Dec. 25, 1945. J. S. PARENTI 2,391,476

MACHINE FOR UTILIZING POWER

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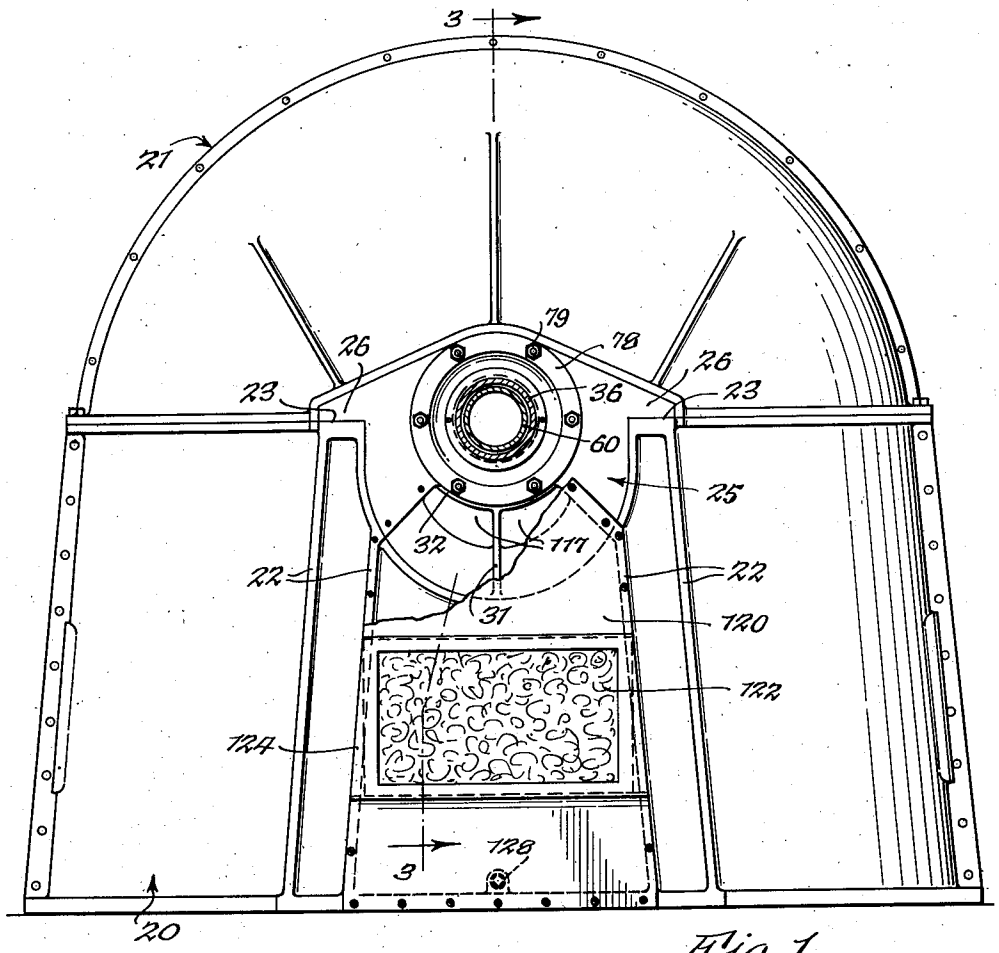


Fig. 1.

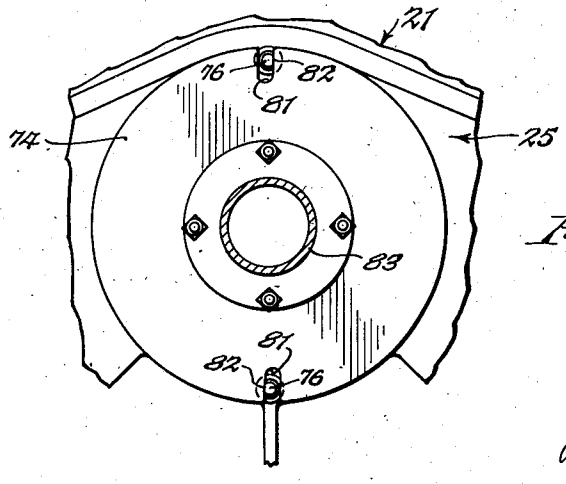


Fig. 2.

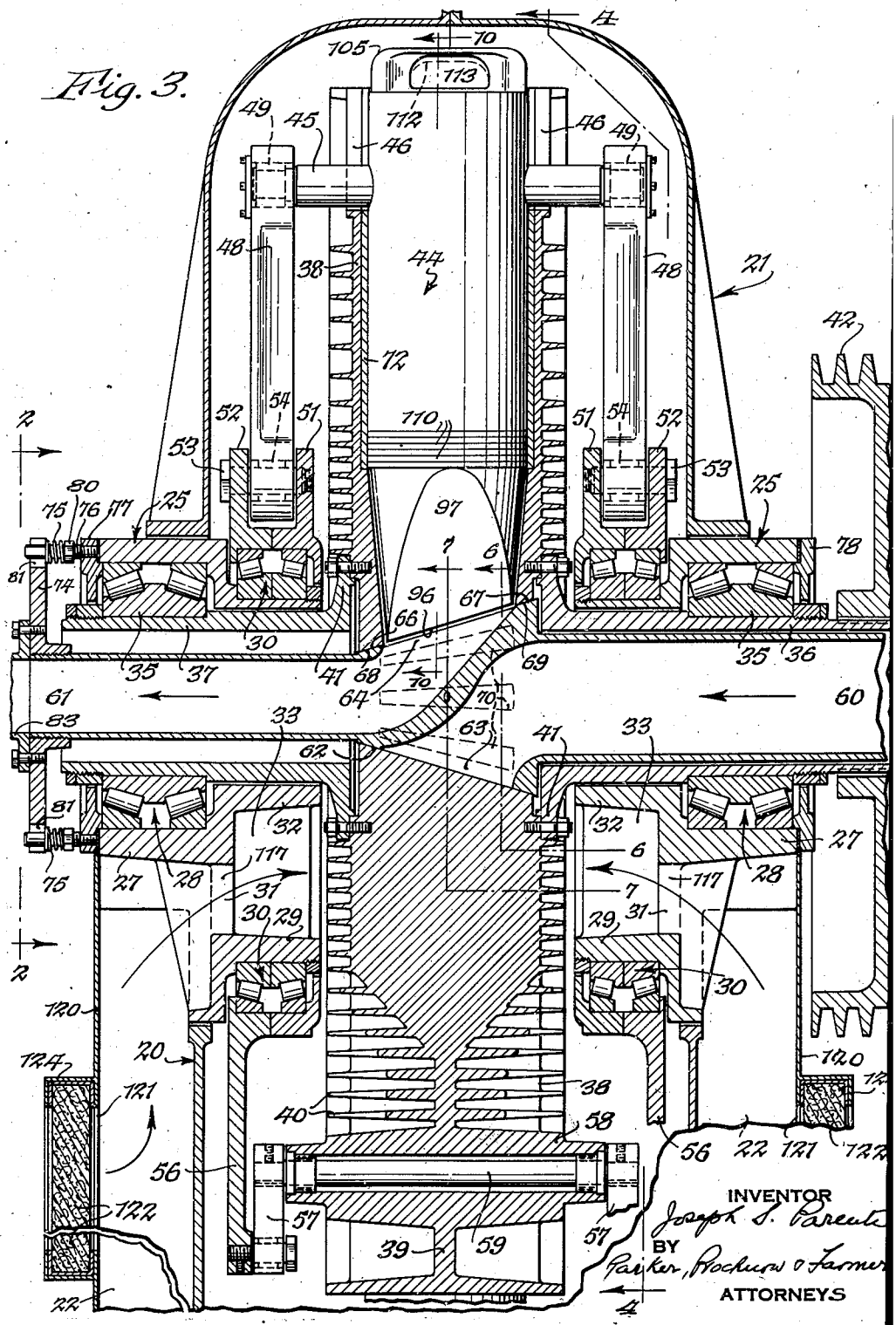
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MACHINE FOR UTILIZING POWER

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Fig. 3.



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Fig. 4.

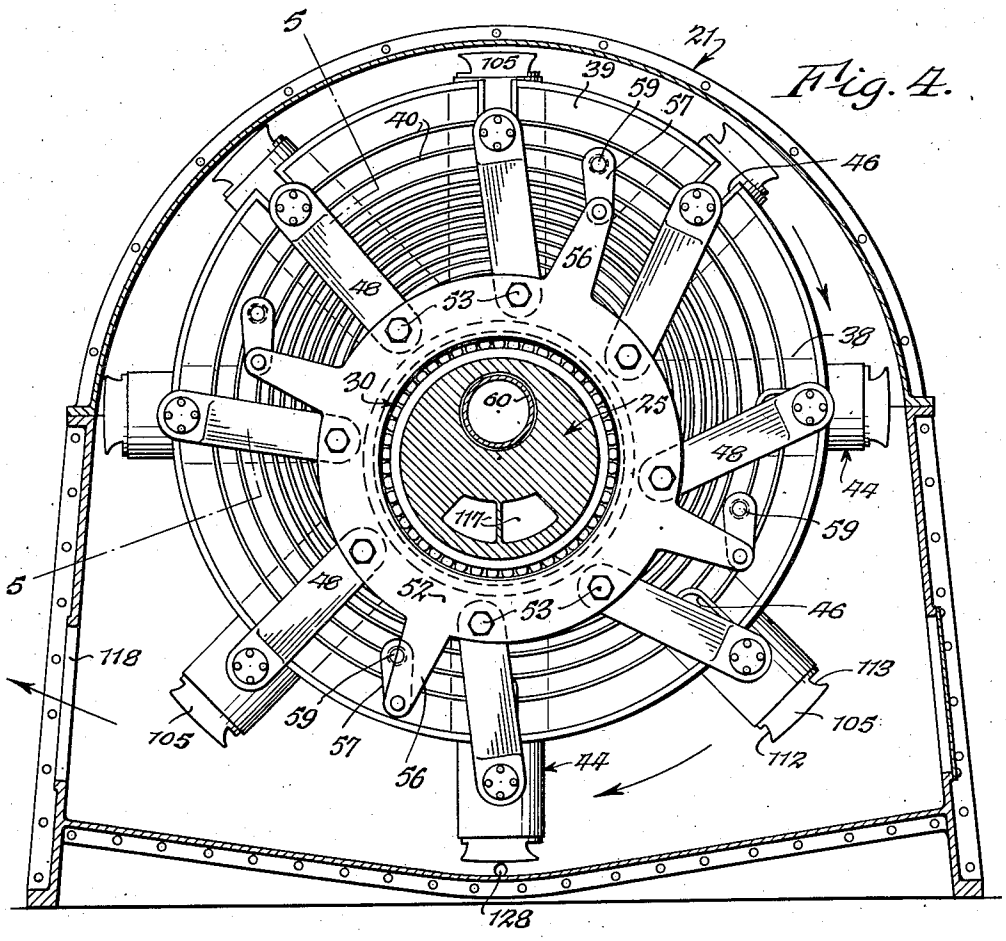
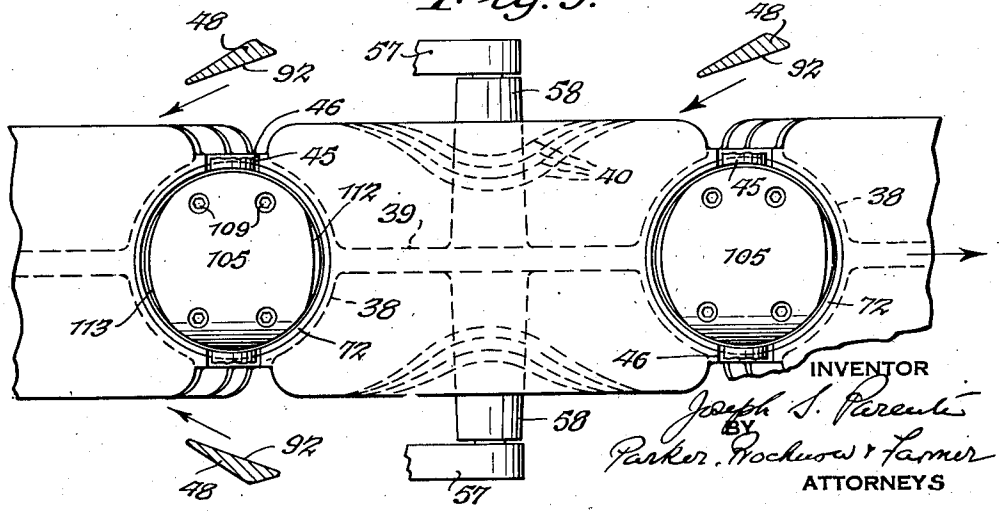


Fig. 5.



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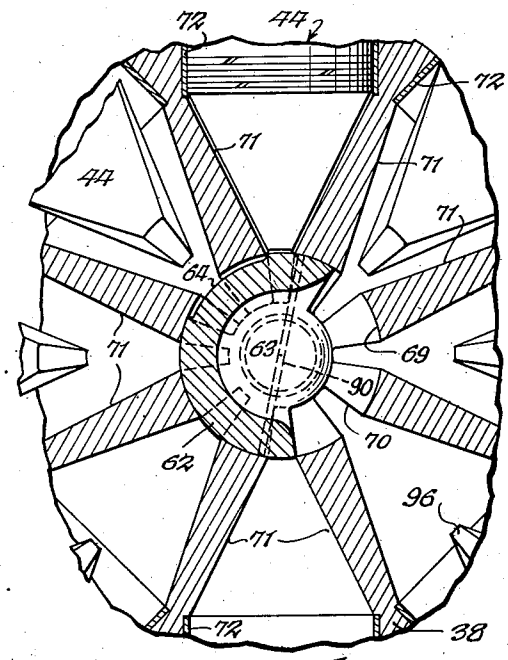


Fig. 6.

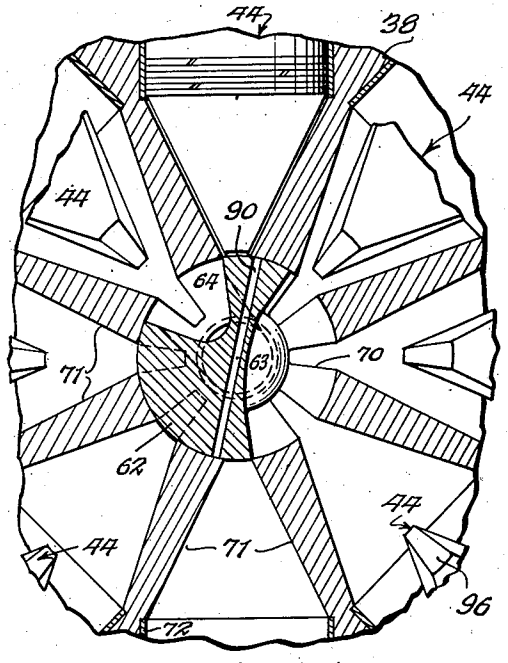


Fig. 7.

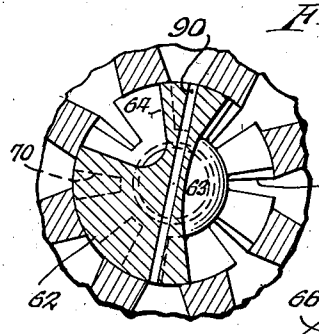


Fig. 8.

Fig. 9.

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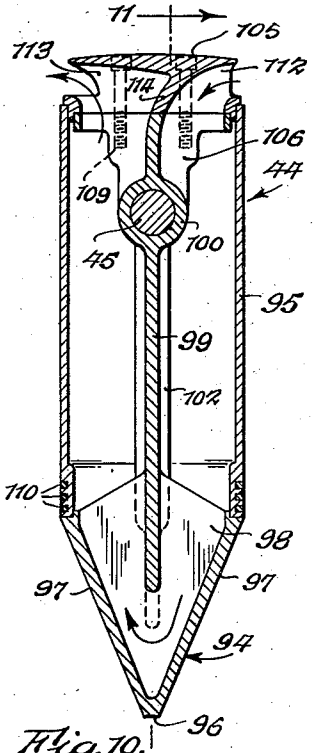


Fig. 10.

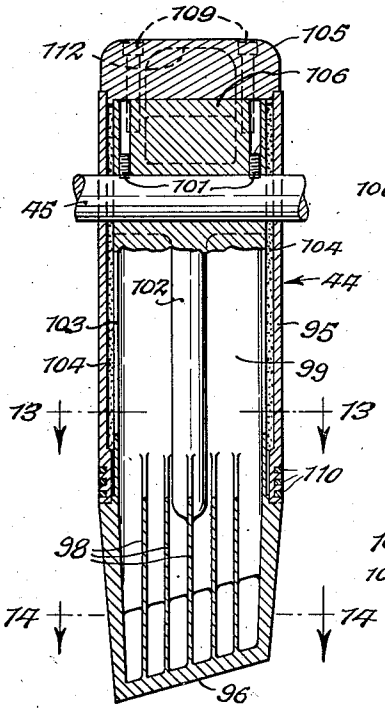


Fig. 11

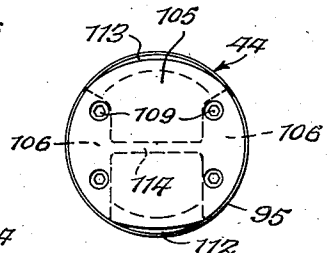


Fig. 12.

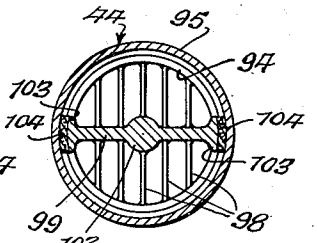


Fig. 13.

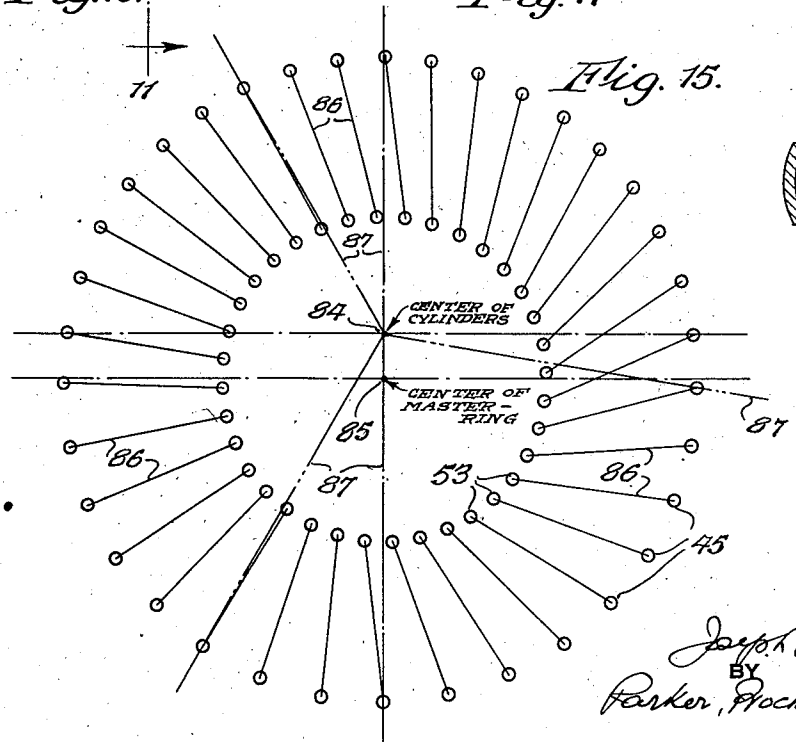


Fig. 15.

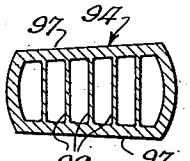


Fig. 14.

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UNITED STATES PATENT OFFICE

2,391,476

MACHINE FOR UTILIZING POWER

Joseph S. Parenti, Buffalo, N. Y.

Application May 19, 1942, Serial No. 443,666

19 Claims. (Cl. 230—177)

This invention relates to improvements in machines of the sliding piston or positive displacement type, which may be used, for example, as compressors or pumps to operate on air and other gases.

One of the objects of this invention is to provide a machine of this type with means of improved construction for reducing side thrust of pistons on their cylinders. A further object of this invention is to provide an improved construction, in which the angular relationship between the pistons and their connecting rods is small when these parts are subjected to their greatest stresses.

A further object of this invention is to provide a machine of this kind with means of improved construction for cooling the same, whereby large amounts of heat can be readily removed from the machine. Another object is to provide a machine of this kind in which heat is removed by air circulating within the pistons. A further object is to provide a machine of the revolving cylinder type in which the pistons extend beyond the outer ends of the cylinders and are provided with air passages through which air passes because of the movement of the pistons relatively to the surrounding air.

Another object of this invention is to provide a compressor of this kind of improved and simplified construction and of high efficiency.

A further object of this invention is to provide an improved method of compressing gas in which residual compressed gas left in a compressing member after exhaust, is added to gas at a lower pressure which is about to be compressed.

It is also an object of this invention to provide compressors with means for injecting a supercharge of gas into a cylinder after completion of its intake stroke. A further object is to provide a compressor of this type with means whereby residual compressed gas remaining in a cylinder after the closing of the discharge valve is added to a charge of gas at a lower pressure, and which is about to be compressed. Another object of this invention is to provide a compressor of the revolving cylinder type, which is provided with a central valve member with which the cylinders cooperate and which has a passage for conducting residual compressed gas from one cylinder to a charge of gas to be compressed in another cylinder.

Another object of this invention is to provide a compressor of the revolving cylinder type with means of improved construction for reciprocating the pistons in the cylinders. It is also an object of this invention to provide single or integral supports which carry both a cylinder wheel bearing and piston rod bearings, so that the forces resulting from the movements of the pistons in their cylinders will react within such supports. A further object of this invention is to provide a compressor of the revolving cylinder type with means of improved construction for cooling the cylinders. A further object is to provide a compressor of this type with means of improved construction for circulating cooling air through the housing of the compressor and to the parts of the compressor requiring cooling. A further object is to so construct the compressor that the cooling air may be filtered or cleaned to prevent abrasive particles from entering the compressor housing. It is also an object of this invention to so construct a compressor that the revolving of the cylinders produces a flow of cooling air through the housing of the compressor. It is also an object to provide connecting rods which are shaped so as to produce movement of air toward the exterior surfaces of the cylinders for cooling them.

It is also an object of this invention to provide an improved piston for use in connection with compressors of this type. A further object of this invention is to provide a piston in which the head of the piston is so arranged relatively to the other parts of the piston as to facilitate cooling thereof and to resist the passage of heat from the head of the piston to the other parts of the piston. Another object of this invention is to improve the construction of pistons to facilitate the cooling of the same.

It is also an object of this invention to provide an improved process of cooling machines of this type by removing more heat from the pistons than from the cylinder walls.

Another object is to provide a machine of this type with means for purifying the air employed for cooling the machine.

It is also an object of this invention to improve the construction of gas compressors of the rotary cylinder type in such a manner as to provide for improved and more efficient compressing of gas.

Other objects of this invention will appear from the following description and claims.

In the accompanying drawings:

Fig. 1 is an end elevation, partly in section, of a compressor embodying this invention.

Fig. 2 is a fragmentary end elevation of the other end of the compressor along line 2—2, Fig.

3, on a larger scale, the discharge tube of the compressor being shown in section.

Fig. 3 is a fragmentary, sectional elevation thereof on line 3—3, Fig. 1.

Fig. 4 is a fragmentary, sectional elevation thereof on line 4—4, Fig. 3.

Fig. 5 is a side view of a portion of the compressor, in which the curved peripheral portions thereof are shown as if in a plane, the view being partly in section, on line 5—5, Fig. 4.

Fig. 6 is a fragmentary, transverse, sectional elevation thereof on line 6—6, Fig. 3.

Figs. 7 and 8 are fragmentary, transverse sectional elevations thereof on line 7—7, Fig. 3, the parts being shown in different positions in the two figures.

Fig. 9 is a fragmentary perspective view of the valve of the compressor.

Fig. 10 is a central, sectional elevation of a piston, the section being taken on line 10—10, Fig. 3.

Fig. 11 is a sectional elevation of the piston on line 11—11, Fig. 10.

Fig. 12 is a top plan view thereof.

Figs. 13 and 14 are transverse sectional views thereof on lines 13—13 and 14—14 respectively of Fig. 11.

Fig. 15 is a diagram showing the relative angular relations between the pistons and their connecting rods while in different positions about the axes of rotation of the cylinders and of the eccentric ring to which the connecting rods are pivoted.

While I have shown my improvements embodied in a rotary cylinder type of compressor, yet it will be obvious that it is not intended to limit all of the improvements herein described to the type of compressor shown in the drawings, since some of the improvements shown may be used in connection with machines for other purposes than compressing gases and with machines in which the cylinders are stationary.

My improved machine may be mounted on any suitable or desired stationary supports and may be enclosed in a housing or casing of any desired construction. In the particular construction illustrated by way of example, I have provided a housing or enclosure, including a lower part 20 and an upper, removable part or cover 21, which may be suitably secured to the main or lower housing part 20. The lower housing part is also provided at its opposite ends with integrally formed pedestals or supports for the revolving parts of the machine, these pedestals including two pairs of upright struts or flanges 22 which may be formed integral with the housing and which are connected at their upper ends by substantial horizontal webs or flanges 23 formed to support the mechanism. A housing and supports of any other suitable or desired construction may be employed, if desired.

The machine shown in the drawings includes two revolving parts which rotate about different axes. In the particular construction shown, the cylinders rotate about an axis which is eccentric with reference to a rotary member which the piston rods are connected to, to produce relative movement between the pistons and their cylinders. I provide at each end of the machine a main stationary bearing support 25 on which the two revolving elements of the machine are journalled and which, in turn, is mounted upon the pedestals or supports 22. Consequently, each end of the machine is provided with one of these bearing supporting members 25 which are of tubular form and have oppositely extending lugs or projections 26 arranged to be mounted on the supporting flanges 23 of the pedestals 22. The bearing supporting members 25 are each provided with an annular cylindrical portion or flange 27 within which a suitable bearing, such as a roller bearing 28, is arranged. Each bearing support is also provided with a cylindrical portion 29 of larger diameter and eccentric with relation to the bearing flange 27. Another bearing 30 is arranged on the periphery of the cylindrical portion 29. These two flanges or cylindrical portions are connected by a vertical web 31. 32 represents an annular flange which is connected by means of radially extending ribs or supporting parts 33 with the cylindrical flange 29. The several parts of each bearing support are preferably formed integral, thus forming a strong and rigid bearing support which is amply capable of withstanding the reacting forces transmitted thereto by the bearings 28 and 30.

The bearings 28 of the two bearing supporting members 25 have their inner races 35 secured to rotatable hollow trunnions or shafts 36 and 37 which extend freely through the stationary bearing supporting members. The inner ends of these trunnions are suitably secured to a cylinder-carrying member or wheel with which the cylinders are preferably formed integral and which includes a plurality of cylinders 38 connected by radially extending webs 39 and also preferably by a series of radiating and reinforcing fins 40 which are substantially annular in form and concentric with the axis of rotation of the cylinder wheel. The trunnions 36 and 37 may be secured to the cylinder wheel in any suitable or desired manner, and in the construction shown, the inner ends of the trunnions are provided with outwardly extending flanges 41 which may be secured by bolts or other means to the cylinder wheel, see particularly Fig. 3. Consequently, the cylinder wheel is rotatably mounted on the bearings 28, and one of the hollow trunnions, for example the trunnion 36, may be provided at the outer end thereof with any suitable means for driving the cylinder wheel, a grooved pulley 42 being shown by way of example in Fig. 3.

The cylinders are provided with pistons 44 which will be hereinafter described more in detail. These pistons may be reciprocated in their cylinders in any desired manner, and in the construction illustrated by way of example, the pistons have pins 45 extending transversely through the same near the outer ends thereof. These pins 45 also extend outwardly beyond the sides of the cylinder wheel, this wheel being provided at the cylinder portions thereof with slots 46 into which the pins 45 may enter when the pistons are in their inner positions. On each end of each pin 45, one end of a piston rod or link 48 is journalled on suitable bearings 49, and the other ends of the piston rods or links 48 are pivoted on master rings which are journalled to rotate about the bearings 30, eccentrically with reference to the axis of rotation of the cylinder wheel. In the particular construction shown, these master rings are each constructed of two parts or halves 51 and 52, secured together by means of screws 53 which also serve as pivots for the other ends of the piston rods or links. Suitable bearings 54 are arranged between the pins 53 and the inner ends of the connecting links or rods. The master rings are arranged at the opposite sides of the cylinder wheel, and since the master rings rotate about the bearings, which are eccentric with reference to the bearings 28 of the cylinder wheel,

it will be obvious that at each rotation of the cylinder and master rings, the pistons 44 will be moved by their piston rods 48 through an inwardly directed working stroke and an outwardly directed intake stroke.

In order to cause the master rings and cylinder wheel to rotate about their axes simultaneously and in correct relation to each other, a suitable connection between these parts is provided. In the construction illustrated by way of example, I have provided the outer portions 52 of the eccentric master rings with a plurality of outwardly extending arms 56, four such arms being shown in Fig. 4. To the outer end of each of these arms, one end of a master ring link 57 is pivotally connected. The other ends of these links are pivotally connected with the cylinder wheel. This may be accomplished in any desired manner, and in the construction shown, the cylinder wheel is provided between some of the cylinders with enlargements or bosses 58 in which pins 59 are arranged, the pins being preferably journalled in these bosses. The ends of the pins are secured to the other ends of the master ring links 57. It will be noted that during the rotation of the master rings and the cylinder wheel, the links 57 occupy various positions, as shown in Fig. 4, and when these master ring links are in or near a plane passing through the two axes of rotation, no driving force can be transmitted through such links, but at such times the other links are not located near this plane and will transmit the necessary force for driving the master ring from the cylinder wheel, which is positively driven from the pulley 42 or other driving means. The distance between pivotal centers of the master ring links 57 must be the same as the distance between the axes of the cylinder wheel and the master ring. By means of this arrangement, the relationship between all of the cylinders and their pistons will be the same as they pass any point in their path of movement about the center of rotation of the cylinder wheel, and also the connecting rods on both sides of the cylinder wheel are kept in alinement with each other so that the resultant of the force transmitted by a pair of rods to its piston is substantially coaxial with the piston, which, in turn, results in elimination of any cocking or wedging action on the pistons and of any tendency to turn or twist the pistons about their axes.

In order to supply gas to be compressed to the cylinders and to discharge the compressed gas from the cylinders, a tubular member is provided having both an inlet passage and a discharge passage therein, the member shown including an inlet duct 60 which extends through the hollow trunnion 36 and a discharge duct 61 which extends through the hollow trunnion 37. These inlet and exhaust ducts are preferably formed integral with a valve member 62 arranged for cooperation with the cylinder wheel at the inner ends of the cylinders 38. This tubular member including the valve 62, as well as the ducts 60 and 61, in the particular construction shown, is stationary with reference to the cylinder wheel, and the valve member is of frusto-conical shape. The valve member is provided with a relatively large inlet port 63 which forms substantially a continuation of the inlet duct or passage 60 and a smaller exhaust or discharge port 64 which forms a continuation of the discharge duct 61. Both of these ports are of elongated form in order to cooperate with elongated ports formed at the inner ends of each of the cylinders 38. The discharge duct 61 may of course be of smaller diameter than the inlet duct, and this enables the discharge duct to be spaced from the trunnions 37. This space between the duct and the trunnion resists the transmission of heat from the hot duct 61 to the trunnion bearing. If desired, suitable heat insulation may be provided in the space between this duct and the trunnion.

The middle portion of the cylinder wheel is provided with a frusto-conical bore formed for close fitting cooperation with the valve member 62, and the cylinder wheel is provided at the opposite ends of its frusto-conical bore with annular imperforate sealing surfaces 66 and 67 which fit against corresponding surfaces 68 and 69 formed on the valve member so that when the valve is in its operative position, discharge of gases past the cooperating sealing surfaces is prevented. The cylinder wheel is provided at its frusto-conical valve-engaging base with an elongated port 70 for each cylinder. The opposite longer bounding edges of these ports 70 are arranged at an inclination to each other because of the frusto-conical form of the valve member, so that all portions of any longitudinal edge of any of the ports 70 will simultaneously come into and pass out of registration with the longitudinal edges of the ports 63 and 64 of the valve member, thus reducing wire drawing to a minimum at the discharge ports.

In order to produce discharge ports of this narrow elongated type, the cylinders are provided at their inner end portions with converging side walls which are formed to converge uniformly from their outer portions of cylindrical cross section to the valve ports 70 thereof. Consequently, the side portions 71 of the cylinder ends which are nearest to adjacent cylinders are preferably substantially flat, see also Figs. 6 and 7. This makes it possible to provide a relatively large number of cylinders in the cylinder wheel, and at the same time keep the valve 62 of relatively small diameter. The cylinders in the construction shown are provided in their cylindrical portions with cylinder sleeves 72 rigidly secured thereto, which may be of a material differing from the material of which the cylinder wheel is made. For example, the cylinder sleeves 72 may be of cast iron and the cylinder wheel may, if desired, be made of a light weight metal or alloy.

By means of the construction of the valve and valve ports, the ports, because of their elongated shape, have the desired cross sectional area and, at the same time, the frusto conical valve member is of comparatively small diameter, so that the lineal speed of the frusto conical portion of the revolving cylinder wheel with reference to the stationary valve, is kept small enough to avoid excessive wear of these contacting surfaces.

The stationary valve may be maintained in tight seating relation to the frusto conical inner portion of the cylinder wheel in any suitable or desired manner, and preferably, this is accomplished by yieldingly urging the valve member and its inlet and discharge passages in a lengthwise direction to seat the valve member in the base of the cylinder wheel. For example, in the construction illustrated, the discharge duct 61 of the valve member is provided with an outwardly extending flange 74 suitably secured to the discharge duct 61, for example, by means of a screw threaded connection, as shown, and this flange 74 is yieldingly urged to the left in Fig. 3, by means of springs 75 extending about bolts or studs 76 which are screwed into a stationary disk or port

77 of the machine. This disk 77 also serves the purpose of holding the bearing 28 in place, as clearly shown in Fig. 3. A similar bearing-retaining disk 78 is provided at the opposite end of the machine, which is held in place by nuts or studs 79, Fig. 1, which engage in threaded holes in the cylindrical portion or flange 27 of the stationary bearing support 25, and similar studs or screws (not shown) may be used for securing the disk 78 to the other stationary bearing shaft 25 on the discharge end of the machine. Consequently, the springs 75 urge the flange 74 to the left in Fig. 3 and urge the valve into seating engagement in the bore of the cylinder wheel. Nuts 80 are adjustably mounted on the studs 76 to permit varying the pressure with which the valve is urged into seating engagement with the bore of the cylinder wheel, so that the pressure of the springs can be varied, depending upon the pressure of the fluid discharged from the cylinders.

The valve construction described is desirable for the reason that the springs automatically compensate for wear of the valve or of the metal at the bore of the cylinder wheel.

The flange 74 and the studs 76 may also be used to hold the tubular member and the valve against turning with the cylinder wheel. For this purpose, the flange 74 may be provided with slots 81, Figs. 2 and 3, into which the ends of the studs 76 extend. Since during the rotation of the cylinder wheel, these studs will bear against one side only of the slots, the studs are preferably provided with flat sides which bear against the sides 82 of the slots, with which they will engage during the rotation of the cylinder wheel, and the slots are also formed so that each side 82 lies substantially in a radial plane extending through the center of rotation of the cylinder wheel. Consequently, the studs 76 oppose force tending to turn the flange 74 without producing radial components of this force. The slots 81 are also made long enough and wide enough to permit any slight movement that may be imparted to the discharge duct 61 because of inaccuracies in machining.

83 represents a pipe or tube which conducts the compressed gas from the discharge duct 61, and which in the construction shown has a flange which is secured to the flange 74. This tube 83 is preferably flexible to allow for any slight movement of the duct 61.

In the operation of the compressor as thus far described, when power is applied to rotate the trunnion 36, the cylinder wheel rotates about its axis. Through the medium of the master ring links 57, rotary motion is imparted from the cylinder wheel to the eccentric master rings arranged at opposite sides of the cylinder wheel and mounted on the bearings 30, which are eccentric with relation to the axis of rotation of the cylinder wheel. Consequently, the pistons will be caused to reciprocate in their cylinders, some of the various positions of the pistons being shown in Fig. 4. In the machine illustrated in the drawings, the axis of rotation of the cylinder wheel is located vertically above the axis of rotation of the master ring and, consequently, when a cylinder reaches approximately the upper portion of the machine, its piston will be in its inner position. Assuming that rotation is in a clockwise direction in Fig. 4, each piston, as it moves with the cylinder wheel from the upper position, will move outwardly, and will move into communication with the last inlet port 63 of the valve member. When it reaches the lower portion of its movement, the piston will be in its outermost position, and from then on to its upper position, it will be moved inwardly in its cylinder to compress the gas taken in. During a part of the time that a cylinder passes through the upper, left quadrant in Figs. 4, 6, 7 and 8, its port moves into registration with the discharge port 64 of the stationary valve, thus discharging the compressed gas into the discharge duct 61. Consequently, it will be noted that the greater portion of the work done by each piston will be in the upper, left quadrant of Fig. 4, and the maximum power is required by the piston during this portion of its stroke. It will also be noted that very little side thrust is applied to the pistons by the piston rods 48 during the intake or suction stroke which takes place during the movement of the piston from the upper to the lower position, since centrifugal force will act on the pistons in a direction to move them radially outwardly. This is due to the fact that the axes of the pistons and cylinders extend radially from the axis of rotation of the cylinder wheel, so that the centrifugal force acting on the pistons produces no side thrusts of the pistons on the cylinders. It will also be noted that the piston rods 48 will occupy positions in angular relation to the axes of their cylinders and pistons in all but two points of their path of rotation, namely, when the piston rods 48 are in radial planes of the cylinder wheel, i. e. in planes in which the axis of rotation of the cylinder wheel lies. Consequently, the piston rods will tend to produce side thrusts on the pistons during all portions of their paths of movement except at said two points when these piston rods are in said radial planes of the cylinder wheel, the extent of the side thrusts depending upon the size of the angle between said radial planes and the piston rods, and upon the amount of force transmitted by the rods to the pistons. Since these side thrusts result in wear on the pistons and cylinders, it is desirable to reduce them to a minimum.

I have found that these side thrusts can be greatly reduced by positioning the master ring with reference to the cylinder wheel in such a manner that the piston axes will lie in the same plane as the centers of the piston rods 48, i. e., in dead-center positions, when the pistons are subjected to high gas pressure. This can be accomplished by so connecting the master ring to the cylinder wheel by means of the master ring links 57 that the master ring will be slightly in advance of the cylinder wheel in the direction of rotation. In other words, if it be assumed that the "normal" position of the master ring would be such that the piston rods lie in the planes of the axes of the pistons, when the pistons are in their uppermost and lowermost positions, and assuming that the cylinders, when in their uppermost positions have just been disconnected from the discharge port 64 of the valve, then according to my invention, I secure the master ring to the cylinder wheel in such manner that the master ring will be in advance of such "normal" position in the direction of rotation. The extent to which the master ring may be advanced depends upon several factors and, consequently, may vary considerably, and in the construction shown by way of example in Figs. 4 and 15, the master ring is shown as advanced seven degrees. The effect of this advance will be apparent upon inspection of Fig. 15, in which 84 represents the center or axis of rotation of the cylinder wheel and 85 the center or axis of rotation of the master rings. In this figure the positions of the piston rods are

shown diagrammatically at intervals of 10° by the lines 86, connecting the pivot pins 53 of the master ring with the pins 45 of the pistons. Any radial line, such as lines 87, drawn from the center 84 to a pin 45 will indicate the axis or center line of the piston in such position, and the radial planes of the cylinder wheel. It will be noted on this diagram that at the left half of the path of movement of the pistons, in which they require the most power, the angles between the radial planes of the cylinder wheel and the piston rods, i. e. between lines 87 and 86, are much less than in the right half of the diagram, in which the forces transmitted by the piston rods to the piston are the least. It will also be noted that radial planes 87 and piston rod lines 86 will coincide at a point somewhat less than 30° from the vertical at the top of the diagram, at which point the pressure of the compressed fluid in the cylinder is approximately at the maximum, and consequently, at this point there will be no side thrust on the piston. At either side of this point, the angle between lines 86 and 87 will be very small, so that the side thrusts at these points will be correspondingly small.

It will also be noted from Fig. 15 that the positions in which the piston rods are in the radial planes of the cylinder wheel are in the left half of the path of rotation, and that the angles between the radial planes 87 and the lines 86 are also smaller in this left half, and since the gas pressures acting on the pistons in this half of their path of movement become increasingly greater, the smallness of these angles results in decreased side thrusts. The construction described consequently results in the piston rods passing through these radial planes 87 twice during and before completing their compression strokes. This greatly reduces the side thrusts of the pistons on their cylinders during the compression stroke.

As a result of the advanced angular relation of the master ring relatively to the cylinder wheel, the angles between lines 86 and 87 at the right half of the path of movement of the pistons will be greater than they would be if the master ring had not been advanced. Since, however, very little power is transmitted to the pistons by the connecting piston rods at this right half of the path, correspondingly small side thrusts will be produced in this half of the path. If it should happen that centrifugal force alone is sufficient to move the pistons outwardly during their suction strokes, then no power would be transmitted by the piston rods 48, and no side thrusts would result, regardless of the angular relation between the lines 86 and 87, because of the fact that the axes of the cylinders and pistons are radial with reference to the axis of rotation of the piston wheel. Even if centrifugal force does not fully eliminate side thrusts, it will nevertheless greatly reduce such side thrusts as occur at the right half of the path of movement of the pistons. The arrangement described consequently materially reduces the wear on the pistons and cylinders resulting from side thrusts produced by the piston rods.

In compressors as now commonly constructed, the residual compressed gas which remains in a cylinder after the closing of the discharge valve, the volume of which depends upon the clearance between the head of the piston and the head of the cylinder, is re-expanded during the initial portion of the intake stroke of the piston, and consequently, this reduces the fresh charge of air which can be admitted to the cylinder during the intake stroke.

In accordance with my invention, I provide an improved method and means whereby this residual gas is discharged into a cylinder in which the piston has just completed its intake, and in which the intake valve is closed. This residual gas, consequently, supercharges the cylinder into which it is discharged, so that this cylinder will compress not only the charge of gas taken in during the suction or intake stroke, but also such residual gas as is delivered to it.

Any suitable or desired means may be employed for carrying out my method. In the machine shown in Figs. 1 to 9, this method can readily be carried out by providing a single relatively small passage through the valve 62, for example, such as the passage 90, shown in Figs. 3 and 6–9. It will be noted that this passage, which in the construction shown may be in the form of a hole drilled in the valve 62, is so arranged that any cylinder after its port passes out of registration with the discharge port 64 of the valve, will momentarily pass into registration with one end of the passage 90. The other end of this passage will be in registration with the port of another cylinder just after the port of such cylinder has moved out of registration with the inlet port 63. In Figs. 6 and 7, the upper cylinder is shown in the position in which it has just passed out of registration with the discharge port 64 of the valve and the lowest cylinder has just passed out of registration with the inlet port 63, and neither of these cylinders has as yet passed into communication with the connecting passage 90. Fig. 8 shows the positions of the cylinders after they have passed through a small arc beyond the positions shown in Figs. 6 and 7, and shows the upper cylinder in registration with the upper end of the passage 90 and the lowest cylinder also in registration with the lower end of this passage. Consequently, residual compressed gas in the upper cylinder will quickly flow through the passage 90 and will, consequently, be expanded during this passage, and the greater portion of this residual charge will be added to the charge of gas in the lowest cylinder, thus increasing the pressure and the quantity of gas in the lowest cylinder and also greatly reducing the amount of residual gas in the uppermost cylinder, so that when the port of this cylinder moves into communication with the inlet port 63 of the valve 62, it will take in a materially larger charge of gas than would be the case if it were first necessary to expand all of the residual compressed gas remaining in the cylinder after exhaust. Consequently, by use of the supercharge passage, the capacity of the compressor is increased, in the first place, because of the fact that with very little residual gas in the uppermost cylinder, this cylinder will take on a proportionately larger charge of fresh gas during its intake stroke. The capacity of the machine is further increased by the fact that the cylinder receiving the residual charge is supercharged and, consequently, compresses a proportionately greater amount of gas than would be the case if it had not been thus supercharged. Any other means for transferring residual compressed gas from a cylinder to supercharge a quantity of gas to be compressed may be provided.

Not only does my improved method greatly increase the capacity of any compressor to which it is applied, but also the efficiency of the compressor is greatly increased thereby. For ex-

ample, the residual compressed gas which is added to the gas which is about to be compressed raises the pressure of this latter gas without requiring any additional work by the compressor. It is consequently also possible to make the intake port 63 larger, so that the intake port of each cylinder may be in communication therewith for a longer period of time, without having the residual compressed gas discharged into the intake passage, which would cause objectionable turbulence of the incoming air. I preferably construct the valve so that the intake starts after the pressure in the cylinders is slightly below atmospheric, and since a number of cylinders are always in communication with the intake port, there will be a constant and steady flow of air in the inlet duct.

A further advantage of the removal of residual gas from a cylinder and employing it to supercharge an intake of gas, is that this enables compressors to compress gases to much higher pressures than has heretofore been possible in a single stage. Heretofore, the pressures which could be produced in a single stage were limited by the clearance between the cylinder heads and the pistons, or in other words, by the amount of residual compressed gas left in a cylinder. If the pressure in a cylinder reached a certain point at which the residual gas required the full stroke of the piston to become reexpanded, obviously no additional gas could be taken in and, consequently no compressed gas would be delivered. Consequently, heretofore, the maximum pressure in any cylinder had a definite limitation because of the expansion of the residual compressed gas. By means of my method and construction, since most of the residual gas is discharged from the cylinder, it follows that only a very slight movement of the piston in the cylinder will expand the very small quantity of residual gas left in the cylinder after supercharging, and consequently the maximum gas pressure that can be delivered by any cylinder is greatly increased.

Because of the large amount of heat developed when the gas is compressed, I provide means of improved construction for cooling the cylinder wheel and also the pistons. As has been stated, the cylinder wheel is provided with a series of substantially circular fins 40 which serve not only to reinforce the cylinder wheel, but also to facilitate the transfer of heat from the cylinder wheel. In order to induce a flow of air into the spaces between the fins during the rotation of the machine, I construct the piston rods or links 48 in such manner that they act as vanes to deflect air against the cylinder wheel. For example, these piston rods may be provided with inclined faces 92 intermediate of their ends, these faces being shaped so as to direct air toward the cylinder wheel, see particularly Fig. 5. The cross sectional shape of the intermediate portions of these piston rods is preferably of air foil or other suitable form to produce the maximum movement of air toward the cylinder wheel. Since the piston rods are located near the cylinder portions 38 of the wheel, it will be obvious that the air deflected by the rods will flow between the annular webs 40 along the walls of the cylinders and into the spaces between the cylinders so as to bring about a very effective exchange of heat between the cylinder wheel and the air. The fact that these air deflecting parts of the piston rods are of substantially air-foil shape also results in a suction or rarified air at the outer trailing ends of these sections, which results in drawing air out of the spaces between the fins 40 toward the trailing edges of the rods, thus producing a turbulence and circulating effect in the air adjacent to the cylinder wheel. The fact that the radial web 37 extends between adjacent cylinder walls, prevents air from being blown by the piston rods 48 from one side to the other of the cylinder wheel and this web also assists in the transfer of heat to the circulating air. The fact that these piston rods occupy different positions relatively to their cylinders at different portions of their strokes also improves the cooling effect by directing cooling air currents to different portions of the cylinder wheel during each rotation. Other means for deflecting cooling air against the sides of the cylinder wheel may be employed if desired.

In accordance with my invention, I obtain very superior cooling effects by circulating cooling air in the interior of the pistons. By having the outer ends of the pistons extend beyond the periphery of the rotating cylinder wheel, air can be circulated through the pistons because of the rapid movement of the outer ends of the pistons through the surrounding air.

The pistons employed in my improved compressor may be of any suitable or desired construction, but in order to effectively cool the same, they are preferably made hollow and are each provided with a passage for receiving and discharging cooling air at their outer portions, such passage receiving air at the portion of the piston which faces forwardly during the rotation of the piston with the cylinder wheel, and discharging heated air at the rear or trailing portion of the piston. Consequently, the pressure of air at the front of the piston, due to its movement through the air when rotating and the suction created at the rear of the piston, results in an effective passage of air through the piston in quantities sufficient to provide ample cooling of the same.

I preferably provide each piston with an inner or head portion 94 which is separate from the cylindrical side wall or skirt 95 of the piston, to interrupt to some extent the passage of heat from the piston head to the skirt or side wall. In the particular construction shown, see particularly Figs. 10–14, each piston has a tapering head portion 94, which is shaped to conform closely to the inner contour of the tapering inner ends of the cylinders, to provide a small clearance between the inner ends of the cylinders and the heads of the pistons, as shown in Fig. 3, when the pistons are in their inner positions in the cylinders. Also, the inner ends 96 of the pistons are inclined to correspond to the inclination or taper of the valve 62, and the opposite sides 97 of the piston head are substantially flat to cooperate with the flat faces 71 of the cylinders.

The head 94 of the piston is preferably also made hollow and is provided with a plurality of webs 98 which are formed integral with and extend between the opposite flat sides 97 of the piston head. These webs serve the two-fold purpose of reinforcing the flat sides of the piston heads to prevent collapse or deformation of the same by the pressure of the compressed gas, and also of transferring heat to cooling air circulating through the pistons. The piston heads also each have a central, diametrically extending web or partition 99 which extends crosswise of the webs 98 and terminates at one end at a distance from the inner ends of the webs 98. This partition 99 extends from the head 94 through the interior of the cylindrical portion or skirt 95 and is preferably provided with an enlarged portion

100 which has a hole therein in which the piston pin 45 is secured, for example, by means of set screws 101, Fig. 11. The partition may be suitably reinforced by means of a bead 102, and the outer edges may be provided with flanges 103. If desired, packing material 104 may be provided between the flanges 103 and the cylindrical portion or skirt 95.

The partition 99 also serves as a connecting member between the head 94 of the piston and a cap member 105 between which the skirt portion may be secured. In the construction shown for this purpose, the partition 99 is provided beyond the enlargement 100 thereof with segmental portions 106 or other enlargements to which the cap member 105 may be secured. This cap member has an annular shouldered part adapted to engage the outer end of the skirt portion 95, the inner end of the skirt portion being seated on a corresponding annular shouldered portion of the head 94. Bolts or screws 109 extend through the cap member and engage threaded holes in the segmental parts 106 of the partition 99 for firmly securing the skirt 95 to the head 94. The skirt may be provided with piston rings 110 adjacent to the head 94.

The cap member is provided with an air inlet opening 112 on the leading side thereof and with an air discharge opening 113 at the trailing side thereof, the openings being separated by a partition 114 which forms substantially a continuation of the partition 99. Consequently, when the piston moves wtih the cylinder wheel in the direction indicated by arrow 115, in Fig. 10, it will be obvious that air will flow into the outlet 112 and down along the piston on one side of the partition 99, through the spaces between the webs 98, around the inner end of the partition 99 in the piston head and upwardly on the other side thereof to the discharge opening 113. The flow of air through the piston will be approximately proportional to the speed of rotation of the cylinder wheel, and since the heat developed in the pistons is also approximately proportional to the speed of rotation of the cylinder wheel, very efficient cooling of the pistons results at all speeds of operation of the machine. The construction described has the further advantage that the different parts of the pistons may be made of different materials most suitable for the particular parts. The contact between the piston head and skirt resists rapid transfer of heat from the head to the piston, and heat insulating washers or gaskets may be interposed between the head and skirt if desired.

By means of the construction described, a rapid flow of cooling air will be forced through each piston because of the rapid movement of the ends of the pistons through the surrounding air and because of the location of the inlet and discharge openings of the air passage in the pistons. The piston heads are subjected to the highest temperatures, and because of the reinforcing and radiating webs between which the cooling air is forced to flow, a large amount of heat is withdrawn from the piston heads. This results in withdrawing more heat from the pistons than from the cylinders, which results in several advantages. In machines in which little or no heat is removed directly from the pistons, such heat is dissipated mostly or entirely through passage from the pistons to the cylinders, through the oil film between the pistons and cylinders. This oil film has a high resistance to the passage of heat therethrough, which retards the heat flow and results in higher temperatures in the pistons, to such an extent that it is often necessary to construct the piston heads of iron or steel. By cooling the piston heads efficiently, as in the construction shown, these heads operate at much lower temperatures, so that the heads may be made of aluminum or its alloys.

In my improved process of cooling machines of this type by cooling the piston heads to a greater extent than the adjacent portions of the cylinders, it follows that more heat from the compressed gas in the head portions of the cylinders will be transferred to the relatively cooler piston heads than to the adjacent portions of the cylinders. Consequently, this reduces the amount of cooling of the head portions of the cylinders that would otherwise be required, and this, in turn, makes it possible to bring the tapered head portions of the cylinders closely together, as is clearly shown in Figs. 6–8. This, in turn, makes it possible to provide a relatively large number of cylinders in the cylinder wheel and at the same time to have the tapering bore in the central portion of the cylinder wheel of small diameter, thus permitting the use of a relatively small valve and, consequently low lineal speeds of the central bore of the cylinder wheel relatively to the valve. Another advantage of removing more heat from the pistons than from the cylinders is that if for any reason the machine becomes heated to high temperatures by maintaining the cylinder heads cooler than the adjacent portions of the cylinders the cylinders will expand, due to heat, to a greater extent than the pistons, thus avoiding the seizing of the pistons in the cylinders, which takes place in machines in which the pistons become heated to higher temperatures than the cylinders. This fact in turn makes it possible, in the construction of my improved machine, to allow for smaller clearances between the pistons and cylinders than is now standard practice. This adds to the efficiency of these machines since less leakage of gas past the pistons will occur. The smaller clearance also adds to the life of the machines since it will require a proportionately longer period of operation of a machine before the cylinders become worn to such an extent as to require reboring of the cylinders or the installation of new pistons.

Consequently, it is obvious that by removing more heat from the pistons than from the cylinders, a very efficient machine can be constructed of smaller size and weight for a given capacity than would be the case if heat were removed mainly through the cylinders. Also, the heat of the pistons is more efficiently and quickly removed from the piston heads, since the interiors of the heads will be dry, so that cooling air will contact directly with the dry metal surfaces in the interiors of the pistons, which results in a much more rapid transfer of heat to the cooling air than is the case in machines in which the heat of the pistons is transferred through an oil film to the cylinder walls before it can be removed by the cooling fluid. Furthermore, no circulating pump or fan is required for circulating the cooling air through the pistons, thus avoiding the necessity for auxiliary cooling equipment and avoiding the possibility of damage to the machine, in the event of failure of such equipment. It will also be noted that the machine shown is so constructed that the caps 105 of the pistons extend beyond the outer periphery of the cylinder wheel even when the pistons are in their

innermost positions in their cylinders, as shown in the upper portion of Fig. 3, so that the air inlet and discharge openings are always in position to receive cooling air.

Any suitable or desired construction may be employed for providing for the circulation of cooling air in the housing of the compressor. In the construction shown, the stationary bearing supporting members 25 are provided with openings 117 in their vertical webs 31 through which air may enter, and a side wall of the housing is also provided with an air discharge opening 118, Fig. 4. The air is impelled in the housing of the compressor in the direction indicated by the arrows in Fig. 4, and since the pistons extend beyond the periphery of the cylinder wheel to the maximum extent in the lower portion of the housing, they will produce a current of air therein directed toward the discharge opening 118. This positive discharge of air from the housing will result in a corresponding in-flow of air through the openings 117, and this incoming air consequently flows against the middle portions of the cylinder wheel, where the greatest amount of heat is generated.

It will be seen that the housing completely encloses the machine and that all the cooling air enters the air inlet openings 117. Consequently, if desired, the cooling air admitted to the housing may be filtered or otherwise freed from dust and abrasive particles, so that no dust or particles will settle on the parts of the pistons which extend out of the cylinders.

I have shown by way of example on Figs. 1 and 3, how air filtering means may be readily applied to the housing shown in the drawings. For example, the outer edges of the two inner flanges 22 on each end of the machine are covered by means of a plate 120 having an opening 121 therein, and an air filter may be arranged on the outer face of the plate 120 across the opening 121, such for example as an air filter cartridge 122, containing any usual or suitable filtermass. This cartridge may be held in a frame 124 secured to the plate 120. This frame may, for example, be open at one side, such as the right hand side in Fig. 1, so that the filter cartridge 122 can be readily inserted and removed for cleaning or for replacing with another cartridge. Consequently, during rotation of the cylinder wheel, air will be drawn through the air filters into the space between the two inner flanges 22 and will then pass through the air inlet openings 117 into the interior of the housing. Any other means for filtering air entering the housing may be provided, or if desired, such filtering means may be omitted.

Any suitable means may be provided for applying lubricant to the relatively movable parts of the machine, no lubricating system being shown. Since the machine shown will tend to throw lubricant out by centrifugal force, it may be collected in the housing of the machine and drained from the bottom of the housing through a drain hole 128, Fig. 4.

While I prefer to construct the machine with revolving cylinders and master rings and stationary bearing supports and valve, yet it will be obvious that certain features of this invention can be used equally well on a machine in which the cylinders and master ring are not rotatable, and in which the bearing supports and valve are rotatable.

I claim as my invention:

1. A machine having rotary cylinders and pistons reciprocable in said cylinders, a pair of rings at opposite sides of said cylinders and mounted to rotate about an axis spaced from the axis of rotation of said cylinders, links connecting said ring and said cylinders for maintaining relative positions of said ring and said cylinders, and a pair of rods for each piston pivotally connected to said rings and to a piston, said rods being arranged to extend in planes substantially parallel with the axes of said pistons and cylinders when said rods transmit the greatest force to said pistons.

2. A machine having a group of cylinders arranged radially about an axis, a valve arranged in said axis, one of which is rotatable relatively to the other about said axis, pistons arranged to reciprocate in said cylinders, a pair of piston rods for each piston and extending along opposite sides of said cylinders, and means for imparting reciprocatory motion to said pistons through said rods and including a pair of master rings, one at each side of said group of cylinders, and journalled eccentrically with reference to said axis and to which said piston rods are connected, links connecting said master ring and said group of cylinders, said rods being so arranged relatively to their cylinders that said rods and the longitudinal centers of said pistons are in the same plane slightly before said pistons complete their compression strokes.

3. A machine having a group of cylinders arranged radially about an axis, a valve arranged in said axis, one of which is rotatable relatively to the other about said axis, pistons arranged to reciprocate in said cylinders, a pair of piston rods for each piston and extending along opposite sides of said cylinders, and means for imparting reciprocatory motion to said pistons through said rods and including a pair of master rings, one at each side of said group of cylinders, and journalled eccentrically with reference to said axis and to which said piston rods are connected, links connecting said master ring and said group of cylinders, said rods being so arranged relatively to their cylinders that said rods pass through radial planes extending through the longitudinal centers of the pistons twice during and before completion of their compression strokes.

4. A machine having a piston arranged to reciprocate in a cylinder rotatable about an axis extending transversely of the cylinder, a ring mounted to rotate about an axis spaced from said first mentioned axis, a link connecting said ring and said piston, and a rod pivotally connected with said ring and said piston, the axes of said pivotal connections of said rod and said ring being arranged to lie in a plane passing through the longitudinal center of said cylinder when compressed fluid is discharged from said cylinder.

5. A machine having a piston arranged to reciprocate in a cylinder rotatable about an axis extending transversely of the longitudinal center line of the cylinder, a ring mounted to rotate about an axis spaced from said first mentioned axis, a link connecting said ring and said cylinder, and a rod pivotally connected with said ring and said piston, the pivotal connections of said rod with said ring and said piston being so arranged that said rod will pass through a radial plane including said axis of rotation of said cylinder and the center line of said cylinder slightly before said piston completes its compression stroke.

6. A machine having a piston arranged to reciprocate in a cylinder rotatable about an axis extending transversely of the longitudinal center line of the cylinder, a ring mounted to rotate about an axis spaced from said first mentioned axis, a link connecting said ring and said cylinder, and a rod pivotally connected with said ring and said piston, the pivotal connections of said rod with said ring and said piston being so arranged that said piston and said rod pass through two radial planes including said axis of rotation of said cylinder and the center line of said cylinder during and before the completion of the compression stroke of said piston.

7. A machine having a group of cylinders arranged radially about an axis, a valve arranged in said axis, one of which is rotatable relatively to the other about said axis, pistons arranged to reciprocate in said cylinders, means for imparting reciprocatory motion to said pistons, the inner ends of said cylinders having ports which are elongated in the direction of said axis and arranged to communicate with ports in said valve, said cylinders having converging substantially flat sides at their inner ends which terminate at the elongated sides of said cylinder ports.

8. A machine having a group of cylinders arranged radially about an axis, a valve arranged in said axis, one of which is rotatable relatively to the other about said axis, pistons arranged to reciprocate in said cylinders, means for imparting reciprocatory motion to said pistons, the inner ends of said cylinders having ports which are elongated in the direction of said axis, and arranged to communicate with ports in said valve, said cylinders having converging substantially flat sides at their enner ends which terminate at the elongated sides of said cylinder ports, said pistons having flat sides at their inner ends to enter between said flat sides of said cylinders.

9. In a machine of the revolving substantially radial cylinder type having pistons arranged to reciprocate in the cylinders, a ring rotatable eccentrically with reference to said cylinders, piston rods connecting said ring with said pistons for imparting reciprocatory motion with said pistons, each piston rod extending along a side of a cylinder and being of vane-shaped cross section to direct cooling air toward its cylinder during the rotation of the same.

10. In a machine of the revolving substantially radial cylinder type having pistons arranged to reciprocate in the cylinders, rings at opposite sides of said revoluble cylinders and mounted to rotate eccentrically with reference to said cylinders, a pair of piston rods connecting each piston with said rings at opposite sides of a cylinder, said links having vane-shaped portions for directing air currents against opposite sides of said cylinder.

11. In a machine of the substantially radial cylinder type including a cylinder wheel mounted to rotate about an axis, pistons reciprocable in the cylinders of said wheel, a ring mounted to rotate eccentrically with reference to said wheel, piston links connecting said ring and said pistons for imparting reciprocatory motion to said pistons, and a unitary bearing support on which both said cylinder wheel and said ring are journalled, whereby the stresses resulting from the reactions between said cylinders and said pistons are transmitted to said bearing support.

12. In a machine of the substantially radial cylinder type including a cylinder wheel mounted to rotate about an axis, pistons reciprocable in the cylinders of said wheel, a pair of rings mounted on opposite sides of said cylinder wheel to rotate eccentrically with reference to said cylinder wheel, piston rods having pivotal connections with said wheel and said pistons for imparting reciprocatory motions to said pistons, and a pair of bearing supports, one arranged at each side of said cylinder wheel, each bearing support having said cylinder wheel and said ring journalled thereon, each of said bearing supports being of integral structure, and a frame on which said bearing supports are rigidly mounted.

13. In a machine of the substantially radial cylinder type including a cylinder wheel mounted to rotate about an axis, pistons reciprocable in the cylinders of said wheel, a ring at each side of said cylinder ring mounted to rotate eccentrically with reference to said wheel, a pair of piston rods at opposite sides of each cylinder and connecting said rings and a piston for imparting reciprocatory motion to said pistons, and a plurality of links pivotally connecting said ring and said cylinder wheel to transmit rotary motion from one to the other.

14. In a machine of the substantially radial cylinder type including a cylinder wheel mounted to rotate about an axis, pistons reciprocable in the cylinders of said wheel, a pair of rings mounted on opposite sides of said cylinder wheel to rotate eccentrically with reference to said cylinder wheel, a pair of piston rods at opposite sides of each cylinder and having pivotal connections with said wheel and said pistons for imparting reciprocatory motions to said pistons, and a plurality of links pivotally connecting each ring with said cylinder wheel to connect said rings and wheel to rotate together about their own axes.

15. A machine having a group of cylinders arranged substantially radially and rotatably about an axis, a stationary part on which said group of cylinders bears, pistons arranged to reciprocate in said cylinders, said cylinders terminating at their head portions in a frusto-conical bore, a stationary valve member having a frusto-conical portion and seated in said bore, and yielding means acting on said valve member and said stationary part for urging said valve in a direction to seat in said bore.

16. A machine having a group of cylinders arranged substantially radially and rotatably about an axis, a stationary part on which said group of cylinders bears, pistons arranged to reciprocate in said cylinders, said cylinders terminating at their head portions in a frusto-conical bore, a stationary valve member having a frusto-conical portion and seated in said bore, yielding means acting on said valve member and said stationary part for urging said valve in a direction to seat in said bore, and means for varying the force exerted by said yielding means in a direction to seat said valve.

17. In a machine of the revolving substantially radial cylinder type having pistons arranged to reciprocate in the cylinders, rings at opposite sides of said revoluble cylinders and mounted to rotate eccentrically with reference to said cylinders, a series of fins on said cylinders substantially concentric with the axis of rotation of said cylinders, a pair of piston rods connecting each piston with said rings at opposite sides of a cylinder, said piston rods having vane-shaped portions for directing air currents against opposite sides of said cylinder and between said fins.

18. A multi-cylinder compressor of the substantially radial revolving cylinder type including a

cylinder wheel having a plurality of substantially radial cylinders formed therein, said cylinder wheel including a central web formed integral with said cylinders, a series of fins extending outwardly from said web and said cylinders, pistons arranged to reciprocate in said cylinders, rings at opposite sides of said cylinder wheel mounted to rotate eccentrically relatively to said cylinder wheel, and piston rods connecting said rings and said pistons for reciprocating said pistons and having parts thereon for directing air currents against opposite sides of said cylinder wheel.

19. In a machine of the substantially radial cylinder type including a cylinder wheel mounted to rotate about an axis, pistons reciprocable in the cylinders of said wheel, a ring mounted to rotate eccentrically with reference to said wheel, piston rods connecting said ring and said pistons for imparting reciprocatory motion to said pistons, and a unitary bearing support on which both said cylinder wheel and said ring are journalled, whereby the stresses resulting from the reactions between said cylinders and said pistons are transmitted to said bearing support, said cylinder wheel having a substantially frusto-conical hub having parts with which said cylinders communicate, a stationary valve having a substantially frusto-conical portion fitting in said hub, and yielding means connecting said valve and said bearing support for urging said valve into seating relation to said hub.

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