume control mechanism may be controlled from any suitable pressure area such as the intake or discharge of the compressor cylinder, a receiver into which the compressor discharges, or any other suitable source, the pressure from this control area acting to control the delivery of an operating pressure fluid which may be taken from a source outside of the pressure circuit of the compressor.

It is to be understood that the invention is not to be limited to the specific construction or arrangement of parts shown but that they may be widely modified within the invention defined by the claims.

What is claimed is:

1. In a compressor, a cylinder, a clearance chamber, a valve for controlling communication between said cylinder and clearance chamber, means for operating said valve and controlling the extent of opening and closing of the valve whereby a variable amount of throttling of the communication between said cylinder and clearance pocket is provided for controlling the degree of unloading of the cylinder, and an automatic check valve in the line of communication between the cylinder and clearance chamber and controlling return of fluid from said clearance chamber to said compressor cylinder, said check valve having sufficient opening area to permit

substantially unthrottled flow of gas from the clearance chamber to the cylinder.

2. In a compressor, a cylinder, a clearance chamber, a valve for controlling communication between said cylinder and clearance chamber, means for operating said valve and controlling the extent of opening and closing of the valve whereby a variable amount of throttling of the communication between said cylinder and clearance pocket is provided for controlling the degree of unloading of the cylinder, means responsive to pressure variances in a predetermined area for operating said valve operating means, and an automatic check valve in the line of communication between the cylinder and clearance chamber and controlling return of fluid from said clearance chamber to said compressor cylinder, said check valve having sufficient opening area to permit substantially unthrottled flow of gas from the clearance chamber to the cylinder.

3. In a compressor, a cylinder, a clearance chamber, a valve for controlling communication between said cylinder and clearance chamber, means for operating said valve and controlling the extent of opening and closing of the valve whereby a variable amount of throttling of the communication between said cylinder and clearance pocket is provided for controlling the degree of unloading of the cylinder, means responsive to pressure variances in the suction line of the compressor for operating said valve opening means, and an automatic check valve in the line of communication between the cylinder and clearance chamber and controlling return of fluid from said clearance chamber to said compressor cylinder, said check valve having sufficient opening area to permit substantially unthrottled flow of gas from the clearance chamber to the cylinder.

4. In a compressor including a cylinder, a variable volume control mechanism including a clearance pocket and a passage establishing communication between the clearance pocket and cylinder, a valve for controlling communication between said clearance pocket and said compressor cylinder, a servo-motor for moving said valve, mechanical means connecting said servo-motor and valve, means responsive to pressure variances in the suction line of the compressor for controlling operation of said servo-motor, and an automatic check valve in said passage and controlling return of fluid from said clearance pocket to said compressor said check valve having sufficient opening area to permit substantially unthrottled return flow of gas from the clearance pocket to the cylinder.

5. In a compressor, a compressor cylinder, a clearance chamber, a valve cylinder between said compressor cylinder and said clearance pocket, said valve cylinder having ports opening into said compressor cylinder and ports opening into said clearance pocket, and a piston valve in said valve cylinder which upon opening movement first opens the valve cylinder to the compressor cylinder and subsequently opens the valve cylinder to said clearance pocket and closes the valve cylinder to the compressor cylinder when in closed position said valve piston having an opening therein whereby the cylinder behind the valve piston is opened to the compressor cylinder upon opening of the valve cylinder to the compressor cylinder.

6. In a compressor, a compressor cylinder, a clearance chamber, a valve cylinder between said compressor cylinder and said clearance pocket,

said valve cylinder having ports opening into said compressor cylinder and ports opening into said clearance pocket, and a piston valve in said valve cylinder which upon opening movement first opens the valve cylinder to the compressor cylinder and subsequently opens the valve cylinder to said clearance pocket and closes the valve cylinder to the compressor cylinder when in closed position, and means for moving said valve gradually in an infinite number of steps for controlling and limiting the amount of port opening and closing thereby providing for unloading and loading the compressor in an infinite number of steps between full and zero capacity of the compressor, said valve piston having an opening extending longitudinally therethrough to permit returning of gas from the clearance pocket to the compressor cylinder, and a check valve carried by said piston and positioned to prevent flow of gas through the valve piston during port opening movement thereof.

7. In a compressor, a compressor cylinder, a clearance chamber, a valve cylinder between said compressor cylinder and said clearance pocket, said valve cylinder having ports opening into said compressor cylinder and ports opening into said clearance pocket, and a piston valve in said valve cylinder which upon opening movement first opens the valve cylinder to the compressor cylinder and subsequently opens the valve cylinder to said clearance pocket and closes the valve cylinder to the compressor cylinder when in closed position, and means for moving said valve gradually in an infinite number of steps for controlling and limiting the amount of port opening and closing thereby providing for unloading and loading the compressor in an infinite number of steps between full and zero capacity of the compressor, said valve piston having an opening extending longitudinally therethrough to permit returning of gas from the clearance pocket to the compressor cylinder, and a check valve carried by said piston and positioned to prevent flow of gas through the valve piston during port opening movement thereof, said check valve having sufficient opening area to permit substantially unthrottled return flow of gas from the clearance pocket to the compressor cylinder.

8. In a compressor, a compressor cylinder, a clearance chamber, a valve cylinder between said compressor cylinder and said clearance pocket, said valve cylinder having ports opening into said compressor cylinder and ports opening into said clearance pocket, and a piston valve in said valve cylinder which upon opening movement first opens the valve cylinder to the compressor cylinder and subsequently opens the valve cylinder to said clearance pocket and closes the valve cylinder to the compressor cylinder when in closed position, a return passage between said clearance pocket and said compressor cylinder, and a check valve in said return passage.

9. In a compressor, a compressor cylinder, a

clearance chamber, a valve cylinder between said compressor cylinder and said clearance pocket, said valve cylinder having ports opening into said compressor cylinder and ports opening into said clearance pocket, and a piston valve in said valve cylinder which upon opening movement first opens the valve cylinder to the compressor cylinder and subsequently opens the valve cylinder to said clearance pocket and closes the valve cylinder to the compressor cylinder when in closed position, said piston valve being hollow to permit the interior of the piston valve together with the interior of the valve cylinder to act as an initial clearance pocket upon opening movement of the piston valve, a return passage between said clearance pocket and said compressor cylinder, and a check valve in said return passage.

10. In a compressor, a compressor cylinder, a valve cylinder, a plurality of clearance pockets about said valve cylinder, said valve cylinder provided with a plurality of ports arranged successively along its length and opening one into each of said clearance pockets, said valve cylinder having its inner end closed and provided with ports in its sides opening into said compressor cylinder, a piston valve in said valve cylinder, and means for moving said valve piston to progressively open or close the ports to said clearance pockets each in progressive degrees whereby said compressor cylinder will be unloaded and loaded in an infinite number of steps, said valve piston acting first upon opening movement to open said ports to the compressor cylinder, each of said clearance pockets having return passages communicating with the compressor cylinder, and check valves in said passages, said check valves having sufficient opening area to permit substantially unthrottled return of gas from the clearance pockets to the compressor cylinder.

11. In a compressor, a compressor cylinder, a piston therein dividing the cylinder into active head and crank ends, a plurality of clearance pockets for the head end of the compressor cylinder, a plurality of clearance pockets for the crank end of the compressor cylinder, a pair of valve cylinders each having a plurality of successively arranged ports opening into the successive clearance pockets for the head and crank ends of the compressor cylinder respectively, one of said valve cylinders having ports opening into the head end of the compressor cylinder, the other of said valve cylinders having ports opening into the crank end of the compressor cylinder, valve pistons in said valve cylinders controlling said ports, a servo-motor and means connecting said servo-motor to said valve pistons for operating the valve pistons in unison for simultaneously unloading the head and crank ends of the compressor cylinder in successive stages of their capacities.

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