Jan. 2, 1934.

J. DUBROVIN

1,942,139

MOLECULAR VACUUM PUMP

Filed Dec. 26, 1930

3 Sheets-Sheet 1

Fig. 1

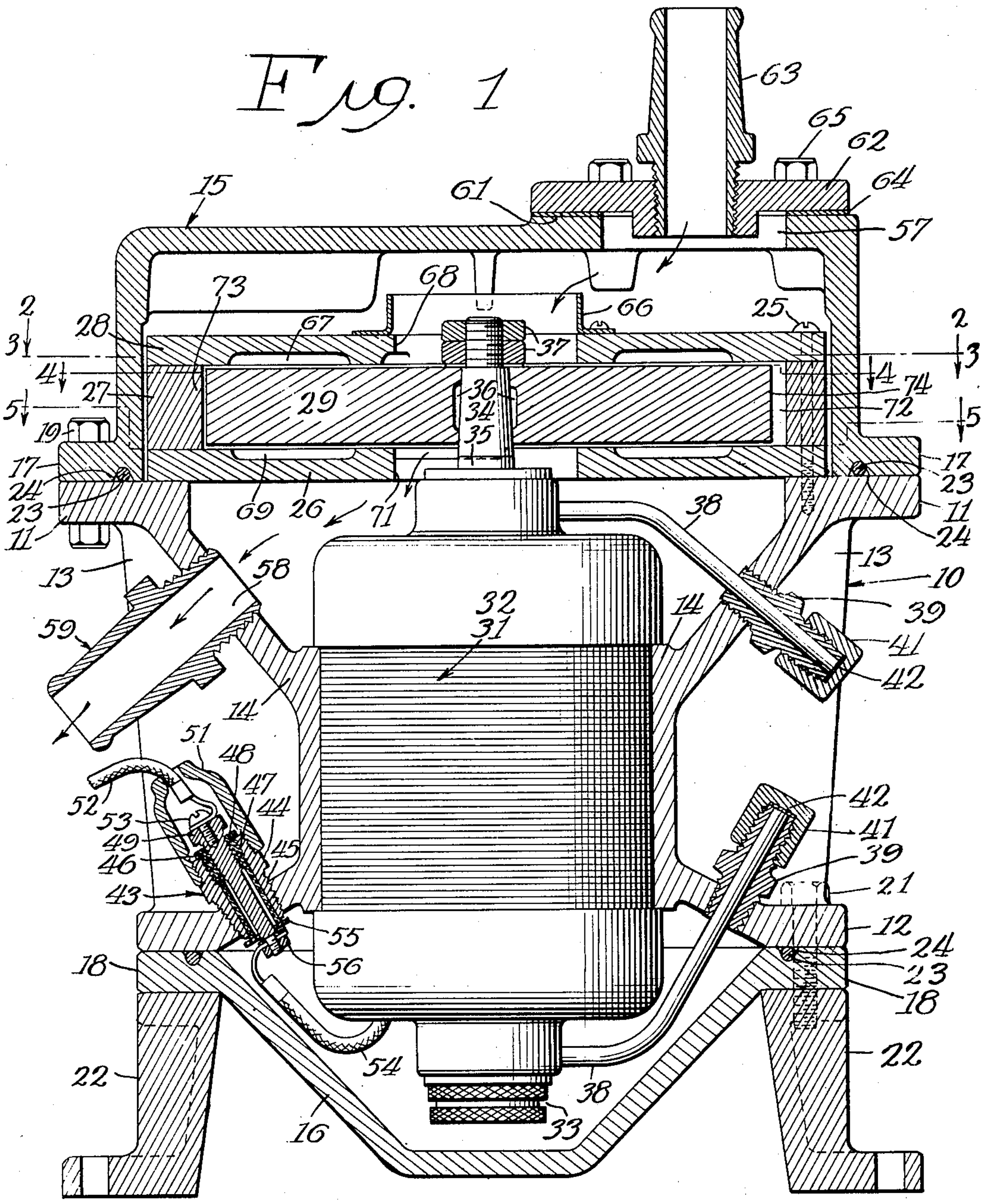

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Fig. 2

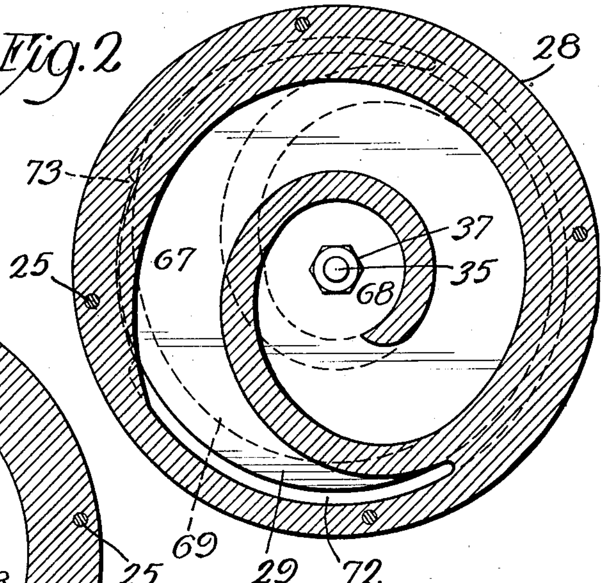

Fig. 3

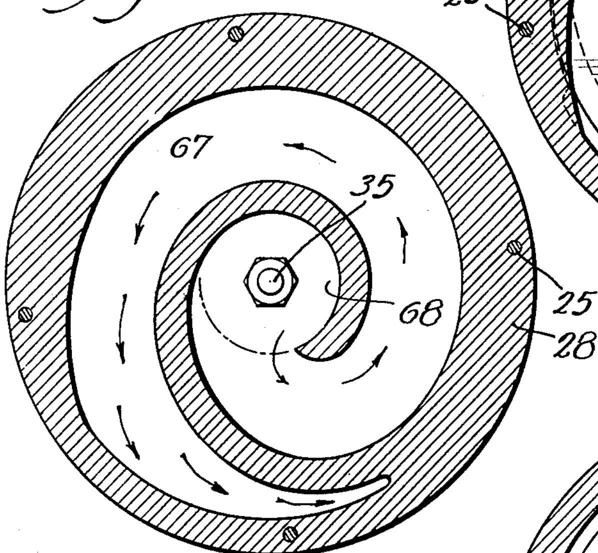

Fig. 4

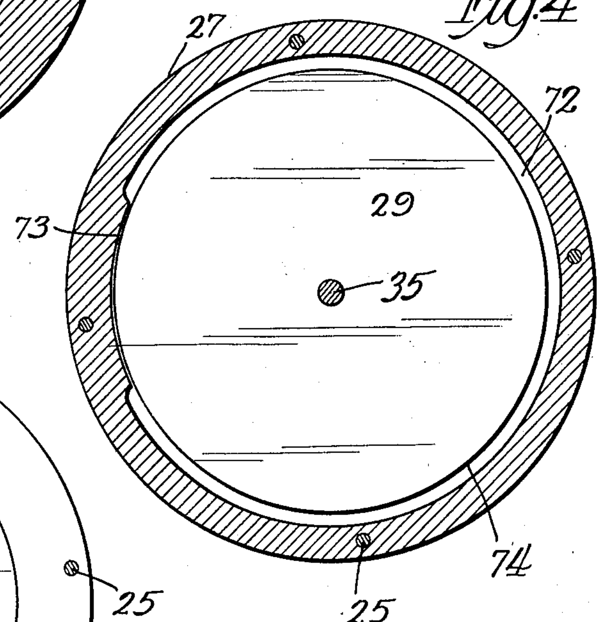

Fig. 5

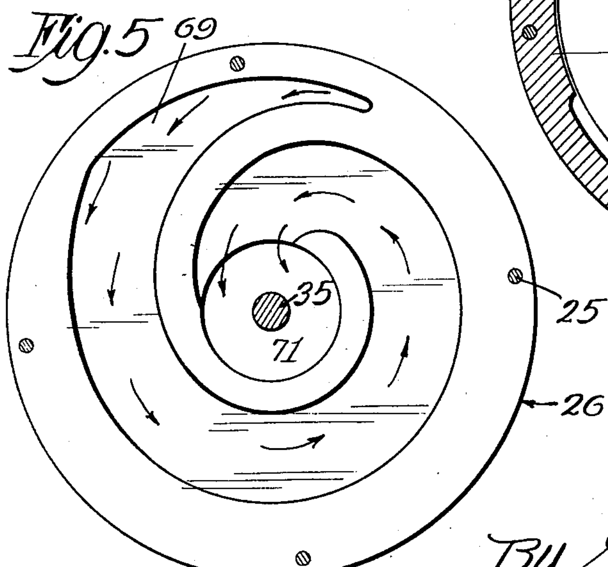

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Fig. 6

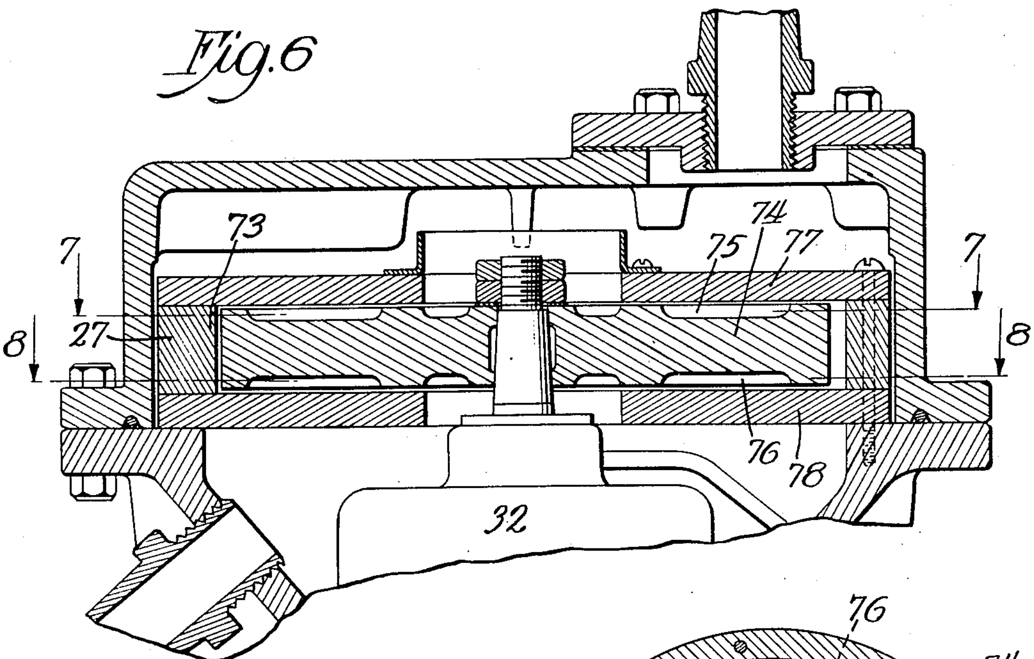


Fig. 7

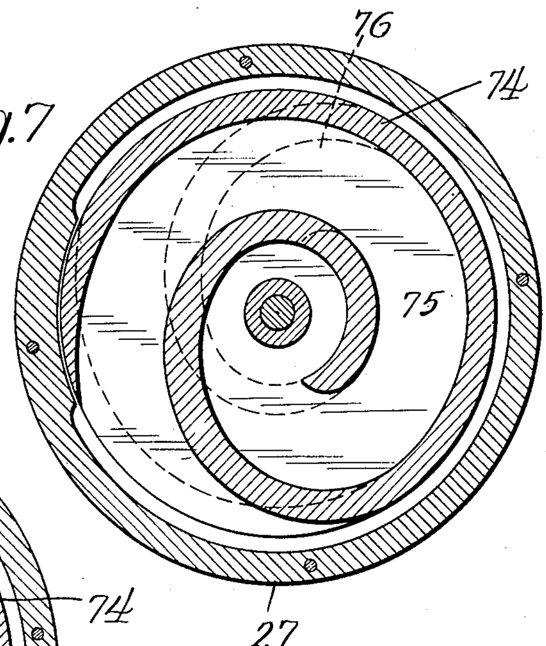
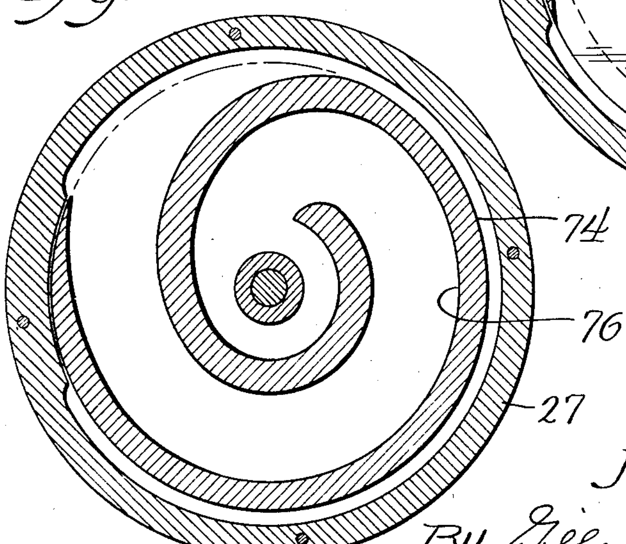


Fig. 8



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Patented Jan. 2, 1934 1,942,139

UNITED STATES PATENT OFFICE

1,942,139

MOLECULAR VACUUM PUMP

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Application December 26, 1930
Serial No. 504,715

9 Claims. (Cl. 230—118)

This invention relates to improvements in molecular vacuum pumps.

The objects of this invention are to produce a practical, effective and more efficient pump; to produce a pump having a compact design, a cheaper construction and a greater simplicity of manufacture.

These and other objects and advantages will become apparent from the specifications and the appended drawings in which—

Fig. 1 is a vertical section through the pump showing the motor, however, in elevation;

Fig. 2 is a section on the line 2—2 of Fig. 1 and indicates by dotted lines the relative position of the two spirals;

Fig. 3 is a section through the upper plate on the line 3—3 of Fig. 1;

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

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

Fig. 6 is a vertical section through a portion of a modified form of pump;

Fig. 7 is a plan view on the line 7—7 of Fig. 6; and

Fig. 8 is a plan view on the line 8—8 of Fig. 6.

The pump comprises a cylindrical casing 10 provided with a top flange 11, and a bottom flange 12, cooling fins 13, 13 and a motor supporting portion 14. The casing is closed by the top cap 15, and the bottom cap 16, each of which carries a flange 17 and 18, respectively, which are drawn tight in companion flange arrangement against the casing flanges 11 and 12. The cap 15 is held by the bolts 19. On the lower flange, certain of the bolts are replaced by the cap screws 21, which are tapped into the legs 22. The casing is made vacuum tight by the circular gaskets 23, 23, which fit in grooves 24, 24, cut into the upper and lower caps. For certain extreme service conditions, the gasket is omitted and the grooves are connected to a separate vacuum pump. With this arrangement proper sealing agents may also fill the groove.

Held to the flange 11 by the screws 25 is an assembly consisting of a lower plate 26, which bears upon the inner portion of the flange 11, a spacing ring 27 and a top plate 28, these together forming the stator element of the pump. A disc 29 mounted between the two plates forms the rotor element. The clearance between the plates and disc and disc and ring (in one place) is exceedingly small (.0015 to .002 inches), which requires that all the surfaces, including the flange 11 be ground and finished with precision.

The plates may be of any metal; I prefer cast iron, but because of the high speed, the rotor 29 should be as light as possible and I find it very advantageous to make this from either hard aluminum or magnesium alloys.

The portion 14 of the casing is bored out to receive the field laminations 31 of a series type motor 32, which are forced home under considerable pressure. The motor itself forms no part of this invention, consequently, its details are not shown. It is, however, provided with a special "step" bearing (shown cased at 33) which adapts it to run in a vertical position. The disc 29 is held on the conical portion 34 of the motor shaft 35 by the Whitworth keys 36, 36 and the nuts 37, 37. The usual oiling means for a motor are not used. Instead the small tubes 38, 38 conduct grease to the bearings. The tubes are carefully sweated into the nipples 39, 39, which are tapped into the casing 10. After the tubes have been filled with grease, the caps 41, 41 are screwed down over the nipples until the gaskets 42, 42 engage the flat outer face of the nipple. This system of lubrication is effective and vacuum tight.

When the pump is in operation, there can be no "ventilation" of the motor, since the atmosphere around it is usually exhausted to below one micron. I find that the long thermal contact between the field laminations and the casing is the most effective means of cooling the motor and the fins 13 are provided to radiate the heat as quickly as possible. They also materially stiffen the casing, a very necessary precaution, since the total clearance in the device is less than five thousandths of an inch.

Current is led into the casing through two bushings 43. They comprise a steel fitting 44 having a taper threaded nipple 45 and an internal bore 46 terminating in the taper tapped portion 47. A sleeve 48 of hard rubber is screwed into the bore and a plug 49 of brass which also bears a taper threaded portion is screwed into the sleeve. I prefer to cover the bushings with the protective cap 51. The lead 52 is connected to the plug by the screw 53 while the motor lead 54 is prevented from shorting by the washer 55 and held connected to the plug by the nuts 56. I have found that hard rubber possesses definite advantages in producing a vacuum seal. It seems to "freeze" both to the steel and the brass. It is only with the greatest difficulty that the bushing can be made vacuum tight if a phenolic sleeve is used.

The intake and outlet for the pump are through the space 57 and the bore 58 of the nipple 59, respectively. It is essential that a backing pump be used. Usually it is sufficient to connect this to the nipple by means of a rubber hose. For the highest vacua, all glass connections should be made between the vessel to be exhausted and the molecular pump. In that case, the manifold tube should have an integral glass flange ground flat to mate with the flange 61 which surrounds the intake, and be sealed thereto with vacuum wax. Rubber connections are a great convenience and are useful in short experiments. The flange 62 carrying the rubber tube nipple 63 is consequently provided which may be pulled tight against the gasket 64 by the cap screws 65.

A baffle or guard ring 66 surrounds the central aperture in the plate 28 to prevent any possibility of broken glass or other material working between the rotor and the plates.

Before discussing the gas path through the device, it is necessary to examine the plates 26 and 28 and the spacing ring 27.

Fig. 2 is a view showing the lower portion of the plate 28 and (dotted) the elements below it. It will be seen that the plate bears a wide, shallow channel 67, shaped as a one turn spiral. Its depth should be large in comparison with the clearance between plate and disc and in this instance is about 3 millimeters deep. The plate also bears a large central aperture 68 forming the inlet passage to the pump elements proper.

The lower plate 26 bears a similar but reversed spiral channel 69 and a large central aperture 71 forming the outlet passage from the pump elements proper. Between the disc 29 and the spacing ring 27, there is a circumferential channel 72 which is blocked over a small sector by an integral projection from the ring forming the barrier 73. Between the barrier and the disc 29 the clearance is as small as is commercially practical.

The path of the gas through the device is shown by the arrows. It enters the intake 57, passes over the baffle 66, through the central orifice 68 in the plate 28, into the spiral channel 67. From there, it is flung against the walls of the spacing ring 27 in the channel 72 and carried along by the cylindrical face 74 of the disc 29 until it reaches the barrier 73. It then enters the spiral 69 and travels therein until it passes through the central orifice 71 in the plate 26 and out into the backing pump through the exhaust passage 58.

In the modification shown in Figs. 6, 7 and 8, the conducting channels are placed in the disc rather than in the plates. The disc 74 has the spiral channel 75 formed in its face, and a like, but reversed channel 76 in its lower face. The plates 77 and 78 present plane surfaces. All other features of the pump remain the same. In operation, this latter pump appears to duplicate the performance of the preferred form, but is more difficult to build since to form oppositely directed spirals in the disc and still have it remain balanced at 18,000 R. P. M. requires very careful work.

For a clear understanding of the function and nature of the improvements which I have herein set forth, the difference between molecular pumps and those bearing a certain mechanical similarity, namely centrifugal pumps and viscosity pumps, must be clearly held in mind.

In a centrifugal pump, the particles of the pumped mass are pressed against the rotating element by some force, usually atmospheric pressure, and as the particle slides out radially across the rotor in response to the centrifugal force, some of the velocity and energy of the periphery of the rotor is gradually imparted to it.

In a viscosity pump the liquid or gas filling the space between the rotor and stator is subject to shearing stress since the fluid tends to adhere to the pump elements and, in yielding to the stress, builds up a pressure differential between the intake and the outlet of the pump.

In a molecular pump, a free moving molecule strikes against the surface of a rapidly whirling element. Some adhere; more bound off in the direction of the resultant force and if a conduit confine their movements, the molecules will bound off the walls, hit the moving element again and generally be driven along in the desired direction. By no means do all the molecules follow a uniform path, nor do all of them progress with the rotor but the statistical result is a pronounced movement toward the outlet and a pressure differential corresponding to the kinetic energy of the mass flow.

Taking one gas to be specific, the average mean free path of a molecule of nitrogen at atmospheric pressure is given as 9.44×10^{-6} cm. When it has travelled through this microscopic distance, the molecule will collide with another. In comparison with the numbers of molecules in the space at this pressure, the chances of many travelling far enough to hit the moving wall are remote. Also those that are displaced are retarded by the cloud of molecules in the space. A molecular pump at such a pressure, though workable, is ineffective. The average mean free path of a molecule of nitrogen at one micron pressure is, however, 71.7 centimeters and its average velocity at 20° centigrade is 496 meters per second. One micron is a pressure which is easily maintained by a good backing pump. In the incredible number of collisions that result, it may be assumed that nearly all the molecules will sometime collide with the moving element. Only the moving area propels the molecules ahead, consequently, the more surface area of the conduit occupied by the moving part, the better is the pump.

It follows that the pump reaches its greatest efficiency when the ratio of the moving surface per unit length of conduit to the cross sectional area of the conduit is as great as practicable. This limit is set by the requirement that the depth of the channel must be large in comparison with the clearance between plate and disc, the limited dimensions of the disc and the certain length of channel that is necessary.

It also follows that, keeping all other conditions constant, the longer the path through the pump, the more effective the pump becomes. It is true also that the efficiency of the pump will rise with increasing motor speed. Whether or not an increase of speed beyond 18,000 R. P. M. is of practical value seems to me questionable, but even at 18,000 R. P. M. tremendous rim speed exists which rigidly limits the diameter of the rotor. The advantage of using both sides and the periphery of the rotor is now apparent. I am able to secure sufficient length and also a wide and shallow channel without increasing the diameter of the rotor to a point where gyroscopic effects are bothersome, or high rim speed reduces the safety factor.

When the mean free path of the molecules equals the depth of the conducting channel, the pump really begins to work and becomes more and more effective as the pressure falls.

In contrast to the usual high vacuum pump which approaches high vacua slowly, at a certain stage in the exhaust, this pump seems to "take hold" and the pressure thereafter falls rapidly. The low limit of this pump is below the sensibility of the usual measuring devices and so far, I am familiar with no method which will determine its ultimate performance with accuracy or precision.

The particular embodiment shown has been chosen by way of illustration only. For example, cylinders might be substituted for the rotor and plates. If the benefit of the long circumferential path around the periphery of the rotor is foregone, other arrangements suggest themselves, viz, the two faces of the disc might be operated in parallel, or if a passage through the disc near its center were provided, the intake and outlet might be at the periphery, or other arrangements and changes might be made without departing from the spirit of the invention herein set forth.

What I claim, therefore, is:—

1. A molecular pump comprising a casing having a flared upper portion and a cylindrical bore portion, a motor positioned within the bore and having its field laminations in close contact with the interior wall of the bore, two plates maintained in spaced relation upon the casing, a disk rotatably mounted between the two plates, said plates having gas conducting channels upon their opposed faces and a connecting channel extending about a major portion of the periphery of said disk, a shaft for said motor connected to said disk for rotating the same, said shaft extending through an enlarged unobstructed opening in one of said plates, caps closing the ends of the casing and an inlet to and outlet from the pump, said outlet being located in the flared upper portion of said casing.

2. In a molecular pump, a casing, a stator member within said casing, an inlet passage for said casing, a rotor member rotatably mounted in said stator member, a shaft for operating said rotor member, the bearings for said shaft being supported independently of said stator member, one of said members having a spiral groove therein, said stator being provided with an opening offset from said inlet for conducting gas from said casing to said groove and a baffle surrounding said opening.

3. A molecular pump comprising a casing having a flared upper portion and a cylindrical bore portion, a motor positioned within the bore and having its field laminations in close contact with the interior wall of the bore, two plates maintained in spaced relation upon the casing, a disk rotatably mounted between the two plates, said plates having gas conducting channels upon their opposed faces and a connecting channel extending a material distance along the periphery of said disk for conducting molecules of gas along the same, the connections between the grooves and the channel being spaced angularly apart around the periphery of the disk, caps closing the end of the casing and an inlet to and an outlet from the pump.

4. In a vacuum pump, a casing, a pair of spaced stationary elements within the casing having a shallow, wide spiral groove formed in their opposed faces, one spiral having a clockwise direction, the opposing spiral having a counter clockwise direction, a rotatable member between the elements, said rotatable member having a peripheral face, and a passage concentric with said peripheral face and extending about a major portion of said rotatable member and connecting at its ends with the ends of the two grooves for conducting gas along the periphery of said disk and from one of said grooves to the other.

5. In a molecular pump, a casing having therein a pair of plates spaced apart and provided with open channels, a disk rotatably mounted between the plates, a passage having its opposite ends connecting the channels in the two plates, said passage extending about a major portion of the periphery of said disk, one of the plates having an aperture to deliver gas to the central portion of the disk and the other plate having an aperture to receive gas discharged by the central portion of the opposite face of the disk.

6. In a vacuum pump, a casing, a pair of spaced plates within the casing having gas conducting channels in their opposed faces, a ring maintaining the plates in spaced relation, a rotatably mounted disk having a cylindrical face between the plates and within the ring and having a sensibly less diameter than the bore in the ring to provide an annular gas passage between the cylindrical face of the disk and the ring, an inwardly extending sector in the ring closely approaching the circumference of the disk forming a barrier in the annular passage, and means connecting each of the gas conducting channels separately with the annular passage at opposite sides of the inwardly extending sector.

7. In a molecular pump, a casing, a stator member within said casing, an inlet passage for said casing, a rotor member rotatably mounted in said stator member, one of said members having a spiral groove therein, said stator being provided with an opening offset from said inlet for conducting gas from said casing to said groove and a baffle surrounding said opening for preventing entrance of foreign matter into the pump.

8. A molecular pump comprising a stator member having a pump chamber therein, a rotor member mounted within said chamber, means for rotating said rotor member, said rotor member being in the form of a disk having its faces in proximity to the walls of said chamber and having its periphery spaced from the peripheral wall of said chamber to form a passage extending a major portion of the distance around said disk, one of said members having spiral channels at opposite sides of said disk for conducting molecules of air across said disk at one side thereof into one portion of said passage and for conducting said molecules from another portion of said passage back across said disk at the other side thereof during the operation of said pump.

9. A molecular pump comprising a casing, two plates spaced apart within the casing, a disk rotatably mounted between the two plates, an intake and discharge for said pump, a passage extending a major portion of the distance about the periphery of said disk, said disk having spiral channels at opposite sides thereof for conducting molecules of gas across one side of said disk into said passage and for conducting said molecules back across the opposite side of said disk during the operation of said pump, the outer ends of said channels being angularly spaced about the peripheral edge portion of said disk.

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