Sept. 27, 1960 E. E. ECKBERG 2,954,157

MOLECULAR VACUUM PUMP

Filed Jan. 27, 1958 3 Sheets-Sheet 1

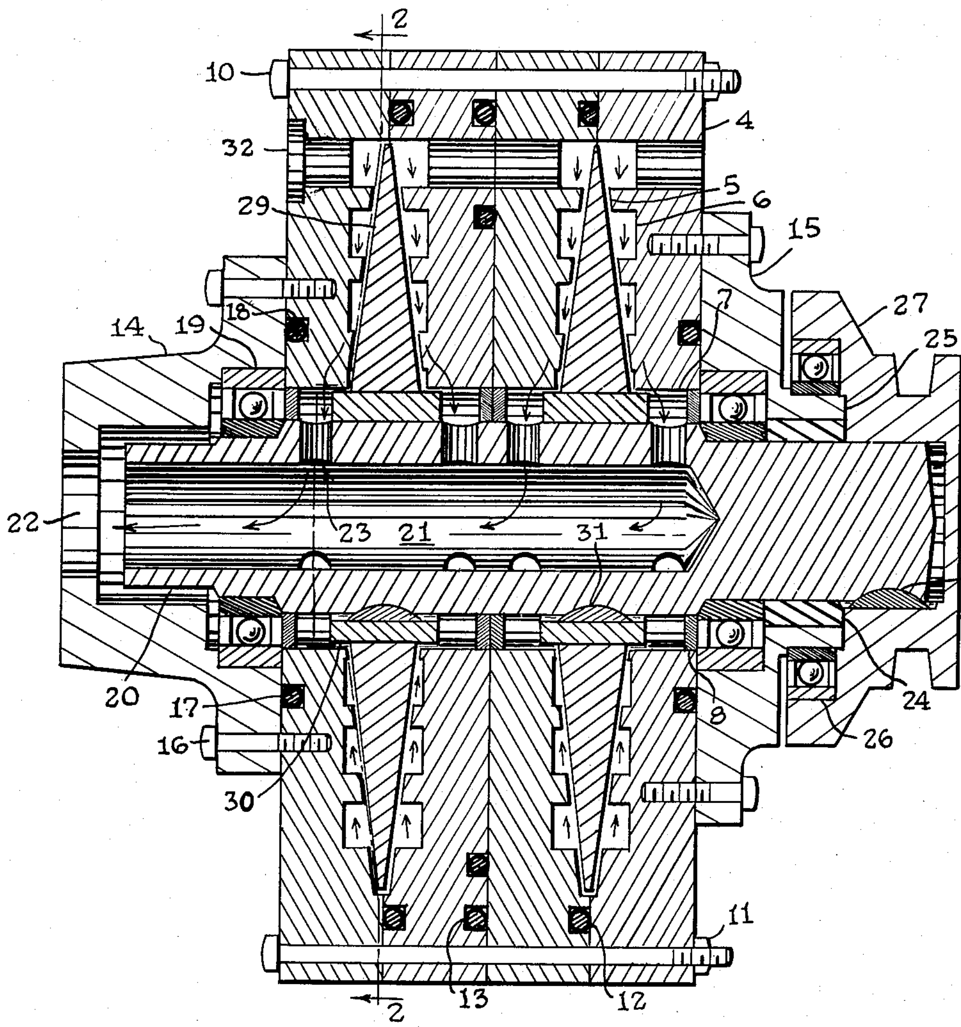

Fig. 1

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Filed Jan. 27, 1958 3 Sheets-Sheet 2

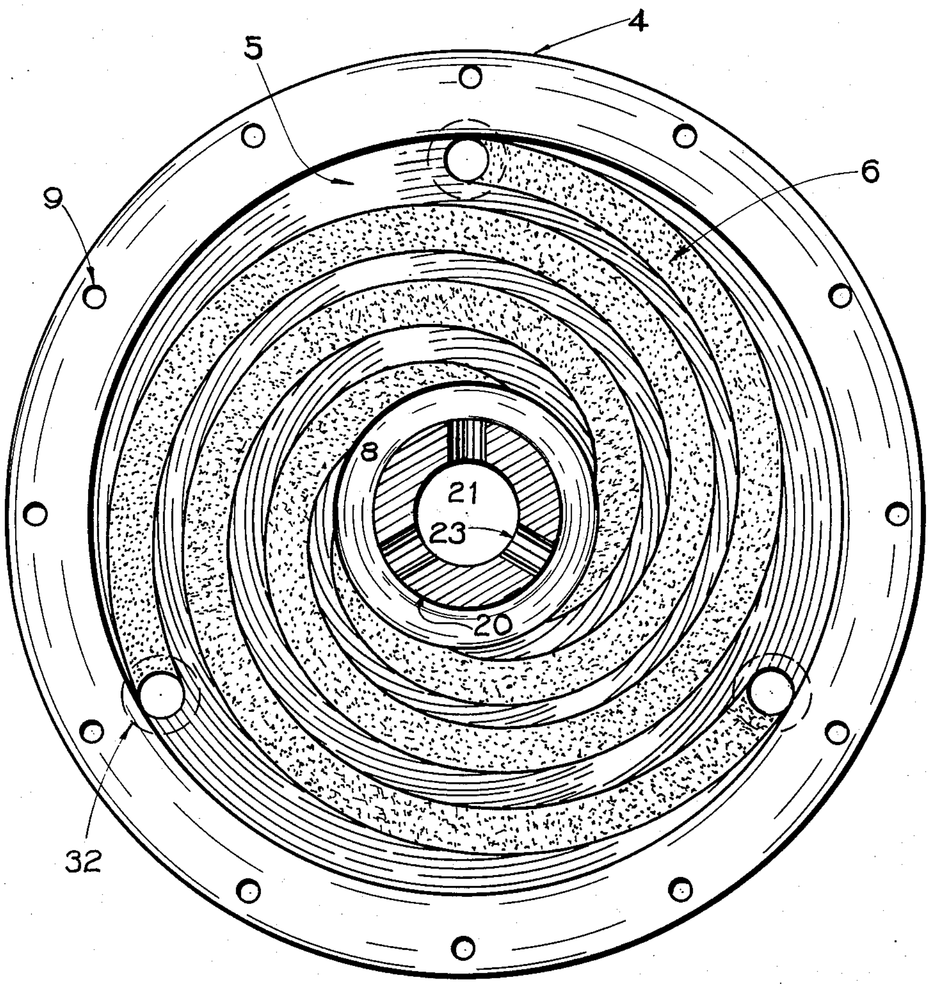

FIG. 2.

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MOLECULAR VACUUM PUMP

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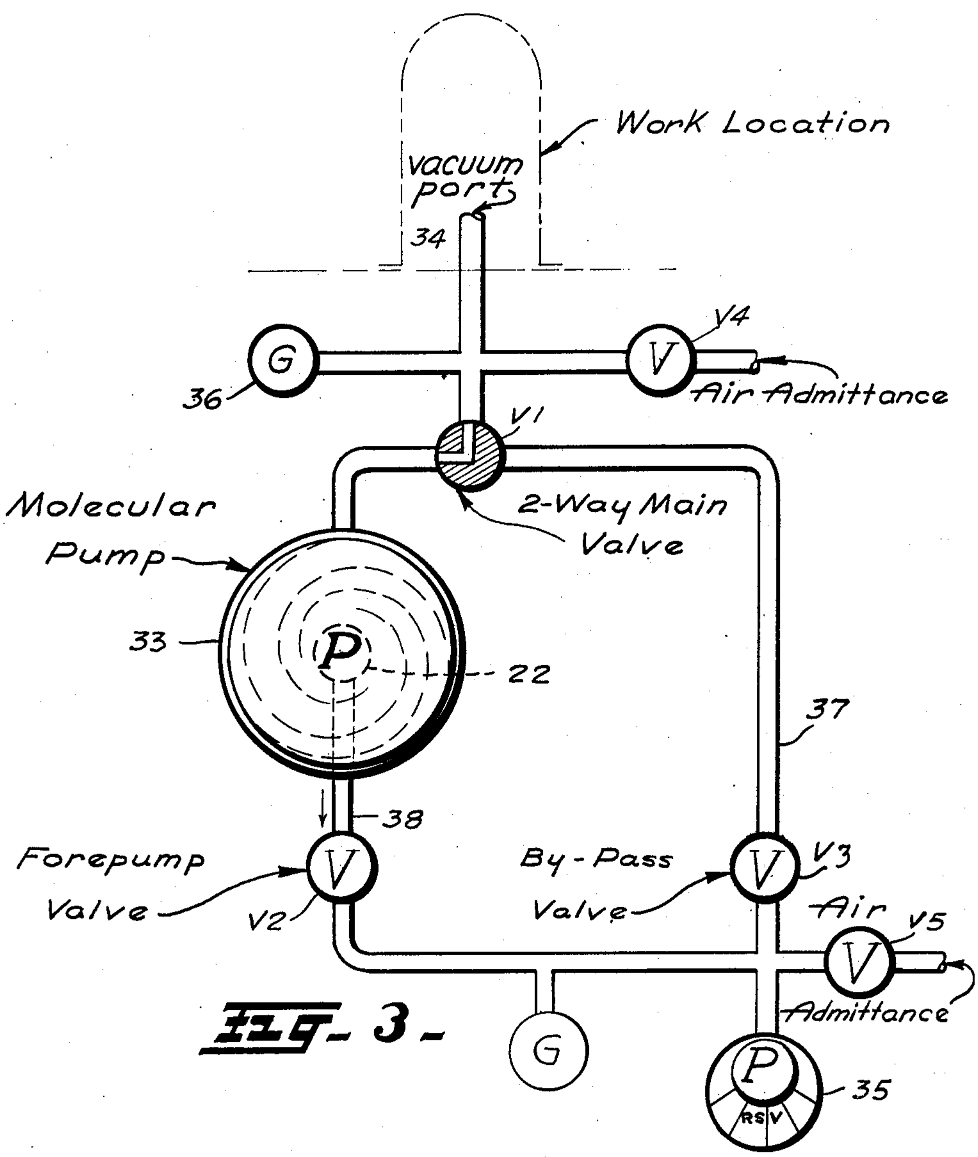

Fig. 3

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MOLECULAR VACUUM PUMP

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1 Claim. (Cl. 230—118)

My invention relates to improvements in molecular vacuum pumps and more particularly to a multiple molecular vacuum pump with mechanism capable of producing the highest of attainable vacua.

The objects of my invention are to produce a more effective and more efficient vacuum pump; to produce a pump of a practical design at a moderate cost yet unstintingly to avail its construction and all its components with the highest qualtiy and a maximum of test capacity maintaining withal a true simplicity with respect to manufacture.

These and other objects will present themselves and become apparent from my specifications and the appended drawings in which—

Fig. 1 is a vertical section through the pump showing however the inlet location and the outlet location by full lines and dotted lines, respectively;

Fig. 2 is a plan view on the line 2—2 of Fig. 1 and indicates the configuration of the spiral grooves; and the probable path of the gas molecules through the pump being suggested by the use of arrows; and

Fig. 3 is a schematic of one form of vacuum system using this invention.

The pump comprises a main body casing group, the members of which are an aggregate or a plurality of paired cylindrical plates **4**, each plate having a recess of tapered shape **5**, centered on one lateral face. This recess is provided with several spiral groves **6** having a uniform width. The depth of the spiral groove varies; equal in depth to its width at the starting point out near the periphery of the plate, gradually decreasing, or lessening, in depth as the spiral makes its progress toward the central portion of the plate, in an Archimedian manner, at which point the bottom or base surface of the spiral groove meets evenly with the surface of the tapered recess. At this location a hole **7**, is provided through each plate, centered with respect to the great circle of both the plate and the tapered recess; bushing **8** is press-fitted into hole **7**. The length of this bushing approximates one-third of the thickness of the cylindrical plate at this point, or at hole **7**. Provided at the outer lateral periphery of the cylindrical plate **4**, a flat rim face is machined on the same lateral face of the cylindrical plate that has the recess with the spiral grooves. This flat rim portion is of sufficient band width to provide space for: bolt holes **9**, through the plate, so indexed and located as to facilitate their exact duplication on all the remaining cylindrical plates. Bolts **10**, with nuts **11**, provide a positive and substantial method of bonding all aggregate plates. Also on the flat rim portion is ample width to provide for circular gasket **12**, with a suitable gasket-groove **13**. This gasket and groove are essential; they are provided singly between each pair of cylindrical plates, and double between pairs of cylindrical plates. A tight vacuum seal is assured by this gasket and gasket-groove assembly. The gasket-grove insures a limit to the compression as imposed upon the gasket material and lends a maximum of strength to the aggregate cylindrical paired and matched plates bonded and bolted together. An observation of the pattern of the spirals as taken from either end of the cylindrical plate group will disclose the spirals make their respective and inward progress in an identical manner; their respective starting points and their respective finishing points all match, one and the other, respectively. Their actual reduction to practice with respect to machining will require close cognizance of the following, to wit: each pair of cylindrical plates will be so laid out for the formation of the spiral that the first plate of the one pair may have the progress of its spiral (for example) in a counter-clockwise fashion. The second plate of this one pair, to match the first plate when assembled, will have the spiral layout so applied as to insure its spiral being machined opposite to that of the first, or clockwise. Thusly a true matching of the spiral grooves may be attained when this first pair are placed together in assembly, spiral grooved face meeting spiral grooved face. And so on for each succeeding pair of spiral grooved cylindrical plates of the main body casing group. The bushings **8**, have an equal bore and likewise a common axis. Concentric, upon the two outer faces of the cylindrical plate group, or aggregate, are provided flanged bearing housings **14**, and **15**. These two flanged bearing housings are aligned and rigidly secured to the main body casing group by means of screws **16**; there also being provided circular gasket **17**, with its gasket-groove **18**, to assure the vacuum tight seal of these respetcive flanged bearing housings at their surface abutment points on the casing. Main bearings **19**, are contained in both flanged bearing hosuings **14**, and **15**, respectively. The two main bearings support the pump shaft **20**, hollow at **21**, from one end only; the hollow portion of the shaft will function as the conductor for the outlet port of the pump at **22**. The latter exhaust port hole (open or hollow shaft end) is that end of the shaft which rides in flanged bearing housing **14**. The shaft has plurality of orifices **23**, permitting a free gas molecule passage through the shaft at locations which approximate the center of that space remaining about the shaft at hole **7**. The other end of the shaft **20**, is supported by the second of the two main bearings **19**, which is contained in flanged bearing housing **15**, at which point the hollow portion of the shaft terminates; the shaft continues through this flanged bearing housing **15**, continues through and beyond the bearing and beyond the housing itself, being reduced somewhat in diameter and solid of character. This solid end portion of the shaft surrounded with extreme close tolerance by a long journal bearing **24**, contained concentrically within flanged bearing housing **15**. A reduced turned section **25**, at the outer end of the hub of flanged bearing housing **15**, accommodates ball bearing **26**, upon which the driven pulley **27** rides freely and true. The driven pulley is counter-bored to receive the end of the shaft, to which it is made rigid and secure by means of key at **28**. The outer lateral face of the driven pulley is solid.

In the double-tapered space formed by the matching of the conical shaped recesses **5**, of each pair of cylindrical plates there is provided with an extreme close tolerance (0.0005 in. to 0.0015 in.), a double-tapered disc **29**, having a hub member press-fitter at **30**, and keyed to the shaft with key **31**. The hub protrudes into the space formed by hole **7**, on both sides of the disc **29**. The hub fits the confines of the hole **7** with respect to rotary freedom with a tolerance approximating that of the double-tapered disc within the confines of the recess. From the end of the protrusion of the hub member **30**, to the closer face of the bushing **8**, a space exists surrounding the shaft at this region—this region is within the limits and the boundary of orifices **23**, and these orifices do not over-lap to the region of either the disc **29**, its hub **30**, or shaft bushing **8**. Inlet port-holes **32**, are located and provided at the starting point of each spiral groove 6, on all aggregate cylindrical casing plate members; these port-holes are so indexed and located as to make corresponding ports on the other plates common and in true alignment; the port-holes will serve as the connecting point(s) to be joined to a common high vacuum manifold.

I have selected hard aluminum or magnesium alloy as the material for the cylindrical plates of the casing group; this material, too, was preferred for the double-convex tapered discs-especially because of the relatively low density of aluminum. The shaft bushings are bronze. The hub member of each disc is made of brass. Both flanged bearings are of milled steel, or iron. The long journal which serves as a seal about the reduced solid portion of the shaft is of a synthetic pressed metallic material—it appears much the same as does bronze. The driven pulley is aluminum. Finally, the shaft is of the finest steel and following preliminary turning is case hardened after which it is hand polished to a very high finish; it is then measured for dimension for the close and accurate fabricate of the disc-hub bore, the main bearing specifications, and the counter-bored driven pulley. The two main bearings are matched and specially balanced. They are single-row ball bearings—their manufacturer claiming speeds in excess of 40,000 r.p.m. for them. The ball bearing within the driven pulley is of a similar quality, and designed and tested for high speed operation.

The path which the gas molecules follow through the pump is best shown by the arrows on the drawing. Entering at the inlet 32, the molecules impinge upon the peripheral surfaces of the rapidly whirling dics. From this impact a majority pick up the general direction and progress of travel within the spiral grooves; progressive-measured for dimension for the close and accurate fabrily they continuously rebound from the static walls of the spiral grooves and again impinge upon the rotating discs. Finally, having made the full journey throughout the entire length of the spiral grooves, they find a ready passage through one of the several orifices provided in the shaft at that point or region. It is of course true that gas molecules at reduced pressures (and we are citing pressures in the order of one micron of mercury—or less), seem not to follow closely to the conventional rules of mechanics, it being claimed that they move and rebound with great abandon and motion. I assume, however, that this is the result of the true state or conditions as exist (in relative terms of microscopic dimensioning) on the surface upon which they impinge. The most highly polished surface would appear, under microscopic examination, as crags and valleys; all nearly of insuperable character to the molecule. The angular structure of these myriad even innumerable irregularities certainly present under this relative concept of this condition a multiple of chance of rebound in a direction as being one not in favor of the desired progress of the gas particle. However, in effect, the required and desired travel toward the central section of the pump is very promptly attained and a successful evacuation of the gas molecules takes place.

The greater the speed of rotation of the discs the more rapid is the evacuation of the gas molecules; a procedure which continues with a smooth and a reliable action. Since it is advisable to use a roughing pump for a fixed fore-pressure, the pump of the present invention has operated effectively at fore pressures as high as forty millimeters of mercury pressure. However, if a lower value is used, say a few microns pressure of mercury, the value of the ultimate fine vacuum pressure of the molecular vacuum pump is definitely more nearly that of an immeasurably low pressure. In truth, the highest of vacua attainable are (without extrapolation) immeasurable. Accepting one gauge range with a high vacuum value of, say 10^{-9} mm. of mercury pressure, with extrapolation,

my pump has been observed in operation, to equal this in performance.

The use of the molecular vacuum pump 33, of Fig. 3, is simple; the design of the vacuum system to which the pump becomes a part is quite optional to the user. Consideration of the conductance of the connecting lines and the various valves included in them, especially on the high vacuum side of the molecular pump 33, is of a major importance. The throughput of the gases as is anticipated and the pumping speed or performance at operating pressures will dictate these conductance considerations and their necessary provision. Large cross-sectional area is indicated for manifold and valves to be used at the extreme low pressures that this type of vacuum pump will produce. One such vacuum system for the pumping or evacuation of gases from contaminated vessels is illustrated in the sketch of Fig. 3. The molecular vacuum pump 33 takes its proper position in the conventional vacuum system in quite the same location as would a diffusion vacuum pump. Usually a series system is provided with the forepump providing the necessary backing or holding pressure suitable for the high vacuum pump to be used. In the case of the system at hand I have selected and provided a by-pass arrangement to the manifolding of the system at branch 37. This makes possible the convenient and the positive isolation of the molecular vacuum pump, 33, during the period of the rough evacuation of the bulk of contaminants in the unit being processed as well as the system. The rough evacuation is carried out with the use of the RSVP 35 operating alone. It also eliminates the greater portion of the atmospheric gas from entering the molecular vacuum pump and in this way will minimize contamination of the molecular pump parts. During this preliminary evacuation this by-pass arrangement also permits an early check on the entire system for in-leakage. When vacua in the order of less than 0.1 mm. of mercury pressure is obtained, as may be measured at the gauge 36, the molecular pump, 33, is then engaged by a simple operation of the two-way main valve and the other single way valves as may be required to provide a path of flow through the molecular pump on to the forepump. A very high vacuum will thusly be produced promptly. The gauges at 36 are provided to determine operating pressures during the entire cycle of evacuation of the work. Air admittance valves, V4 and V5, are added to the system to facilitate the admission of full atmospheric air pressure into the system at certain desired times—such as: the maintenance of the system, and the change of a unit being processed. No traps need be used. Specifically, therefore, we may now outline a complete cycle of pumping or evacuation process of the efficient removal of contaminating gases from a vessel or unit, with the use of the molecular vacuum pump, as follows:

FIRST, A contaminated vessel or unit is provided and is attached to the vacuum port at 34. This vacuum port may be in the form of a bell-jar with its necessary base plate. Then, SECOND, With all the valves closed off, that is V1 through V5 inclusive, forepump RSVP 35 is put into full mechanical operation; a brief period of time now being allowed for this unit to warm up. Then, THIRD, By-pass branch 37 is now made conductive from the work or vacuum port location 34 on through to the RSVP 35 by opening V1 and V3. Optionally, at this time, V2 may be opened; this to remove the bulk of contaminant gases within the molecular pump 33. Finally, and FOURTH, When gauge 36 indicates an approximate pressure of one-tenth millimeters of mercury pressure (100 microns) the main two-way valve, V1, is turned over toward the molecular pump 33 side, at branch 38 of the by-pass manifold. The molecular pump P33 is simultaneously now put into full mechanical operation. (Note: If valve V2 was not opened priorly stated in the above as being optional, during preliminary evacuation, it must now be open.) Valve V3 may now be closed off. A use is now being made of branch **38** of the by-pass, the molecular P33, and the forepump RSVP **35**, operating in full cooperation with one another. The molecular pump, P33, will now function and will insure the swift and definite pressure drop as may be observed and measured at the gauge **36**. The cause of a failure for this pressure drop taking place at this time would be found to reside in either an excess of in-leakage, or an excess of gas evolution as may issue from the contaminated vessel being processed. If either source of gases is continuous and is greater than twenty-five percent of the capacity of the forepump used, or RSVP **35**, at its operating rated pressure, proper action and performance of the molecular pump P33, is retarded. However, we may summarize and evaluate as follows: With the necessary forepressure, as is provided at the outlet **22**, of the molecular pump P33; said forepressure of a relatively constant value as is provided by the RSVP **35**, and is accepted, arbitrarily, as being at a pressure of approximately ten microns of mercury pressure, or less, said forepressure providing a satisfactory holding pressure at the exhaust termini of the P33, molecular vacuum pump, the latter by its inherent design and its function in operation does and will develop extreme low pressure value at its inlet port. One conservative pressure ratio for vacuum pumps of the molecular type is stated as being 1 to 25,000. Experience has indicated higher ratio difference, or those as high as 1 to 40,000. This in effect means that in the case at hand with a forepressure of ten microns in value, or 0.01 mm. mercury pressure, a high vacuum value of 2×10^{-6} mm. of mercury pressure may be expected at the inlet port(s) of the molecular vacuum pump. It has been my experience to attain results equal to this; I deduce that for all practical purpose the value of ultimate vacua, using a perfectly tight and closed system, may be considered immeasurable.

The trade is familiar with the physics governing the operation of this type of vacuum pump, namely the molecular high vacuum pump. It is well known, for example, that such a device will exhaust the heavier gas molecules more readily than the lighter gas molecules. This feature of the molecular vacuum pump was of inestimable value to early atomic workers. Then too this type of vacuum pump can and does handle condensable vapors with great expedition. This eliminates the expensive use of liquid refrigerants. With respect to speed of pumping in terms of unit volume per unit time; the molecular pump may be considered as being unlimited; the more speed to the rotating discs, the greater the pumping speed. The increase obtained is linear in character, with time as a parameter and actually, mechanics of construction prove the only restriction.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

A molecular vacuum pump comprising a casing of an aggregate of paired and matched cylindrical plates, a recessed portion on one face of each plate concentrically positioned formed by a radially extending wall and matching the similarly recessed portion on its twin plate of that pair of plates and for all paired and matched plates, a plurality of grooves formed in the radially extending walls of each and all recesses progressing in a spiral manner from their respective starting points out at the periphery of the recess inwardly to the central area, a plurality of rotors rotatably mounted to closely occupy the spaces as presented by the paired and matched recesses between all paired plates, a hollowed drive-shaft perforated at points adjacent to the termini of all spiral grooves, inlet ports at the starting points of all grooves and through all plates at common points to each respectively, and a common outlet passage presented by the hollow portion of the perforated hollowed drive-shaft of the molecular pump.

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