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W. W. B. SCHUMACHER

3,150,818

VACUUM PUMP

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2 Sheets-Sheet 1

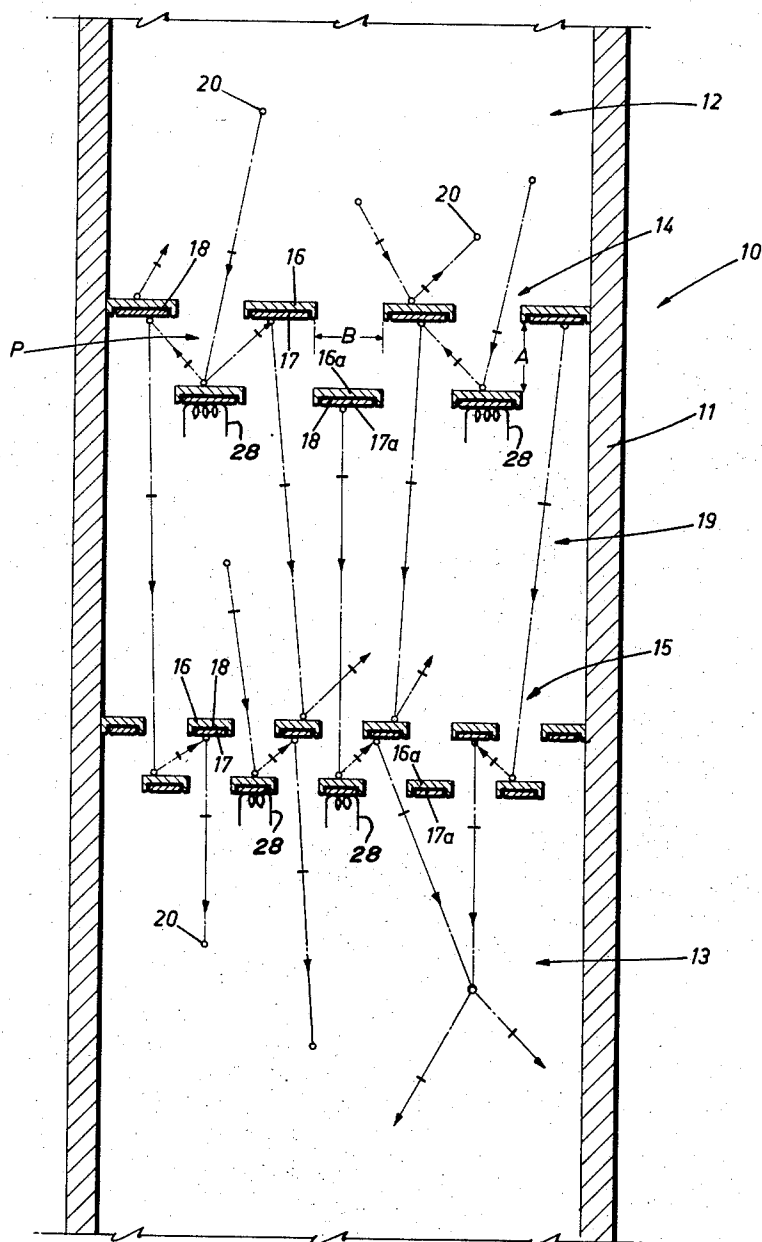


FIG. 1

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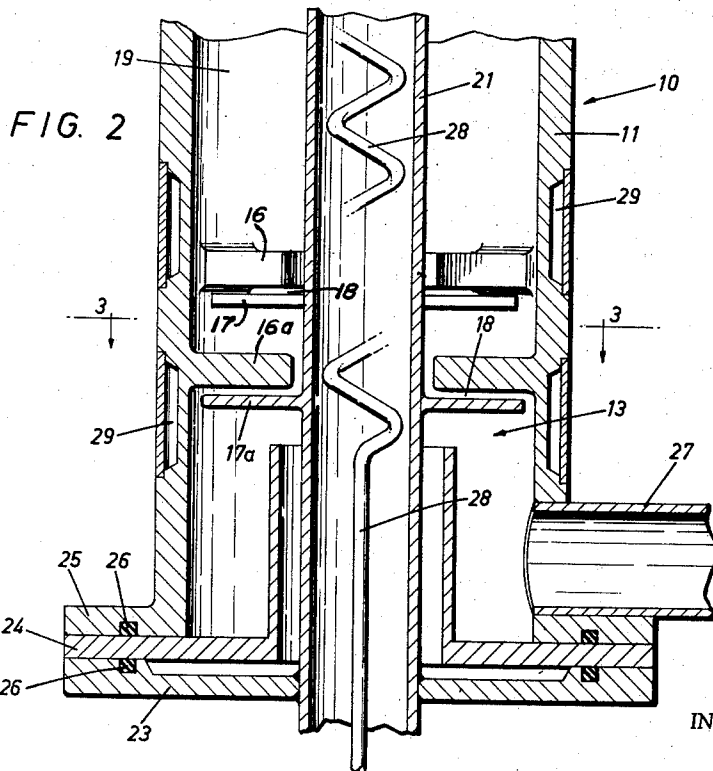
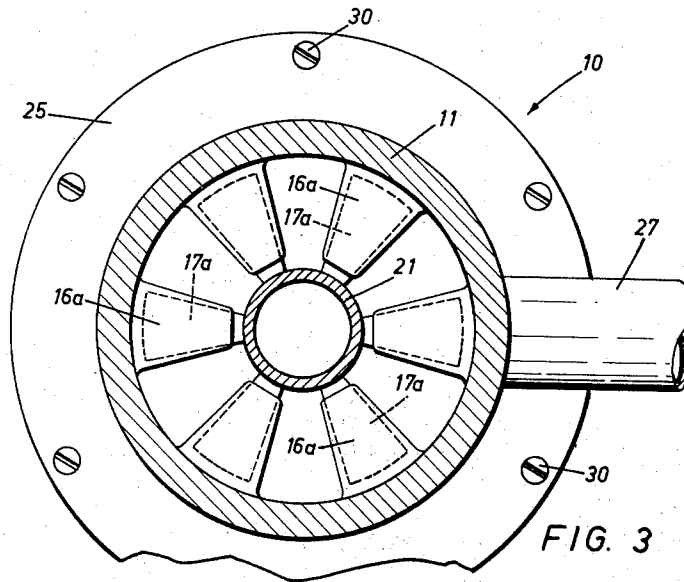
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2 Sheets-Sheet 2



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VACUUM PUMP

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This invention relates to a new and useful vacuum pump or what may be termed a thermal gradient pump. More particularly, this invention relates to a vacuum pump which has no moving parts, no fluid driving medium and which is capable of operating continuously. Even more particularly, this invention relates to a vacuum pump which utilizes hot and cold surfaces to prevent gas molecules from diffusing back into the recipient with high velocity and to give gas molecules an increased velocity away from the recipient and towards the fore vacuum of the vacuum pump.

As is well known, it is the purpose of vacuum pumps to remove gas molecules from a container, usually called the recipient, until as few as possible or, ideally none at all, of the gas molecules remain in the recipient.

Usually the vacuum pump is connected to the recipient by a short pipe which defines a high vacuum compartment. The gas molecules, because of their natural thermal movement, diffuse from the recipient into the high vacuum compartment and into the so-called suction part of the vacuum pump. In order for the molecules to be moved further, especially in order to prevent them from diffusing back into the recipient, the pump must operate in such a manner that an additional velocity is imparted to the molecules in the direction away from the recipient and towards the fore vacuum compartment of the vacuum pump, or the atmosphere.

It is well known that many vacuum pumps require a fore vacuum compartment, since not all vacuum pumps are able to exhaust gas from the high vacuum compartment with a pressure of, for example, 2×10^{-6} Torr directly into the atmosphere. Between the fore vacuum compartment with a pressure of, for example, between 10^{-2} Torr and 10 Torr and the atmosphere there is usually provided a mechanical pump having a piston and valve system. The mechanical pump is not suitable for the production of high vacuum but can be used to exhaust the fore vacuum compartment. Notwithstanding the fact that generally speaking two different kinds of pumps, as aforementioned, are employed in series for the creation of a high vacuum, each pump alone is generally referred to as a vacuum pump.

With respect to the operating principle of a vacuum pump, especially a high vacuum pump, all molecules entering the pump from the recipient are moved from the high vacuum compartment to the fore vacuum compartment. There are two types of high vacuum pumps in general use which produce this effect. One type is the so-called molecular drag pump, while the other type is the so-called vapour jet pump. Molecular drag pumps all employ rotors which run at a high speed and which are either smooth or are provided with some type of turbine blades. Whenever a gas molecule hits the rotating rotor it is given an additional velocity component in the desired direction, namely from the high vacuum compartment to the fore vacuum compartment. On the other hand, in vapour jet pumps the gas molecules are permitted to diffuse into the region of a direct vapour jet, and gas molecules to be evacuated from the recipient are pushed in the required direction by collisions with the vapour molecules. In both types of these prior art vacuum pumps it is possible for some of the molecules to diffuse backwardly into the recipient. In the case of vapour jet

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pumps, it also is possible that the vapour molecules can diffuse back into the recipient, this being a considerable disadvantage. Molecular drag pumps, on the other hand, are both heavy and expensive because of the fast rotating rotor and necessarily employ moving parts.

Accordingly it is one object of my invention to provide a vacuum or thermal pump which has no moving parts.

It is another object of my invention to provide a vacuum pump which does not employ any liquid or gaseous driving mediums.

Another type of vacuum pump in general use operates on the principle of trapping and binding the gas molecules by chemical absorption or freezing. The disadvantage of such pumps is that they do not work continuously but operate only until a saturation level is reached.

Accordingly another object of my invention is to provide a vacuum pump which is capable of continuous operation.

Yet another object of my invention is to provide a vacuum pump which is simple to manufacture and inexpensive and simple to both assemble and dismantle.

The operating principle of a vacuum pump embodying my invention rests in giving the gas molecules to be evacuated from the recipient a preferred velocity and movement by letting such gas molecules strike a surface which is at a high temperature and from which the gas molecules can escape in only one range of directions.

In brief, a vacuum or thermal gradient pump embodying my invention comprises a housing which defines a fore vacuum compartment and a high vacuum compartment, the latter being adapted to be arranged in fluid-flow relationship with a recipient. In accordance with my invention, there are first and second layers of bars in the vacuum pump, each layer comprising laterally spaced-apart sets of first and second bars, the layers being positioned between the high vacuum and fore vacuum compartments. The first bars of the first layer are positioned with surfaces thereof adjacent the high vacuum compartment, while the second bars of the first layer are shielded from the high vacuum compartment by the first bars of the first layer. The second layer is positioned on the side of the first layer remote from the high vacuum compartment with the second bars of the second layer being shielded from the high vacuum compartment by the first bars of the second layer. The first and second layers are longitudinally spaced apart from each other, and the sets of first and second bars of the second layer are offset laterally with respect to the sets of first and second bars of the first layer, the former being positioned intermediate adjacent ones of the latter sets. The spacing between the first and second layers is substantially equal to the lateral spacing between the sets of first and second bars. Means are provided to maintain a temperature differential between the first and second bars with the first bars being maintained at a lower temperature than the second bars.

My invention will become more apparent from the following detailed description taken in conjunction with the drawings in which:

FIGURE 1 is a schematic representation of a vacuum pump embodying my invention,

FIGURE 2 is a section through a vacuum pump embodying my invention, and

FIGURE 3 is a section taken along line 3-3 in FIGURE 2.

Referring first to FIGURE 1, I have shown a vacuum pump 10 which has a tubular housing 11 which defines a high vacuum compartment 12 and a fore vacuum compartment 13. High vacuum compartment 12 is adapted to be arranged in fluid-flow relationship with a recipient (not shown) by connecting housing 11 in fluid-tight re-

lationship with the recipient. Positioned in housing 11 and extending thereacross are upper and lower longitudinally spaced apart groups 14 and 15 respectively of bars 16 and 17 and 16a and 17a. Bars 16 and 17 and bars 16a and 17a are formed into sets which are laterally spaced away from each other by gaps B. In each group 14 and 15 the sets of bars 16 and 17 and 16a and 17a are arranged in an upper and a lower layer, bar 16 and 17 being in the upper layer and bars 16a and 17a being in the lower layer. Bars 16 of group 14 in the upper layer are positioned with surfaces thereof adjacent high vacuum compartment 12, whereas bars 17 in the upper layer of group 14 are shielded from high vacuum compartment 12 by their corresponding bars 16, which not only overlie the upper surface of bars 17 but also extend downwardly around the side edges of bars 17. The bars 16a of the lower layer of group 14, as well as their corresponding bars 17a, are positioned on the side of the upper layer which is remote from high vacuum compartment 12, with bars 17a being shielded from the high vacuum compartment by bars 16a of the lower layer. It will be noted that each set of bars 16 and 17 and 16a and 17a are positioned closely adjacent their corresponding bar. The space 18 therebetween may be filled with a solid heat insulator such as glass or ceramic, if desired. The upper and lower layers of bars in group 14 are longitudinally spaced apart from each other by distance A. The sets of bars 16a and 17a in the lower layer are offset laterally with respect to the sets of bars 16 and 17 in the first layer and are positioned intermediate adjacent ones of the sets of bars 16 and 17 in the upper layer. It will be appreciated that the upper and lower layers of group 15 are constructed in the same manner as the upper and lower layers of group 14. It will be noted, however, that it is advisable that the width of gaps B and the distance A in the case of group 15 be less than in the case of group 14. Any suitable means, such as heating coils 28 shown in FIGURE 1, or such as referred to hereinafter in connection with FIGURES 2 and 3, are employed to maintain bars 17 and 17a at a higher temperature than bars 16 and 16a respectively. Fore vacuum compartment 13 is connected to a suitable fore vacuum pump (not shown) which may be of the type hereinbefore mentioned. Groups 14 and 15 are spaced apart by a compartment 19.

In describing the operation of the vacuum pump 10 shown in FIGURE 1 it will be assumed, for the sake of simplicity, that group 15 of bars 16 and 17 and 16a and 17a are not present, and consequently that compartments 19 and 13 together constitute the fore vacuum compartment.

The kinetic theory of gases teaches that gas molecules striking the surface of a hot object will first stick to the object for a short time before moving away therefrom. The molecules are thus given a velocity which corresponds in the average to the temperature of the surface of the heated object, and the directional distribution of molecules moving away from the surface is a cosine distribution. The higher the temperature of the surface, the higher also will be the mean velocity of the gas molecules leaving that surface. This principle is utilized in practicing my invention. Referring to FIGURE 1, it will be seen that molecules 20 to be evacuated from a recipient will diffuse naturally from high vacuum compartment 12 into the space P between upper and lower layers of bars 16 and 17 and 16a and 17a. Because of the arrangement of these bars, the majority of the molecules from high vacuum compartment 12 can only move from high vacuum compartment 12 to the fore vacuum compartment in a zig-zag path, as is shown in FIGURE 1. The length of the arrows in FIGURE 1 is a measure of the velocity of the molecules in each part of their path. Molecules 20 which come from the region P down towards the fore vacuum compartment obviously all have a high velocity, because they are moving away from hot bars 17 or 17a. In con-

trast, the molecules 20 which move from region P into high vacuum compartment 12 all assume a lesser velocity because they are directed into compartment 12 from relatively cold bars 16 and 16a. As exemplary only, bars 16 and 16a may be maintained at 20° C., whereas the temperature of bars 17 and 17a may be maintained anywhere between 100 and 2000° C. It will be seen from the foregoing that the average velocity of all the molecules 20 which enter the region P is downwards into the fore vacuum compartment.

In the fore vacuum compartment the fast molecules 20 coming from hot bars 17 and 17a will hit the cold walls of the fore vacuum compartment or other cold objects, or they will undergo collision with other gas molecules in the fore vacuum compartment. In each of these cases the high energy molecules lose their high velocity and assume an average velocity corresponding to the temperature in the fore vacuum compartment. In principle it can be considered that what is present is a fore vacuum compartment with one wall hot (all bars 17 and 17a) and with a cold wall (the portion of the fore vacuum compartment remote from bars 17 and 17a). It will be apparent that throughout the fore vacuum compartment there must exist a temperature gradient within the gas present therein. However, since the pressure throughout the fore vacuum compartment is the same, there is a density gradient connected with the aforementioned temperature gradient, and the gas density near the hot wall (bars 17 and 17a) is lower than near the cold wall (the portion of the fore vacuum compartment remote from bars 17 and 17a). From the cold zone with its high gas density, the gas will be sucked away by the fore vacuum pump (not shown) whereas a possible back diffusion into high vacuum compartment 12 can take place from the hot zone where the gas density is low. Finally an equilibrium is reached in which the number of molecules diffusing through the zone P in each direction is equal. Because the gas temperature on each side of zone P is not the same and does not automatically equalize, because of the enforced zig-zag path of gas molecules in zone P, this state of equilibrium will be accompanied by a pressure gradient, and until this state is reached, gas will flow from high vacuum compartment 12 to the fore vacuum compartment. Of course, if the fore vacuum compartment is being continuously evacuated by a fore vacuum pump, there will be a continuous flow of gas from high vacuum compartment 12 to the fore vacuum compartment. There is, as mentioned, a thermal gradient across each of the regions P. One may therefore call this new pump a thermal gradient pump.

It will be appreciated that the aforementioned pumping effect can be achieved by employing only one layer of sets of bars 16 and 17 rather than the two layers which are associated with each group 14 and 15. However, such an arrangement is not as effective as that shown in FIGURE 1, because with such a single layer arrangement more molecules can proceed directly backwards from the fore vacuum compartment to the high vacuum compartment without hitting one of the hot or cold surfaces, thereby producing an undesirable degree of back diffusion.

In order to increase the pressure gradient which can be achieved, a plurality of groups of layers of bars 16 and 17 and 16a and 17a may be provided as is shown in FIGURE 1, by groups 14 and 15, these groups being arranged in longitudinal series in housing 10. The provision of a plurality of such groups does not greatly alter the suction speed of the vacuum pump, because this is determined by the extent of the gaps B provided between zone P and high vacuum compartment 12.

It will be apparent that the operation of a device embodying my invention is most efficient when the molecules in zone P can travel therein without undergoing collisions with other gas molecules. Consequently it is preferred that the distance A should be not more than

about four times the mean free path of the molecules 20 and preferably should be about the same order of magnitude as or less than this mean free path. Similarly gaps B should not be more than about four times the mean free path of the gas molecules 20 and preferably about the same order of magnitude as or less than this mean free path. It is well known that the mean free path of gas molecules is inversely proportional to the pressure. Consequently where a series of longitudinal spaced groups are employed as in the case of FIGURE 1, the size of gaps B and the distance A will decrease continuously throughout the vacuum pump, the aforementioned parameters being largest for the group positioned closest to the high vacuum compartment and smallest in the group furthest away from the high vacuum compartment.

Referring now to FIGURES 2 and 3, I have shown a vacuum pump 10 embodying my invention. This vacuum pump has a tubular housing 11 and a support 21 in the form of a tube coaxially mounted in tubular housing 11. One group 15 of layers of bars 16 and 17 and 16a and 17a is shown. It will be noted that bars 17 and 17a are secured to support 21 and project outwardly therefrom towards housing 11. Bars 16 and 16a are secured to housing 11 and project inwardly therefrom towards support 21. The sets of bars 16 and 17 and 16a and 17a are laterally spaced with respect to the radial axis. Support 21 is fastened to a base-plate 23 which in turn is fastened by any suitable removable means such as bolts 30 through another plate 24 to a flange 25 provided on housing 11. O-ring seals 26 are provided in recesses in plate 23 and flange 25. A tube 27 extends through housing 11 into fore vacuum compartment 13 and may be connected to any suitable type of fore vacuum pump. An electrical heater 28 is provided in support 21 and is used for the purpose of heating bars 17 and 17a. Channels 29 are provided in housing 11, and any suitable cooling liquid, such as water, may be passed there-through for the purpose of maintaining bars 16 and 16a at a low temperature. Thus it will be seen that bars 16 and 16a are cooled by heat conduction, whereas bars 17 and 17a are heated by heat conduction.

In order to remove support 21 from housing 11 for the purpose of cleaning the same it is only necessary to remove the fastening devices securing plate 23 to flange 25 and turn support 21 through a small angle, pulling it out one step at a time. It is also possible, where radial bars 16 and 16a, 17 and 17a are provided, as in the case of FIGS. 2 and 3 to arrange these bars on a screw-line, in which event inner support 21 can be removed from housing 11 by a screw movement. With such a construction it is not necessary for the gaps B between the sets of bars to be wider than the bars themselves, particularly when this width varies for the reasons previously noted, although this is required with the type of device shown in FIGURES 2 and 3 to permit removal of support 21.

It will be appreciated from the foregoing that a vacuum pump embodied in my invention has no mechanical moving parts and no fluid driving medium. The vacuum produced by it is both clean and dry. There is no necessity for baffles and similar devices for catching vapours. At the same time the pump is simple in design and simple to manufacture. It will be noted that it is possible to build a vacuum pump embodying my invention with a large number of longitudinal serially arranged groups, such as 14 and 15, but still keep the manufacturing costs within economical limits.

Those skilled in the art will appreciate that while I have described certain preferred embodiments of my invention nevertheless changes and modifications may be made therein without departing from the spirit and scope of my invention. The hot bars may not only be heated by conduction but, for instance by passing an electric current through them. The surface of the bars 16 and

16a, 17 and 17a, may be specially prepared (e.g. made rough) to cause a maximum amount of adaptation of the gas molecules to the temperature of those bars.

What I claim as my invention is:

1. A vacuum pump comprising a housing defining a fore vacuum compartment and a high vacuum compartment, said high vacuum compartment being adapted to be arranged in fluid-flow relationship with a recipient, first and second layers each comprising laterally spaced apart sets of first and second bars and positioned between said high vacuum and fore vacuum compartments, said first bars of said first layer being positioned with surfaces thereof adjacent said high vacuum compartment, said second bars of said first layer being shielded from said high vacuum compartment by said first bars of said first layer and being positioned closely adjacent said first bars of said first layer, said second layer being positioned on the side of said first layer remote from said high vacuum compartment, said second bars of said second layer being shielded from said high vacuum compartment by said first bars of said second layer, said second bars of said second layer being positioned closely adjacent said first bars of said second layer, said first and second layers being longitudinally spaced apart from each other by an amount substantially equal to the lateral spacing between said sets of first and second bars, said sets of said first and second bars of said second layer being offset laterally with respect to said sets of said first and second bars of said first layer and being positioned intermediate adjacent ones of said sets of said first and second bars of said first layer, and means for maintaining a temperature differential between said first bars and said second bars with said first bars at a lower temperature than said second bars.

2. A vacuum pump according to claim 1 wherein there are a plurality of groups of said first and second layers, said groups of said first and second layers being arranged in longitudinal series in said housing with said first layer of each group being adjacent and spaced from said second layer of the preceding group.

3. A vacuum pump according to claim 2 wherein the lateral spacing between said sets of said first and second bars and the longitudinal spacing between said first and second layers graduates continuously throughout said groups of said first and second layers, the aforementioned parameters being largest in the group of said layers positioned closest to said high vacuum compartment and smallest in the group of said layers furthest away from said high vacuum compartment.

4. A vacuum pump according to claim 1 wherein said last-mentioned means comprises means for electrically heating said second bars.

5. A vacuum pump according to claim 4 wherein said first bars are maintained at room temperature.

6. A vacuum pump according to claim 4 wherein said first bars are liquid cooled.

7. A vacuum pump according to claim 1 wherein said last-mentioned means comprises means for cooling said first bars by heat conduction and means for heating said second bars by heat conduction.

8. A vacuum pump according to claim 1 including a support coaxially mounted in said housing, said first bars being secured to the walls of said housing and projecting inwardly therefrom towards said support, said second bars being secured to said support and projecting outwardly therefrom towards said walls.

9. A vacuum pump according to claim 8 wherein said support is rotatable about the longitudinal axis thereof, the size of said bars and the spacing between said sets of said first and second bars being such that said support may be withdrawn from said housing by rotating said support and moving said support longitudinally.

10. A vacuum pump according to claim 8 wherein said last-mentioned means comprises an electrical heater posi-

tioned in said support and liquid cooling passages provided in said walls.

11. A vacuum pump system comprising a recipient and a housing defining a fore vacuum compartment and a high vacuum compartment, said housing being connected in fluid-tight relationship with said recipient, and first and second layers each comprising laterally spaced apart sets of first and second bars and positioned between said high vacuum and fore vacuum compartments, said first bars of said first layer being positioned with surfaces thereof adjacent said high vacuum compartment, said second bars of said first layer being shielded from said high vacuum compartment by said first bars of said first layer and being positioned closely adjacent said first bars of said first layer, said second layer being positioned on the side of said first layer remote from said high vacuum compartment, said second bars of said second layer being shielded from said high vacuum compartment by said first bars of said second layer, said second bars of said second layer being positioned closely adjacent said first bars of said second layer, said first and second layers being longitudinally spaced apart from each other by an amount substantially equal to the lateral spacing between said sets of first and second bars, said sets of said first and second bars of said second layer being offset laterally with respect to said sets of said first and second bars of said first layer and being positioned intermediate adjacent ones of said sets of said first and second bars of said first layer, and means for maintaining a temperature differential between said first bars and said second bars with said first bars at a lower temperature than said second bars.

12. A vacuum pump according to claim 1 wherein the spacing between said first and second layers and the spacing between adjacent ones of said first and second sets of bars is less than about four mean path lengths.

13. A vacuum pump according to claim 3 wherein the spacing between said first and second layers and the spacing between adjacent one of said first and second sets of bars is less than about four means path lengths.

14. A vacuum pump comprising a housing defining a fore vacuum compartment and a high vacuum compartment, said high vacuum compartment being adapted to be arranged in fluid-flow relationship with a recipient, first and second layers each comprising laterally spaced apart sets of first and second bars and positioned be-

tween said high vacuum and fore vacuum compartments, said first bars of said first layer being positioned with surfaces thereof adjacent said high vacuum compartment, said second bars of said first layer being shielded from said high vacuum compartment by said first bars of said first layer and being positioned closely adjacent said first bars of said first layer, said second layer being positioned on the side of said first layer remote from said high vacuum compartment, said second bars of said second layer being shielded from said high vacuum compartment by said first bars of said second layer, said second bars of said second layer being positioned closely adjacent said first bars of said second layer, said first and second layers being longitudinally spaced apart from each other by an amount substantially equal to the lateral spacing between said sets of first and second bars, said sets of said first and second bars of said second layer being offset laterally with respect to said sets of said first and second bars of said first layer and being positioned intermediate adjacent ones of said sets of said first and second bars of said first layer, and means for maintaining a temperature differential between said first bars and said second bars with said first bars at a lower temperature than said second bars, said vacuum pump including a support coaxially mounted in said housing, said first bars being secured to the walls of said housing and projecting inwardly therefrom towards said support, said second bars being secured to said support and projecting outwardly therefrom towards said walls, said support being rotatable about the longitudinal axis thereof, the size of said bars and the spacing between said sets of said first and second bars being such that said support may be withdrawn from said housing by rotating said support and moving said support longitudinally, said means for maintaining a temperature differential comprising an electrical heater positioned in said support and liquid cooling passages provided in said walls.

15. A vacuum pump according to claim 1 wherein the surfaces of said first and second bars on which gas molecules impinge are rough.

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