Dec. 14, 1937. W. W. WISHART 2,102,346

COMPRESSOR

Filed April 11, 1935 4 Sheets-Sheet 1

FIG. 1.

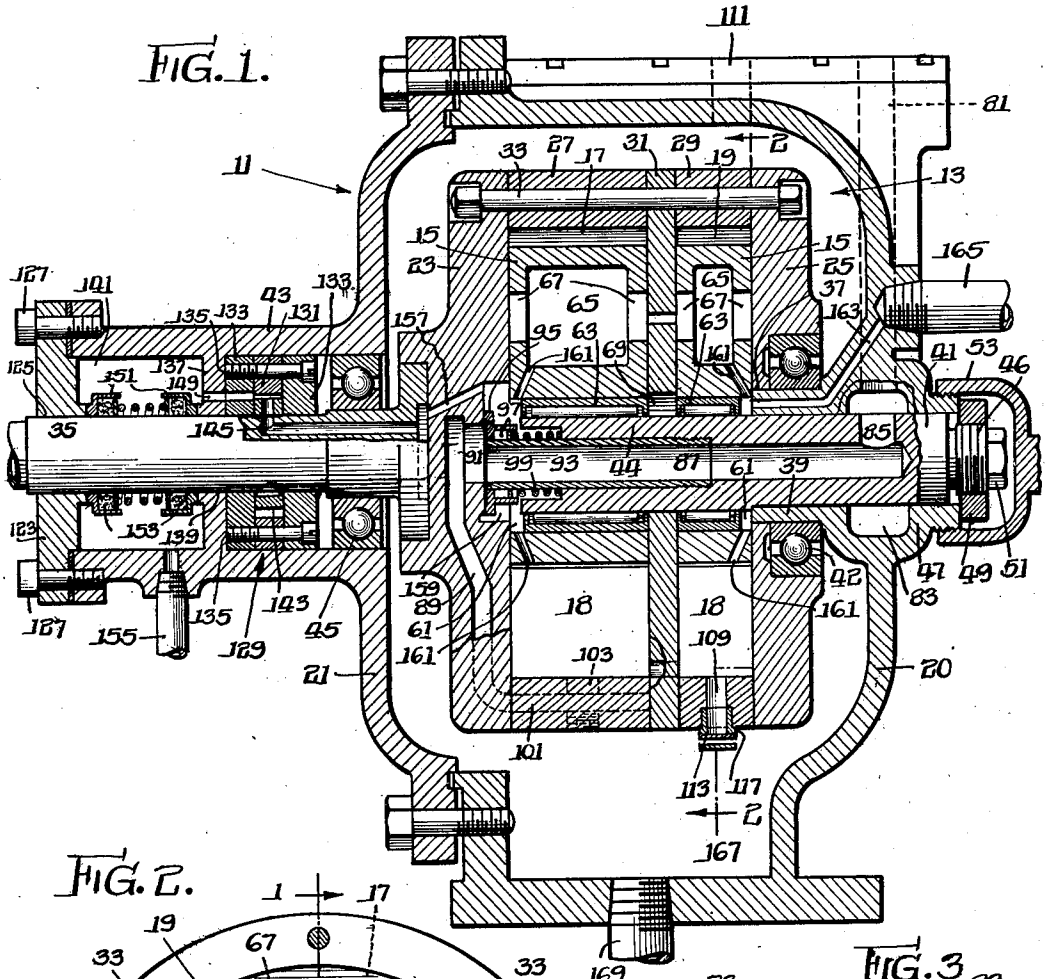


FIG. 2.

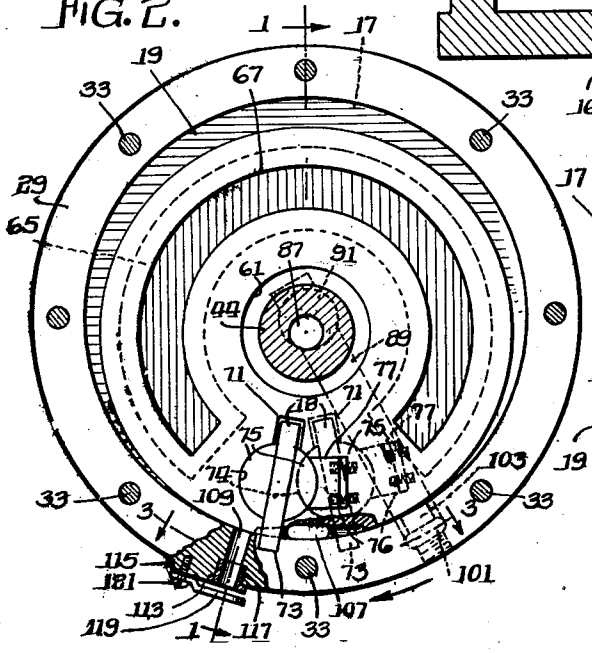
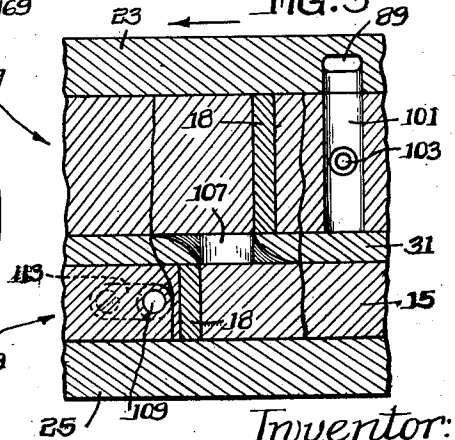


FIG. 3

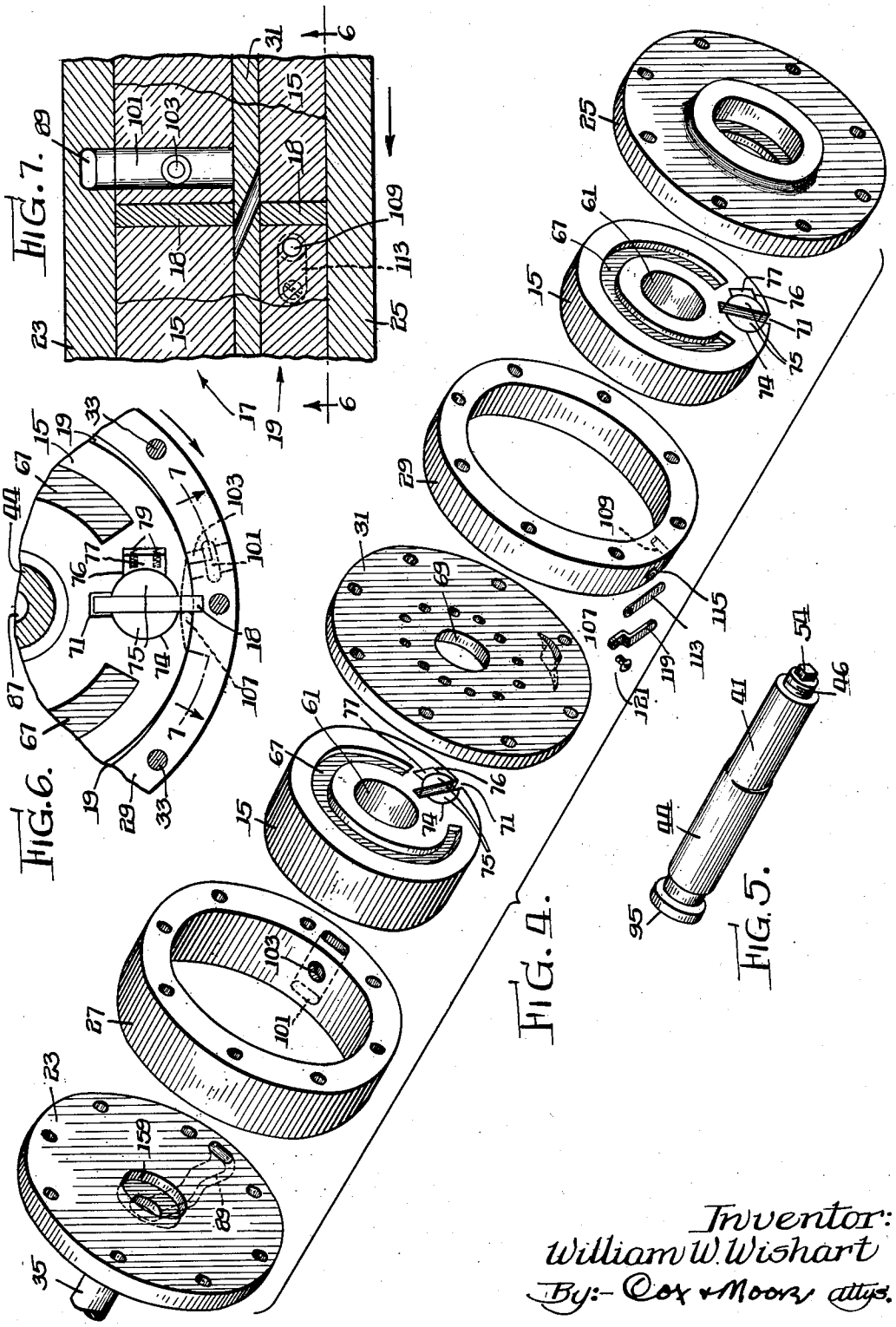


Inventor:
William W. Wishart
By:- Cox & Moore attys.

Dec. 14, 1937. W. W. WISHART 2,102,346

COMPRESSOR

Filed April 11, 1935 4 Sheets-Sheet 2



Inventor:
William W. Wishart
By:- Cox & Moore Attys.

Dec. 14, 1937. W. W. WISHART 2,102,346

COMPRESSOR

Filed April 11, 1935 4 Sheets-Sheet 3

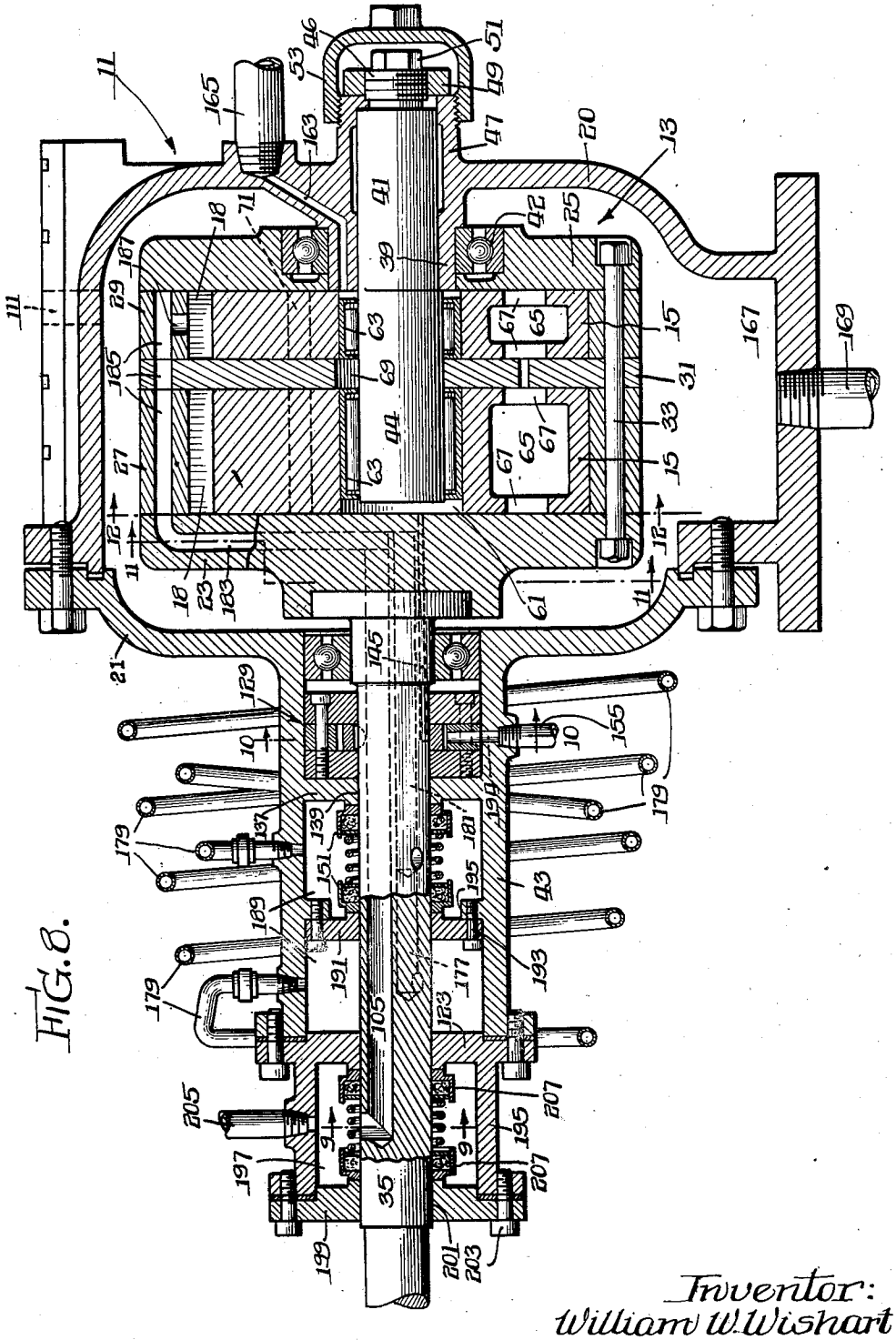


FIG. 8.

Inventor:
William W. Wishart
By:- Cox & Moon, Attys.

Dec. 14, 1937. W. W. WISHART 2,102,346

COMPRESSOR

Filed April 11, 1935 4 Sheets-Sheet 4

FIG. 9.

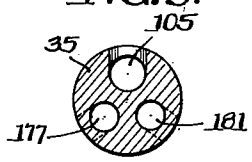


FIG. 10.

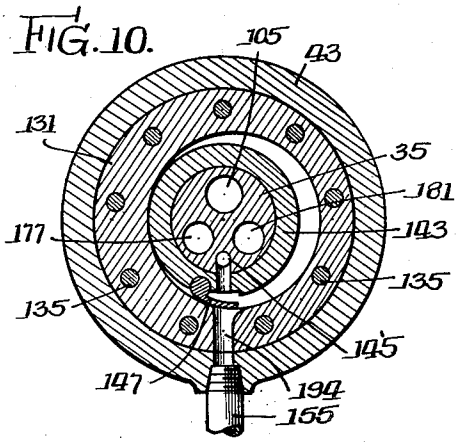


FIG. 11.

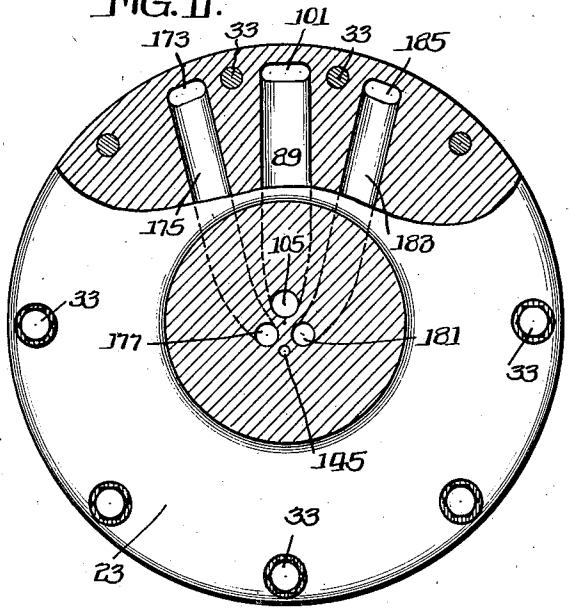


FIG. 13.

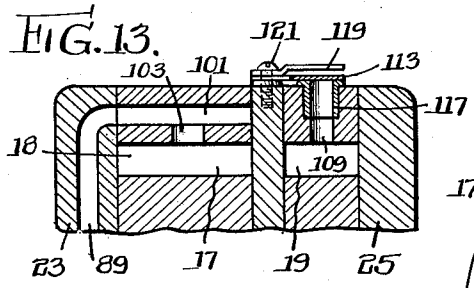


FIG. 12.

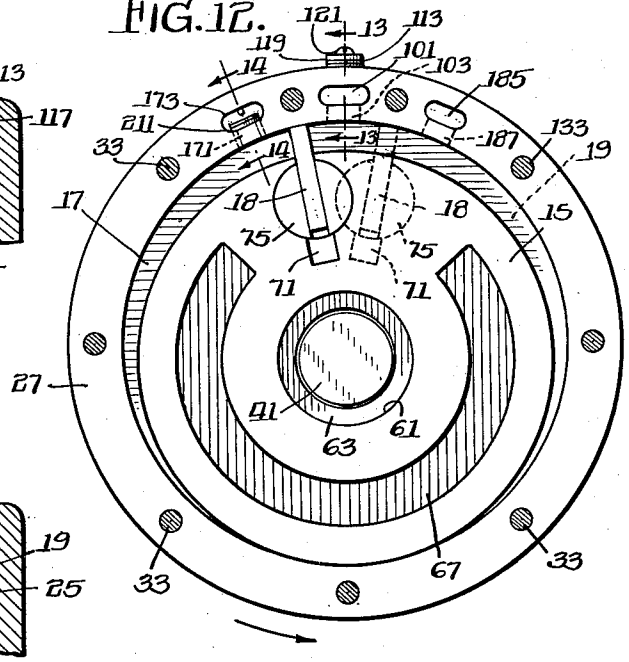
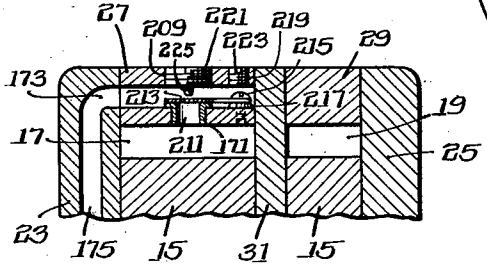


FIG. 14.



Inventor:
William W. Wishart
By:- Cox & Moore attys.

Patented Dec. 14, 1937 2,102,346

UNITED STATES PATENT OFFICE

2,102,346

COMPRESSOR

William W. Wishart, Chicago, Ill.

Application April 11, 1935, Serial No. 15,830

3 Claims. (Cl. 230—140)

My invention relates in general to fluid flow apparatus and has more particular reference to rotary pumps or compressors.

An important object of the invention is to provide a fluid flow device having a plurality of working chambers arranged in tandem so that the work medium is delivered in succession through the several chambers, the invention more especially residing in the provision of a multi-stage device especially adapted for use in compressing the fluid media with great efficiency at relatively high delivery pressures.

Another important object of the present invention is to provide apparatus of the character mentioned having improved means for sealing the same against leakage of the fluid media between the various stages, particularly the stages in which the fluid medium is under high compression.

Another important object is to provide a multi-stage device of the character mentioned wherein each stage comprises a cylinder and co-operating piston, the cylinders and pistons of the several stages being of like diameter, the volumetric displacement of each stage being determined by the width of the pistons and cylinders in order to minimize the use of and facilitate the fabrication of the multi-stage device and eliminate manufacturing difficulties incurred in the determination of the relative size of several cylinders.

Among the other objects are to arrange the several cylinders of the device as a unit in end-to-end alignment; to mount the pistons of the several stages on a common support shaft to facilitate alignment of the pistons in their co-operating cylinders; to provide for adjusting all of the pistons within the cylinders simultaneously; to assemble and secure the several cylinder elements together in co-axial alignment by and between end plates with partition plates mounted between adjacent cylinder elements; to provide the cylinder assembly with a support shaft having a duct or ducts communicating with each cylinder and through which the work medium may flow; to provide novel means for cooling the work medium during its travel between successive stages in order to prevent the device from becoming overheated in operation; to provide means, preferably built into the apparatus, for adequately lubricating the working parts; to provide for discharging the fluid work medium from one stage of the device into an adjacent stage through a duct formed directly in an intermediate partition separating the stages and forming an integral part of the cylinder assembly; to provide a check valve in the discharge outlet of each stage; and to provide a unitary cylinder assembly forming a plurality of working spaces, the assembly including a support shaft having a plurality of separate ducts each communicating with one of the cylinder spaces; a further object being to support the shaft in a mounting forming several sealed chambers into each of which opens a duct of the shaft.

Numerous other objects, advantages, and inherent functions of the invention will become apparent as the same is more fully understood from the following description, which, taken in connection with the accompanying drawings, discloses selected embodiments for the purpose of illustrating the invention.

Referring to the drawings:

Figure 1 is a sectional view taken longitudinally through a fluid flow device embodying my present invention;

Figure 2 is a sectional view taken substantially along the line 2—2 in Figure 1;

Figure 3 is a sectional view taken substantially along the line 3—3 in Figure 2;

Figure 4 is an exploded view showing interrelated parts of the device in perspective;

Figure 5 is a perspective view of a piston supporting shaft used in conjunction with certain of the parts shown in Figure 4;

Figure 6 is a fragmentary sectional view similar to the showing contained in Figure 2 and illustrating a modified arrangement of the parts;

Figure 7 is a sectional view taken substantially along the line 7—7 in Figure 6;

Figure 8 is a sectional view taken longitudinally through a modified construction embodying my present invention;

Figures 9, 10, 11, and 12 are sectional views taken substantially along the lines 9—9, 10—10, 11—11, and 12—12 in Figure 8; and

Figures 13 and 14 are sectional views taken substantially along the lines 13—13 and 14—14 in Figure 12.

To illustrate my invention, I have shown on the drawings a multi-stage fluid flow device 11 comprising essentially cylinder means 13 and piston means 15 extending within the cylinder means and adapted to co-operate therewith and act upon a fluid medium. The invention more particularly applies to rotary devices, and consequently the cylinder and piston means are of cylindrical shape and mounted for relative movement in order to accomplish the function of the device.

In the illustrated embodiment, the relative movement of the cylinder and piston means is

accomplished by the rotation of these parts about relatively eccentric axes, the piston means defining, with the cylinder means, a plurality of substantially crescent-shaped work spaces 17, 19, between the operating parts. The relative movement of the parts causes the work spaces to circulate relatively around the cylinder means, and, although I have shown the piston and cylinder means both mounted for rotation about their respective axes, it will be apparent that the invention is not necessarily restricted to a rotary device wherein the piston and cylinder are both mounted for rotation about eccentric axes. In fact, the invention may be incorporated in numerous other mechanical arrangements for circulating the work medium between the operating parts in accomplishing the function of the device.

I prefer, however, to mount the piston means, as well as the cylinder means, for rotation about relatively eccentric axes and, where the device is used as a pump or compressor, to provide a driving connection between the parts. Means is also provided for driving at least one of the parts, the other, in turn, being rotated by the driven part through the driving connection therebetween. I may, of course, provide means for driving either of the parts, but I prefer to drive the cylinder means and to utilize blade means 18, carried rigidly by the cylinder means and having bearing relationship with the piston means, for the purpose of driving the same.

The invention more particularly relates to a multi-stage compressor, and the cylinder means 13 is arranged to provide a plurality of work chambers, there being a separate piston 15 in each and the structure includes a channel, through which the work medium may travel into one of the chambers and ducts through which the compressed medium may be discharged into succeeding work chambers. In this way, by compressing the work medium successively in the several chambers, I am able to produce unusually high pressures in fluid media such as air and other gases and liquids. The cylinder and piston means are preferably mounted in a frame or casing 20, comprising a generally cylindrical housing having an open end and a cover 21 for closing said end so that the operating parts are sealed within the housing.

The cylinder means 13 comprises spaced end plates 23 and 25 and a plurality of annular rings 27 and 29 mounted in end-to-end relationship between the end plates, there being an annular ring for each stage or compression space of the device. Partition means 31 is or may be mounted between the abutting ends of adjacent rings 27 and 29, and the parts are clamped together and secured by and between the end plates 23 and 25 in any suitable fashion, as by fastening members 33, which preferably comprise headed bolts and co-operating nuts positioned in spaced apart circular arrangement in the assembly and serving to clamp the parts together. The end plate 23 is formed with a projecting shaft 35 extending from the cylinder assembly in alignment with the axis of the annular portions 27 and 29. The end plate 25 is formed with an opening 37 adapted to receive a sleeve-like projection 39 forming a part of the frame or casing 20, and suitable bearing means 42 is interposed between the opening 37 and the sleeve 39 to permit the end plate to turn upon and be supported by the projection 39.

It will be understood that a fluid work medium is delivered through the stages 17 and 19 in succession so that the work medium is under different pressures in the several stages. Where the device embodying the invention is a pump or compressor, the work medium will be under relatively greater pressure during its passage through a succeeding stage of the device such as the stage 19, than during its passage through an earlier stage. Consequently, it is necessary to fabricate the device with the displacement volume of the second stage, that is to say, the volume of the space 19 is considerably smaller than the displacement volume of the first stage, to-wit, the volume of the space 17. The relative size of the spaces 17 and 19 will depend upon the coefficient of expansion of the work medium, the temperature at which it enters the device, and other operating constants.

It will be noted, however, that the size of the spaces 17 and 19 is a direct function of the width of the cylinder stages, that is to say, the width of the rings 27 and 29, so that by forming the rings 27 and 29 with the same radial dimensions, the problem of obtaining a desired ratio of displacement volumes in the several cylinders is greatly simplified, since it is necessary only to finish the rings 27 and 29 to widths corresponding to the desired ratio of displacement volumes desired in the several stages of the device.

By utilizing rings of equal radial dimensions, the pistons 15 of the several stages also have the same dimension, which facilitates fabrication of the same and furthermore permits said pistons to be mounted on a common support 44.

Although many of the features of my present invention may be incorporated in compressors, in which the ratio of displacement volumes of the several stages is accomplished by varying the radial dimension of the cylinders instead of the width thereof, particular advantages are had by maintaining radial dimensions constant throughout the several stages. For example, the piston support 44 need not be formed as a crank as is necessary where the several stages have unlike radial dimensions. Other advantages reside in forming the several stages to like radial dimensions including the saving derived from the fabrication of the rings 27 and 29, since the same pattern or stroke may be used in forming the rings 27, 29 of the several stages. This is a manufacturing advantage which will be apparent to those skilled in the fabrication of articles of the general character mentioned. It is thought also that the simplicity of assembling the rings 27 and 29 between the end plates 23 and 25, which simplicity arises from the fact that all of the rings have a common radial dimension, provides appreciable advantages.

The cover 21 is formed with a sleeve-like extension 43 receiving the shaft 35, there being suitable anti-friction bearing means 45 for the purpose of rotatably supporting the shaft 35 in said sleeve-like extension so that the cylinder assembly is journaled in the casing at its opposite ends. The sleeve-like extension 39 carries a piston supporting shaft 41 therein, the shaft 41 having an end 44 extending within the annular rings 27 and 29, and said end carries the pistons 15. The shaft 41 has an outer end threaded as at 46 and projecting outwardly through a threaded embossment 47 formed in the wall of the casing 20. The projecting threaded portion of the shaft carries a clamping nut 49 adapted to engage the outer end of the boss for the purpose of securing the shaft against turning movement in the sleeve 39.

The shaft portion 44 is supported within the

cylinder means 13 with its axis relatively eccentric with respect to the axis of the cylinder rings 27 and 29 so that the pistons, carried on the shaft portion, likewise are supported with their axes relatively eccentric with respect to the axis of the cylinder rings, and the eccentricity of the cylinder and piston axes is such that the pistons and cylinder rings define the crescent shaped work spaces 17, 19, therebetween.

I also provide for adjusting the eccentricity of the cylinder rings and pistons. To this end, the shaft 41 is formed, as at 51, to receive a wrench or other implement to permit the shaft to be turned in the sleeve 39 after the nut 49 is loosened. A cover 53, adapted for threading engagement on the boss 47, is also preferably provided for the purpose of enclosing the projecting end of the shaft. The channel of the sleeve 39 is relatively eccentric with respect to the axis of the shaft 35 and hence with respect to the cylinder assembly and the piston-carrying portions 44 of the shaft 41 are preferably relatively eccentric with respect to the shaft portions held in the sleeve 39. The eccentricity of the shaft portion 44 with respect to the portions carried in the sleeve 39 is substantially less than the eccentricity of the piston axes with respect to the cylinder axis when the pistons are adjusted to the operating position in contact with the cylinder rings. By turning the shaft 41 in the sleeve 39, as aforesaid, the relative eccentricity of the pistons carried on the shaft with respect to the rings 27 and 29 may be adjusted in order to determine the clearance between the pistons and the cylinders at their points of peripheral contact.

By providing an adjustment of this character, the cylinder bearings and the shaft 41 need not necessarily be located in the frame with any especially fine degree of accuracy, since the parts may be readily adjusted from the outside of the casing after the device is assembled. The foregoing adjustment also provides means for compensating for wear of the parts in service.

The efficiency of pumps and compressors of the general character treated herein depends to a great extent upon the seal accomplished between the piston and cylinder at the peripheral contacting point, and it will be appreciated that the adjustment heretofore described provides a means for maintaining contact sufficiently snug at all times to permit maximum operating efficiency without undue wear at the points of contact.

The pistons 15 comprise cylindrical blocks of lesser diameter than the internal diameter of the rings 27 and 29. Each block preferably has a central opening or channel 61 for the reception of bearings 63, by means of which the pistons are rotatably mounted on the shaft portion 41. The pistons are also formed each with an internal crescent-shaped chamber 65 and the opposite sides of the pistons are formed with preferably crescent-shaped openings 67 communicating with the internal chambers. The pistons are substantially equal in width to the width of the rings 27 and 29 of the cylinders so that the opposite side surfaces of the pistons engage the facing surfaces of the partition means and the end plates of the cylinder assembly. The partition means, needless to say, is formed with an opening 69 through which the piston-carrying portion 44 of the shaft extends.

Each piston also has a radial slot 71 extending between the opposed ends of the chamber 65 and opening on the cylindrical surface of the piston. The slots 71 of the pistons receive the blades 18, which, as heretofore mentioned, are mounted rigidly in the cylinder assembly. A separate blade is provided for each stage. Each blade is mounted in position extending radially inwardly of the inner surface of its associated cylinder ring. Each cylinder ring 27, 29 is formed with a notch 73 for receiving the outer edge of its corresponding blade, and the blades, between opposed edges, are as wide as, or slightly wider than, the ring with which associated. The blades are compressed and snugly held by and between the end plates and the partition means, and are assembled in position before the parts of the cylinder assembly are clamped together. If desired, the facing surfaces of the partition means and end plates may also be grooved for the reception of the opposite ends of the blades 18. The blades extend radially inwardly of the rings 27 and 29 and are received in the slots 71 of the pistons. During the rotation of the cylinder and pistons, the blades will rock and reciprocate in the slots 71, which are preferably formed with semi-cylindrical sockets 74 in their opposite faces, said sockets receiving semi-cylindrical bearing blocks 75 adapted to snugly receive the blades therebetween, so that the blades 18 are rockingly and reciprocably received in the slots and may tilt and slide therein freely between the blocks during the rotation of the cylinder and pistons about their relatively eccentric axes.

The cylinder means and pistons, in the illustrated embodiment, are adapted to be driven in one direction, to-wit, a clockwise direction, as shown by the arrow in Figures 2 and 6 of the drawings, in order to accomplish the compressing or fluid-forcing function of the device. The pistons consequently will be driven each through the leading block 75, i. e. the block on the left hand side of the blade, viewing Figures 2 and 6, by pressure exerted through the blade 18, as will be clearly apparent from an inspection of the drawings. The leading blocks, therefore, during the operation of the apparatus, will be constantly and continuously under compression and will be forced into the seats provided in the leading sides of the radial slots. The trailing blocks, however, will be relatively loosely held in their seats. The looseness of these blocks may increase as the apparatus becomes worn in service. One of the functions of the blocks 75 is to prevent leakage of the fluid medium between the blades and the adjacent piston surfaces in the slots 71 from the high to the low pressure sides of the work spaces and I provide an extension 76 in the trailing seat 74 of each piston for the purpose of receiving means for yieldingly urging the trailing block at all times against the blade. This urging means comprises a block 77 conforming with the curved surface of the trailing block and mounted in said recess 76, and spring means 79 in position to press the block 77 against the back of its associated trailing bearing block 75.

As the parts rotate, it will be seen that the crescent-shaped work spaces 17 and 19 will retain the position shown in Figure 2. Since the parts rotate about their relatively eccentric axes, however, the work spaces, in effect, travel relatively around the circumference of the cylinders, with the result that the blades 18 sweep through the spaces 17 and 19 in a counter-clockwise direction, viewing Figure 2. This movement of the blades, when the device is functioning as a pump or compressor, will build up pressure in front of the blades and create suction behind the blades in the crescent-shaped work spaces. Work me-

dium, drawn into the work spaces behind the blades during one revolution or working stroke of the cylinder and pistons, will be compressed and forced out of the space in front of the blade during the succeeding revolution or stroke at the same time that a successive charge is entering the work space behind the blade.

I provide for introducing a fluid work medium into the work space of one cylinder or stage behind the blade of said cylinder so that the medium may be drawn into and forced through the work space and delivered, as aforesaid, in compressed condition into a succeeding cylinder in order therein to be further compressed in like manner. To this end, the compressed medium is discharged from the working space of the first cylinder in front of the advancing blade thereof and is delivered into the work space of a succeeding cylinder behind the blade of said cylinder and eventually is discharged from the high compression cylinder from in front of its blade.

The work medium may, of course, be introduced to the first or low pressure cylinder in any suitable manner. As shown in Figure 1, the work medium is introduced to the low pressure cylinder through a duct 81 formed in the casing 20 and communicating with an annular space 83 formed in the sleeve-like shaft support 39, thence through channels 85 and 87, formed in said shaft 41, and into a radial duct 89 formed in the end plate 23. The duct 89, in turn, connects with the work space 17 in front of its co-operating blade 18.

The inner end of the radial duct 89 opens, through a port 91, on the inner face of the end plate 23 approximately opposite the abutting inner end of the shaft 41. A suitable seal is provided for sealing the channel 87 of the shaft with the port 91. The seal preferably comprises a sleeve 93 fastened in the end of the shaft 41 and having a projecting end carrying a seal ring 95. The seal ring provides a pocket for a gasket 97 and the sleeve 93 carries a spring 99 encircling its projecting end, said spring bearing, at its opposite ends, against the end of the shaft 41 and against the gasket 97, whereby to compress the gasket within the pocket of the seal ring and to press the seal ring against the surface of the end plate, in which the port 91 is formed. The outer end of the radial duct 89 opens on the inner face of the end plate 23 opposite the ring 27, which is formed with a channel 101 extending through the ring between the opposite faces thereof. The channel is formed in position to communicate at one end with the outer end of the duct 89, the other end of the channel 101 being closed by the partition 31.

An inlet port 103 is formed in the ring 27 to communicate the channel 101 with the inner surface of said ring behind its associated blade 18.

Instead of introducing the work medium into the radial duct 89 through the channels 81, 83, 85, and 87, I may employ a modified arrangement, such as is shown in Figure 8, wherein the opening 91 is blocked and the work medium introduced through a channel 105, formed longitudinally in the shaft 35, such channel communicating at its inner end with the inner end of the radial duct 89. Any suitable expedient may be employed for connecting the outer end of such axially extending shaft channel with a source of the fluid work medium. It will be noted that the blades 18, shown in Figures 2 and 3 are relatively staggered, the blade of the stage 17 being located toward the right of the blade of the second stage 19 in said Figures 2 and 3. In the embodiment, as illustrated in Figures 6 and 7, the blades 18 of the several stages are in alignment.

The fluid work medium introduced into the compression space of the first stage through the opening 103 on one side of the blade 18 will, when the piston and cylinder means are rotated in a clockwise direction viewing Figures 2 and 6, be delivered under pressure on the opposite side of the blade 18 of said stage, whence it may escape directly through an opening 107 formed in the partition 31 into the second stage 19. The opening 107 communicates with the work space of said second stage 19 behind the blade 18 of said stage so that the compressed medium is delivered from the pressure side of the first stage directly into the suction side of the second stage. During the operation of the device, the compressed work medium thus introduced in the suction side of the second stage 19 will be forced through said stage in the manner heretofore described and delivered in still more highly compressed condition to the blade 18 of the second stage. It will be obvious that additional compression stages may be incorporated if desired and the work medium delivered in succession therethrough.

I have, however, illustrated a device containing two stages and the compressed medium is discharged from the pressure side of the second stage through an outlet 109 comprising a channel formed through the annular ring 29 defining said second stage so that the compressed work medium is delivered from the second stage into the housing formed by the casing 20 and its cover 21. The compressed gases are automatically discharged from the housing through an opening 111 formed in said housing.

I prefer also to provide a valve in the outlet channel 109 of the second stage in order to prevent compressed gases from returning through said opening from the casing 20 into the second stage. This valve may be of any suitable form or construction, but I prefer to utilize a flexible leaf element 113 preferably a metal such as steel. The leaf 113 is anchored at one end to the ring 29, which is preferably formed with a boss 115 for receiving an end of the leaf. The opposite end of the leaf overlies the outer end of the channel 109, which is preferably fitted with an insert 117, upon which the leaf may snugly fit. To limit the valve-opening movement of the leaf 113 from the seat provided by the insert 117, a guard element 119, forming a stop, is mounted on the boss 115, the guard and the leaf being secured on the boss in any suitable fashion as by means of the fastening screw 121. If desired, a check valve may be arranged in the opening 107 to prevent return of the compressed medium from the suction side of the second stage to the pressure side of the first stage and while, for maximum efficiency, a check valve is desirable, I have omitted illustration of the same in the devices shown in Figures 1 through 7, since the valve is not absolutely essential and satisfactory performance may be had without including the same. If a check valve is used in the opening 107, it may be necessary to increase the thickness of the partition 31. Any suitable type of valve may be employed.

The outer open end of the sleeve-like extension 43 is closed by a cover plate 123 having a central opening 125 through which the outer end of the shaft 35 extends. The cover 123 is secured in place on the extension 43 in any suitable fashion

as by means of the screws 127. The inner end of the sleeve-like extension 43 carries the shaft bearing 45.

Where the device of my present invention is embodied as a pump or compressor for use in forcing fluid media containing or comprising a suitable lubricant, it may not be necessary to provide for lubricating the apparatus other than by utilizing the working medium itself. I may, however, incorporate a lubricating system and, to this end, I have shown lubricant circulating means, namely a pump 129 drivingly connected with the axle or shaft 35, although, of course, a separately driven lubricant pump may be employed if desired. The pump 129 preferably comprises an annular stator or cylinder 131 held between end plates 133 and mounted within the extension 43. The stator and end plates are preferably held together and in place in the extension in any convenient manner as by the studs 135, which secure the pump assembly to and on one side of a partition 137 formed within the extension 43.

The partition 137 has an opening 139, through which the shaft 35 extends. This partition divides the space within the extension 43 into a compartment 141 extending between the cover plate 123 and the partition, and a second compartment containing the pump 129 and the shaft bearing 145.

The cylinder ring 131 and end plates 133 form a compression space in which a piston or rotor, forming a fluid-forcing element 143, is mounted for operation, said rotor being splined on the shaft 35 and having an outer surface relatively eccentric with respect to the inner surface of the ring 131. The piston 143 is thus driven by rotation of the shaft 35 within the cylinder 131. The rotor 143 is preferably formed with a substantially radial duct extending inwardly from the periphery of the rotor and communicating with a longitudinal duct 145 formed in the shaft 35 and serving to conduct the lubricant from the pump 129 to the operating parts of the device within the casing 20.

The rotor also carries a fluid-forcing vane 147 adjacent said radial duct, which vane is adapted to bear upon the inner surface of the cylinder ring 131 as the piston rotates with the shaft 35, so that lubricant is drawn from the chamber 141 through a duct 149, formed in the partition 137 and communicating the chamber 141 with the interior of the cylinder 131, and may be expelled from the pump under pressure through the radial duct and into the duct 145.

The lubricant pump is first assembled in the extension 43 and the bearing 45 is fitted to the shaft 35. The cylinder and piston means is then assembled in the casing 20 with the end plate 25 fitting upon the sleeve-like support 39. The cover member 21 is then applied to the shaft 35 and secured in place on the casing 20. If the cover holding studs are tightened, the sleeve or extension 43 is drawn onto the bearing 45, which, in turn, is forced along the shaft 59, the frictional resistance of the parts causing the shaft and cylinder to move toward the right, viewing Figure 1, until the bearings 41 and 45 assume assembled position. In this way, the cylinder means 13 and pistons become properly positioned within the casing merely as an incident to the application of the cover 21. Finally, the cover 123 may be secured in place.

The compartment 141 is adapted to receive a lubricant and forms a seal chamber. To this end, the facing surfaces of the cover 123 and the partition 137 are formed with embossments encircling the shaft 35 and adapted to receive sealing devices 151 comprising annular cup-shaped rings carrying annular gaskets 153 and adapted to seat upon the embossments of the cover and partition, and spring means for forcing the sealing devices 151 oppositely on the shaft and into sealing engagement with the embossments.

Lubricant is delivered into the chamber 141 from a suitable source of supply through a connection 155. From the chamber 141, the lubricant is drawn through the duct 149 by the pump 129 and delivered under pressure in the duct 145. The duct 145 communicates with a duct 157 formed in the end plate 23 and opening in a recess 159 formed on the inner surface of said end plate in position opening upon the aligned bores 61 of the pistons so that lubricant, delivered under pressure through the ducts 145 and 157 into the recess 159, may serve to lubricate the piston bearings 63 as well as the seal 95 when the same is utilized in the structure.

The pistons are provided with ducts 161 extending from the axle openings 61 to the internal chambers 65 at the pistons so that these chambers 65 may receive lubricant through the openings 161 whence the lubricant may reach the inner faces of the end plates and the faces of the partition 31 through the openings 67. A continuous flow of lubricant is provided past the operating parts, the lubricant escaping through a duct 163 formed in the sleeve-like support 39 and communicating at one end with the aligned openings 61 of the pistons, the other end of the duct 163 is connected with a conduit 165, through which the lubricant may be returned to the chamber 141 either directly or through an intermediate reservoir, with which the chamber 141 is connected by means of the conduit 155. The bearings 42 and 45 receive their lubrication by seepage and any lubricant which escapes from the operating parts will be gathered in a sump 167 formed in the lower part of the casing 20. The sump 167 is or may be connected to a conduit 169, through which the gathered lubricant may be returned to the lubricant circulating system.

In many cases, particularly where unusually high pressures are to be developed in the work medium, it is desirable to provide for abstracting the heat of compression generated in the work medium as the same is delivered from one stage to the succeeding stage. To accomplish this purpose, I may provide an inter-cooler as shown in the embodiment illustrated in Figures 8 through 14, wherein the piston support shaft is solid, the seal 95 eliminated and the work medium is delivered to the first stage 17 of the compressor through the duct 105 formed in the shaft 35 and the radial duct 89. The medium, compressed in the first stage, instead of being delivered directly into the suction side of the second stage as previously described, is discharged through a valved outlet 171 formed in the stage ring 27 and into a duct 173 formed in said ring. The duct 173 is closed at one end by the partition 31 but communicates at its other end with a radial duct 175 formed in the end plate 23, the inner end of the duct 175 communicates with a channel 177 formed in the shaft 35 and connected with a cooling coil 179. The work medium discharged from the first stage may thus be delivered through the ducts 173, 175, and 177 to the cooling coil, which forms an inter-cooler for remov-

ing the heat of compression from the work medium. After the medium has been cooled, it is conducted through a channel 181 formed longitudinally in the shaft 35 and communicating with a radial duct 183 formed in the end plate 23. The other end of the radial duct 183 connects with a duct 185 comprising aligned channels formed in the rings 27 and 29 and the partition 31. The duct 185 communicates through an opening 187 with the compression space of the second stage 19 behind the partition 18 of said stage so that after being cooled, the work medium compressed in the first stage may be delivered to the suction side of the second stage through the ducts 181, 183, and 185 and the second stage inlet opening 187. The medium, so introduced to the suction side of said second stage, will be compressed in said second stage in the manner heretofore described and delivered in compressed condition in the stage in front of the blade 18, whence the compressed medium will be discharged through the outlet opening 109 of said second stage.

The sleeve-like extension 43 of the cover 21 may be utilized to form transfer chambers for the fluid medium in entering the duct 105 leading to the suction side of the first stage 17 and also for the gas leaving the duct 177 and entering the duct 181 after passing through the inter-cooler coil 179. To this end, the partition 137 is imperforate save for the opening 139, through which the shaft extends, and the pump 129 is arranged with a radial inlet 194 comprising a duct formed in the pump ring 131 and communicating the inlet connection 155 directly with the interior of said pump ring so that the lubricant may be drawn from the reservoir directly to the pump and discharged thence through the radial duct of the piston directly into the longitudinal duct 145 and thence to the operating parts of the device as heretofore described.

The sleeve 43 is extended sufficiently to provide two compartments 189 between the cover 123 and the partition 137, said compartments 189 being separated within the sleeve 43 by means of a removable partition 191 secured in any suitable fashion, as by the fastening studs 193, upon a flange 195 formed within the sleeve 43. The partition 191 has an opening, through which the shaft 35 extends and the sealing means 151 is interposed between the partitions 137 and 191. The ducts 177 and 181 open each into a separate compartment 189 on opposite sides of the partition 191. The inter-cooler coil 179 comprises a pipe or conduit connected at one end in one of the chambers 189 and at the other end in the other of said chambers so that the heated medium delivered under pressure from the first stage through the channel 177 enters a compartment 189 and then passes through the inter-cooler coil 179 and enters the other compartment 189 escaping to the channel 181 to the suction side of the second stage. The coil 179 may be of any suitable heat-conducting material sufficiently strong to withstand the pressure imparted in the medium by the first stage of the compressor.

If desired, the coil 179 may be immersed in water or other refrigerating means in order to increase the cooling effect, or the same may be disposed in a stream of air. As shown in Figure 8, the coil 179 is arranged conveniently about the extension 43 and in the path of air currents circulated about the outer surfaces of the casing 21. Such air-circulation may be promoted by a fan (not shown) connected on the outside of the extension 43.

Any suitable expedient may be adopted for introducing the work medium into the duct 105 leading into the suction side of the first stage. I prefer, however, to accomplish this by forming the extension cover 123 with annular walls 195 extending outwardly of the end of the extension 43 and forming a compartment 197, a cover 199 having an opening 201, through which the shaft 35 may extend, being secured as by means of the fastening studs 203 upon the outer end of the walls 195. The duct 105 opens into the chamber 197 and receives the medium to be compressed from said chamber. The work medium is introduced into the chamber 197 through an inlet connection 205. I prefer also to seal the shaft in the places where it passes through the covers 123 and 199 and this may be accomplished by forming said covers with embossments and by providing seals 207 riding on said embossments, said seals preferably being similar to the seals 151 previously described.

As heretofore mentioned in connection with the embodiments shown in Figures 1 through 7, it may, in certain instances, be desirable to interpose a check valve between the stages in order to prevent the work medium, discharged under pressure from the pressure side of the first stage, from returning into said work space of said stage. Such a check valve is shown in the embodiment illustrated in Figures 8 through 14 and is preferably applied as close to the outlet 171 as is possible. As shown, the ring is formed with an opening 209 extending between the outer surface of the ring 27 and the channel 173. The outlet opening 171 may then be drilled in the ring 27 between the opening 173 and the inner surface of said ring, the drill being inserted through the larger opening 209. The opening 209 also permits an insert 211 to be assembled in the drilled outlet opening 171, the head of the insert extending in the channel 173 and forming a seat for a flap valve 213 comprising a strip of resilient material mounted at one end, as by means of the fastening screw 215, upon an embossment 217 formed within the opening 173. The free end of the valve element 213 overlies and seats upon the insert 211.

To facilitate assembly of the valve elements and more particularly to permit the fastening element 215 to be applied, the ring element 27 is formed with an opening 219 drilled therein opposite the embossment 217 between the outer surface of the ring and the duct. After the valve parts have been assembled as aforesaid, the openings 209 and 219 may be closed by means of plugs 221 and 223 respectively. The plug 221 is or may be formed with a projection 225 adapted to form a stop behind the free end of the valve element 213 in order to limit its valve opening movement away from the seat provided by the insert 211.

While the invention has been particularly described as embodied in a compressor, it is obvious that many features may be applied in multi-stage fluid motors as will be appreciated by those skilled in the art of hydrodynamics, to which my present invention has broad application.

It is thought that the invention and numerous of its attendant advantages will be understood from the foregoing description and it is obvious that numerous changes may be made in the form, construction, and arrangement of the several parts of the illustrated apparatus without de-

parting from the spirit or scope of my invention or sacrificing any of its attendant advantages, the preferred modes and forms herein described being merely for the purpose of illustrating the invention.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is as follows:

1. A device of the character described comprising cylinder means providing a plurality of pressure stages, piston means associated with each of said stages, blade means associated with the piston and cylinder means in the several stages, said cylinder means comprising an end wall having a projecting shaft whereby the cylinder means may be supported for rotation about its axis, duct means extending axially in said shaft, said end wall having a plurality of substantially radially extending ducts connecting with said duct means, at least one of said radially extending ducts being in communication with one of said pressure stages at one side of the blade means, and another of said radially extending ducts communicating with said stage on the opposite side of said blade means, said piston and cylinder means being operable to develop a pressure differential on opposite sides of the blade means in the several stages when the cylinder means is rotated.

2. A device of the character described comprising cylinder means providing a plurality of pressure stages, piston means associated with each of said stages, blade means associated with the piston and cylinder means in the several stages, said cylinder means comprising an end wall having a projecting shaft whereby the cylinder means may be supported for rotation about its axis, duct means extending axially in said shaft, said end wall having a plurality of substantially radially extending ducts connecting with said duct means, at least one of said radially extending ducts being in communication with one of said pressure stages at one side of the blade means, another of said radially extending ducts communicating with said stage on the opposite side of said blade means, and still another of said radially extending ducts communicating with another of said stages on one side of said blade means, said piston and cylinder means being operable to develop a pressure differential on opposite sides of the blade means in the several stages when the cylinder means is rotated.

3. A device of the character described comprising cylinder means providing a plurality of pressure stages, piston means associated with each of said stages, blade means associated with the piston and cylinder means in the several stages, said cylinder means comprising an end wall having a projecting shaft whereby the cylinder means may be supported for rotation about its axis, duct means extending axially in said shaft, said end wall having a plurality of substantially radially extending ducts connecting with said duct means, said radially extending ducts communicating, at the periphery of said end wall, with longitudinally extending ducts formed in cylindrical wall portions of said cylinder means, at least a pair of said longitudinally extending ducts opening upon one of said pressure stages on opposite sides of the blade means, said piston and cylinder means being operable to develop a pressure differential on opposite sides of the blade means in the several stages when the cylinder means is rotated.

WILLIAM W. WISHART.