Oct. 2, 1934. J. DUBROVIN 1,975,568

MOLECULAR VACUUM PUMP

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Fig. 1

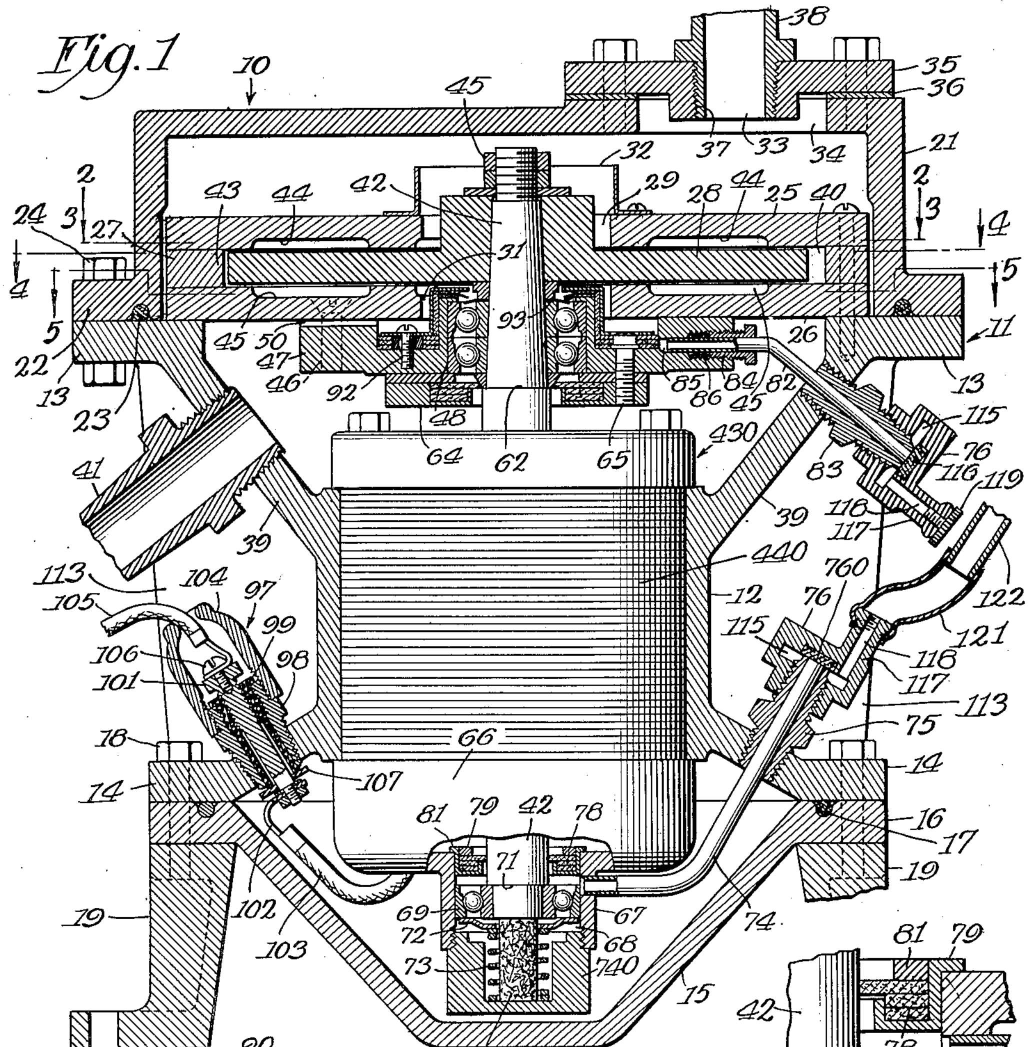

Fig. 6

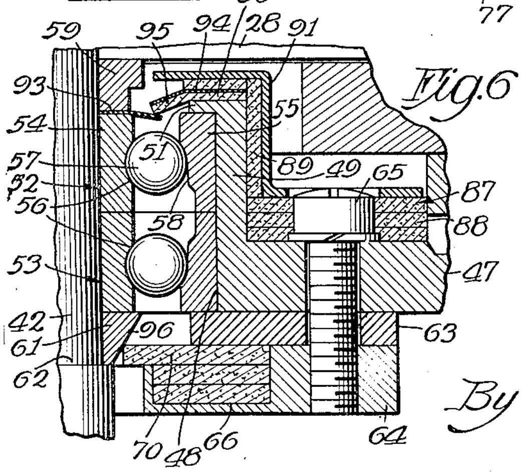

Fig. 7

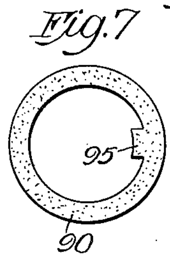

Fig. 8

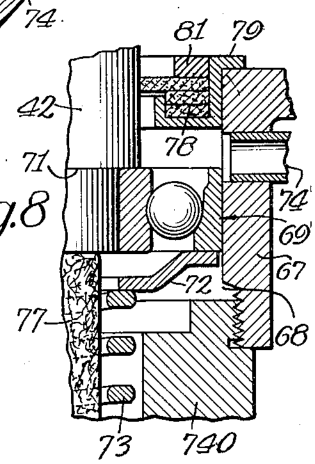

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Fig. 2

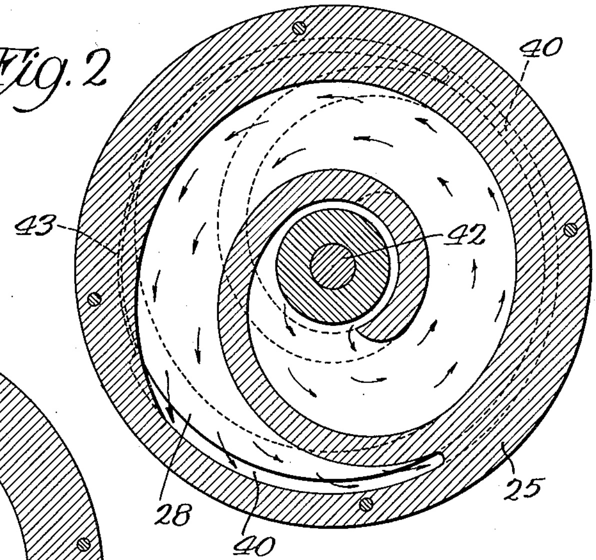


Fig. 3

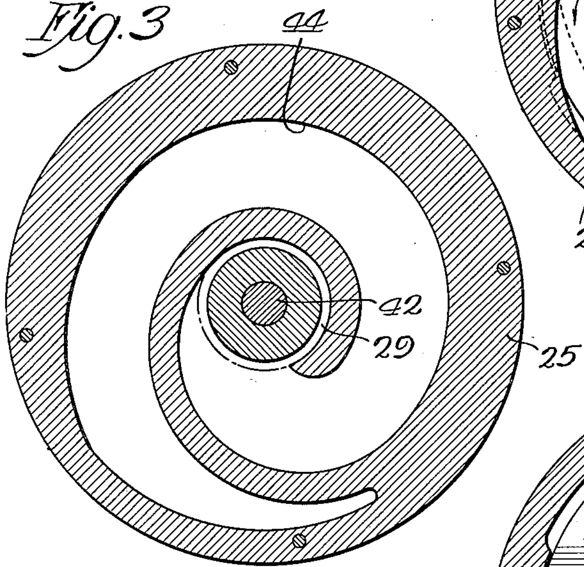


Fig. 4

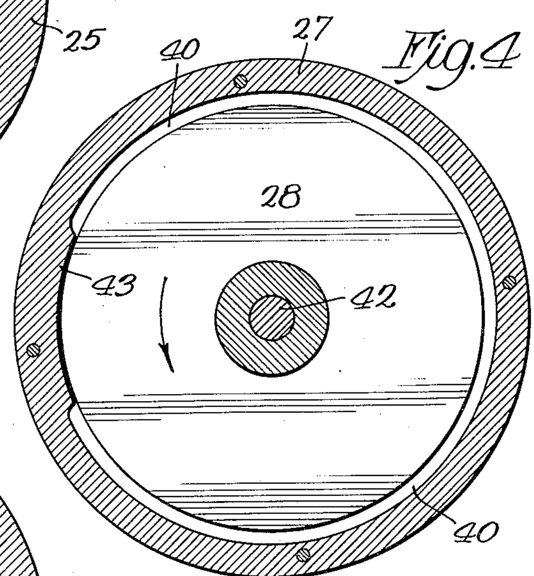
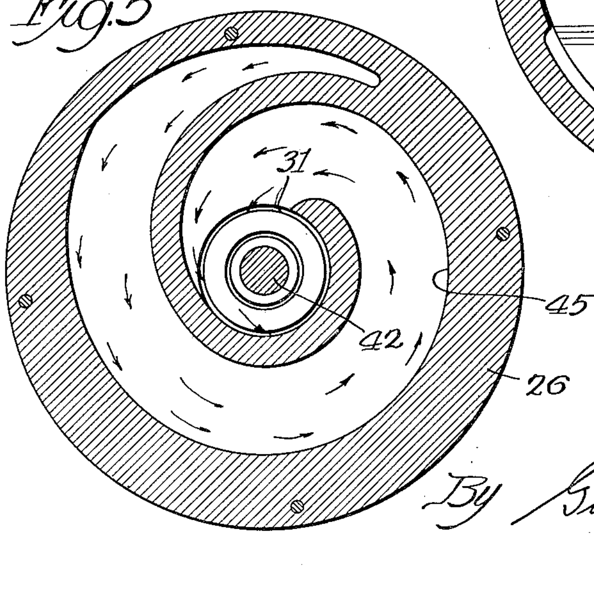


Fig. 5



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MOLECULAR VACUUM PUMP

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Fig. 9

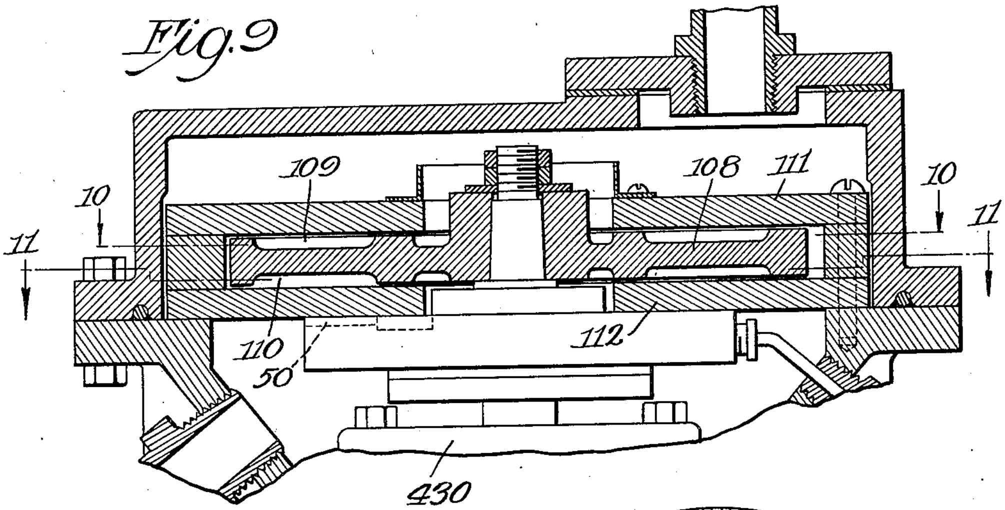
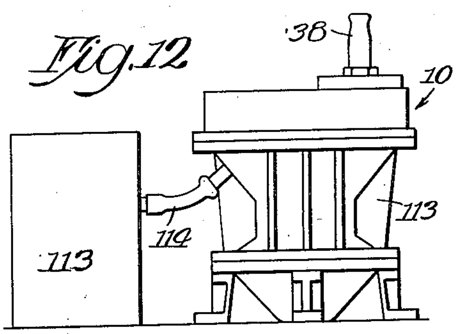


Fig. 12



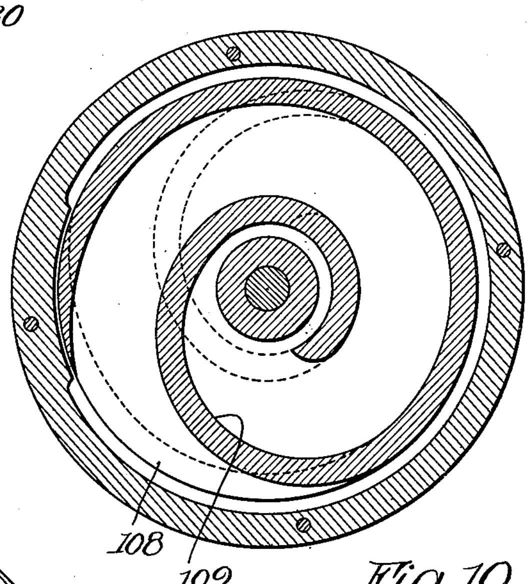


Fig. 10

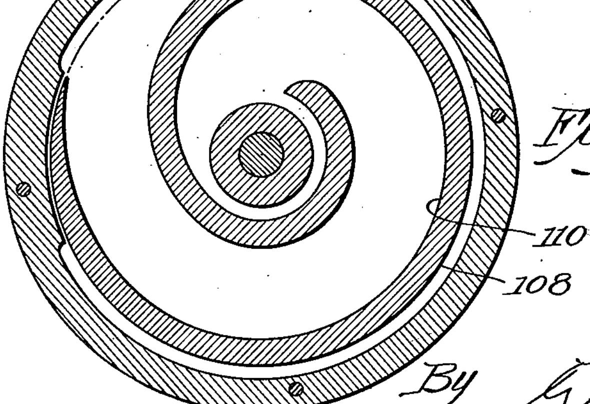


Fig. 11

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UNITED STATES PATENT OFFICE

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MOLECULAR VACUUM PUMP

John Dubrovin, Chicago, Ill., assignor to Central Scientific Company, Chicago, Ill., a corporation of Illinois

Application March 18, 1932, Serial No. 599,620

2 Claims. (Cl. 230—118)

This invention relates to vacuum pumps and, more particularly, to the type known as molecular pumps and is a continuation in part of my application, Serial No. 504,715 filed December 26, 1930.

One of the objects of the invention is the provision of a new and improved molecular pump having novel means for supporting the rotor.

Another object of the invention is the provision of a new and improved molecular pump having novel bearing and supporting members for the operating shaft.

A further object of the invention is the provision of a new and improved molecular pump having a novel arrangement of grooves or air passages in the operating parts.

A still further object of the invention is the provision of a novel molecular pump having a new and improved arrangement of parts for lubricating the bearings of the operating mechanism.

Another object of the invention is the provision of a new and improved moleular pump that is simple in construction, efficient in operation, composed of few moving parts, has a minimum of clearance between the stator and rotor and that is provided with means for compensating for the elongation and contracting of the operating shaft due to temperature variation without affecting the operation of the rotor.

Other and further objects and advantages of the invention will appear from the following description taken in connection with the accompanying drawings, in which—

Fig. 1 is a vertical section of the device with parts broken away;

Fig. 2 is a section on the line 2—2 of Fig. 1 with parts omitted for the sake of clearness;

Fig. 3 is a section on the line 3—3 of Fig. 1 with parts omitted;

Fig. 4 is a section on the line 4—4 of Fig. 1;

Fig. 5 is a section on the line 5—5 of Fig. 1;

Fig. 6 is an enlarged vertical section of a portion of the upper bearing and associated parts;

Fig. 7 is a perspective view of one of the rings associated with the oiling mechanism;

Fig. 8 is a vertical section of a portion of the lower bearing for the motor shaft and associated elements with parts broken away;

Fig. 9 is a section similar to Fig. 1 showing only the upper portion of the device and showing a modified form of construction;

Fig. 10 is a section on the line 10—10 of Fig. 9 with parts omitted for the sake of clearness;

Fig. 11 is a section on the line 11—11 of Fig. 9, with parts omitted; and

Fig. 12 is a side elevation of the pump connected to a backing pump and shown more or less diagrammatically.

In the construction of vacuum or molecular pumps or pumps for obtaining extremely high vacuum, it is necessary that the clearness for the moving parts be reduced to a minimum; that the speed of the rotor be high; and that the parts be so constructed that there is no leakage of air into the pump.

In the present construction the entire pump and motor for operating the same are enclosed in an air-tight casing in such a manner that the air may be exhausted from the casing by a backing pump and the pump itself operated at a high speed without over-heating the motor and associated mechanism.

The parts are so constructed that the motor is so efficiently air cooled that the rotor of the pump may be operated at a very high rate of speed.

Referring now to the drawings, the reference character 10 designates the molecular pump which comprises a casing 11 provided with a restricted or motor supporting portion 12 and having upper and lower laterally extending flanges 13 and 14, respectively. The lower end of the casing 11 is closed by a cap 15 which is provided with a flange 16 for engaging the flange 14 on the casing 11. A gasket 17 interposed between the flanges 14 and 16 and located in a groove in the face of one of the flanges insures an air tight joint when the parts are clamped together by the bolts or screws 18. Certain of the screws 18 are tapped into the legs 19 for holding the latter in position.

The upper end of the casing is closed by a cap 21 which forms a housing for the stator and rotor elements of the pump. This cap is provided with a laterally extending flange 22 which engages the flange 13 of the casing 11. An annular gasket 23 located in a groove between the flanges forms an air-tight joint when the two flanges are clamped together by the bolts 24, or the like.

Mounted within the housing 21 are the two plates 25 and 26 which form the stator element of the molecular pump. These members are held in spaced relation by the annular spacer member 27. A disk 28 mounted to rotate between the plates 25 and 26 constitutes the rotor element of the pump.

The clearance between the disk and plates, and between the disk and ring at one place is exceedingly small, often not exceeding .00075 to .001 of an inch, which requires that all surfaces including the flanges 13 and 22 be ground and finished with precision and the bearings and operating parts be fitted with the greatest accuracy.

The plate 25 is provided with an axial opening 29 which constitutes an inlet port for the pump proper and a corresponding axial opening 31 in the lower plate 26 constitutes the outlet passage thereof. An upstanding baffle 32 extending about the intake 29 is provided for preventing the entrance into said port of foreign matter.

Since the clearance between the moving and stationary elements of the pump proper is extremely small and the parts are so accurately adjusted, it is necessary that no foreign matter of any kind enter the passage 29 with gas or air during the operation of the pump. The inlet 33 for the housing 10 is arranged adjacent the outer edge of the same whereby the direction of the air or gas will be changed in passing from the inlet 33 to the pump inlet 29 thereby causing the foreign matter to be separated therefrom by its inertia. The baffle 32 will also assist in separating foreign matter from the air by again changing the direction of flow of the air.

The inlet 33 may be constructed in any suitable manner. As shown, an enlarged opening 34 is provided in the cap 10 adjacent to one edge thereof and this opening is covered by a plate 35 clamped against a gasket 36 for forming an air-tight joint and having a threaded opening 37 in which is secured a coupling or nipple 38 of any suitable material. The nipple is adapted to be connected to the vessel that is to be exhausted in the usual manner.

The upper flared portion 39 of the casing 11 is provided with a discharge opening in which is secured a coupling or nipple 41 which is adapted to be connected to a backing pump.

The rotor 28 is a circular disk mounted to rotate within the ring or annular spacer member 27 between the stator members 25 and 26 and is accurately ground to form smooth plane surfaces on each of its sides. Likewise the peripheral edge is accurately finished. The ring or spacer member 27 has its inner surface spaced from the periphery of the disk to form a channel or conduit 40 except at a small section of its circumference which forms a barrier 43, as will presently appear.

The upper section or plate 25 of the stator is provided on its lower surface with a spiral groove 44 that is in communication at its inner end with the intake opening 29 and at its outer end with the channel 40 adjacent to the barrier 43, as clearly shown in Fig. 3 of the drawings. Preferably the spiral groove makes one complete turn.

The lower plate 26 of the stator member is provided on its upper surface with a spiral groove 45, see Figs. 1 and 5, similar to the groove 44 but in a reverse direction. The spiral groove at its outer end is in communication with the passage 40 as indicated in dotted lines in Fig. 2 and with the discharge opening 31 at its inner end. It is preferably also one complete turn.

Suitable means are provided for operating the rotor. In the form of construction selected to illustrate one embodiment of the invention, the rotor 28 is mounted on the armature shaft 42 of a motor 430 mounted entirely within the casing 11.

The restricted portion 12 of the casing is bored out to receive the field laminations 440 of the motor which are forced home under considerable pressure. The motor is preferably arranged directly beneath the rotor whereby the armature shaft may be extended and rigidly connected to the rotor for operating the same.

By utilizing the motor shaft as the operating shaft for the rotor, extreme accuracy in mounting of the rotor is more easily obtained since a slight error in the mounting of the bearings of a long shaft would affect the position of the rotor much less than if the rotor were provided with a short shaft.

The rotor 28 is rigidly secured to the upper end of the armature shaft 42 in any suitable manner. As shown, the shaft is tapered and engages a correspondingly tapered axial opening in the rotor and is held in position by the nuts 45 which clamp the parts against a shoulder 62 on the shaft 42, as will presently appear.

The shaft 42 is preferably, though not necessarily, provided with ball bearings both above and below the motor. The upper bearings are held in position by a construction which will now be described.

Rigidly attached to the underside of the lower plate 26 of the stator, as by the screws 46, is a bearing support 47 which has an enlarged axial opening 48. An annular projection 49 extends upwardly about the opening and has its upper portion provided with an inwardly extending retaining flange 51 for engaging the outer race of the upper ball bearing, as will presently appear.

A pair of ball bearings 52 and 53, see Fig. 6, are provided for the upper portion of the shaft 42. Each of these bearings comprises an inner ball race 54 fixed to the shaft 42 and an outer ball race 55 secured to the support 47 within the opening 48. The outer ball race 55 of the upper bearing 52 seats against the flange 51. The outer race is provided with an annular recess 58 curved in cross section and so arranged that it is inclined whereby when moved in one direction it will clamp the balls.

The bearing 52 is arranged opposite, or reverse, to that of 53 so that the thrust on the balls when clamping the bearings in position will be equalized.

The inner bearings are clamped between the spacing member 59 which engages the rotor 28 and an oil slinger 61 which seats against the shoulder 62. The outer races are confined between the flange 51 on the annular projection 49 and a spacer 63 which in turn is held in position against the under side of the bearing support 47 by a plate 64. The plate 64 is clamped in position by suitable bolts or screws 65. It is provided with an annular oil receiving channel or sump 66 for receiving excess oil as will presently appear.

The dimensions of the ball races, the construction of the inclined surfaces and sizes of the different elements are constructed with such precision that when the parts are assembled and the ball races are clamped between the flange 51 and the spacer 63, and the spacer 63 is clamped against the plate 47, there will be accurate adjustments of the parts without binding of the antifriction elements.

During the operation of the device, the shaft 42 will expand or elongate more or less due to the operation of the motor and if the same were permitted to expand only in an upward direction, it would carry the rotor toward the upper stator plate 25 and in order to accommodate this expansion, additional clearance would be necessary between these parts thereby materially decreasing the efficiency of the pump.

In order to avoid this difficulty, suitable means are provided for permitting the operating shaft 42 to elongate or expand downwardly. In the construction disclosed, as an example, the lower bearing for the armature shaft 42 is movably mounted in its support. As shown, the lower portion 66 of the motor shell is provided with a downwardly extending projection 67 (see Fig. 1) having a bore 68 coaxial with the shaft 42. Slidably mounted within the bore 68 is an anti-friction bearing, as the ball bearing 69. This bearing seats against a shoulder 71 on the lower end of the shaft 42 and is held against said shoulder by the annular plate 72 which engages the outer ball race and is urged upwardly against the same by a spring 73 seated in a cap 740 threaded in the lower end of the annular projection 67.

In the operation of the device, when the temperature of the motor shaft increases and the shaft elongates or expands, it is free to elongate or expand downwardly forcing the bearing 68 downward against the plate 72 and compressing the spring 73. The spring 73 is of such tension that its pressure on the plate 72 will be sufficient to hold the outer race of the ball bearing in snug engagement with the anti-friction ball members thereby automatically compensating for wear in the lower bearing.

Suitable lubricating means for the upper and lower bearings are provided. For oiling the lower bearing an oiling tube 74 is employed, which tube is secured at its lower end in the projection 67 adjacent to and just above the bearing 69 and having its other end extending through a plug 75 threaded in the flange 14 of the casing 11. A suitable cap 76 provided with a gasket 760, or the like, is threaded on the plug for closing the tube 74 to the entrance of air, provision being made on the cap for lubricating the pump during its operation, as will presently appear. Lubricant will pass from the tube through the bearing 69 and the surplus will be directed by the disked plate 72 into the recess containing the spring 73. A wick 77 may be provided in said recess within the spring 73 for contacting the lower end of the shaft 42 which will permit the oil elevated by capillarity to work back into the bearing after it has all passed out of the tube 74 into the recess in the cap 740. An annular felt member 78 held in position by the holding members 79 and 81 secured in the upper end of the opening 68 is provided for contacting the shaft 42 for preventing the oil from working upward along the shaft during the operation of the motor.

The upper bearing is lubricated in a similar manner through a tube 82 which extends through a plug 83 secured in the upper flaring portion 39 of the casing 11. The inner end of this tube extends through a plug 84 secured in the enlarged outer end of the passage 85 in the plate 47. Suitable packing 86 in the enlarged portion of the passage 85 is adapted to be compressed by the plug 84 for making an oil-proof joint about the inner end of the tube 82.

A hat shaped wick 87, see Fig. 6, having an outwardly extending flange portion 88, an annular vertical portion 89 corresponding to the shape of the projection 49 and an inwardly extending flange-shaped portion 90 having an inwardly extending projection or finger 95 and held in position by a similarly shaped metallic member 91, is provided for conducting oil to the bearing from the tube 82. The metallic clamping member 91 is held in position by screws 92, one of which is shown in Fig. 1.

A thin, metal disk 93, see Fig. 6, is clamped between the spacer member 59 and the inner ball race 54 of the upper ball bearing 52 and has its peripheral edge inclined downwardly. A thin sheet metal disk 94, see Fig. 6, is clamped in position in the inner edge of the wick 87 and has its peripheral edge downwardly inclined for engaging the inwardly extending projection or finger 95 of said wick for forcing the same into engagement with the disk 93 for depositing oil on the disk which by the action of gravity and centrifugal action will cause the same to fall or be thrown upon the balls 57 and from there the oil falls by gravity onto the balls of the bearing 53. Excess oil is collected in the sump 66 in which is mounted a wick 70 which contacts the oil slinger 96 and prevents oil from passing down the shaft 42. The oil slinger having its inverted cone-shaped surface 96 is adapted to assist in preventing oil from following down the shaft. Any oil collecting or deposited on the surface 96 will pass upwardly along said surface and be thrown outwardly by centrifugal force into the space between the ball races for oiling the bearings.

Current for operating the motor is led into the casing through suitable bushings 97. Each comprises a steel fitting or plug 98 having a tapered, threaded end engaging an internal bore through the casing. The steel fitting has a central bore within which is mounted a sleeve 99 of hard rubber, or the like, and a plug 101 of brass, or the like, is screw threaded in the sleeve 99 and has its lower end threaded for receiving a nut for clamping a terminal 102 of a conductor 103. The bushing may, if desired, be covered by a suitable cap 104. The lead 105 is connected to the plug 101 in any suitable manner, as by screw 106. The terminal 102 is prevented from shorting by a washer 107. I find that hard rubber posseses definite advantages in producing a vacuum seal. It seems to "freeze" both to the steel and to the brass. It is only with the greatest difficulty that the bushing can be made vacuum-tight, if a phenolic sleeve is used.

In Figs. 9, 10 and 11 is shown a modified form of construction. This construction differs from that described above in that the rotor 108 is provided with a spiral groove 109 on its upper face and with a corresponding spiral groove 110 on its lower face. The groove 110 extends in the opposite direction from that of 109. The inner surface of the plates 111 and 112 of the stator are smooth.

The remaining parts of this form of the pump are substantially the same as that described above.

In both forms of the construction, suitable means are provided for air cooling the motor. In the form of construction shown, radiating fins 113 are attached to the casing 11. These fins not only assist in radiating the heat generated by the operation of the motor but they also afford rigidity to the structure.

In order to secure the best results, a backing pump is preferably employed in conjunction with the molecular pump. As shown in Fig. 12, a vacuum or backing pump 113 of the usual or any well-known construction is connected in series with the molecular pump 10. Under favorable circumstances a vacuum as low as approximately 2 to 4×10^{-7} mm. has been obtained with the pump operating at about 10,000 R. P. M. A vacuum this low is possible only if the parts be accurately ground and fitted; the rotor almost perfectly balanced to prevent vibration; and the clearances between the movable and stationary parts be reduced to a minimum in order to prevent leakages. In the present construction, clearances of approximately .00075 to .001 in. have been found to be practical even though the clearances are further slightly reduced when the temperature increases due to the slight differential expansion of the aluminum rotor over the spacer of the rotor which is of mild steel because of the provision for elongation of the operating shaft downwardly from the pump to compensate for temperature changes without appreciably affecting the relative positions of the rotor and stator members.

A pump with such clearances would "seize" were the lower bearing not slidably mounted or other means provided for permitting the linear expansion of the shaft in the direction away from the rotor instead of toward it. Furthermore, if the shaft 42 expanded upwardly instead of downwardly, see Fig. 1, the rotor 28 would be carried upwardly with the shaft and even though sufficient clearance be provided above the rotor to prevent the same from coming into contact with the upper plate 25, the rotor would be carried away from the lower plate 26, thus increasing the clearance between these members and thereby decreasing the efficiency of the pump.

During the operation of the pump, the gas in the vessel that is being exhausted will expand and the molecules will enter the intake port 29 into the spiral groove or channel 44 of the upper plate 25 of the rotor and being confined in the channel they will, on account of their molecular movements, repeatedly bombard or come into contact with the rotating disk 28. This rotating disk will, at each impact, impart—or tend to impart—to the molecules a forward movement thus causing them to travel along the spiral passage 44 to the periphery of the rotating disk and from thence into the spiral channel or passage 45 on the lower plate 26 and out through the discharge passage 31 at the axis of the pump. From the discharge passage these molecules travel through the passage 50 to the passage 114 and from thence to the backing pump 113 (see Fig. 12) which is employed to maintain a low pressure on the discharge side of the molecular pump.

Since the pump with the operating mechanism is entirely enclosed within an airtight casing and the motor so arranged that the field thereof is in intimate contact with the metallic casing for dissipating the heat generated by the operation of the motor, the mechanism is not only prevented from overheating but the pump is capable of an exceedingly high degree of efficiency, due partly to the speed at which it may be operated, partly to the accurate balancing, finishing and fitting of the various elements and partly to the nature of the mechanism employed.

The speed of the motor will depend on a number of factors. With a rotor having a diameter of approximately 7 inches, a speed of 10,000 R. P. M. has been found to give satisfactory results. Higher speeds may be employed. By providing a channel at the periphery of the rotor as a portion of the pump passage, the diameter of the rotor over one having channels adjacent the sides only, may be greatly reduced without reducing the length of the passage through the pump.

This is considered an important feature of the device since sufficient length of channel is obtained without increasing the diameter of the rotor to a point where gyroscopic action would be troublesome at high speeds, or where high rim speed would reduce the safety factor.

In the operation of the pump it is sometimes desirable to lubricate the mechanism while the pump is in operation as when, through inadvertence, the mechanism is not properly lubricated before beginning the operation.

Under such circumstances, it is necessary that the lubricating operation be performed without permitting air to enter the casing as otherwise the vacuum in the casing will be lost or reduced and the efficiency of the device will be temporarily impaired.

Any suitable mechanism may be employed for this purpose. In the form of construction shown, the plugs 75 and 83 are provided with caps 76. Each cap is adapted to be threaded on the outer end of the plug and is provided with an internal recess 115 in which is seated a gasket of lead, or the like, for engaging the outer end of the plug 75. The cap is also provided with a nipple or extension 117 having a bore 118 extending therethrough in connection with the recess 115. The outer end of the bore 118 is internally threaded and plug 119 is adapted to be screwed in the end of the nipple for closing the passage 118. When it is desired to lubricate the pump while same is in operation or after it has been operating and a partial vacuum has been produced in the casing, the plug 119 is removed and coupling 121, of rubber or the like, is attached to the outer end of the nipple as clearly shown in Fig. 1 of the drawings.

A glass tube 122 is secured in the opposite end of the coupling 121. After the tube 122 and coupling 121 have been attached to the nipple, as shown in Fig. 1, and lubricant is poured into the tube, the cap 76 is slightly released and the pressure of the air on the outer column of lubricant in the tube 122 will force the same along the lubricating passages to the interior of the pump.

Before the level of the oil in the tube 122, which can be seen through said tube, reaches the coupling 121, the cap 76 is turned back on the plug 75 to close the oil passage after which the process may be repeated, or, if sufficient oil has been supplied, the coupling 121 may be removed from the nipple 117 and the plug 119 restored to its position to prevent the entrance of dirt and foreign matter into the passage 118.

It is thought from the foregoing taken in connection with the accompanying drawings that the construction and operation of my device will be apparent to those skilled in the art and that changes in size, shape, proportion and details of construction may be made without departing from the spirit and scope of the appended claims.

What I claim is:

1. A molecular pump comprising a stator member, a disc rotor member spaced from the stator at a minimum clearance and cooperating therewith to form a molecular pumping unit, an elongated shaft for rotating the rotor, a motor for driving the shaft, a pair of bearings for the shaft including a fixed bearing closely adjacent to the rotor for maintaining a substantially fixed spaced relation between the rotor and stator, and a slidable bearing for the outer end of the shaft, whereby the major portion of the shaft extends between said bearings and the shaft may freely elongate in the direction of its outer end consequent upon the expansive effect of heat developed by the motor without appreciably varying the clearance between the rotor and stator and without straining the shaft or either of the bearings.

2. In a molecular pump, an airtight casing, a motor in the casing having an elongated shaft, a rotor mounted on the shaft, a stator fixed in the casing spaced from the rotor at a minimum clear-

ance and cooperating with the rotor to provide a molecular pumping unit, a pair of spaced bearings for the shaft including a bearing fixed in the casing closely adjacent to the rotor and a bearing mounted in the casing remote from the rotor and slidable with relation to the casing, whereby the major portion of the shaft extends between said bearings and the shaft may freely elongate under the influence of heat developed by the motor without appreciably varying the clearance between the rotor and the stator and without straining the shaft or either of the bearings.

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