

May 22, 1962

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3,035,879

MEANS FOR CENTERING THE PISTON OF A PISTON COMPRESSOR

Filed March 10, 1959

4 Sheets-Sheet 1

Fig. 1.

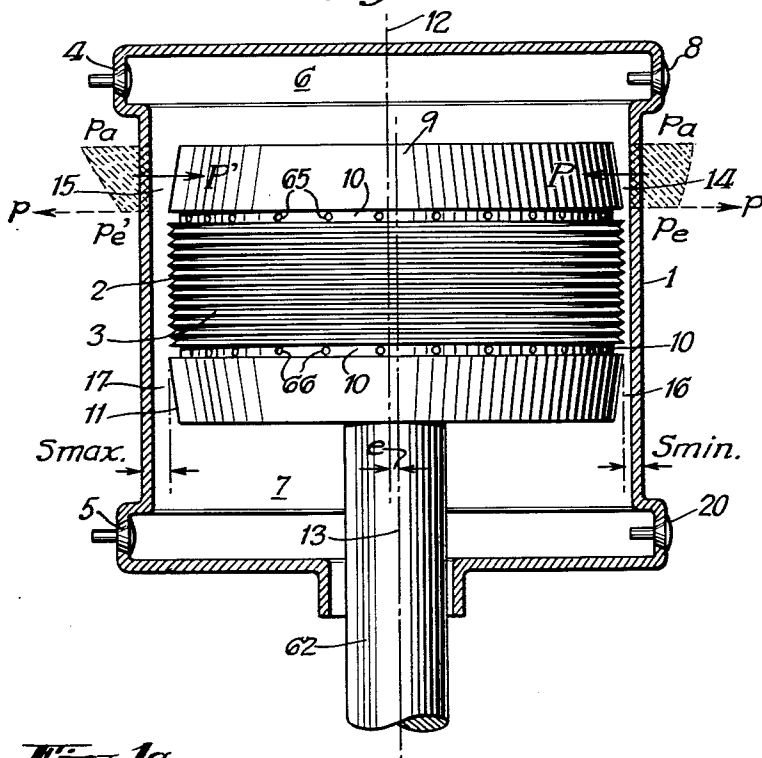


Fig. 1a.

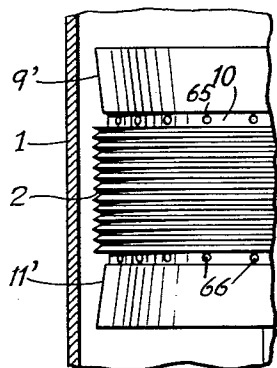


Fig. 2.

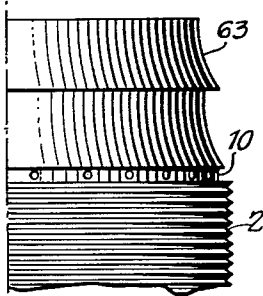
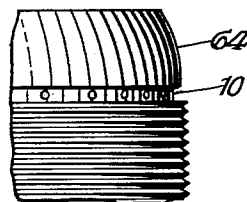


Fig. 2a.



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Fig. 1b.

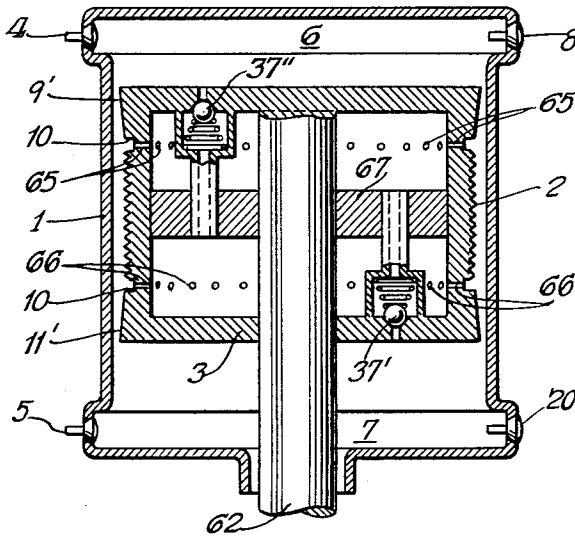
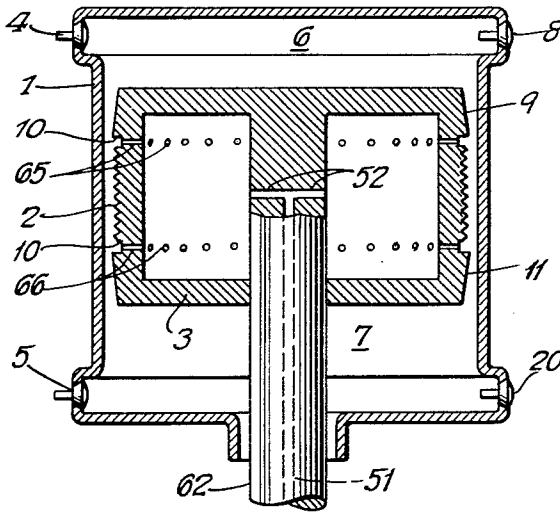


Fig. 1c.



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Fig. 3.

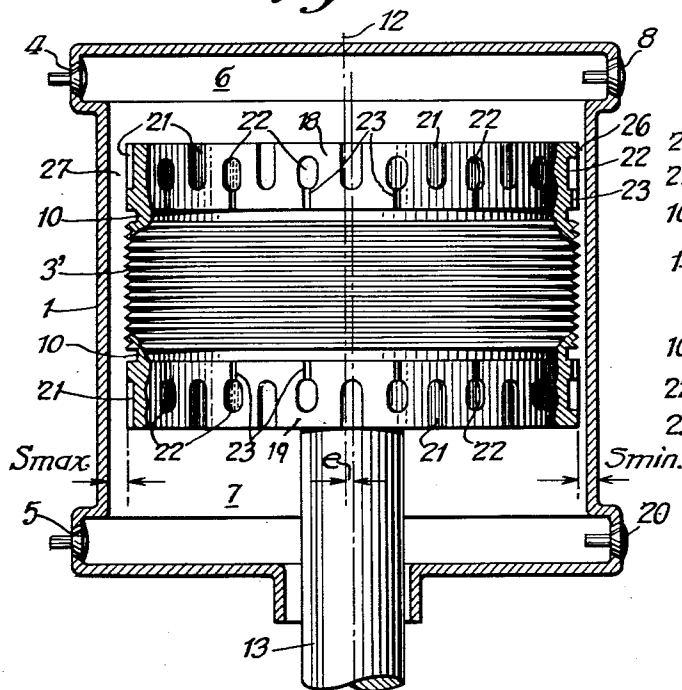


Fig. 3a.

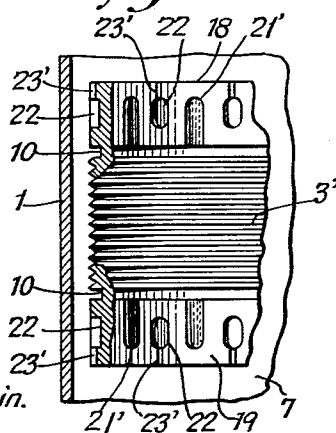
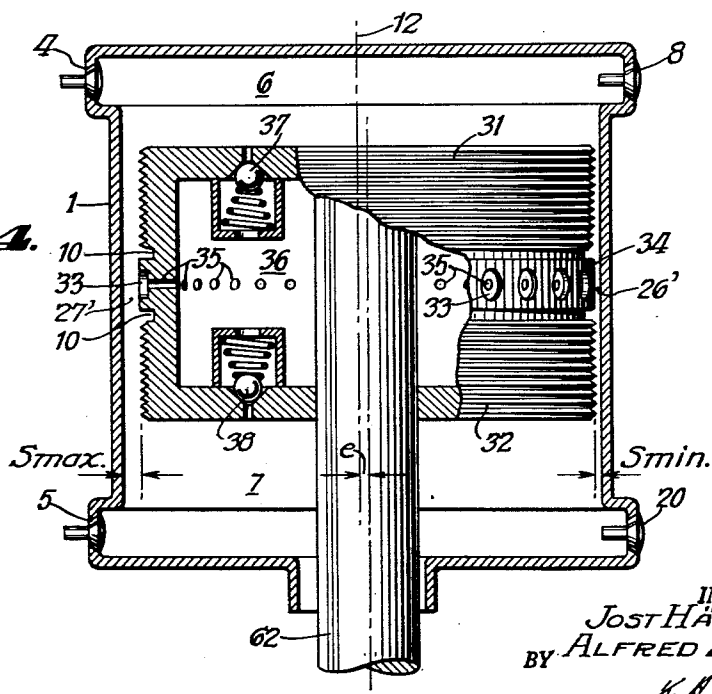


Fig. 4.



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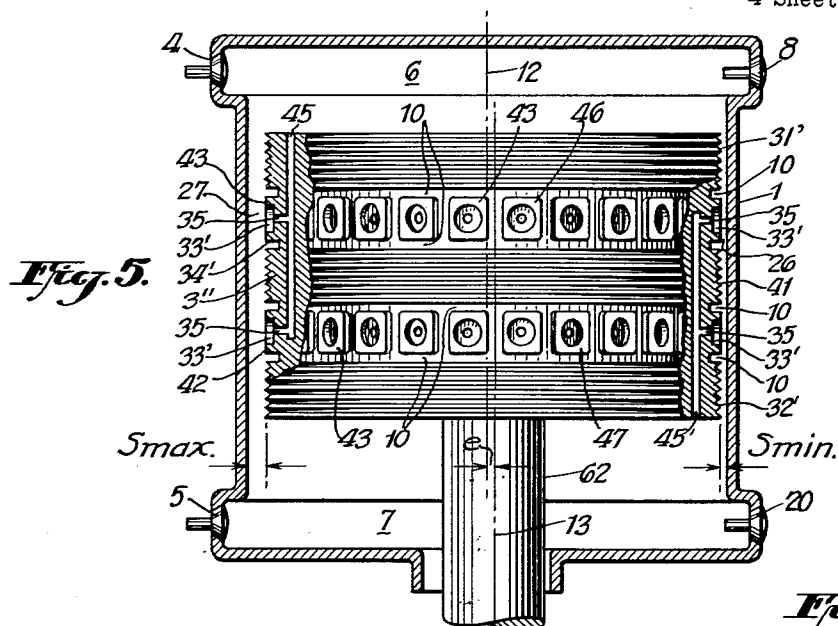
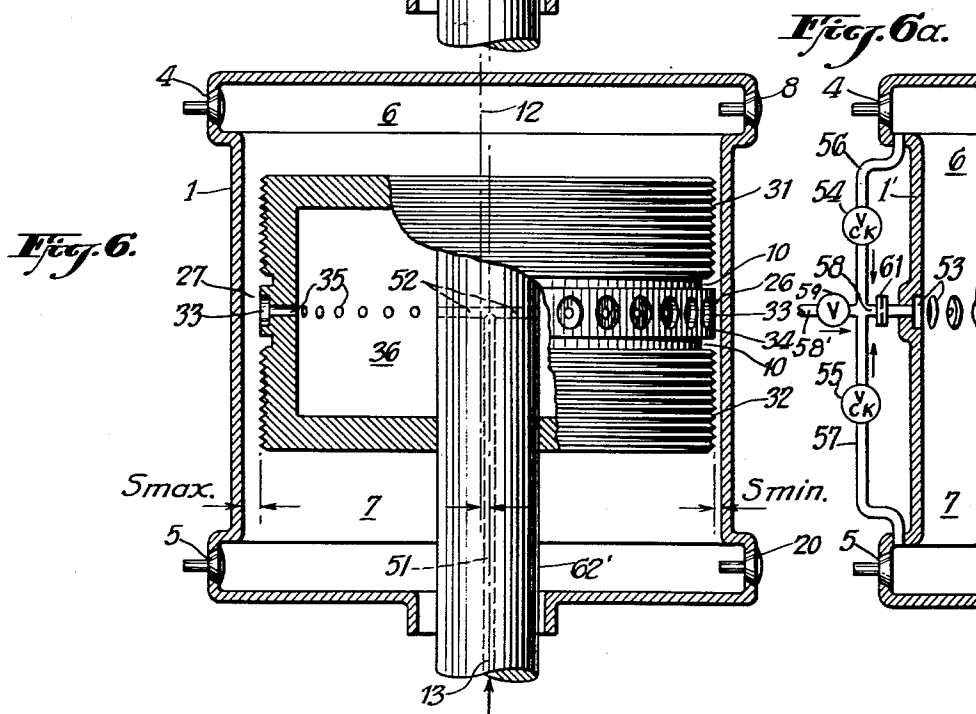
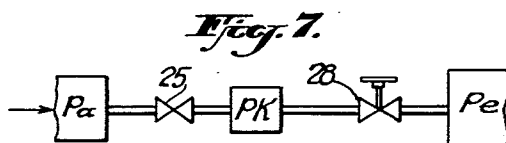
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MEANS FOR CENTERING THE PISTON OF A PISTON COMPRESSOR

Filed March 10, 1959

4 Sheets-Sheet 4



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3,035,879

MEANS FOR CENTERING THE PISTON OF A PISTON COMPRESSOR

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Filed Mar. 10, 1959, Ser. No. 798,461

Claims priority, application Switzerland Mar. 14, 1958
5 Claims. (Cl. 309—5)

The present invention relates to means for centering the piston of a piston compressor for compressing gases in which the cylindrical surface of the piston is provided with circumferential grooves or other labyrinth-like recesses having a self sealing effect so that no foreign lubricant need be present in the cylinder.

In conventional compressors of this type the piston is guided by means located outside of the cylinder, namely by the crosshead guide and a guide engaging the piston rod.

In the system according to the invention a force is produced during operation of the compressor which force acts in radially inward direction and is increased upon a decrease of the spacing between the piston and its cylinder. Action of the force in the opposite direction is impeded. This centering force may be aerodynamic and produced inside or outside of the cylinder, whereby, in the latter case, a foreign gas may be introduced into the cylinder. The force may also be magnetic and act from the outside of the cylinder.

In the compressor according to the invention either the piston or the cylinder or both may be provided with means producing aerodynamic centripetal forces acting on the piston whereby the operating medium may be taken from the medium pumped by the compressor. These means may be in the form of chambers provided in the circumferential outside surface of the piston and filled with compressed gas from the compression chamber of the compressor cylinder or from an outside source. Alternatively, the centering means may be formed by conical surface portions on and coaxial of the cylinder along which passes compressed gas, particularly during the compression stroke, from the compression chamber of the cylinder or, for example when starting the compressor gas which is introduced from the outside through the piston rod.

In compressors equipped according to the invention and having a very small clearance between the piston and its cylinder which clearance normally increases due to abrasion, this abrasion is much reduced so that the desired small clearance is retained and the piston or its self packing coat need be replaced much less often than in conventional compressors. If the compressor must produce a high pressure and/or operate at high efficiency, the initial clearance between the piston and its cylinders can be made smaller than in conventional self packing compressors.

A compressor equipped according to the invention can be subjected to greater vibrations than a conventional compressor without danger of contact between the piston and the cylinder. A guide of the piston rod between the crosshead guide and the piston can be omitted so that the piston rod can be made shorter.

In the conventional self packing compressor the self packing means extend over the whole cylindrical surface of the piston. This is not possible with the piston according to the invention because of the space required for the centering means, unless the latter are made part of the cylinder. This, however, does not reduce the self packing effect because, if the piston is centered according to the invention, the clearance between the piston and the cylinder can be so much reduced that a piston

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having less self sealing surface has a better self packing effect as a conventional piston of the same length and whose self sealing surface is not reduced. This has been proven by tests.

For aerodynamically centering the piston preferably the gas in the compression space of the cylinder or leakage gas therefrom is used. An outside gas, preferably of the same character as the compressed gas may be used, particularly during the starting period when there is no pressure or an insufficient gas pressure in the compression space of the cylinder and centering by leakage gas is insufficiently effective. In both cases, when leakage gas is used as well as when outside gas is used, the gas is either conducted to the cylindrical outside surface of the piston and/or to the interior surface of the cylinder.

The novel features which are considered characteristic of the invention are set forth with particularity in the appended claims. The invention itself, however, and additional objects and advantages thereof will best be understood from the following description of embodiments thereof when read in connection with the accompanying drawing in which:

FIGS. 1 and 3 to 6 are part sectional views of six modifications of a cylinder and piston arrangement of a compressor according to the invention.

FIG. 1a illustrates a portion of a modification of the piston shown in FIG. 1.

FIG. 1b is a diagrammatic longitudinal sectional view of a compressor piston according to the invention.

FIG. 1c is a diagrammatic longitudinal sectional view of a modified compressor piston according to the invention.

FIGS. 2 and 2a illustrate modifications of a portion of the piston shown in FIG. 1.

FIG. 3a illustrates a portion of a modification of the piston shown in FIG. 3.

FIG. 6a is a longitudinal sectional view of a portion of a compressor cylinder provided with centering means according to the invention.

FIG. 7 diagrammatically illustrates the operation of the modification illustrated in FIGS. 3 to 6.

Referring more particularly to the drawing, numeral 1 designates the cylinder of a piston compressor whose piston is provided with circumferential grooves 2. The piston 3 is connected to a piston rod 62 and is double acting. The gas to be pumped is alternately introduced through suction valves 4 and 5 into compression chambers 6 and 7, respectively, and relieved to the outside through pressure valves 8 and 20. The end portions of the piston 3 in FIG. 1 are provided with conical centering portions 9 and 11 whose surfaces are in a plane. These conical surface portions are separated from the central portion of the piston which is provided with the annular grooves 2 by means of annular pressure equalizing grooves 10. The conical surfaces are so placed that the taper is directed towards the compression spaces 6 and 7. The centering portion 9 has a centering effect upon upward movement of the piston whereas the portion 11 is effective during the downward movement of the piston.

At the moment which is illustrated in FIG. 1 the axis 13 of the piston does not coincide with the cylinder axis 12 but is moved to the right, the distance between the axes 12 and 13 amounting to e . The clearance between the piston and the cylinder at the right side of FIG. 1 at 14 amounts to $S_{\min}$ whereas the clearance at 15 on the left side amounts to $S_{\max}$; the clearances are shown exaggeratedly. Two schematic diagrams are shown at the elevation of the centering portion 9 wherein the abscissae indicate the pressures and the ordinates indicate the axial extension of the portion 9. Tests have shown that, if the pressure in the compression chamber 6 amounts to p_a

the pressure p_e in the clearance on the right side and at the lower end of the surface 9 is somewhat smaller than the pressure p_a . The pressure p_e' at the left side and at the lower end of the surface 9 is smaller than the pressure p_e . The entire force P corresponding to the hatched area of the diagram at the right side and directed towards the axis 13 is greater than the pressure P' acting on the left side and corresponding to the hatched area on the left side. This centering force is produced in the entire clearance between the surface 9 and the cylinder 1. The centering force is uniform all around the piston, if the latter is in central position. If the piston moves to an eccentricity e , the pressure at 14 automatically increases corresponding to the reduction of the clearance. A maximal centering force is exerted upon contact between the piston and the cylinder. This causes the piston 3 to move towards the axis 12 of the cylinder. The pressure difference is equalized in the groove or channel 10.

When the piston moves downward and the gas in the chamber 7 is compressed the action in the clearances 16 and 17 at the elevation of the conical surface 11 is the same as the afordescribed action on the conical surface portion 9.

The conicity of the portions 9 and 11 may be reversed as shown in FIG. 1a wherein the conical surfaces are designated by numerals 9' and 11'. Tests have shown that if the centering portions are shaped as shown in FIG. 1a a satisfactory centering effect is produced whereby the centering portion 11' acts upon upward movement of the piston and the centering portion 9' acts upon downward movement of the piston.

In single acting compressors in which the bottom of the chamber 7 is open, the centering portion 11 can be omitted. If the piston is shaped as shown in FIG. 1a, the centering portion 9' can be omitted so that the portion 11' has the desired centering effect.

The centering surfaces 9, 11 and 9', 11' may be concavely shaped as shown in FIG. 2 at 63 or may be convexly shaped as shown in FIG. 2a at 64 and a plurality of axially juxtaposed centering portions may be provided as shown in FIG. 2.

Gas delivery orifices 65, 66 may be provided in the bottoms of the annular grooves 10 and a centering gas may be blown out through these apertures. These apertures are particularly useful in the structure shown in FIG. 1a. The apertures 65 communicate with the upper part of the interior of the piston 3 and through suitable channels, shown in FIG. 1b, with the lower compression chamber 7. The apertures 66 communicate with the lower part of the interior of the piston 3, which is separated by a partition 67 from the upper part of the interior, and through suitable channels with the upper compression space 6. The channels connecting the apertures 65 with the space 7 are provided with a check valve 37' which opens upon the downward stroke of the piston and the channels connecting the apertures 66 with the space 6 are provided with a check valve 37'' which opens upon the upward stroke of the piston. In this way, centering gas flows at the downward stroke of the piston from the space 7 through the apertures 65 into the channel 10 and becomes active at the centering portion 9' whereas at the upward stroke of the piston gas from the space 6 is conducted through the apertures 66 into the lower channel 10 which gas becomes effective opposite the centering portion 11'. Gas may be admitted to the apertures 65 and 66 from the outside through suitable channels 51, 52 in the piston rod 62, as shown in FIG. 1c. This is of particular advantage when starting the compressor and the pressure in the spaces 6 and 7 is insufficient for producing the desired aerodynamic centering effect.

In the example shown in FIG. 3 recesses or centering chambers 22 are provided in the upper circumferential end portion 18 of the piston 3'. Similar recesses 22 are provided at the lower circumferential portion 19 of the piston. These recesses or centering chambers communi-

cate through throttling channels 23 with annular grooves 19. Interspersed between the chambers 22 are slots 21 which are open at the ends of the piston. During the downward stroke of the piston, as long as the pressure in the chamber 7 is higher than that in the chamber 6, gas flows from the chamber 7 through the upper annular groove 19 and the upper throttling channels 23 into the centering chambers 22 of the piston portion 18. If the piston is in eccentric position gas may flow from the chambers 22 through the relatively wide portion 27 of the clearance between the piston and its cylinder into the slots 21 and therefrom into the space 6 or may directly escape from the chambers 22 into the space 6. The centripetal force at this portion of the circumference of the piston is, therefore, relatively small. On the opposite portion 26 of the circumference where the clearance is relatively small the pressure in the chambers 22 will increase and produce a pressure tending to center the piston. During the upward stroke of the piston the chambers 22, channels 23 and slots 21 in the lower circumferential end portion 19 of the piston act similarly as the corresponding devices in the portion 18.

If the chambers 22 and the slots 21 are arranged conversely as shown in FIG. 3a where these parts are designated by numerals 21', 22, 23' gas flows at the upward stroke from the compression space 6 through the throttling channels 23' into the centering chambers 22 of the piston part 18 so that the pressure adjacent to the chambers 22 at the relatively narrow clearance portion 26 is higher than adjacent to the chambers 22 which are located at the relatively wide clearance portion 27. In this case the gas flows mainly from the chamber 22 at the wide clearance portion 27 through the channels 21' into the upper annular groove 19. At the downward stroke of the piston gas flows from the compression chamber 7 through throttling channels 23' into the chambers 22 of the piston portion 19. The centering effect is obtained in the same manner as described with respect to the upper portion 18 of the piston.

If the compressors shown in FIGS. 3 and 3a are single acting and the bottom of the space 7 is open, only the centering means 21, 22, 23 of the lower piston portion 19 or the centering means 21', 22, 23' of the upper piston portion 18 are active.

The piston of the modification shown in FIG. 4 is hollow and has grooved upper and lower self packing portions 31 and 32. Between these portions a centering portion 34 is arranged having a plurality of centering cavities 33 equally spaced all around the piston. On either axial side of the portion 34 annular grooves 10 are provided. The cavities 33 communicate through throttling channels 35 with the interior 36 of the piston. Gas flows into the interior of the piston through a check valve 37 upon the upward stroke and through a check valve 38 upon the downward stroke. The valves 37 and 38 are preferably provided with springs permitting opening of the valves only after building up a considerable pressure at the compression side of the piston. The gas flows from the interior of the piston through the channels 35 into the cavities or chambers 33. In those of the latter which are opposite to the relatively narrow clearance portion 26' a higher pressure will be built up than on the opposite cavities or chambers 33 where the clearance 27' is wider so that a centering effect acting from the right side to the left side in FIG. 4 is produced. At the narrow portion of the clearance gas passes from the cavities 33 into the grooves 10 and is conducted through the latter to the wide clearance portion 27 and therefrom into one of the compression chambers.

The piston 3'' shown in FIG. 5 is provided with three self packing portions 31', 41 and 32' and has two centering portions 34' and 42 interposed between the self packing portions. Each centering portion is separated from the adjacent self packing portions by annular grooves 10.

The centering portions 34' and 42 are subdivided by

axial channels into a plurality of quadratic protuberances 43 equally spaced all around the piston. Each protuberance is provided with a cavity or chamber 33'. Pairs of axially aligned chambers 33' are alternately connected by channels 45 to the upper compression chamber 6 and by channels 45' to the lower compression chamber 7. The action of the centering means 10, 33', 43 is similar to the action of the centering means 33, 34 shown in FIG. 4. The arrangement in FIG. 5, however, does not require check valves, the chambers 33' communicating through channels 45 directly with the compression chambers of the piston.

The embodiment of the invention illustrated in FIG. 6 corresponds to that shown in FIG. 4, however, the cavities or chambers 33 are fed with gas introduced from the outside through channels 51 and 52 in the piston rod 62'. Preferably the same type of gas is used as is compressed by the compressor.

FIG. 6a shows how means for producing a centripetal force can be associated with the cylinder 1'. The latter is provided with cavities 53 which are equally spaced around the inside wall of the cylinder and which are connected through a conduit 58 in which a throttling orifice 61 may be provided to conduits 56 and 57 in which check valves 54 and 55, respectively, are interposed. The conduits 56 and 57 terminate in the compression chambers 6 and 7, respectively. As a modification the conduit 58 may be supplied with outside gas, particularly during starting of the compressor, a conduit 58' with a valve 59 being provided for this purpose.

FIG. 7 diagrammatically illustrates the operating conditions in the modifications of the invention illustrated in FIGS. 3 to 6. The gas flowing through channels 23 (FIG. 3), 35 (FIGS. 4 to 6), or 56 to 58 (FIG. 6a) into the centering cavities or chambers 22, 33, 53, respectively, has a pressure p_a . The throttling channels correspond to a throttle valve 25. p_k indicates the pressure in the centering cavities or chambers 22, 33, 53. The clearances 26, 27 act like a throttling device 28 whose flow area is different at the different chambers 22, 33, or 53; the flow area is smallest where the clearance 26 is smallest and becomes continually larger with increasing distance of the chambers from the most narrow portion 26 of the clearance. The largest flow area of the throttling means 28 corresponds to the widest clearance portion 27. After passage of the gas through the clearance portions 26, 27 the gas flows through the slots 21 and/or the annular grooves 10 wherein the pressure is p_e . The pressure p_a is greater than the pressure p_k which is greater than p_e . The difference between p_k and p_e is greatest at the side of the piston where the clearance 26 is smallest. The difference between p_k and p_e is smallest, in fact disappears altogether, at the opposite side where the clearance 27 is largest.

The centering means shown in FIGS. 4 to 6 can also be used in connection with single acting compressors. In this case, the bottom of the cylinder is open and the valves 5 and 20 are omitted. Also omitted are the valve 38 in FIG. 4, the channels 45' and the chambers 33' connected thereto in FIG. 5, and the conduit 57 containing the valve 55 in FIG. 6a.

The systems shown in the individual figures may be combined, for example, a conical centering portion as shown in FIGS. 1 and 1a may be used in combination with centering chambers as shown in FIGS. 3 to 6 whereby the latter may be supplied with gas from outside of the compressor. The piston may be provided with conical centering portions and centering chambers may be provided on the inside wall of the cylinder.

We claim:

1. In a piston compressor, a hollow cylinder having substantially flat interior end surfaces normal to the longitudinal axis of the cylinder, a laterally unguided piston reciprocating in said cylinder, the entire circumferential surface of said piston being spaced from the opposed inside surface of said cylinder for frictionless movement of said piston within said cylinder, said piston having substantially flat end surfaces normal to the longitudinal axis of the piston and at least one smooth frustoconical circumferential surface portion coaxial of the piston.
2. In a piston compressor as defined in claim 1 wherein said frustoconical surface portion tapers toward the free end of said piston.
3. In a piston compressor as defined in claim 1 wherein said frustoconical surface portion tapers toward the end of said piston which end is averse from the free end of the piston.
4. In a piston compressor, a cylinder, a laterally unguided hollow piston reciprocating and alternately defining a high pressure chamber and a low pressure chamber in said cylinder, the entire circumferential surface of said piston being spaced from the opposed inside surface of said cylinder for frictionless movement of said piston within said cylinder, said piston having at least one smooth circumferential frustoconical surface portion coaxial of said piston, circumferentially spaced apertures in said piston communicating the interior of the piston with the circumferential outside thereof and placed adjacent to the end of said frustoconical surface portion which end is axially closer to the axial center of the piston than the second end of said frustoconical surface portion, and valved apertures in said piston communicating the compression chambers in said cylinder with the interior of said piston and closing the suction chambers of said cylinder against the interior of said piston.
5. In a piston compressor, a cylinder, a laterally unguided hollow piston reciprocating and alternately defining a high pressure chamber and a low pressure chamber in said cylinder, the entire circumferential surface of said piston being spaced from the opposed inside surface of said cylinder for frictionless movement of said piston within said cylinder, said piston having at least one smooth circumferential frustoconical surface portion coaxial of said piston, circumferentially spaced apertures in said piston communicating the interior of the piston with the circumferential outside thereof and placed adjacent to the end of said frustoconical surface portion which end is axially closer to the axial center of the piston than the second end of said frustoconical surface portion, a piston rod connected to said piston, and a channel in said piston rod terminating in the interior of said piston for supplying a gas from the outside of said cylinder to the interior of said piston and to said apertures.

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