United States Patent

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[73] Assignee The Bendix Corporation

[54] **HIGH-VACUUM MECHANICAL PUMP**
12 Claims, 6 Drawing Figs.

[52] U.S. Cl. 417/353, 415/90
[51] Int. Cl. F04b 17/00
[50] Field of Search 415/76, 90; 417/352, 353, 354

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ABSTRACT: A new type multistage molecular drag pump wherein the pumping chamber contains rotating surfaces having an area much greater than the stationary surface area of the pumping chamber.

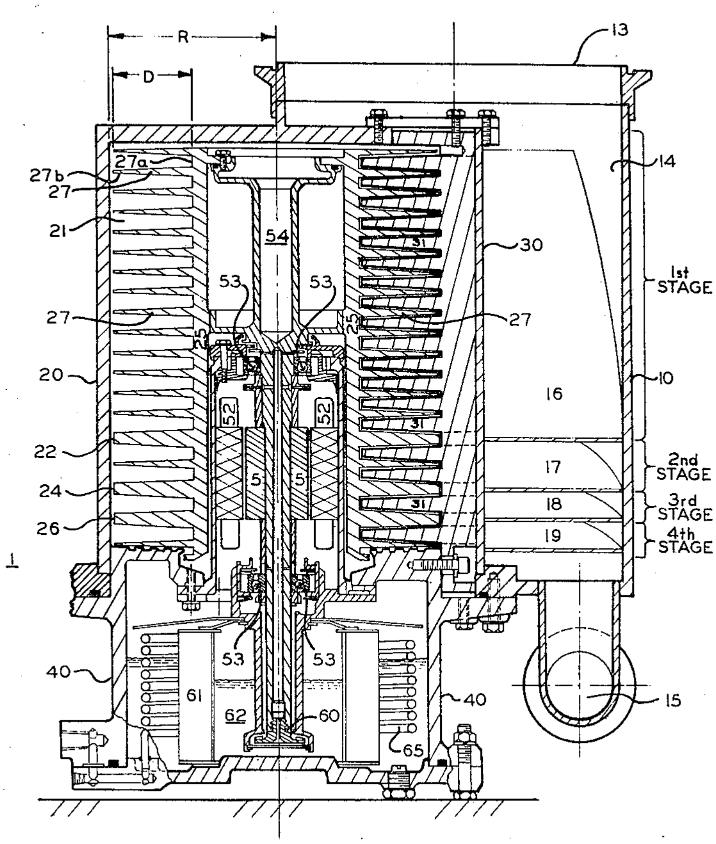

FIG. 1

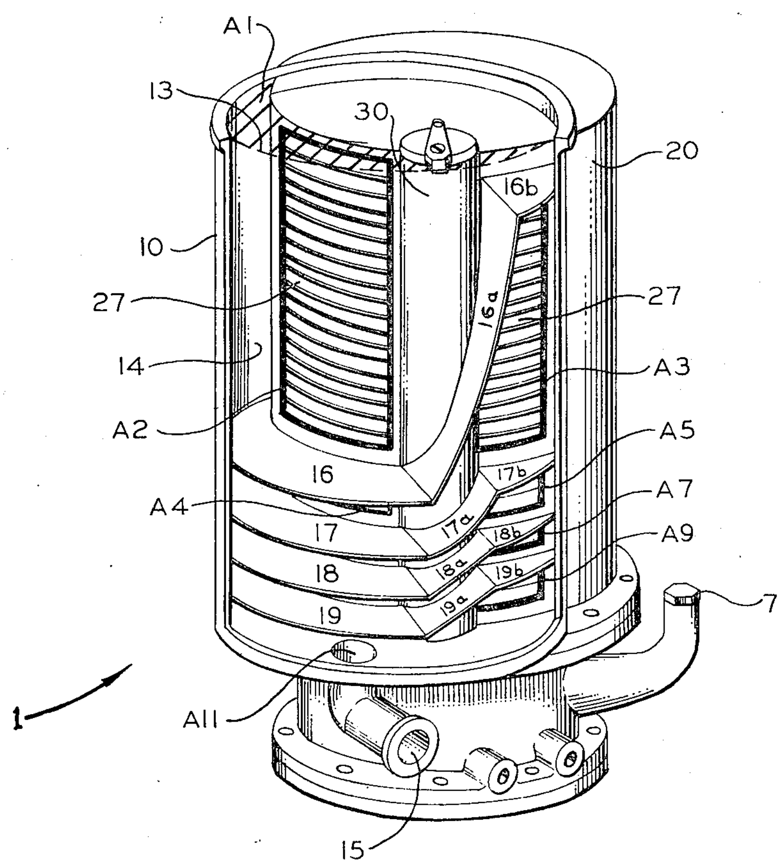

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FIG. 2

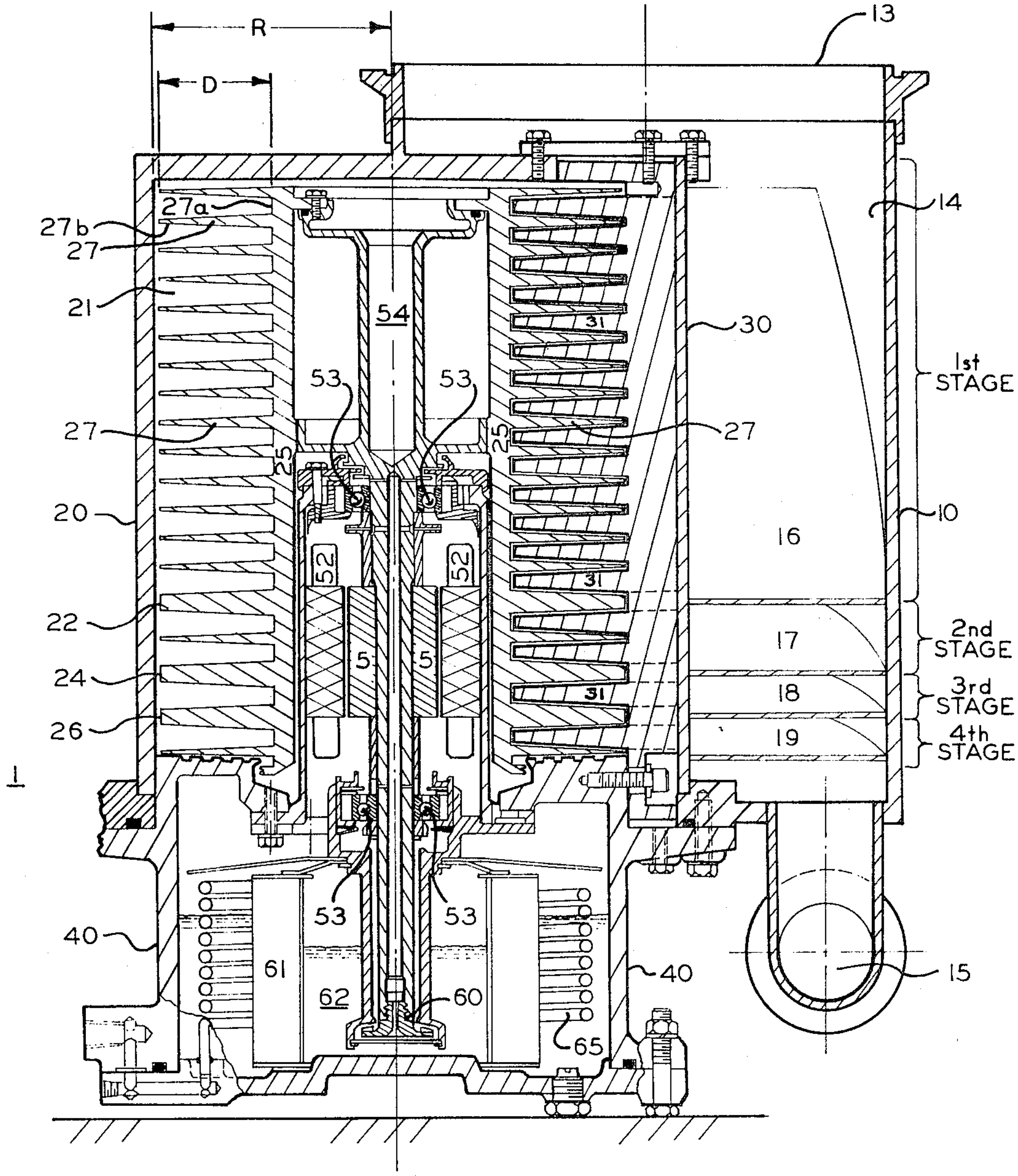

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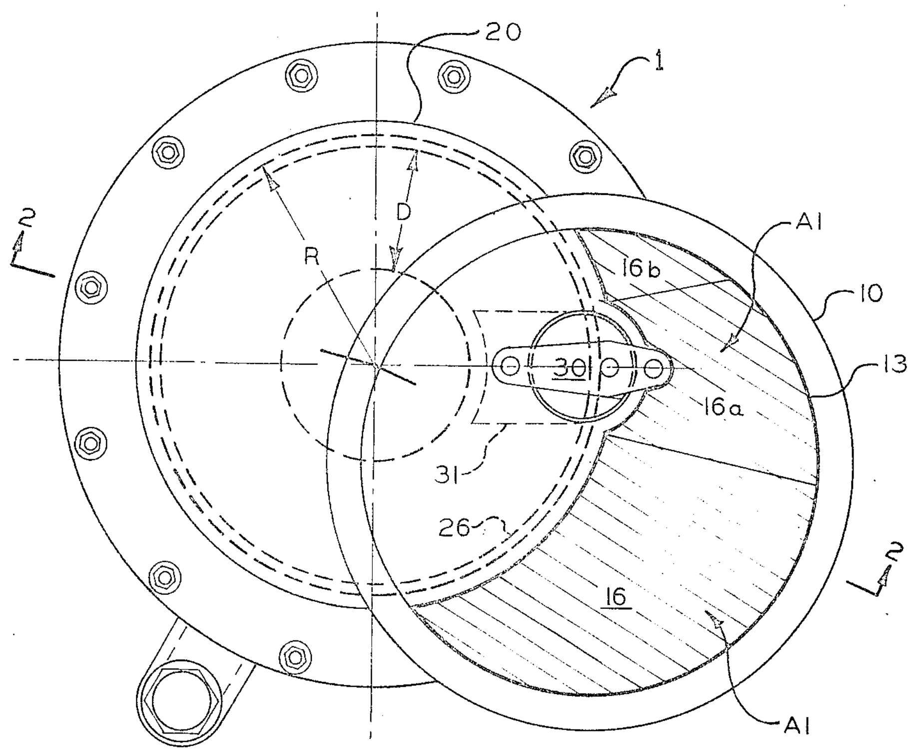
FIG. 3



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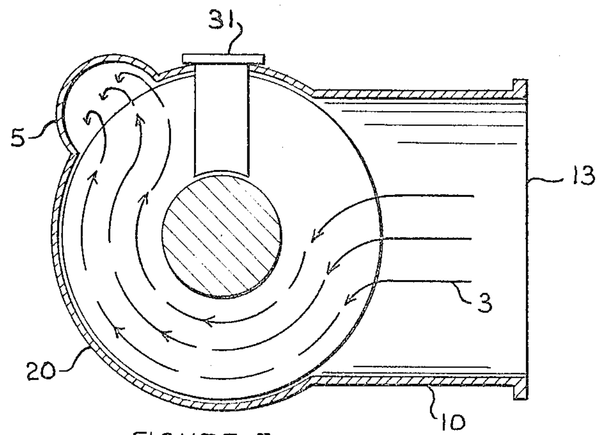

FIGURE 5

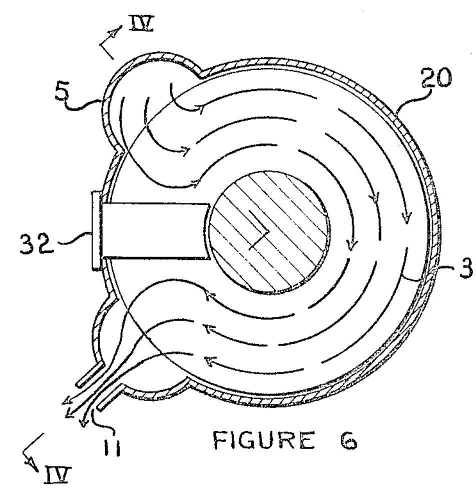

FIGURE 6

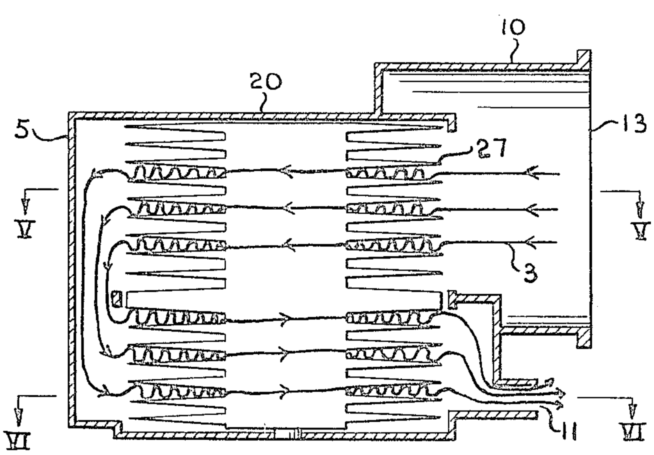

FIGURE 4

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HIGH-VACUUM MECHANICAL PUMP

BACKGROUND OF THE INVENTION

This invention relates to vacuum pumps and more specifically to a molecular drag pump of the type having a cylindrical housing having an inlet and an outlet, and containing a plurality of rotatable disks that drive molecules entering the inlet through the housing and out the outlet.

Of all the mechanical pumps designed for creating high vacuums, Gaede's Molecular Drag Pump was the most significant and yet has been the most ignored and neglected. This fact is evidenced by the absence of any significant improvement of Gaede's U.S. Pat. Nos. 1,029,862 (1912) and 1,069,408 (1913). Perhaps the reason for this is the two major disadvantages of Gaede's Molecular Drag Pump which are low pumping speed and the ultimate vacuum attainable. The pumping speed of a drag pump is low compared to that of an oil diffusion pump of about the same physical size and the ultimate vacuum attainable by a molecular drag pump is only 10^{-6} torr. Possibly the reason that these two disadvantages have not been overcome in the years since Gaede's basic patent issued is that the disadvantages are a result of more than one factor. For instance, the factors contributing to the disadvantages of Gaede's pump are: (1) the pump ran too slow (8,000 to 12,000 revolutions per minute), making the angular velocity of the moving surfaces too low with respect to the average velocity of the molecules to be pumped; (2) the conductance between stages was poor; (3) the ratio of the inlet area (A_1) to the pumping entrance area (A_2) was out of proportion (e.g., a long inlet with a small diameter which communicated with the pumping chamber); and (4) the ratio of the stationary wall area of the pumping chamber to the moving surface area was much too large. This last ratio may also be expressed as a ratio of the pumping chamber radius (R) to the radial depth (D) of the grooves between the rotating disks. For Gaede's pump the ratio R/D was always greater than 3 and, in fact, the R/D ratio is greater than 5 for the Gaede pump shown in the aforementioned patents. Another disadvantage of Gaede's molecular pump was the rotating shaft which extended through the pump housing and required a vacuum seal.

SUMMARY OF THE INVENTION

To increase the pumping speed and the ultimate vacuum attainable by a molecular drag pump, the relative speed of the rotor has been increased, the conductivity between pump stages and the ratio of inlet area to pumping entrance area has been maximized, and the moving surface area within the pumping chamber has been increased.

The invention is characterized by a molecular drag pump which has a ratio R/D less than 3 where D is the radial depth of the space between the rotating surfaces (disks) in the pumping chamber and R is the radius of the pumping chamber. The invention is further characterized by a drag pump wherein the ratio A_1/A_2 is greater than 0.5 but less than 2 where A_1 is the effective cross-sectional area of the inlet to the drag pump and A_2 is the cross-sectional area of the opening between the inlet and the pumping chamber containing the rotating disks. Additional distinguishing features of the improved molecular drag pump are that it operates at speeds such that the velocity of portions of the rotating surfaces are greater than 20,000 cm./sec. and a motor for operating the pump is located within the pumping chamber.

Accordingly, it is an object of this invention to provide an improved molecular drag pump.

It is another object of this invention to improve the performance of a molecular drag pump.

It is another object of this invention to improve the pumping speed of a molecular drag pump.

It is another object of this invention to improve the ultimate vacuum attainable by a molecular drag pump.

It is still another object of this invention to eliminate the need for a vacuum seal for the rotor shaft coupled to an external driving means by locating an electric motor inside the pump casing.

The above and other objects and features of the invention will become apparent from the following detailed description taken in conjunction with the accompanying drawings and claims which form a part of this specification.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of an improved molecular drag pump.

FIG. 2 is a cross-sectional view of the improved molecular drag pump.

FIG. 3 is a top view of the improved molecular drag pump shown in FIG. 2.

FIG. 4 is a diagrammatic view of an alternate embodiment of a two-stage improved molecular drag pump.

FIG. 5 is an end view taken in the plane of the first stage showing the general direction of molecular flow.

FIG. 6 is an end view taken in the plane of the second stage showing the general direction of molecular flow.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring now to the drawings, FIG. 1 illustrates a molecular drag pump which utilizes the principles of the invention. The housing 1 of the pump includes two eccentrically arranged cylinders 10, 20 having chambers therein that overlap and communicate with each other through an opening.

The first cylinder 10 has an inlet 13, an outlet 15 and an inner wall 14. Arranged within the first cylinder are a plurality of members 16, 17, 18 and 19 which divide the first chamber into compartments or sections. As can be seen from the drawing, each compartment or section in the first cylinder 10 communicates with the chamber of the second cylinder 20. The first compartment in the cylinder 10 communicates with the inlet 13 and the last compartment communicates with the outlet 15.

The second cylinder 20 has a cylindrically shaped chamber which contains a rotor (not shown) for rotating a plurality of disks 27. Arranged in the coincident portion of the two cylinders is a comb assembly 30 for blocking the passage of molecules in the second chamber. The comb assembly 30 divides the opening into the chamber of the second cylinder 20 into two portions which may be considered the inlets and the outlets to the pump stages of the second chamber. The pump illustrated is a four-stage pump, although more or less stages may also be used. A pump stage is defined as that portion of the cylindrical chamber containing a plurality of disks 27 and having an inlet (A_2, A_4, A_6, A_8) and an outlet (A_3, A_5, A_7, A_9). The dividing members 16, 17, 18 and 19 together with the inner wall 14 of the first chamber form the compartments or communicating links between the inlet and outlet of each stage of the pump. The space between any two consecutive dividers provides the communicating link between the outlet of one stage and the inlet of the next. Therefore, each stage of the pump has an inlet area and an outlet area which is separated by one of the dividing means 16, 17, 18 and 19. The inlet area to the first stage of the pump is the area A_2 and the outlet area of the first stage is the area A_3. Dividing means 16 separates the first stage inlet A_2 from the first stage outlet A_3. Dividing means 16 separates the first stage inlet A_2 from the first stage outlet A_3. Similarly, the inlet area A_4 and the outlet area A_5 of the second stage are on opposite sides of dividing means 17. The outlets for succeeding stages are shown as A_7 and A_9.

To prevent pressure losses between stages and between the inlet and outlet of each stage, it is necessary that the ratio of the inlet areas between stages and the inlet and outlet of the same stage have a decreasing relationship. The following is a table of the inlet and outlet areas to the different stages of a pump constructed in accordance with the principles of this invention.

Area	$Inches^2$

*Pump Inlet A_1'	39
1st Stage Inlet A_2	45
1st Stage Outlet A_3	13
2nd Stage Inlet A_4	6
2nd Stage Outlet A_5	2
3rd Stage Inlet A_6	1.5
3rd Stage Outlet A_7	0.9
4th Stage Inlet A_8	1.5
4th Stage Outlet A_9	0.9
Pump Outlet A_{11} (1 11/16 -in. dia.)	2.2

Areas	Ratio
1st A_2 to 2nd Inlet A_4	7.50
2nd Inlet A_4 to 3rd Inlet A_6	4.00
3rd Inlet A_6 to 4th Inlet A_8	1.00
4th Inlet A_8 to 4th Outlet A_9	1.66
4th Inlet A_8 to Unit Outlet A_{11}	0.67
Pump Inlet A_1' to 1st Stage Inlet A_2	0.86

*Effective Area (A_1') of Inlet A_1 is the area perpendicular to the middle of A_2 which compensates for reduction of Area A_1 by the rising portion of dividing member 16.

FIG. 2 is a cross-sectional view of a four stage molecular drag pump shown in FIG. 1. To facilitate the distinction of stationary and moving parts the nonrotating portions are marked by crosshatch or diagonal lines which extend upwardly from left to right and the rotating portions are marked by only diagonal lines which extend downwardly from left to right. The right-hand portion of FIG. 2 shows the first cylinder 10, which includes the inlet 13 and, the outlet 15 of the pump housing 1. The dividing members 16, 17, 18 and 19, together with the inner wall 14 of the first cylinder, form the communicating link between the output of one stage and the input to the next stage of the pump.

Located within the chamber of the second cylinder 20 is an electric motor which includes a motor assembly 51 and a stator 52. The rotor assembly 51 includes a plurality of disks 27. Although individual disks may be mounted on the rotor assembly 51, in this particular embodiment the disks are an integral part of the rotor assembly 51. To reduce the stress on the disks 27 when they are rotated, the disks are triangularly shaped, increasing in width as they approach the center line of the rotor. Generally, the size of the disks 27 is the same except for those disks 22, 24 and 26 which separate one stage from another. This particular pump shown is a four-stage pump. Bearing 53 separate the rotor from the stationary portions within the second chamber 20. To reduce the weight of the rotor assembly 52 on the bearings 33, portions of the rotor are hollowed out 54, 55. The hollow portion 55 of the rotor also serves as a lubricating line to the bearings 53 from the centrifugal oil pump 60. The oil pump 60 includes an oil filter 61 and oil 62. Coil 65 is used for circulating a coolant, such as water, to maintain the oil at the proper temperature.

An important feature of the invention is the relationship between the radius (R) of the cylindrically shaped chamber to the depth (D) of the space between the disks 27. The smaller the ratio, the larger is the moving surface area available to pump molecules. Preferably, this ratio R/D should be less than 3 and in this embodiment is approximately 2. Located between the first and second cylindrically shaped chamber is a comb or blocking assembly 30 which has a plurality of teeth or members 31 which extends between the disks 27. These blocking members extend in a spaced relationship complementary to the spaced relationship between the disks 27. It is the function of these blocking members 31 to block the passage of molecules as they travel around the second cylindrically shaped chamber between a pair of disks 27. Therefore, the number of teeth generally equals the number of spaces between the disks. The comb assembly 30 also separates the stage inlet (A_2, FIG. 1) from the stage outlet (A_3, FIG. 2) and is located adjacent the cylindrical chamber so that the comb teeth 31 can project into the chamber. Further, the comb assembly 30 is located within the confines of the first cylinder 10 and not outside the housing so that no seal to atmospheric pressure is required. The construction of this embodiment is such that the double cylinders 10 and 20 may be lifted from the rotor assembly 51 to facilitate comb teeth 31 and disk 27 clearance measurements.

FIG. 3 is a top view of the molecular drag pump shown in FIG. 2. The double cylinders 10 and 20 of the housing 1 are eccentrically arranged so that there is a coincident portion. Located within the coincident portion is a comb assembly 30 having a plurality of teeth 31 which extend between the disks 26. The radius R of the second cylindrically shaped chamber and the radial depth D of the space or slot between the disks 26 are shown. The inlet area A_1 through the first stage is emphasized by a series of diagonal lines. The member 16 which divides the outlet of the first stage from the inlet to the second stage includes a lower portion, an upper portion parallel to and spaced from the lower portion, and a diagonal portion which extends between the upper and lower portions. Therefore, the effective area A_1' of the inlet 13 is the area perpendicular to the area A_2 halfway between the upper and lower portions of member 16. As can be seen from the drawing the dividing members 16 and the chamber wall 14 form communicating links between each stage of the pump. The eccentric cylinders 10 and 20 are arranged so that these communicating links have a fairly large cross-sectional area in proportion to the inlet of a pump stage.

FIG. 4 is an embodiment of a two-stage improved molecular drag pump similar to that shown in FIGS. 1, 2 and 3. Additional stages may be added as required. In this embodiment the communicating links between the stages are not located in the coincident portion between the two cylinders but on the outside of the cylinder 20 which is located perpendicular to the inlet conduit 10. The inlet conduit 10 has an inlet 13 which communicates with the cylinder 20. The cylinder 20 includes an outlet 11 and a communicating passage 5 which connects the first outlet to the second stage inlet. Shown within the second cylinder 20 are the rotatable disks 27 and the general path 3 which molecules follow through the cylinder 20. Not shown is the molecule-blocking comb assembly (30, FIG. 1).

FIG. 5 is a diagrammatic cross-sectional view of the first stage of the pump shown in FIG. 4 taken in plane V. The first stage includes a comb assembly 31, for blocking the passage of molecules, and the entrance to the passage 5 which connects to the next stage. The passage 5 is the passage through which molecules travel between the first stage outlet and second stage inlet. The general path that the molecules follow through the first stage is indicated by the direction lines 3.

FIG. 6 is a diagrammatic cross-sectional view of the second stage of the pump shown in FIG. 4 taken in plane VI. The second stage includes an independent comb assembly 32 for blocking the passage of molecules; the exit from the passage 5 which connects to the preceding stage; and the pump outlet 11. The general path that the molecules travel through the second stage is indicated by direction lines 3.

OPERATION

Referring now to FIGS. 1 and 2, the improved molecular drag pump is used in combination with a forepump and operates in the following manner. The inlet 13 of the pump housing 1 is connected by suitable means to an enclosure to be evacuated. The electric motor 50 is energized by suitable means causing the rotor 51 and the disks 27 to rotate at a speed in excess of 12,000 r.p.m., and preferably at about 20,000 r.p.m. At this speed the inner portions 27*a* of the rotor 27 is moving at about 13,600 cm./sec. while the outer portion 27*b* of the rotor 27 is moving at about 26,500 cm./sec. and approaches the average velocity of a molecule at room temperature (about 41,000 cm./sec.).

Molecules leaving the enclosure to be evacuated pass into the volume defined by the inlet 13, the cylinder wall 14 and the dividing means 16. Once in this volume, the molecules pass through the inlet A_2 and into the first stage of the pump where they are struck by the rotating disks 27. Once molecules enter a space between two disks, they are caused, by the rotation of the disks, to follow a path around the inside of the cylindrical chamber until they strike one of the blocking members 31 and pass through the first stage outlet A_3. Molecules pass into the second stage of the pump by leaving the outlet A_3 of the first stage of the pump and traveling between the cylinder wall 14 and the dividing means 16 and 17 until they enter the inlet A_4 of the second stage. The molecules repeat this type of path from stage to stage until they reach the housing outlet A_{11} and are subsequently discharged through outlet 15.

In accordance with the inventor's object to improve the performance of a molecular drag pump, he considers it helpful that in determining the pressure ratio of each pump stage the following parameters be considered:

Stage-pressure ratio $= e\ kCLV/A$

where

k= constant

A= area of the flow path and is the area between a pair of disks 27 from the chamber wall 20 to the main shaft of the rotor 27*a*.

C= length of the perimeter of the area A.

L= length of the path 3 which molecules travel from the inlet to the outlet of a stage.

V= average velocity of the flow path which includes the velocities of the rotating disks 27, 27*a*, 27*b* and the stationary wall 20 within the flow path.

Based upon the above generalized formula it can be seen that the ratio C/A is a relationship which must be kept as large as possible to maintain a reasonable pressure ratio. Reducing only A is not desireable, as a reduction in the area of the flow path A reduces the capacity of the pump. Therefore, the values of C and A must be considered together and one traded off against the other so as to maximize the performance of the pump.

While a preferred embodiment of the invention has been disclosed, it will be apparent to those skilled in the art that changes may be made to the invention as set forth in the appended claims and, in some cases, certain features of the invention may be used to advantage without corresponding use of other features. For example, the arrangement of the cylinders 10 and 20, the comb 30 and the motor 50 may be combined in different ways to achieve the objects of this invention. For instance, two cylindrical chambers are not required, as chamber 10 may be formed by separate external conduits mounted on the main cylindrical housing 20 each of which connects an inlet to an outlet. Further, this pump may be combined with other types of pumps to evacuate enclosures. Accordingly, it is intended that the illustrative and descriptive materials herein be used to illustrate the principles of the invention and not to limit the scope thereof.

Having described the invention, what is claimed is:

1. An apparatus which comprises:

a housing having an inlet, an outlet, a first chamber and a second cylindrically shaped chamber having an opening communicating with said first chamber and said inlet;

a rotor disposed in said second cylindrically shaped chamber so that the longitudinal axis of said rotor is disposed longitudinally of said cylindrically shaped chamber;

a plurality of disks mounted in spaced relationship on said rotor so that the axis of said disks coincide with the longitudinal axis of said rotor and wherein the ratio

$$R/D \text{ is less than } 3$$

where D is the depth of the space between said disks and R is the radius of said second cylindrically shaped chamber;

means for dividing said first chamber into a plurality of sections each of which communicates with said second chamber;

a plurality of members mounted inside said housing which extends between said rotor disks; and

means for rotating said rotor whereby said disks rotate within said second chamber.

2. An apparatus as recited in claim 1 wherein the ratio

$$A_1/A_2$$

is greater than 0.5 but less than 2, where A_1 is the cross-sectional area of the inlet to said housing and A_2 is the cross-sectional area of said opening between said second cylindrical chamber and the first section of said first chamber.

3. An apparatus as recited in claim 1 wherein said means for rotating said rotor includes a motor disposed in said second cylindrical chamber of said housing.

4. An apparatus as recited in claim 3 wherein the ratio

$$A_1/A_2$$

is greater than 0.5 but less than 2 where A_1 is the cross-sectional area of the inlet to said housing and A_2 is the cross-sectional area of said opening between said second cylindrical chamber and the first section of said first chamber.

5. A molecular pump comprising:

a housing having a first chamber, a second cylindrically shaped chamber adjacent said first chamber, said chambers communicating with each other through a common opening, and an inlet for introducing molecules into one end of said first chamber and an outlet for discharging molecules from the other end of said first chamber;

a rotor disposed axially of said second cylindrically shaped chamber;

a plurality of disks mounted in spaced relationship on said rotor and extending across the common opening between said first and second chambers, said disks mounted so that

$$R/D \text{ is less than } 3$$

where D is the depth of the space between said disks and R is the radius of said second cylindrically shaped chamber;

means for dividing the common opening between said chambers into two parts, said dividing means having a plurality of spaced members which extend into said second chamber and between said disks to block the passage of molecules and divert molecules into said first chamber;

means for dividing said first chamber into a plurality of sections each of which communicates with said second chamber, said sections including a first section which communicates with said housing inlet and a last section which communicates with said housing outlet; and

means for rotating said rotor whereby molecules entering through said housing inlet into said first section of said first chamber pass into said second chamber and are caused to travel through said second chamber by impinging some of said rotating disks until said common opening and are thereby directed into each succeeding section of said first chamber until said molecules pass out of said housing discharge outlet.

6. An apparatus as recited in claim 5 wherein the ratio

$$A_1/A_2$$

is greater than 0.5 but less than 2 where A_1 is the cross-sectional area of the inlet to said housing and A_2 is the cross-sectional area of said opening between said second cylindrical chamber and the first section of said first chamber.

7. An apparatus as recited in claim 5 wherein said means for rotating said rotor includes a motor disposed in said second cylindrical chamber of said housing.

8. An apparatus as recited in claim 7 wherein the ratio

$$A_1/A_2$$

is greater than 0.5 but less than 2 where A_1 is the cross-sectional area of the inlet to said housing and A_2 is the cross-sectional area of said opening between said second cylindrical chamber and the first section of said first chamber.

9. An apparatus for transmitting molecules which comprises:

a housing which includes:

a first chamber having an inlet for receiving air molecules and an outlet for discharging air molecules; and

a second cylindrical chamber eccentrically arranged with said first chamber so that said chambers have a coincident portion;

a plurality of members for dividing said first chamber into compartments including a first compartment which communicates with said housing inlet and a last compartment which communicates with said housing outlet, said compartments communicating with said cylindrical chamber;

a rotor disposed in said cylindrical chamber so that the longitudinal axis of said rotor coincides with the longitudinal axis of said cylindrical chamber;

a plurality of disks mounted in spaced relationship on said rotor;

means for rotating said rotating said rotor including a motor disposed in said second cylindrical chamber;

a plurality of members for blocking the passage of molecules mounted in said housing and extending between said rotor disks, said members arranged in spaced relationship in said coincident portion of said housing cavity so that when said disks are rotated air molecules entering said first chamber on one side of one of said dividing members impinge some of said disks and are caused to travel in a path which takes the molecules through said cylindrical chamber until they strike some of said blocking members which cause the molecules to reenter said first chamber on the other side of said dividing member where the molecules strike other of said disks and reenter said cylindrical chamber, the molecules repeating this type of path through said chambers until they reach the housing outlet in said first chamber and are discharged.

10. An apparatus as recited in claim **9** wherein the ratio

$$R/D \text{ is less than } 3$$

where D is the depth of the space between said disks and R is the radius of said second cylindrically shaped chamber.

11. An apparatus as recited in claim **9** wherein the ratio

$$A_1/A_2$$

is greater than 0.5 but less than 2 where A_1 is the cross-sectional area of the inlet to said housing and A_2 is the cross-sectional area of said opening between said second cylindrical chamber and the first section of said first chamber.

12. An apparatus as recited in claim **10** wherein the ratio

$$A_1/A_2$$

is greater than 0.5 but less than 2 where A_1 is the cross-sectional area of the inlet to said housing and A_2 is the cross-sectional area of said opening between said second cylindrical chamber and the first section of said first chamber.

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