June 16, 1942. R. M. WATSON 2,286,522

CENTRIFUGAL COMPRESSOR

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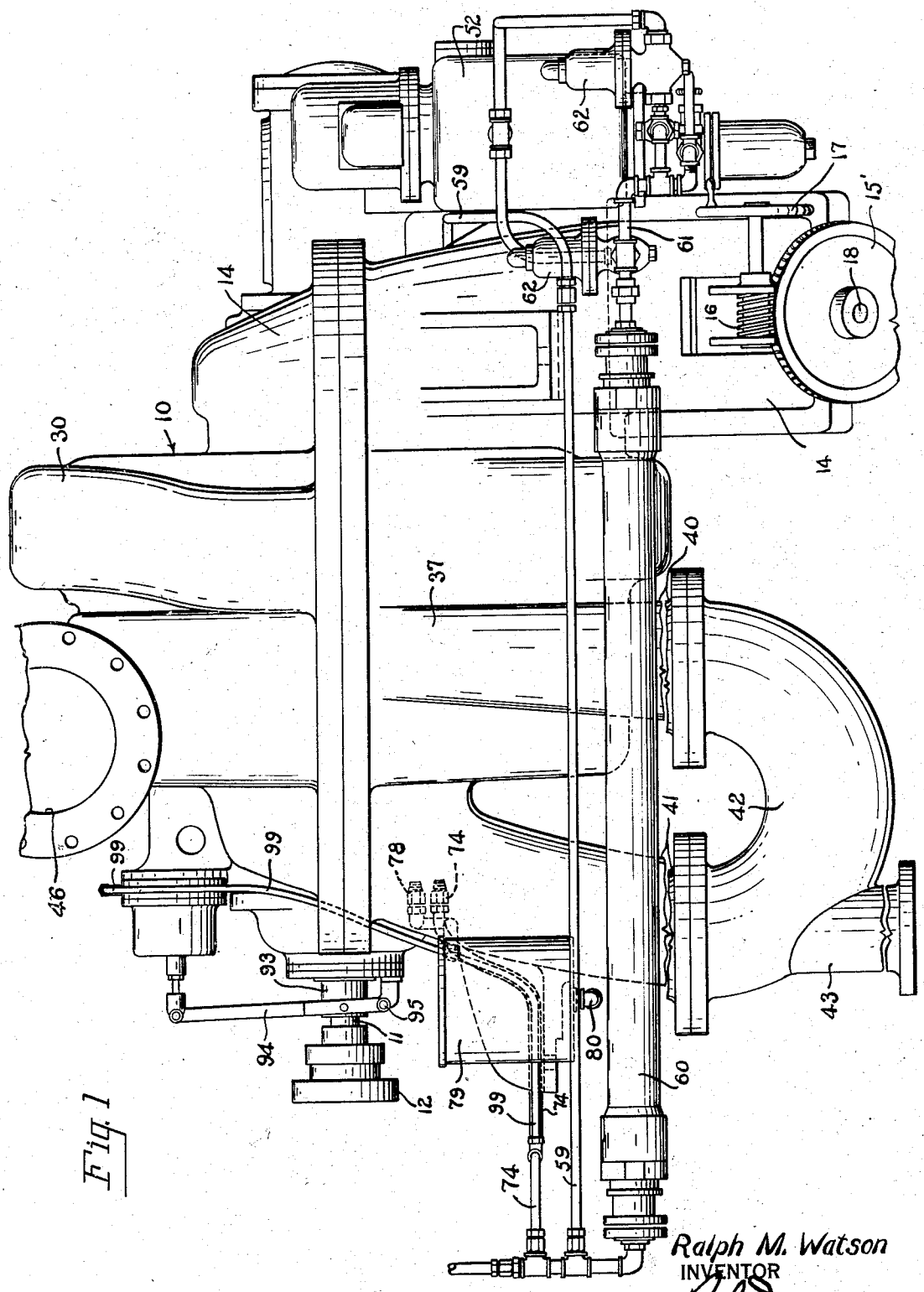


Fig. 1

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INVENTOR

BY Robe Thayer

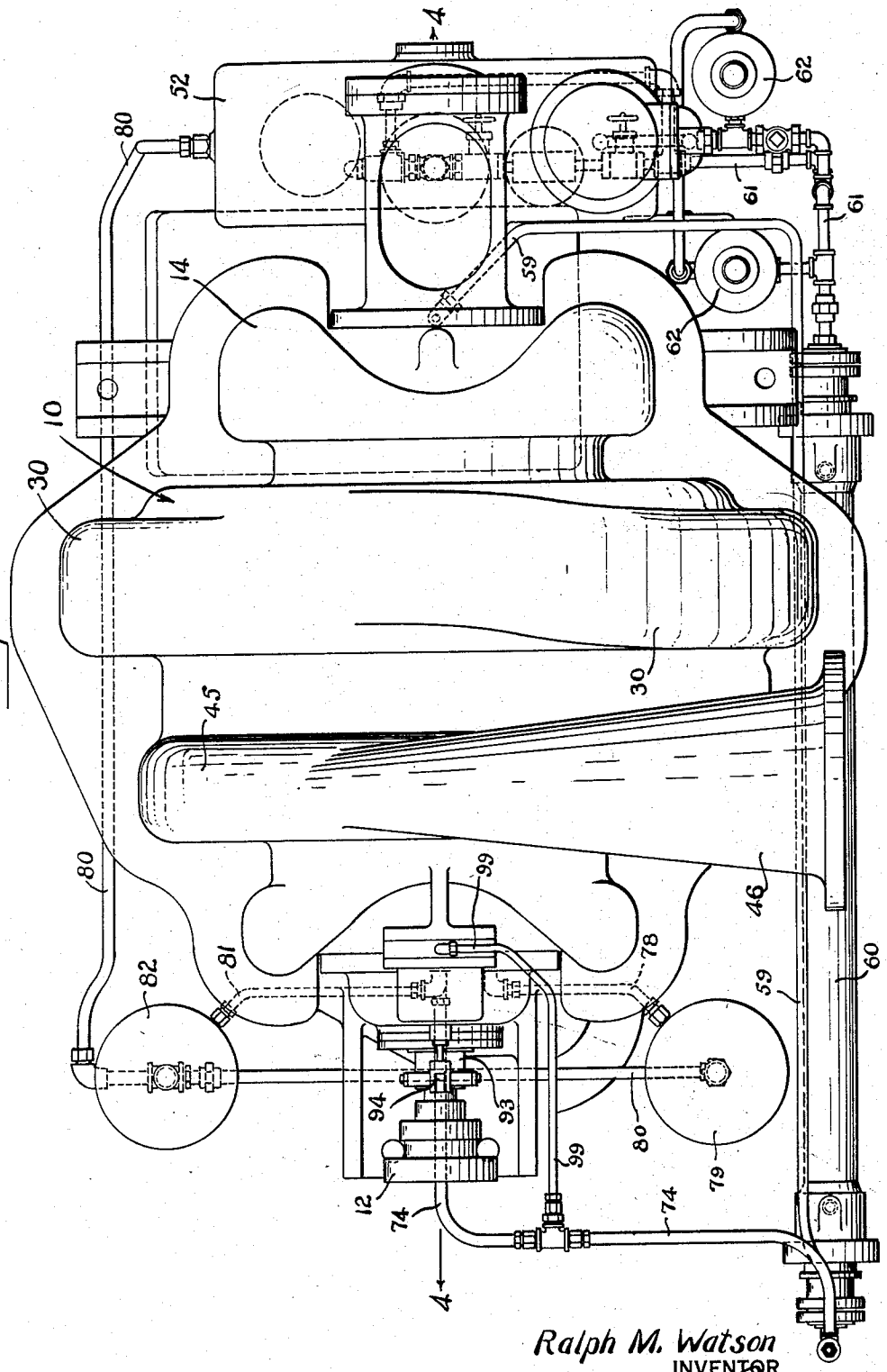
ATTORNEY

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CENTRIFUGAL COMPRESSOR

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Fig. 2



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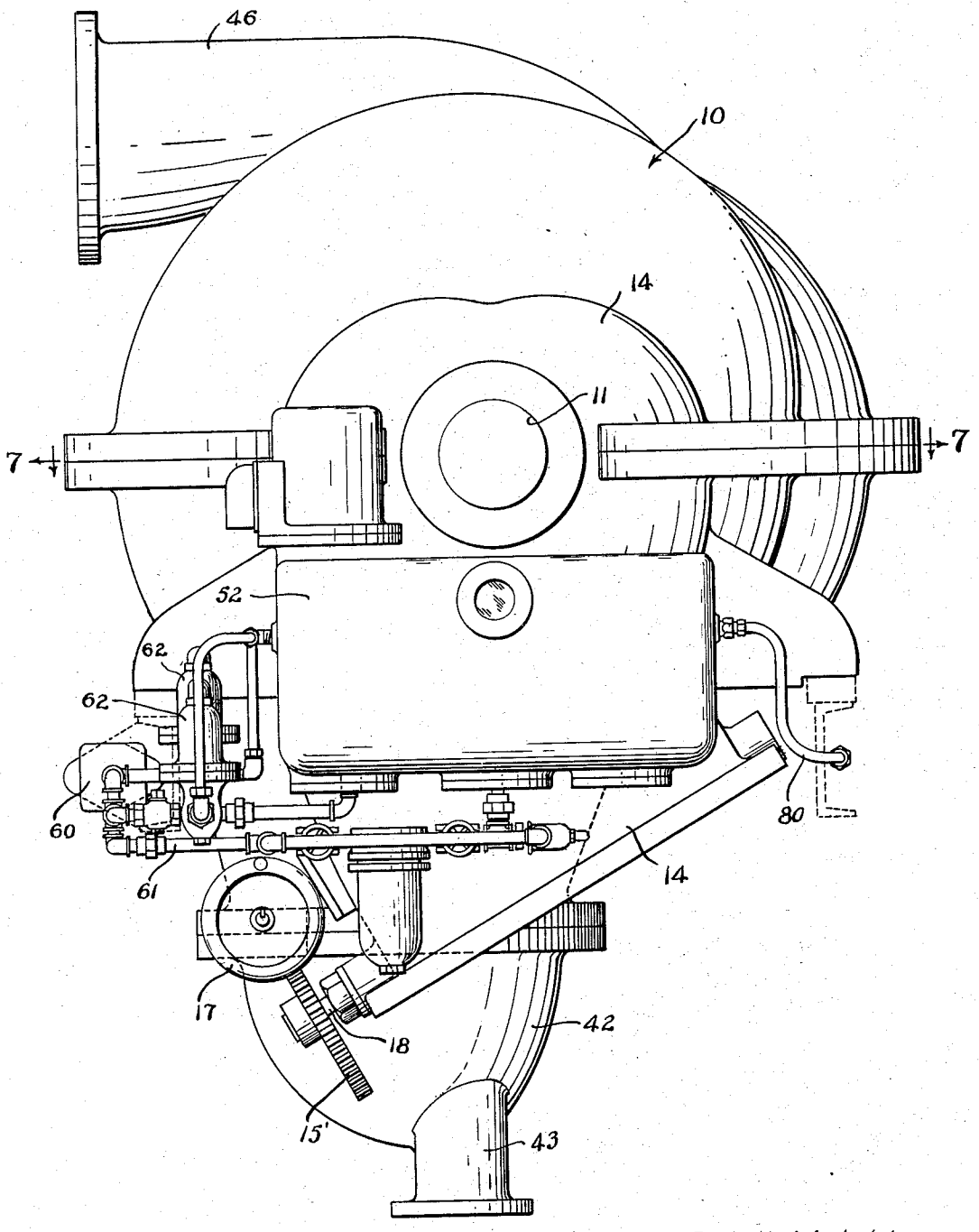
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CENTRIFUGAL COMPRESSOR

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Fig. 3



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CENTRIFUGAL COMPRESSOR

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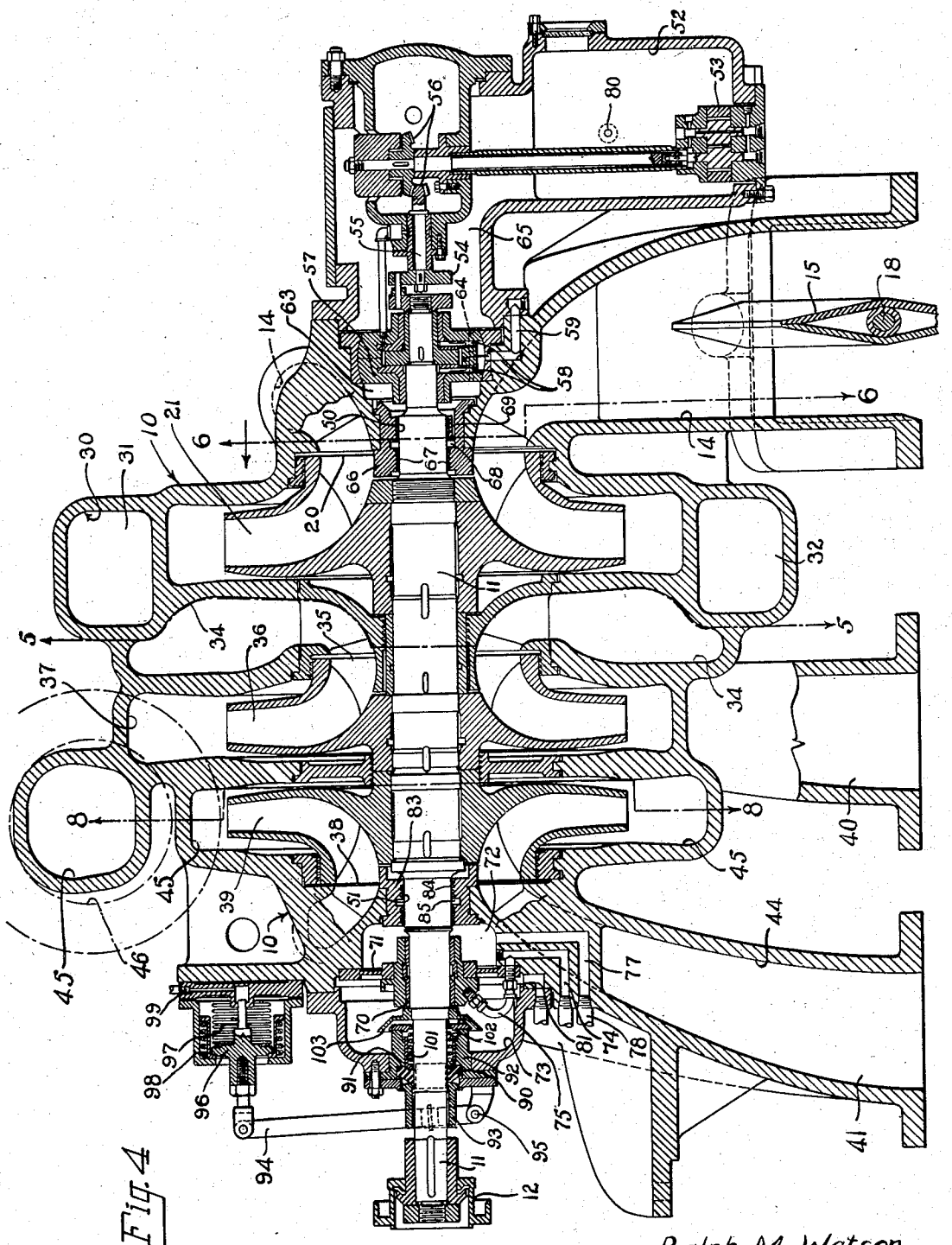


Fig. 4

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CENTRIFUGAL COMPRESSOR

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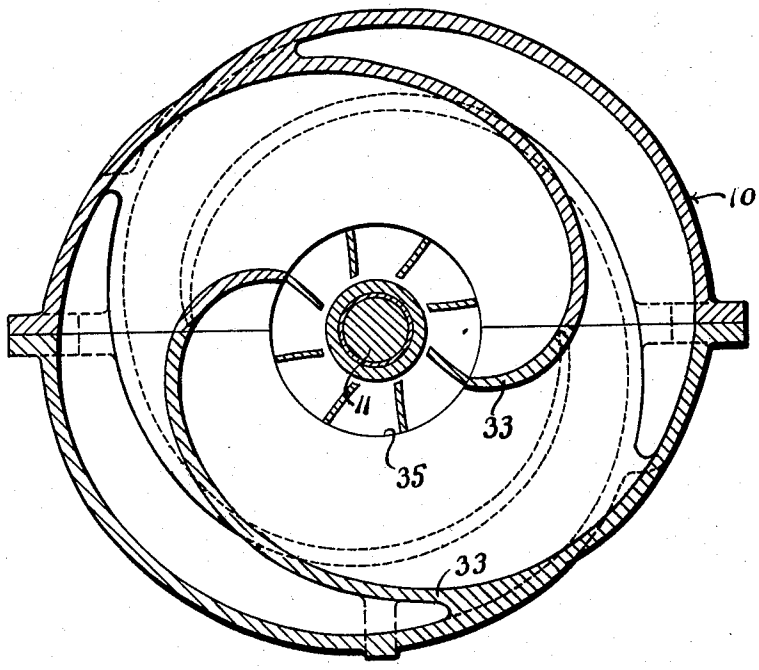


Fig. 5

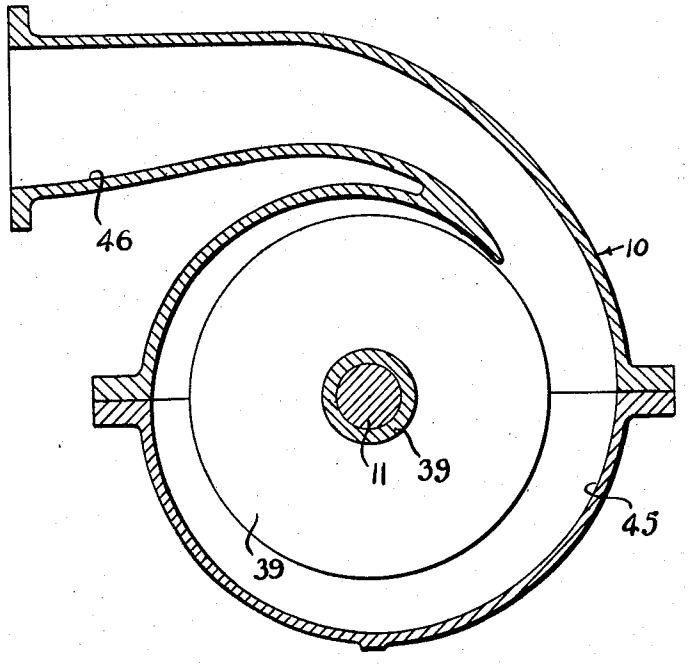


Fig. 8

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Fig. 6

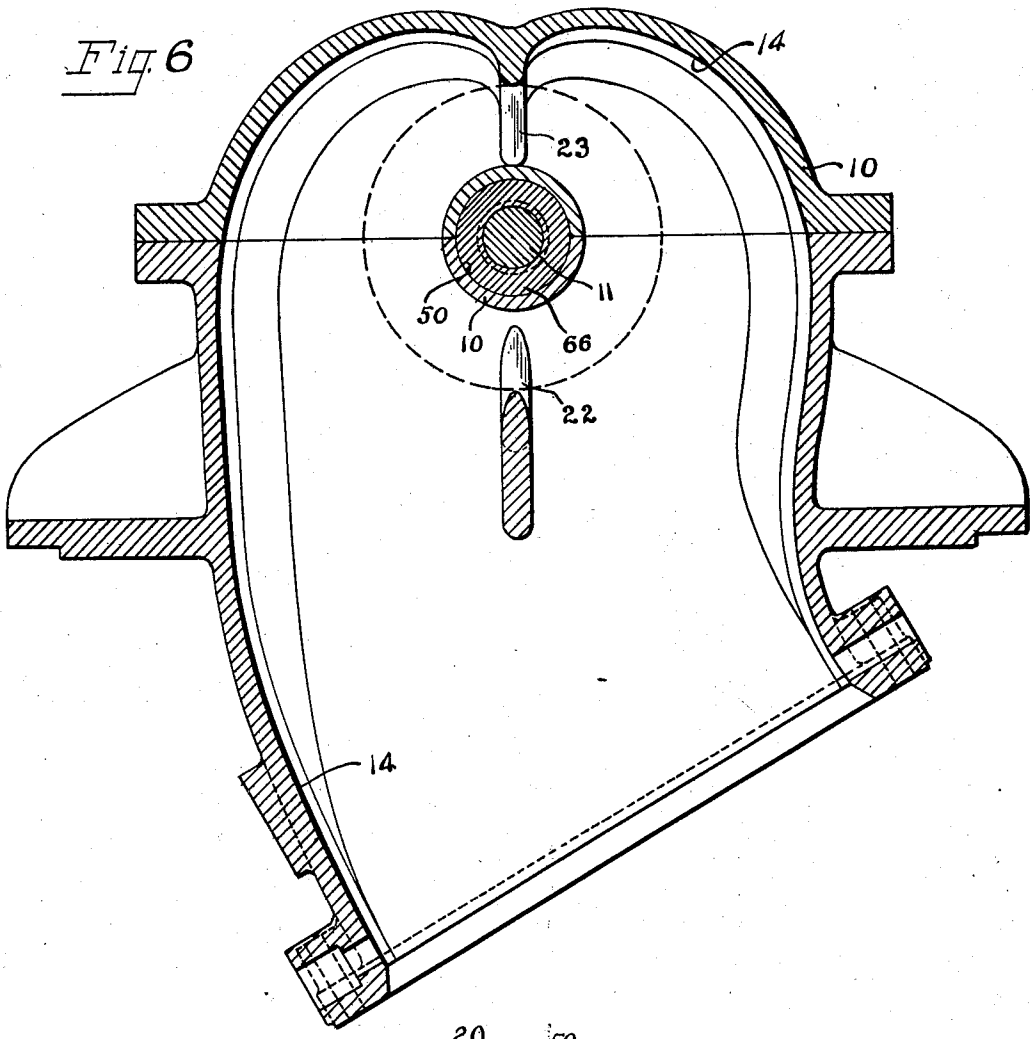
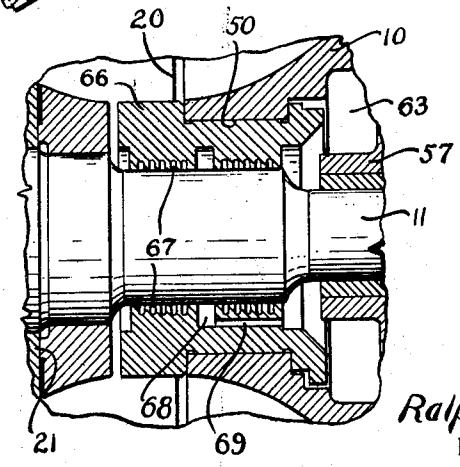


Fig. 9



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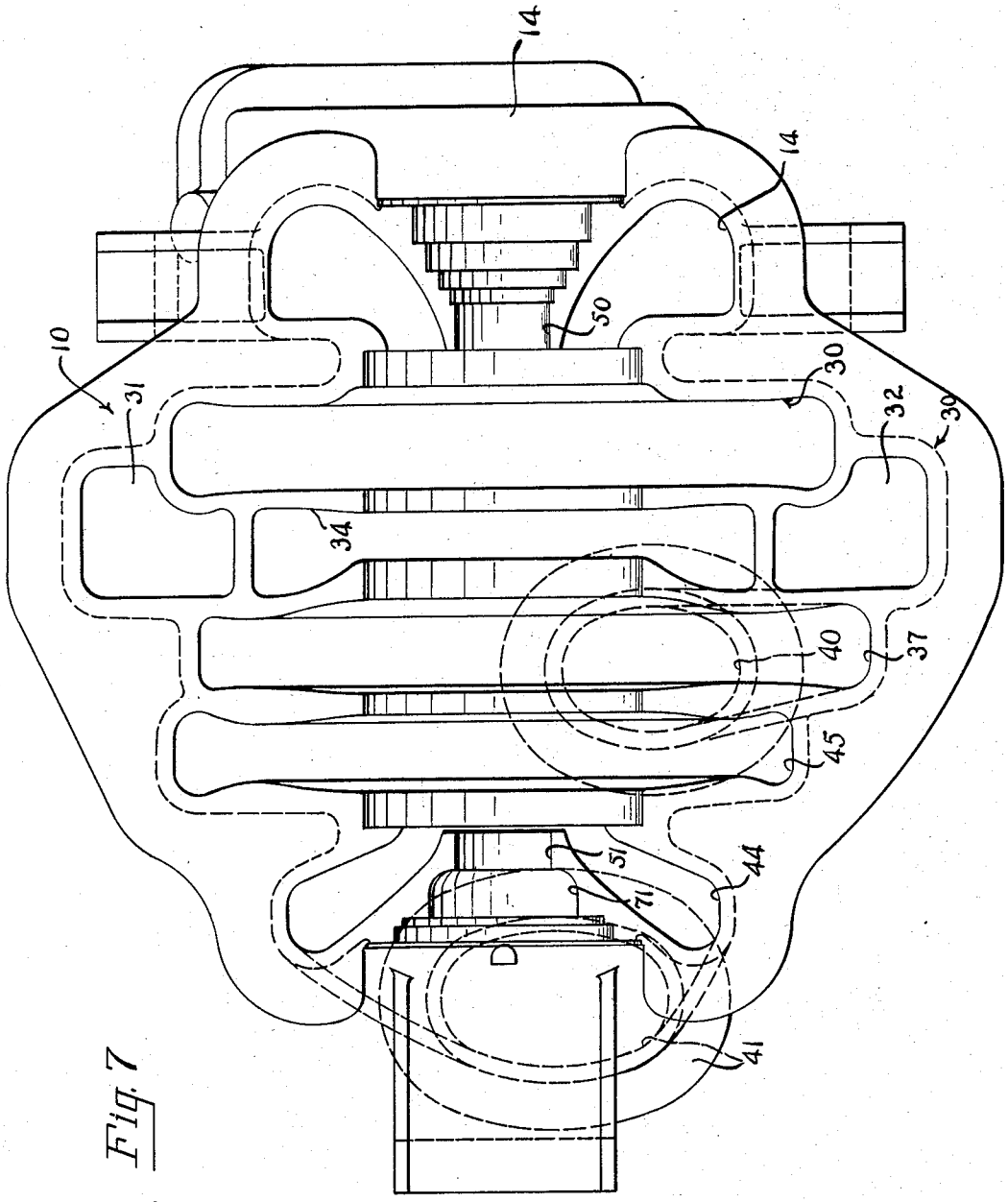


Fig. 7

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Patented June 16, 1942 2,286,522

UNITED STATES PATENT OFFICE

2,286,522

CENTRIFUGAL COMPRESSOR

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Application April 13, 1940, Serial No. 329,498

9 Claims. (Cl. 230—130)

This invention relates to centrifugal gas or vapor compressors, and more particularly to a centrifugal compressor for use in refrigerating systems for handling a volatile liquid of low vapor pressure and high density, such for example as trichlorofluoromethane, methylene chloride or the like. In compressors of this type commonly in use, complicated and expensive mechanisms or structures are necessary due to the design of the compressors employed, for balancing the end thrust in the compressor and sealing the openings in the casing through which the driving shaft extends against the compressor pressures to prevent leakage of the refrigerant vapors to the atmosphere and leakage of air into the compressor.

An object of the present invention is to provide a centrifugal compressor in which volutes are employed, in connection with impellers arranged in a novel manner to provide a highly efficient, compact compressor in which any end thrust is substantially eliminated by balancing of the impellers in such manner that certain of them provide a counter-balancing end-wise thrust against the end-wise thrust of the other impellers, thereby eliminating expensive and complicated thrust balancing means.

Another object of the invention is to provide a centrifugal compressor in which the impellers are arranged whereby the seals or packing at the openings in the casing through which the shaft extends are subjected to pressures below the discharge pressure of the compressor and whereby the differential across the seals is relatively small, thereby simplifying the problem of sealing such openings against leakage.

A further object of the present invention is to provide in a centrifugal compressor means for delivering lubricating oil to the bearings of the compressor at a pressure slightly in excess of the pressure in the compressor at either end of the bearings at the shaft openings to prevent leakage of vapor or gas through the shaft bearings and to provide a lubricating system embodying a plurality of chambers under various degrees of pressure in the return line of the lubricant from the bearings to the circulating oil pump so as to separate the entrained refrigerant from the oil.

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

In the drawings:

Figure 1 is a side elevation of the improved centrifugal compressor.

Figure 2 is a top plan view of the compressor.

Figure 3 is an end view of the compressor looking toward the suction or inlet end.

Figure 4 is a longitudinal section through the compressor taken on the line 4—4 of Figure 2.

Figure 5 is a cross-section of the compressor taken on line 5—5 of Figure 4.

Figure 6 is a vertical cross-section through the suction inlet of the compressor taken approximately on the line 6—6 of Figure 4.

Figure 7 is a horizontal longitudinal section through the compressor casing alone, showing the volutes and passages, taken on the line 7—7 of Figure 3.

Figure 8 is a vertical cross-section through the final discharge volute of the compressor taken approximately on the line 8—8 of Figure 4.

Figure 9 is an enlarged view, in section, of a portion of the compressor showing the casing bushing.

The centrifugal compressor of the present invention utilizes the principle of impeller and discharge volute in lieu of the general practice of employing diffusion vanes in the discharge passage of the compressor with the result that the efficiency of the compressor is materially increased and frictional losses diminished. The compressor comprises a horizontally split casing 10, through the axis of which extends the driving shaft 11. The driving end of the shaft 11 may be connected by any approved type of coupling 12 with any approved type of prime mover. The shaft 11 carries the various impellers of the centrifugal compressor, the number of which and consequently the number of stages of the compressor depends entirely upon the conditions of the installation in which the compressor is to be incorporated and the work to be performed by the compressor.

In the present application a three stage compressor is illustrated, but it is to be understood that the principles of the invention as set out in the claims are equally applicable to centrifugal compressors, regardless of the number of stages or impellers.

Referring specifically to the drawings, the casing 10 has a suction or inlet connection 14 at one end thereof, through which the vapors to be compressed enter the compressor. The inlet

passage 14 has a butterfly valve or damper 15 therein, by means of which the active, vapor passing cross-sectional area of the passage 14 may be regulated. This butterfly valve 15 may be operated by any suitable mechanism. A hand wheel operated gear and pinion structure is shown in Figures 1 and 3 of the drawings, in which the gear 15' is rotated by the pinion 16. The pinion 16 is in turn rotated by a hand wheel 17. The gear 15' is mounted upon or suitably connected to the carrying shaft 18 of the valve 15. The inlet passage 14 curves upwardly and laterally into the suction or inlet eye 20 of the first or suction stage impeller 21.

The inlet passage 14 is partially bifurcated by means of dividing vapor-directing ribs 22 and 23, the latter of which is substantially an inwardly extending projection of the uppermost portion of the side wall of the inlet passage where the two side sections or portions meet, as clearly shown in Figure 6 of the drawings. This particular construction of the suction inlet passage facilitates the distribution of the refrigerant vapors in the suction or inlet eye of the first stage impeller 21 and suppresses the creation of eddies and vacuous pockets in the inlet passage. By particular reference to Figures 4 and 6 of the drawings it will be noted that the inlet passage 14 curves in a smooth curvature in all directions towards the inlet eye 20.

The first stage impeller 21 of the compressor discharges into a double or twin volute 30 formed of the two volute passages 31 and 32, clearly shown in Figures 4 and 5 of the drawings. The defining walls 33 of the double volute passages curve circumferentially and laterally into the suction passage 34, which opens into the inlet or suction eye 35 of the second stage impeller 36.

The provision of the double or twin volute 30 decreases the machine dimensions and balances any radial thrust which would arise in the first stage of the compressor due to operation at conditions other than those for which the specific compressor was designed. This provision of the twin or double volute, together with the staggered arrangement of the volutes of the remaining stages of the compressor, will approximately take care of or balance any radial thrust which may occur in the entire compressor during "off standard" operating conditions.

The second stage impeller 36 discharges into a single volute 37, which is connected by a suitable passage to the suction eye 38 of the third stage impeller 39. The passage which connects the discharge volute 37 of the second stage impeller 36 to the third stage impeller 39 is shown in the drawings as comprising the nozzles 40 and 41, which are formed on the casing 10 of the compressor and are connected by a U-coupling 42. The U-coupling 42 has a connection 43 formed thereon which opens into the passage 44, which establishes communication between the second and third stage impellers so as to permit the introduction of vapors into an intermediate stage of the compressor. While the coupling 43 is shown arranged to permit the introduction of vapor into the third stage of the compressor, it is to be understood that such a connection may be connected at any suitable point to the casing of the compressor to permit the introduction of vapor into any one of the stages of the compressor following the first stage. The third stage impeller 39, which in the construction shown in the drawings is the final stage, discharges through its volute 45 into a discharge nozzle 45.

By utilizing volutes at the discharge of the various stages in lieu of diffuser vane structures, and by the various construction of cross-over connecting passages between the stages, a compact, relatively inexpensive centrifugal compressor may be provided in which the various impeller stages may be arranged to effect an approximate balance in the compressor, thereby eliminating the need of employing expensive and relatively complicated end thrust balancing mechanism.

In the drawings, wherein a three stage compressor is shown, it will be noted that the first two stages, that is the impellers 21 and 36, are disposed in a parallel pair, with the back of the first stage impeller 21 facing the suction of the second stage impeller 36. Thus the combined end thrust of these two stages will be toward the right (Fig. 4), while the impeller 39 of the third stage of the compressor is disposed in a direction opposite to that of the impellers 21 and 36, with its back facing the back of the second stage impeller 36. Consequently the end thrust of the third stage impeller 39 will be toward the left (Fig. 4) and in an opposite direction to the end thrust of the impellers 21 and 36. Since impeller 39 is the highest pressure impeller and the end thrust produced by this impeller will be substantially equal to the end thrust produced by impellers 21 and 36, counterbalancing end thrusts are set up in opposite directions in the compressor which will approximately balance each other and permit the use of a simple, inexpensive thrust balancing bearing as shown at 57 in Figure 4 of the drawings.

In the present construction of centrifugal machine or compressor for compressing gas or vapor the pressure of fluid compressed increases in geometric progression from stage to stage with the absolute discharge pressure of each stage bearing a substantially constant ratio to its inlet pressure, and by reference to Figure 4 of the drawings it will be noted that the successive stages of compression in the compressor decrease in volumetric capacity. That is, the second stage impeller 36, while being of substantially the same diameter as the first stage impeller 21, is narrower and consequently has less volumetric capacity than the first stage impeller, while the third stage impeller 39, which is also of substantially the same diameter as the impeller 21 and 36, is narrower than the impeller 36 and consequently has less volumetric capacity.

While the drawings show a three stage compressor with the impellers arranged as above specifically described, it is to be understood that the essence of this balancnig feature of the present invention comprises the arranging of the impellers in a multi-stage compressor in such a manner that the stages are divided, each set disposed in the opposite direction to the other set, creating end thrust substantially equal to the end thrust created by the impellers of the other set, for the purpose of counterbalancing end thrust in the compressor.

Centrifugal compressors of the type above described and illustrated in the drawings, when used or employed in refrigeration or air conditioning systems generally receive the vapor or refrigerant gases into the first stage suction at a pressure of approximately seven pounds (7 lbs.) below atmosphere. The third or final stage of the compressor receives the vapor into its suction at a pressure slightly above or below atmosphere, for instance atmosphere plus or minus three

pounds (3 lbs.). Thus it will be seen that the opposite ends of the interior of the casing 10 will be subjected to subatmospheric pressure at the initial inlet end of the casing and to approximately atmospheric pressure at the other end of the casing, that is, the end adjacent to the driving end of the shaft 11. It is desirable, of course, to prevent leakage of air into the compressor casing, and also to prevent the leakage of valuable refrigerant vapors from the compressor casing into atmosphere. Therefore the present construction embodies means for effectively sealing the openings in the ends of the casing through which the shaft 11 extends.

In the present invention sealing of these openings is effected during the operation of the compressor through a combination of close fitting bearings for the shaft and the lubricating system for such bearings, while a special mechanism is provided for sealing the casing when the compressor is idle.

Due to the arrangement of the impellers in the compressor as above specifically described, not only is end thrust in the compressor approximately counterbalanced, but the arrangement also provides that the shaft opening 50 at the initial suction end of the compressor is subjected to the pressure of the vapor at the initial inlet, while the shaft opening 51 at the opposite end of the casing is subjected to the suction pressure of the vapor at the third stage suction. Therefore neither of these openings will be subjected to the highest pressure developed in the compressor, which fact materially simplifies and reduces the cost of the mechanism for sealing such openings in that, for one thing, it reduces the pressure of the lubricating oil.

An oil reservoir 52 is provided in which an oil pump 53, of any approved construction, is mounted. The oil pump 53 is driven from the shaft 11 through a coupling structure 54, shaft 55 and suitable transmission 56, which in the present instance is shown as beveled gears.

At the initial suction end of the compressor a bearing structure 57 is provided which is carried by the casing 10 and which has suitable oil ducts 58 extending radially therethrough to lubricate the bearing. Oil is supplied to the ducts 58 from an oil inlet line 59 which receives the oil from the discharge end of an oil cooler 60. The oil is pumped by the pump 53 through a suitable piping system 61 into and through the cooler 60. Pressure regulating valves 62 of any approved type or construction may be connected in the pipe line 61 for the purpose of regulating the pressure of the oil if it is desired. The oil passes through the bearing 57 in both directions and that which passes through the bearing inwardly toward the compressor passes into a chamber 63 and returns through a drain opening or drain openings 64 through the bearing into the chamber 65. The oil which passes through the bearing outwardly or away from the casing 10 passes into the chamber 65 and from this chamber drains into the reservoir 52. The chamber 65 is under a subatmospheric pressure. That is, it is under the pressure of the vapor as it enters the initial inlet of the compressor. A stationary bushing 66 is mounted about the shaft 11 between the bearing 57 and the impeller 21. This bushing has its inner surface provided with a plurality of longitudinally spaced circumferential grooves, as shown at 67, and it prevents creeping of oil along the shaft into the compressor. The bushing 66 has an oil collection chamber 68 formed therein with which a drain opening 69 communicates. The drain opening leads back to the chamber 63 so that any oil which would pass through the bushing 66 into the chamber 68 would be drained back eventually into the reservoir 52.

At the opposite end of the casing 10 from the bearing 57 a second bearing 70 for the shaft 11 is provided. While the particular construction of the bearing and its companion parts which form the seal for the casing 10 are the subject matter of Patent No. 2,254,862 issued September 2, 1941, the structure will be specifically described herein to establish its action and cooperation in the general combination of the compressor.

The bearing 70 is a tight-fitting bearing and since the machines of this type the shaft frequently gets slightly out of alignment due to various causes such as whip in the shaft when rotating at high speeds, means are provided to maintain proper tight-fitting engagement between shaft and bearing at all times so as to provide an effective seal for the shaft opening in the casing. The bearing 70 is connected to the casing 10 by a flexible disc 71. This disc 71 is made of strong, flexible metal so that it will flex during operation of the compressor to permit movement of the bearing 70 with movement of the shaft 11 other than rotary movement so as to maintain at all times the tight fit between the bearing and shaft to preserve the seal and to prevent excess wear on the bearing. The shaft opening 51 opens into a chamber 72, into which the inner end of the bearing 70 also extends, while the outer end of the bearing extends into a chamber 73. The chamber 72 is subjected to a pressure of approximately atmosphere, that is, a pressure slightly above or below atmosphere, namely the suction pressure of the vapor at the inlet of the impeller 39, while the chamber 73 is subjected to atmospheric pressure. Oil is delivered to the interior of the bearing 70 intermediate its ends from the oil inlet line 74 through a suitable connection 75. The inlet line 74 receives oil from the outlet end of the oil cooler 60. The oil passes longitudinally through the bearing in both directions, part of it passing into the chamber 72 from which it drains through suitable drain outlets 77 and pipe connections 78 to a collection chamber 79. From that chamber 79 the oil returns to the reservoir 52 through the pipe system 80. The oil which flows outwardly through the bearing into the chamber 73 passes through suitable drain openings 81 into the collection chamber 82, from which it passes through the collection piping system 80 back to the reservoir 52.

The interior of the oil chamber 52 is under the same pressure as the shaft opening 50, viz., the pressure of the vapor at the initial inlet to the compressor. By having it under such relatively low pressure refrigerant which is carried thereto by the oil and is consequently delivered to the chamber at a pressure in excess of the pressure therein is released.

A bushing 83 is positioned between the chamber 72 and the impeller 39, similar in its construction to the bushing 66, having a plurality of annular grooves 84 spaced longitudinally along its bore, and is provided with an oil collection chamber 85 from which oil drains through a suitable drain 86 into the chamber 72. The bushing 83 forms a dam to hinder leakage of oil into the suction of the impeller 39.

The construction of the bearing 70 and the lubrication of the bearing in the manner above

described will effectively seal the opening 51 from both leakage of vapor out of the casing and leakage of air into the casing, during the operation of the compressor. But when the compressor is shut down the delivery of lubricating oil to the bearing will be stopped and consequently it is necessary to provide means to prevent either internal leakage of air or external leakage of vapor out of the casing through the opening 51 at such times.

The structure provided for this purpose includes a packing collar 90, which is of any suitable type of soft, resilient material not susceptible to objectionable corrosion or deterioration under action of the refrigerant vapor compressed. There are many substances of which this collar may be constructed, such as "Neoprene" and the like. This soft resilient packing collar 90 snugly fits about the shaft 11 and its inner side near its periphery contacts an annular shoulder 91 formed on a suitable collar 92. The outer side of the soft resilient packing collar 90, near its inner periphery, is engaged by a co-acting face forced on the inner end of a sliding sleeve 93, which slides upon the shaft 11. A lever 94 is pivotally supported at 95 and is connected to the sleeve 93 and to a pressure actuated piston 96, which is shown as connected to a bellows 97. The piston 96 is urged inwardly, compressing the bellows 97, by a spring 98. During the operation of the compressor the tension of the spring 98 is overcome by the pressure of oil from the lubricating system of the compressor, which is delivered to the interior of the bellows 97 through the connection 99, thus expanding the bellows and forcing the piston 96 outwardly, which moves the sleeve 93 outwardly, relieving the soft, resilient packing collar 90 of pressure from the sleeve 93. When the compressor is stopped and consequently the pressure of oil in the bellows 97 is relieved, the spring 98 will move the piston 96 inwardly and through the medium of the lever 94 force the sleeve 93 inwardly against the collar 90, tightly squeezing the collar against the shaft to form a tight seal about the shaft. For the purpose of insuring the movement of the packing collar 90 into a pressure relieved position during the operation of the compressor, a follower 101 is mounted about the shaft 11 and engages the inner side of the collar 90 inwardly of the shoulder 91. A spring 102 engages the follower 101 for urging it outwardly thus moving the collar 90 out of tight sealing engagement with the shaft when the collar is relieved of pressure of the sleeve 93.

A dish-shaped slinger 103 is mounted on the shaft 11 for rotation therewith, between the collar 90 and the bearing 70, and in the chamber 73. This dish-shaped slinger 103 is provided for throwing oil away from the shaft 11 so as to prevent oil from leaking along the shaft to the collar 90.

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

What is claimed is:

1. In a multi-stage centrifugal machine for compressing gas or vapor, a casing, three stage impellers in said casing, the first and second stage impellers arranged in a set with their discharge sides facing the discharge side of the third stage impeller and having combined discharge pressures approximately equal to the discharge pressure of the third stage.

2. In a multi-stage centrifugal machine for compressing gas or vapor, a casing, three stage impellers in said casing, the first and second stage impellers arranged in a set with their discharge sides facing the discharge side of the third stage impeller and having combined discharge pressures slightly greater than the discharge pressure of the third stage impeller to substantially balance end thrust by leaving a small unbalance of end thrust to avoid reversal of thrust during operation.

3. In a multi-stage centrifugal machine for compressing gas or vapor, a casing, three stage impellers in said casing, the first and second stage impellers arranged in a set with their discharge sides facing the discharge side of the third stage impeller and having combined discharge pressures approximately equal to the discharge pressure of the third stage, said first stage impeller having a twin volute casing with the two throat sections thereof disposed approximately 180° apart, the second and third stage impellers each having a single volute casing, said single volute casings being angularly disposed with their throat sections arranged relative to each other so that the side thrusts of one volute are counterbalanced by the side thrusts of the other volute.

4. In a multi-stage centrifugal machine for compressing gas or vapor, a casing, three stage impellers in said casing, the first and second stage impellers arranged in a set with their discharge sides facing the discharge side of the third stage impeller and having combined discharge pressures approximately equal to the discharge pressure of the third stage, said first stage impeller having a twin volute casing with the two throat sections thereof disposed approximately 180° apart, the second and third stage impellers each having a single volute casing, said single volute casings being angularly disposed with their throat sections arranged relative to each other so that the side thrusts of one volute are counterbalanced by the side thrusts of the other volute, said second and third stage impellers being disposed back-to-back and in close relation to each other whereby the side thrusts of the two volutes are approximately in the same plane.

5. In a multi-stage centrifugal machine for compressing gas or vapor wherein the pressure of material compressed increases in geometric progression from stage to stage with the absolute discharge pressure of each stage bearing a substantially constant ratio to its inlet pressure, a casing, a plurality of impellers of substantially equal diameter in said casing, said impellers arranged in sets of unequal numbers of impellers with the impellers in each set constituting successive stages of compression and with the impellers in one set disposed in back to back relation with the impellers in the other set to approximately equalize the end thrust of the impellers.

6. In a multi-stage centrifugal machine for compressing gas or vapor wherein the pressure of material compressed increases in geometric progression from stage to stage with the absolute discharge pressure of each stage bearing a substantially constant ratio to its inlet pressure, a casing, a plurality of impellers of substantially equal diameter in said casing, said impellers arranged in sets of unequal numbers of impellers with the impellers in each set constituting successive stages of compression and with the im-

pellers in one set disposed in back to back relation with the impellers of the other set and with the total absolute discharge pressure of one set being slightly greater than the total absolute discharge pressure of the other set to substantially balance end thrust but leaving a small unbalance of end thrust to avoid reversal of thrust during operation.

7. In a multi-stage centrifugal machine for compressing gas or vapor, a casing, three stage impellers in said casing, the first and second stage impellers arranged in a set with their discharge sides facing the discharge side of the third stage impeller and having combined discharge pressure approximately equal to the discharge pressure of the third stage, the discharge stage and one other of the stages of the compressor being provided with single discharge volutes arranged relative to each other to balance side thrusts of the said stages, the remaining stage of said compressor being provided with a twin discharge volute with the two throat sections thereof disposed relative to each other to balance the side thrust of said stage of the compressor.

8. In a multi-stage centrifugal machine for compressing gas or vapor wherein the pressure of fluid compressed increases in geometric progression from stage to stage with the absolute discharge pressure of each stage bearing a substantially constant ratio to its inlet pressure, a casing, a plurality of stage impellers in said casing, said impellers having progressively decreased volumetric capacity from the inlet stage to the final discharge stage, said impellers arranged in sets of unequal numbers of impellers with the impellers in each set constituting successive stages of compression, the impellers of one set having combined discharge pressures approximately equal to the combined discharge pressures of the other set and arranged to substantially balance end thrust during operation of the compressor.

9. In a multi-stage centrifugal machine for compressing gas or vapor wherein the pressure of fluid compressed increases in geometric progression from stage to stage with the absolute discharge pressure of each stage bearing a substantially constant ratio to its inlet pressure, a casing, a plurality of stage impellers in said casing, said impellers having progressively decreased volumetric capacity from the inlet stage to the final discharge stage, said impellers arranged in sets of unequal numbers of impellers with the impellers in each set constituting successive stages of compression, the impellers of one set having combined discharge pressures approximately equal to the combined discharge pressures of the other set and arranged to substantially balance end thrust during operation of the compressor, one of said stages of the larger volumetric capacity having a twin discharge volute, and the remaining stages being provided with single discharge volutes arranged relative to each other to balance side thrusts of the stages.

RALPH M. WATSON.