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[54] **VACUUM PUMP WITH LUBRICANT METERING GROOVE**

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[21] Appl. No.: **423,130**

Related U.S. Application Data

[63] Continuation of Ser. No. 47,239, June 18, 1970, abandoned.

[52] **U.S. Cl.** **418/76,** 418/79, 418/91, 418/96, 418/97

[51] **Int. Cl.** ... **F01c 21/04,** F04c 27/02, F04c 29/02

[58] **Field of Search** 418/76, 79, 82, 87, 91, 418/92, 94, 96–99

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[57] **ABSTRACT**

A vacuum pump having an improved lubricating and sealing system providing for metered oil flow from an end plate to the center plate with a return provided along the shaft supporting the pump rotor. A novel inlet plate is provided to guard against entry of contaminants into the lubricating and sealing system.

9 Claims, 9 Drawing Figures

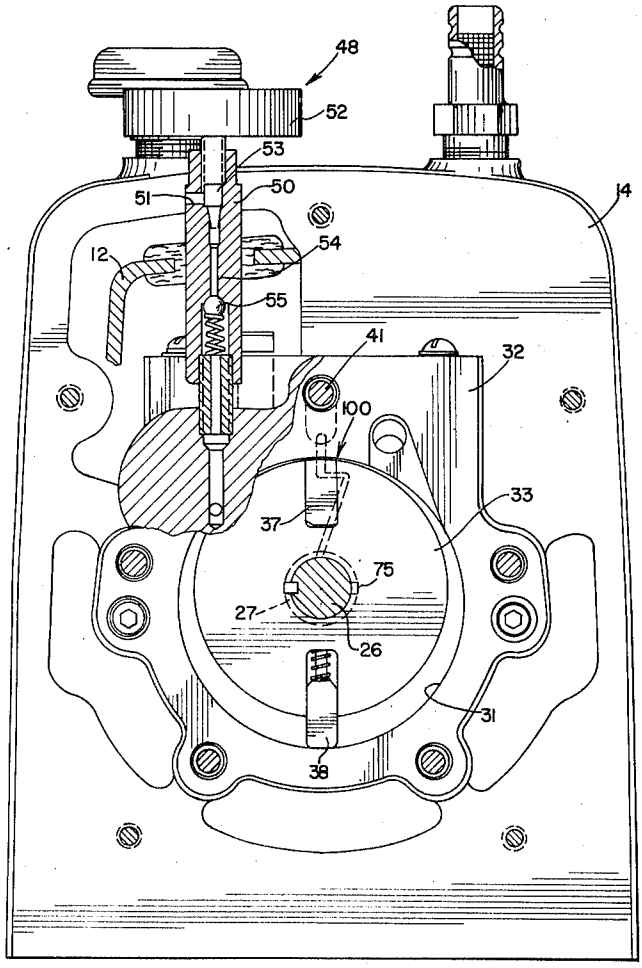
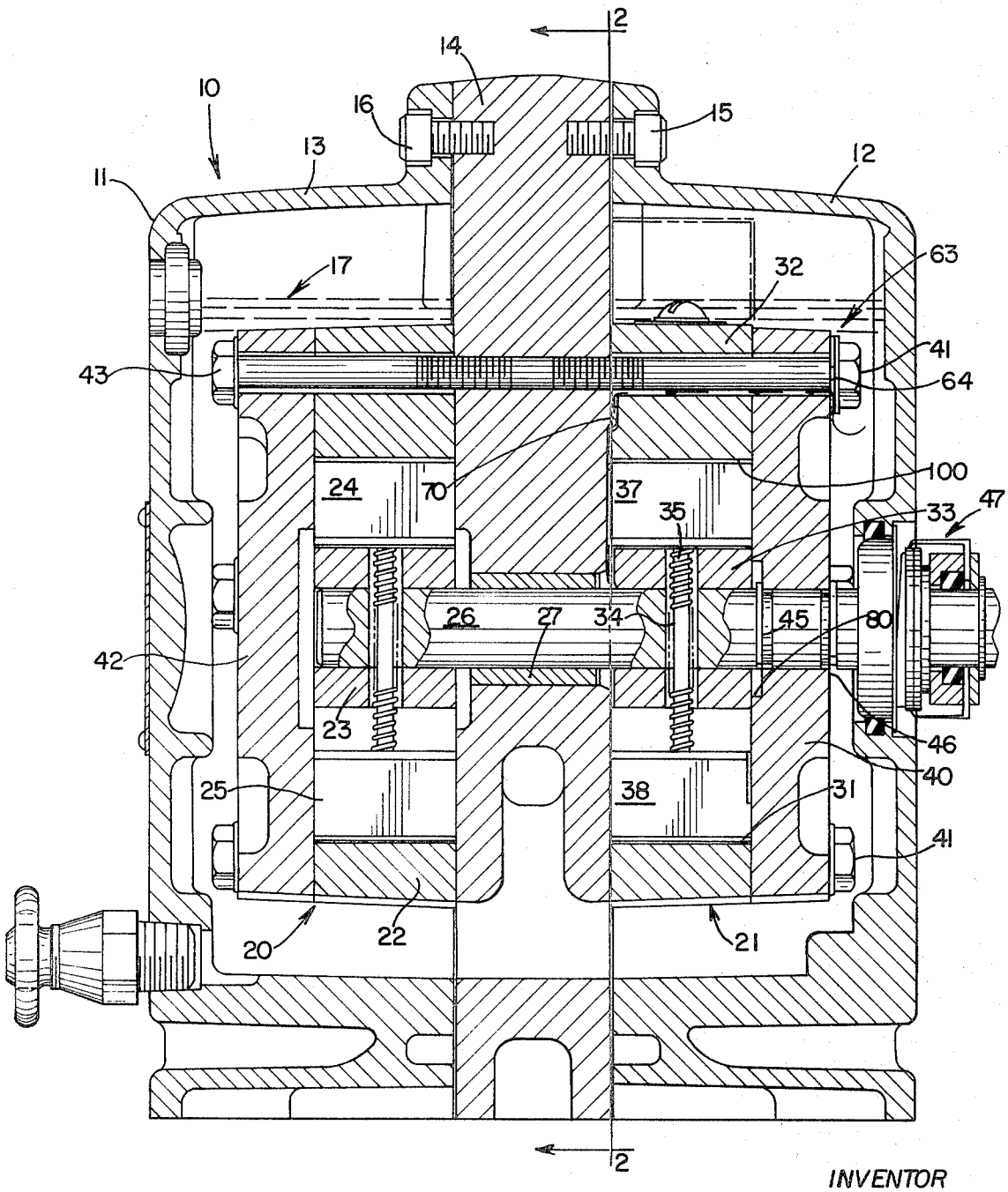
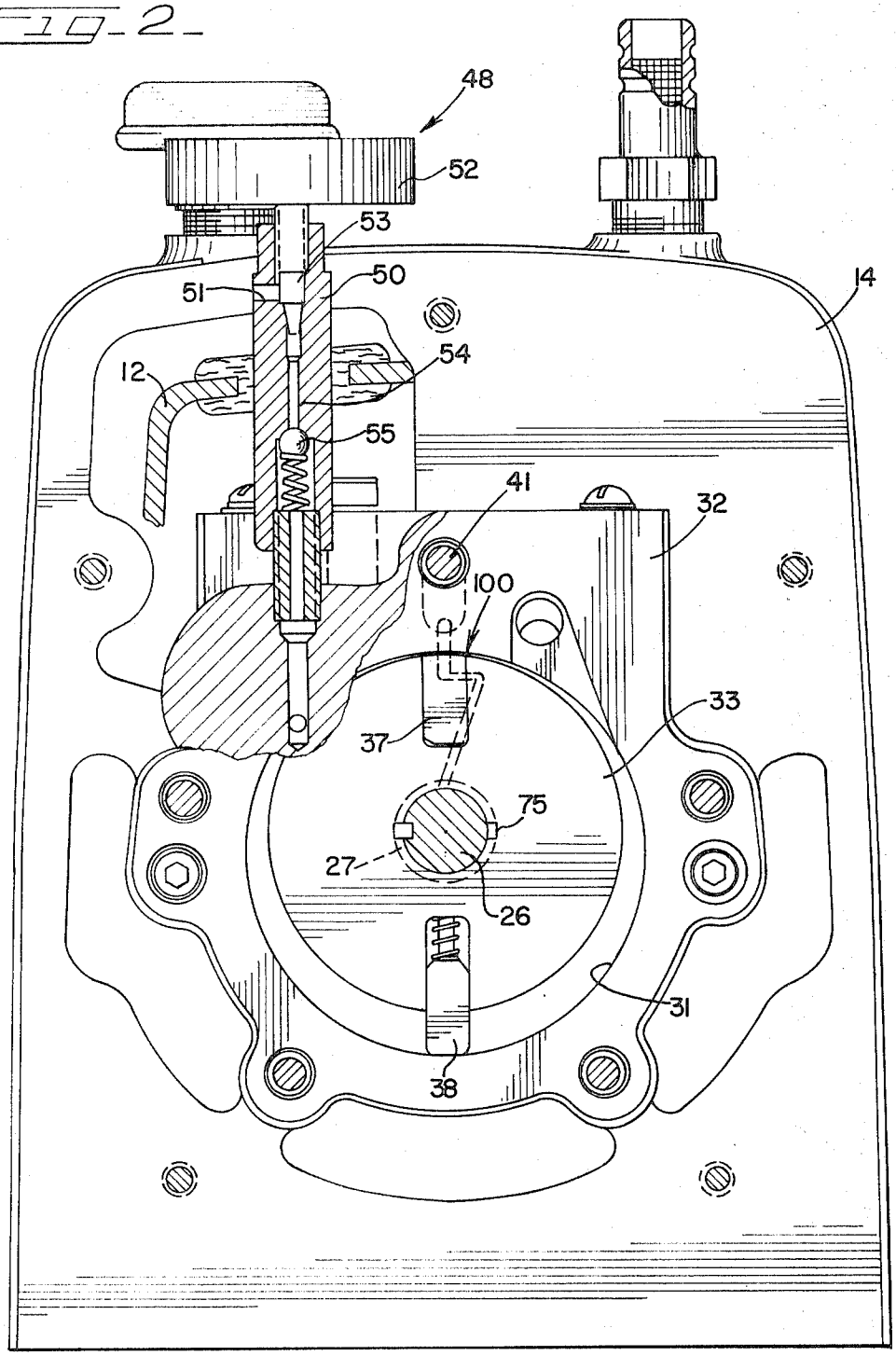


FIG. 1



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FIG. 2



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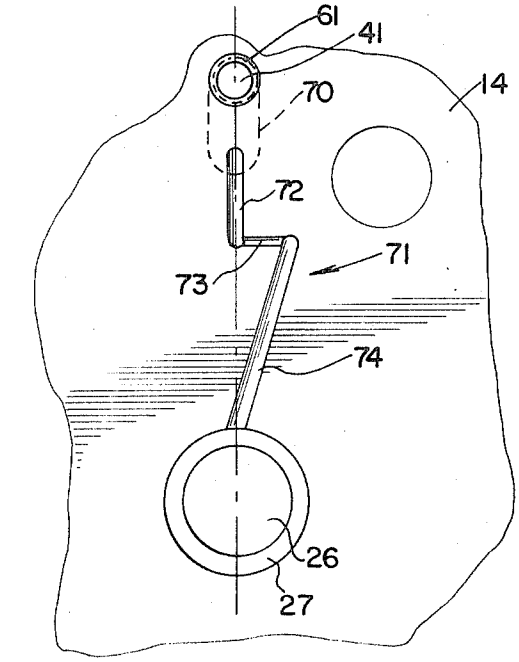


FIG. 3

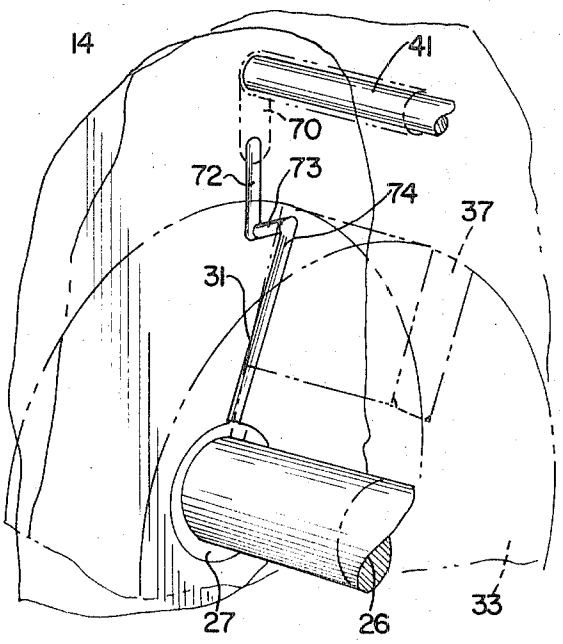


FIG. 4

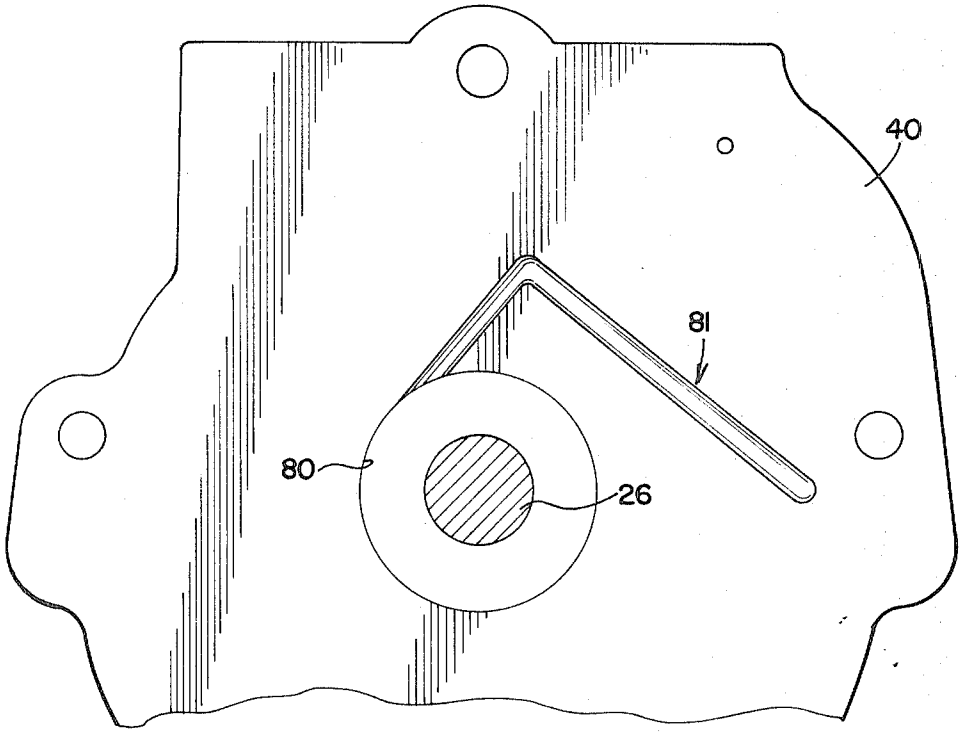


FIG. 5

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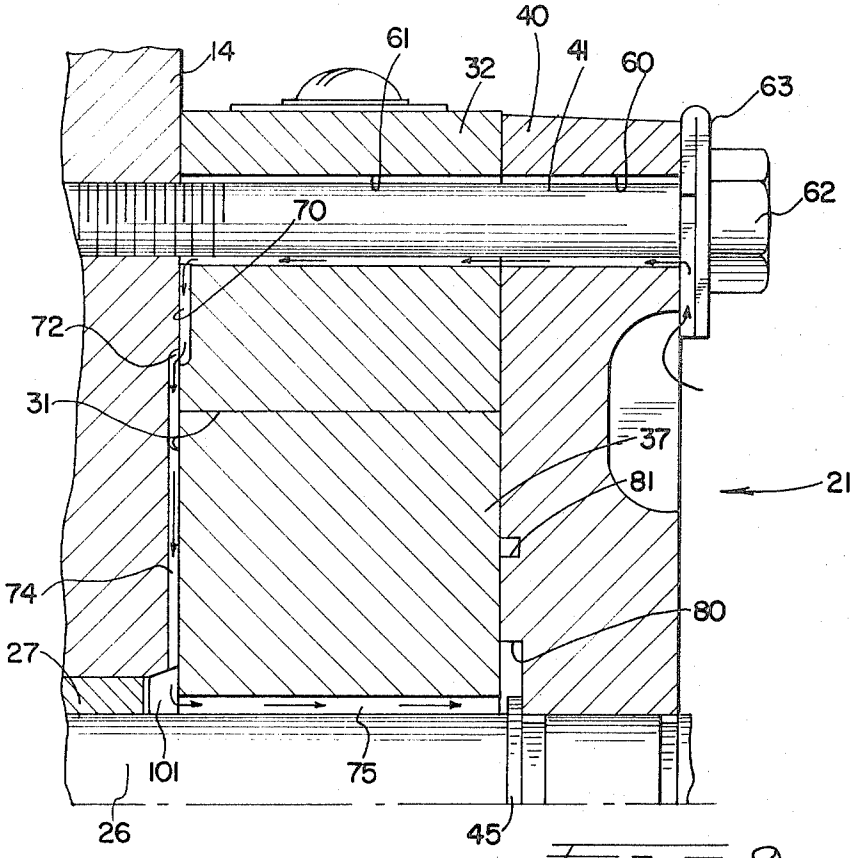


FIG. 9

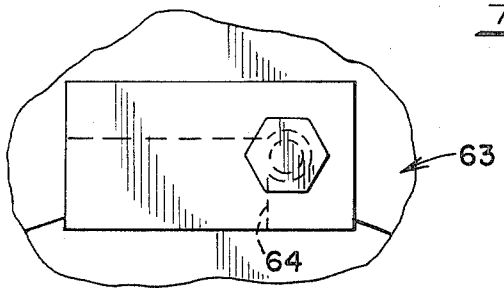


FIG. 6

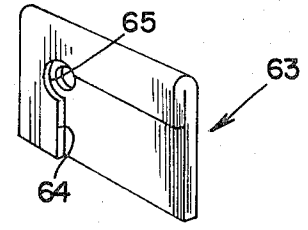


FIG. 8

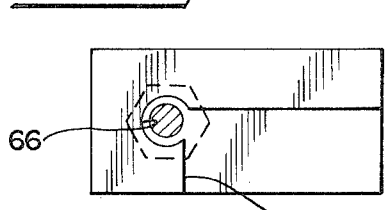


FIG. 7

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VACUUM PUMP WITH LUBRICANT METERING GROOVE

This is a continuation, of application Ser. No. 47,239, filed June 18, 1970 and now abandoned.

This invention relates to improvements in vacuum pumps in general and, more specifically, is directed to a new and improved system for providing metered oil flow to the moving parts to improve the sealing, recovery, lubrication and gas ballast characteristics of the pump.

Multistage mechanical vacuum pumps of the vane type are well known. The general elements composing a simple form of a two-stage pump consist of an intake stage and an exhaust stage. Each stage is provided with a stator having an interior chamber receiving a rotor mounted for rotation within the chamber. The rotor diameter is somewhat less than the diameter of the chamber and it rotates on an axis which is offset or eccentric relative to the geometric axis of the chamber of the stator. A typical rotor includes a pair of oppositely biased vanes which extend axially from one end of the chamber to the other and are movable in slots in the rotor so as to be pressed against the interior of the walls of the chamber throughout rotation and thereby function to sweep the fluid pumped, such as air molecules, toward the exhaust.

Vane-type mechanical vacuum pumps oftentimes immerse the entire stage or stages in a bath of oil so that continuous lubrication is available and to permit the oil to assist in sealing between stages where differential pressures exist. Ordinarily, when a pump has been idle, the pumping chambers will fill with oil, which oil is expelled through the first few revolutions of the rotor. The exhaust duct or port of the pump is provided with a tortuous path or other means to prevent exclusion of the oil and, normally it is discharged so as to be led back to the area around the pumping chamber.

Known types of vacuum pumps have various means and methods for providing lubrication to the center plate of the pump which is located between the two stages. Generally, this lubrication is not in the form of any positive flow arrangement but through a very small orifice or the like in the stator, end plate or center plate which is intended to meter a small amount of oil into the stator chamber and hopefully migrate to the area of the center plate to provide for lubrication. This form of lubrication has proved to be unsatisfactory for many reasons. The location of the orifice is such that oftentimes contaminants on the surface of the oil or which are entrained in the oil cause the orifice to become clogged and thereby starve the stator chambers from a continuous supply of lubrication. Enlarging the hole to avoid clogging has been proposed as a solution, however, in such event, the oversupply of such lubrication causes what is known as "hydraulic knock" which is undesirable and reduces the over-all efficiency of the pump. Vacuum pump manufacturers have continued with this technique of lubrication for lack of a suitable alternative.

The present invention relates to a new and improved lubricating system for a vacuum pump to provide constant metered flow to the moving parts of the vacuum pump and thereby overcome the difficulties heretofore experienced. Since a continuous and complete supply of the oil is available with the present invention, constant sealing between stages and areas of differential pressures is assured. Improved gas ballast is experienced. Because of the improved lubrication and sealing qualities, a quicker recovery is possible after the vacuum has been broken. Improved performance is experienced in work in which contaminants can be pumped and expelled, such as would be encountered in freeze drying work and the like.

The present invention provides an extremely simple and economical, but highly effective, lubricating arrangement in the exhaust stage of the pump which is formed mostly by removing existing material in the stator and center plate. An improved oil inlet plate is provided at the intake to preclude entry of floating contaminants into the pump. Oil flows in and around an existing bolt which functions to join the end plate, stator and center plate. On reaching the area of the center plate, the oil flows through a vertical groove in the stator to a vertical groove in the center plate and then down in a generally radial direction toward the axis of rotation of the rotor. Oil is distributed to the rotor vane and the center bearing with any excess oil led along the rotor shaft, where it lubricates the vanes, to the bearing area in the end plate for discharge into the oil bath surrounding the stages. As will be seen, since the oil flow is metered, excess oil is not a problem.

Through the unique metering system, a continuous supply of sealing oil is provided to the center plate wall to lubricate the moving parts and provide good sealing between areas of differential pressure. An oil inlet plate of novel design is provided to prevent the introduction of contaminants into the lubricating system. A machined groove in the center plate forms a fixed orifice of predetermined size so as to limit the flow of oil to the center bearing area and into the pumping stage. The location of the orifice is such that the action of the sides of the vanes of the rotor passing over the orifice will maintain the orifice free of contaminants in the event they should enter the system, thereby assuring a continuous metered flow of lubricant to the moving parts.

From the foregoing general description, it can be seen that through the present invention, a mechanical vacuum pump is provided having improved vacuum, better lubrication, better sealing between the points of differential pressure, achievement of better gas ballast control and also providing means to prevent the entrance of contaminants into the lubricating system.

It is an object of this invention to provide a new and improved mechanical vacuum pump having the above-stated attributes and which overcomes the problems outlined.

It is a further object of this invention to provide a new and improved vane-type vacuum pump in which metered constant flow of lubricant is provided through the provision of a novel lubrication system.

It is a further object of this invention to provide a mechanical vacuum pump of the vane type in which a novel oil inlet plate is provided to reduce the possibility of the entrance of contaminants into the novel lubrication system.

It is a still further object of this invention to provide a new and improved lubricating system having a fixed orifice for controlling lubricant flow, the orifice being strategically located so as to be continuously swept clean of any contaminants through the sweeping or wiping action of the vane.

Objects in addition to those specifically set forth will become apparent to the man skilled in the art upon

consideration of the drawings and following description in which like reference characters will be used wherever feasible to designate the same or equivalent structures.

IN THE DRAWINGS

FIG. 1 is a longitudinal cross-sectional view of a vacuum pump;

FIG. 2 is a cross-sectional view taken generally along line 2—2 of FIG. 1 and illustrating the lubrication path in the center plate in dotted lines;

FIG. 3 is an enlarged elevational view of the center plate showing the lubrication path in full elevation;

FIG. 4 is a perspective view of the center plate with the stator and rotor shown in phantom lines to illustrate the sweeping action of the rotor vanes;

FIG. 5 is a fragmentary elevational view of the end plate of the pump showing the lubricant groove;

FIG. 6 is a plan view of the oil inlet plate of the present invention;

FIG. 7 is a rear elevational view of the plate shown in FIG. 6;

FIG. 8 is a perspective view of the oil inlet plate of FIGS. 6 and 7; and

FIG. 9 is an enlarged cross-sectional view of the novel lubricating system of the present invention with arrows to show the general flow path of lubricant.

Referring now to FIG. 1, reference character 10 indicates a multistage vacuum pump having the general characteristics outlined above. The pump includes an outer housing 11 composed of right-hand and left-hand casings 12 and 13, respectively, which are joined to a common center plate 14 by means of cap screws 15 and 16 or the equivalent. The housing halves 12 and 13 form with the center plate a tank or chamber to receive the lubricating and sealing oil, the level of which is indicated by the arrow 17. Openings (not shown) in the center plate permit the oil to flow freely between the housings 12 and 13.

Disposed within the housing 11 is a first or intake pumping stage indicated generally at 20 and an exhaust stage indicated generally at 21. The intake stage includes a customary stator 22 which houses a rotor 23 having spring loaded vanes 24 and 25. The rotor is keyed to a shaft 26 which is supported by a bearing 27 carried in the center plate 14.

The exhaust stage 21 includes a stator 32 having a cavity 31 receiving a rotor 33 which is also keyed for rotation with the shaft 26. A spring guide pin 34 extends through the shaft and supports a spring member 35 which urges the vanes 37 and 38 outwardly against the inner circumference of the cavity 31 of the stator 32. An end plate 40 is joined with the stator 32 to the center plate by means of bolts 41. Similarly, an end plate 42 is provided in the intake stage 20, also being joined to the center plate by means of bolts 43.

The shaft 26 extends through the end plate 40 and is supported thereby with a pair of thrust washers 45 and 46 acting between grooves in the shaft and the thrust bearing surfaces on the end plate 40 to take any axial or end loads on the shaft 26. A sealing assembly indicated generally at 47 seals the shaft 26 as it exits the housing. The seal 47 is of a known type commonly referred to as a face seal in which radially extending surfaces sealed to the housing and shaft, respectively, move relative to each other while in contact with each other. The shaft 26 is illustrated as being broken away at its right-hand end, however, in practice is extended and supports a pulley which is adapted for driving by a belt.

A gas ballast valve assembly 48 of known type is shown in FIG. 2 and is adjustable to permit the introduction of gas such as air into the exhaust stage of the pump. The gas ballast valve assembly 48 includes a valve body 50 supported by the stator 32 and having gas intake ports 51. A control knob 52 permits adjustment of the movable valve member 53 to control the flow from the opening 51 through a central bore 54. A spring-biased or one-way ball valve 55 is provided at the lower end of the cylindrical valve body 50 and is preloaded to the desired degree. In operation, when the knob 52 is opened, outside air may be admitted to the exhaust chamber just prior to pressure buildup and discharge of the fluid pumped in order to assist in flushing the chamber. This will be described in greater detail with reference to the description of the operation of the pump.

Referring now to FIG. 9, it can be seen that the body of the bolt 41 at the top of the exhaust stage 21 is of lesser diameter than the diameter of the opening 60 in the end plate 40 and the opening 61 in the stator 32. This provides clearance around the circumference of the bolt 41 with the opening to form a path or conduit through which lubricating oil may flow to the center plate. The bolt 41 is a conventional hexagonal head 62 which clamps an oil intake plate of novel design, indicated generally at 63, over the outer end of the opening. With reference to FIGS. 6, 7 and 8, the intake plate may be inexpensively formed through use of sheet metal stamped to the desired shape and folded in the manner illustrated. A cutaway section 64 is formed on one side of the plate for communication with an enlarged opening 65 approximating the diameter of the opening 60 in the end plate 40. A second opening 66 is formed in the outer portion of the plate and provides sufficient clearance to admit the body of the bolt 41. The opening 65 is bounded through approximately 270° in order to transmit and distribute the clamping pressure of the bolt head 62 over a wide area on the end plate 40. In practice, the cutaway section 64 is disposed below the level of the oil, thereby assuring that the oil will be taken in through the path shown in FIG. 9 below the surface of the oil. In this manner, contaminants floating on the surface of the oil are less likely to enter the system.

The inner end of the stator 32 is machined to provide a recess 70 which communicates with the opening 61. The lower end of the opening 70 communicates with a vertical lubricating path indicated generally at 71 in FIG. 3 which is formed in the center plate 14. The lubricating path 71 may be formed in any manner such as by milling a vertical groove 72, communicating at its lower end with a horizontal metering groove 73 which is of lesser dimension than the groove 72. A groove of increased width 74 extends diagonally from the opposite end of the groove 73 and provides a flow path into the area of the bearing 27 and the shaft 26. Grooves 72 and 74 may be formed with a lesser degree of precision than the metering groove 73. The dimension of the metering groove is determined for each size of pump and in manufacturing is carefully controlled, as this metering groove 73 functions as a flow restrictor to meter the flow of lubricant into the area of the bearing 27. An ad-

equate, but not excessive, amount of oil is continuously available.

As is evident in the cross-sectional view of FIG. 2, a keyway 75 in the rotor 33 provides a path to direct the oil from the area of the center bearing back to the end plate 40 to provide lubrication for the thrust bearings and supporting bearings on the shaft 26.

Referring now to FIG. 5, the end plate 40 is shown in broken-away elevation. The shaft 26 is shown in cross section and surrounding the shaft is a cavity 80 which forms an exhaust area for the lubricating oil which has been metered from the center plate across and along the rotor shaft. A groove which is of inverted V shape is shown at 81 and communicates with the cavity 80. The shape of the groove provides a path for the lubricating oil to be discharged into a low pressure area of the exhaust section of the pump cavity, thus assuring that the oil will be vented into an area where the gases are not yet fully compressed. Any oil reaching the cavity is expelled by conventional means. In this manner, the flow of oil in the circuit path shown by the arrows in FIG. 9 is continuously assured, thereby providing for maximum improved lubrication and anti-seize protection, as well as substantially improving the pump characteristics.

In operation, the first pumping gauge 20 is connected through a conduit (not shown) to the device to be evacuated. Rotational motion is applied to the shaft 26 by a pulley and belt or other conventional drive (not shown). On the first few revolutions of the shaft 26, oil is expelled from the pumping chambers (see FIG. 2) while a film of lubricant remains between the working parts, especially at the sealing seat indicated generally by the arrow and reference numeral 100 in FIG. 2. The sealing seat 100 is in continuous contact with the rotor 33 so as to divide the stator chamber and thereby assure the expelling of the fluid pumped.

In the known form of prior art pump, an orifice is provided in the end plate 40 adjacent the top of the rotor to allow oil to drip into the exhaust stage pumping chamber, with reliance on the movement of the pump to distribute the lubricant. Distribution of lubricant by this technique is less than satisfactory. If the pump is rotated for prolonged periods, the surfaces can and do become dry, causing the shaft, rotor and vanes to seize, requiring the pump to be disassembled and reworked before it is again operational. The problem of seizing is virtually assured in those instances in which the tiny orifice through the end plate becomes plugged with contaminants, thereby starving the internal working parts of the pump of any lubrication. It is also more expedited and pronounced in applications in which contaminants are pumped, such as in freeze drying, vacuum deposition of metals and the like.

In the present design, after the pump has reached an operational condition, a continuous supply of lubricant enters along the oil inlet plate 63 in the manner shown in FIGS. 1 and 9 by the arrows. Inasmuch as the oil rotary opening is well below the operating level 17 of the oil, the likelihood of floating surface contaminants entering the pumping chamber is materially reduced. Moreover, floating contaminants will not be introduced when the chamber is vented to atmosphere, as would occur during periods of nonuse, change-over or the like. Should contaminants enter the system, the wiping action of the inner sides of the vanes passing the fixed orifice or metering groove 73 keeps the groove from becoming obstructed (see FIG. 4). In addition, the wiping action of the sides of the rotor 33 and vanes 37 and 38 acts as a turbine pump to impel the oil along the groove 73 which has been illustrated as being straight. It is clear that the rotating rotor 33 and vanes 37 and 38 form a constantly moving side of metering groove 73, which contacts and is adhered to by the oil flowing through the groove 73 and impart momentum to the oil to impel it along the metering groove 73. Obviously, the groove 73 may be arcuate if desired.

Oil can and does flow freely along the circumference of the bolt 41 into the recess 70 where it flows into the vertical groove 72. Because of the reduced cross-sectional area of the groove 73 connecting the grooves 72 and 74, the flow of oil is restricted. The dimensions of the flow restrictor groove 73 are carefully designed and controlled during manufacture to obtain the precise metering rate for adequate, but not excessive, lubrication for each size of pump design. Design dimensions are readily obtained through application of trial-and-error techniques for each pump size.

The rate of flow of oil into the groove 74 is controlled by the fixed orifice 73 (see FIG. 3). The oil exits the groove 74 into a circumferential chamber 101 formed by the recess receiving the bearing 27. When filled with lubricant, the chamber 101 forms a liquid seal between the intake stage and exhaust stage as well as providing a ready supply of lubricant to continuously lubricate the bearing 27. The oil exits the chamber 101 and flows along the keyway 75 and shaft into the area of the thrust washer being ultimately discharged through the specially shaped groove 81 into a region of low pressure in the area of the exhaust section of the pump so as to prevent contamination or entrainment of air in the medium pumped in the oil. It is then exhausted to the tank for recirculation.

The present pump, insofar as gas ballast is concerned, operates in a manner somewhat similar to the conventional vane-type pump in that there is a connection directly to atmosphere from the exhaust chamber. With particular reference to FIG. 2, when the moving vane sweeps around the bottom of the chamber as in the case of the vane 38, the pressure in the chamber is normally subatmospheric. When the metering or needle valve 53 is opened, air may enter the port 51 and, under the influence of atmospheric pressure, presses the ball 55 away from the seat to permit the entry of air into the exhaust chamber. In prior art pumps, the quantity of air introduced had to be kept fairly small because of the strong likelihood that excessive air would find its way into the intake stage of the pump.

In the present invention, large amounts of air may be introduced without such a problem occurring since adequate oil is available at the sealing seat 100 and in the center bearing 27 and along the moving surfaces acting as a liquid barrier to prevent the gas ballast and fluid pumped from entering other parts of the pump. The vane 38 in FIG. 2, which is moving in a counterclockwise direction, compresses the gas introduced from atmosphere as well as the fluid pumped exhausting all fluids through the exhaust opening as the vane 38 approaches the seat 100. As the pressure builds up ahead of the vane, the spring biases the ball 55 into engagement with the seat, precluding further introduction of atmosphere into the exhaust chamber.

A continuous and adequate supply of lubrication is provided to reduce internal leakage between stages.

The oil functions as a liquid seal between the stages as well as between the exhaust and intake portions of the pump. The correct amount of oil is metered to the exhaust chamber, minimizing hydraulic knock. Moreover, the turbine action of the vane assures uniformity in the flow rate of the oil.

In summary, the pump of the present invention provides faster evacuation at lower pressures which is sometimes referred to as "merit factor." This is the percentage of pumping speed retained by the pump at low pressures. The supply of oil being the optimum or right amount at all times provides for metered internal lubrication and, therefore, less gas (air) enters the pump when it is exposed to atmosphere.

As pointed out above, the provision for increased or full gas ballast is provided. In present applications of vacuum pumps, such as freeze drying, thin film coating and color television tube evacuation, the removal of gas dissolved in the pump oil is absolutely required. The full gas ballast assists in preventing condensible gases from becoming entrained in the oil and permits removal of dissolved gases by bleeding large amounts of air into the exhaust stage of the pump to provide for rapid oil purging. Known forms of pumps permit only a limited supply of air to be introduced because of the problem of the air entering the preceding stage of the pump and areas where it cannot be readily exhausted.

In addition, the ultimate pressure with or without gas ballast is decreased because of the improved lubrication and sealing. A pump incorporating the present invention will reach a pressure of at least 10 to 100 millitorr below that of known types of pumps commercially available. In many instances, pressures of up to 1 or 2 millitorr may be achieved with the present pump with the gas ballast valve wide open. In addition to the foregoing, the present pump will recover faster after opening to atmospheric pressure since the lubrication is uniform in all the working parts of the pump to preclude the entry of air. This reduces the recovery time considerably, which is quite desirable in cyclical processes. The present pump is expected to provide longer life because of the adequacy of lubrication at all times.

Upon a consideration of the foregoing, it will become obvious to those skilled in the art that various modifications may be made without departing from the invention embodied herein. Therefore, only such limitations should be imposed as indicated by the spirit and scope of the appended claims.

I claim:

1. In a vacuum pump having a stator disposed between first and second end plates, a shaft extending between and supported by the end plates for angular movement relative to the stator, and a rotor having vanes positioned for rotation on the shaft in engagement with the inner circumference of a pumping cavity in the stator, a lubricant distributing system comprising:

the first end plate having a metering groove with an inlet end and an outlet end formed therein extending from said inlet end to said outlet end in the direction of rotation of the rotor and vanes, the rotor and vanes being arranged to sweep across the open surface of said metering groove in close proximity thereto, said metering groove being sufficiently shallow to permit the sweeping of the rotor and vanes across the open surface thereof to produce a turbine action that continuously impels a lubricant through said groove at a desired predetermined rate without being affected by contaminants that may be in the lubricant;

input means to introduce the lubricant to said inlet end of said metering groove; and

output means to direct the lubricant at said outlet end of said metering groove to the appropriate portion of the pump.

2. In a vacuum pump having a stator disposed between first and second end plates, a shaft extending between and supported by the end plates for angular movement relative to the stator, and a rotor having vanes positioned for rotation on the shaft in engagement with the inner circumference of a pumping cavity in the stator, a lubricant distributing system comprising:

the first end plate having a continuous flow lubricating path formed therein and extending in a generally radial direction toward the shaft;

a metering portion of said lubricating path interconnecting two enlarged flow portions of said lubricating path and arranged to have the rotor and vanes impel lubricant therethrough to cause a predetermined amount of lubricant to be continuously passed through said lubricating path during operation of the pump irrespective of pressure conditions and contaminants in the lubricant;

insertion means to introduce the lubricant into said lubricating path; and

withdrawal means to pass the lubricant from said lubricating path to the shaft supports and to the pumping cavity in the stator.

3. A lubricant distributing system as claimed in claim 2 wherein said metering portion is generally transverse to said enlarged flow portions and impedes lubricant flow through said lubricating path in the absence of the impelling action of the rotor and vanes.

4. A lubricant distributing system as claimed in claim 2 wherein said insertion means comprises:

an opening extending through the upper ends of the second end plate and the stator;

an input passage to introduce lubricant to said opening; and

a vertical recess in the stator adjacent the first end plate and extending downwardly from said opening to said lubricating path.

5. A lubricant distributing system as claimed in claim 2 wherein said withdrawal means comprises:

a chamber in the first end plate about the shaft to receive lubricant from said lubricating path;

a keyway extending along the shaft from said chamber;

an exhaust area in the second end plate communicating with the keyway; and

a discharge groove to convey lubricant from said exhaust area into the pumping cavity.

6. A lubricant distributing system as claimed in claim 2 wherein:

said metering portion of said lubricating path is an open groove extending in the direction of rotation of the rotor and vanes; and

the rotor and vanes sweep across the surface of said groove to impel the lubricant therein through said groove at a desired predetermined rate.

7. A lubricant distributing system as claimed in claim 6 wherein said groove is shallow relative to said en-

larged flow portions to provide a restricted metering groove.

8. In a multistage vacuum pump of the oil sealed type having a pump housing containing an oil bath, a stator disposed between a center plate and an exhaust end plate joined by a bolt at the upper ends thereof and all located in the oil bath, a shaft extending between and supported by the plates for angular movement relative to the stator, and a rotor having outwardly biased vanes positioned for rotation on the shaft in a pumping cavity in the stator which has intake and exhaust sections thereof, a lubricant distributing system comprising:

an opening about the bolt extending through the end plate and the stator;

an input passage located below the level of oil in the pump housing to introduce oil to said opening to cause oil flow through the end plate and the stator;

a vertical recess in the stator adjacent the center plate and extending downwardly from said opening;

a continuous flow lubricating path in the center plate comprising a first enlarged flow portion communicating with said recess and extending downwardly therefrom, a restricted metering groove having a first end communicating with said first enlarged flow portion and extending therefrom in the direction of rotation of the rotor so that the rotor and vanes sweep across the surface of said metering groove to impel oil therethrough at a predetermined rate, and a second enlarged flow portion extending from the other end of said metering groove toward the shaft;

a chamber in the center plate about the shaft to receive the oil from said lubricating path;

a keyway extending along the shaft from said chamber;

an exhaust area in the end plate communicating with said keyway; and

a discharge groove to convey oil from said exhaust area into the exhaust section of the pumping cavity at a region of low pressure.

9. A lubricant distributing system as claimed in claim 8 wherein said restricted metering groove is shallow relative to said enlarged flow portions and impedes lubricant flow through said lubricating path in the absence of the impelling action of the rotor and vanes.

* * * * *