

April 26, 1960

B. D. POWER
VAPOUR VACUUM PUMPS OR OTHER APPARATUS
EMPLOYING VAPOUR NOZZLES

2,934,258

Filed Aug. 29, 1957

3 Sheets-Sheet 1

FIG. 1.

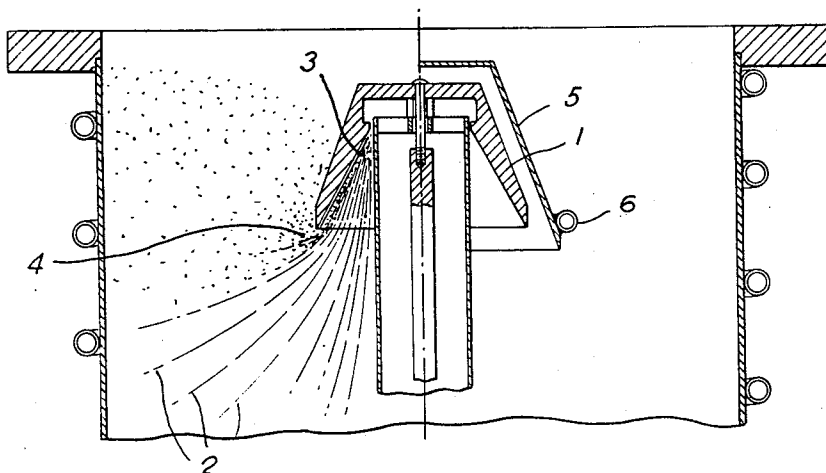
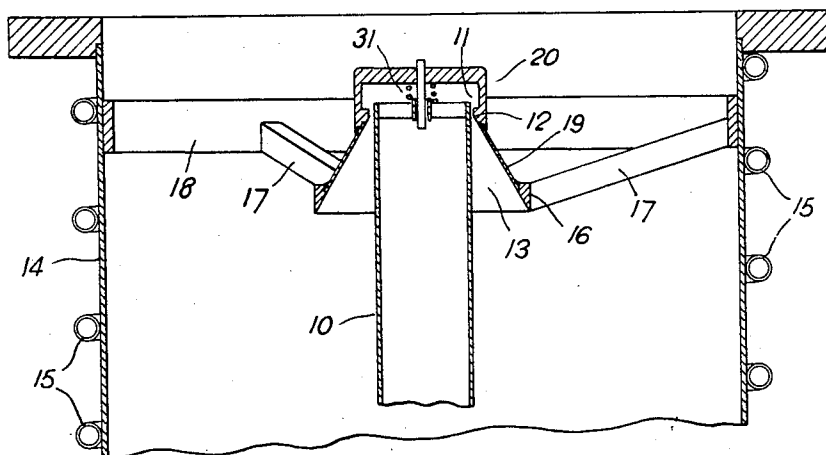


FIG. 2.



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3 Sheets-Sheet 2

FIG. 3.

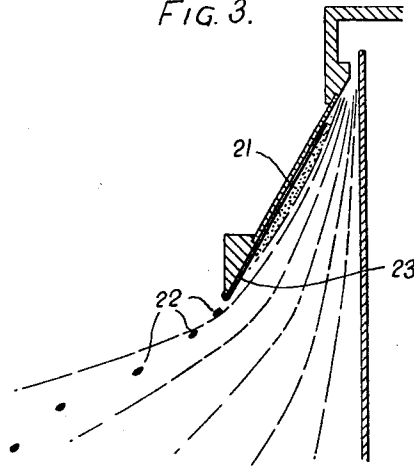


FIG. 4.

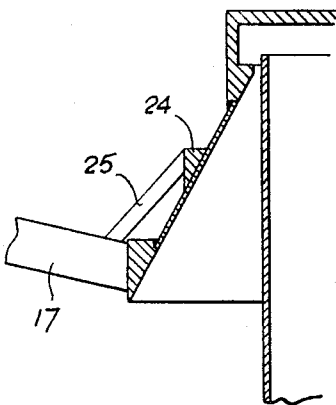
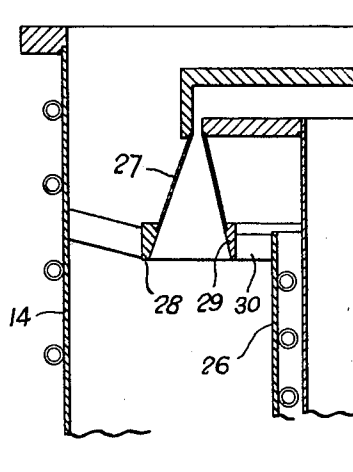


FIG. 5.



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3 Sheets-Sheet 3

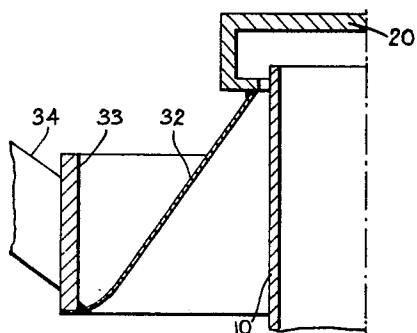


FIG. 6.

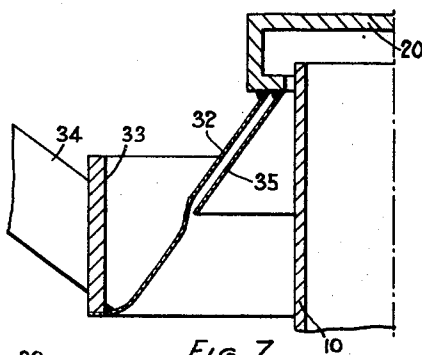


FIG 7.

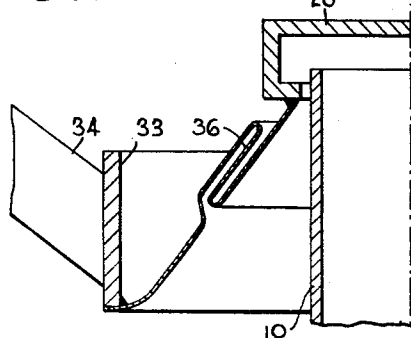


FIG 8.

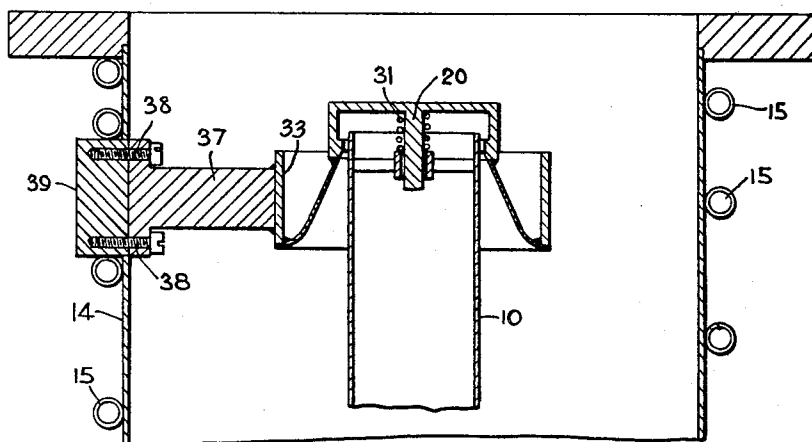


FIG 9.

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1

2,934,258

VAPOUR VACUUM PUMPS OR OTHER APPARATUS EMPLOYING VAPOUR NOZZLES

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Application August 29, 1957, Serial No. 681,080

Claims priority, application Great Britain September 3, 1956

14 Claims. (Cl. 230—101)

The present invention relates to vapour vacuum pumps or other apparatus employing vapour nozzles. In vapour vacuum pumps of the "condensation" type (the so called booster and diffusion pumps), and also of the "ejector" type, the vapour jets emerge from the nozzles, over a wide range of operating conditions, into a region of comparatively low, or extremely low gas pressure.

There is associated with all such vapour jets a phenomenon commonly known as "backstreaming" which consists of the more or less random backward migration of vapour molecules from the region of the pumping stage, against the pumping direction, and in numbers greater than would be accounted for by the mere re-evaporation of vapour molecules from the cooled pump walls at a rate appropriate to wall temperature.

Among the factors which may contribute to backstreaming are the following:

- i. The random inter-collision of vapour molecules in the vapour jets resulting in some molecules acquiring velocity components in the backstreaming direction.
- ii. Incomplete accommodation of the vapour molecules to the cooled wall temperature of the condensing vapour at first impact (i.e. inefficient condensation).
- iii. Random evaporation of liquid from any "wet" patches on the outside, or lips, of the hot vapour nozzles.
- iv. The over expansion or "over divergence" of the vapour jet as it leaves the nozzle.
- v. The emergence from under the nozzle lip of randomly moving vapour due to causes to be discussed in detail later.

Backstreaming constitutes a back migration of vapour molecules into the system being pumped by the vapour pump, at a rate in excess of the theoretical minimum rate i.e. the rate that would provide a vapour pressure just equal to saturation pressure at the temperature of the cooled wall of the pump.

Saturation pressure at system temperature is therefore very likely to be exceeded and heavy condensation of pump fluid vapour inside the system, resulting in severe system contamination, is likely to result.

Backstreaming, because it constitutes a "screen" of vapour molecules moving in a direction opposed to the normal pumping direction, might be expected to have an adverse effect on the pumping of gases by the pump due to collision between the backstreaming vapour molecules and the forward moving gas molecule hindering the migration of the gas molecules into the pumping stage.

This adverse pumping effect is in fact very often negligible, but where severe over-divergence of the jet or jets of the pump is one of the factors contributing to backstreaming, the effect on pumping speed can be very serious, the over-divergent vapour which reaches and condenses on the cooled walls also powerfully contributing to the reverse pumping action.

Clearly, the backstreaming effect referred to is very undesirable because, apart from reducing the pumping speed, interference with the process being carried out

2

by the pump may result in, for example, contamination of surfaces or poisoning of filaments or decomposition to undesirable breakdown products in electrical discharge devices being exhausted and so on.

- Further investigation has shown that the most important source of backstreaming molecules in many pumps is in the region of the lip of the vapour nozzle itself and accordingly, if the backstreaming from this source can be reduced or eliminated, the total backstreaming can be very much reduced. It is convenient to consider the probable reasons for the assertion just made and for the purpose of explanation reference will be made to Figure 1 of the accompanying drawings which shows diagrammatically a portion of a conventional form of pump.

- The fluid used in vapour vacuum pumps is always phlegmatic and usually has a quite low latent heat. The walls of the nozzle 1 which may run at a temperature of the order of 200° C. are continually losing heat by radiation. Some condensation of vapour on the inside of the nozzle wall is therefore quite likely as the vapour stream 2 expands through the nozzle. A liquid film thus formed may be augmented by liquid droplets or spray carried by the vapour from the boiler, not shown, and thrown against the inside of the nozzle cap as the vapour stream is deflected outwards and downwards by the cap. The effect of upward splashing of liquid droplets and spray are referred to in the specification of British Patent No. 700,978 which describes the use of baffles to reduce the effect.

- The liquid film formed in the manner described travels down the nozzle wall with the vapour stream and although liquid drops may in bad cases be blown off the nozzle lip by the vapour stream, much of the liquid must evaporate randomly as it emerges from under the lip of the hot nozzle cap from a zone of higher pressure than that of the high vacuum outside the cap and whilst still in contact with the hot cap and the hot vapour stream. This random evaporation can contribute largely to the backstreaming vapour flow, the magnitude of the contribution depending on the extent to which the pump designer has been able to limit the formation of the liquid film usually by reducing heat loss from the cap and by arresting the droplets carried in the vapour stream. The emergence of liquid on to the hot nozzle lip from inside the jet in quantity depending on the pump design and operating conditions, provides one possible reason why the region of the nozzle lip is an important source of backstreaming vapour. A second reason is provided by a wellknown phenomenon common to all gas and vapour nozzles, but particularly important in nozzles operating at very low pressures, such as the air nozzles of low pressure wind tunnels, or the vapour nozzles of a vapour vacuum pump.

- Such nozzles are designed with the intention that the gas or vapour be expanded from the pressure it has in the supply reservoir or boiler in such a manner that it is all accelerated efficiently and that it all emerges from the nozzle exit as a high velocity and coherent stream with the desired directional characteristics. Such a result is never perfectly achieved and one cause of the imperfect practical performance obtainable is the progressive growth of a so called "boundary layer," that is to say, a region where velocity gradients are very high and where there is a great deal of random motion of gas or vapour molecules, between the nozzle inner wall and the high velocity vapour stream as the vapour travels along the nozzle.

- The boundary layer is produced because of the momentary arrest and random reflection of gas or vapour molecules within reach of the nozzle wall and which may strike it as the gas or vapour stream is accelerated

through the nozzle and may also—on random reflection from the wall, strike and deflect other molecules near the edge of the gas or vapour stream. Boundary layer growth is more pronounced in nozzles etc. operating at low pressures, because molecular mean free paths are longer so that there is a thicker layer adjacent to the nozzle wall from within which molecules may be able to collide with the wall and throughout which they are likely to be able to disturb the flow after rebound. The boundary layer tends to thicken progressively as the nozzle exit is approached both because more and more molecules have their direction of travel disturbed by the sorts of collision described as the expansion proceeds and also because the mean free paths of the boundary layer molecules are greater at the lower pressures existing near the nozzle exit.

Boundary layer growth can be so severe in low pressure wind tunnel work that a great part of the nozzle exit area may be occupied by boundary layer and only a small section at the centre be occupied by the desirable high velocity gas stream. A wellknown method of limiting boundary layer formation in this type of work is to suck the layer away by fast pumps through slots cut in the wall against which the boundary layer is forming.

Fig. 1 illustrates both how the liquid film 3 emerging onto the nozzle lip may randomly evaporate causing backstreaming, and also how the boundary layer molecules may be expected to pour out as a random cloud 4 of molecules having a considerable velocity spread so that after repeated intercollisions or collisions with molecules of the high velocity main vapour-stream many may migrate in the backstreaming direction.

It will be noticed that the main high velocity vapour stream 2 has been illustrated as diverging sharply as it emerges from within the nozzle. This divergence is a characteristic of vapour jets employing the types of vapour most usual in vacuum pumps, when the vapour jet emerges into a very low pressure region and probably creates increased opportunity for undesirable collisions between boundary layer molecules and the main vapour stream.

Although the region of the nozzle lip has been recognised by a number of workers as an important source of backstreaming and the effects consequent upon any liquid film running down inside the nozzle onto its lip have also been appreciated, the certainty of the formation of a boundary layer and its significance in relation to backstreaming does not appear to have been previously appreciated by vacuum pump designers. Efforts have therefore been made to prevent liquid film formation by polishing the nozzle cap to reduce radiation loss, by radiation shielding the nozzle cap, by providing spray arrestors etc. above the pump boiler, and by heating the nozzle cap either by conduction from a hotter part of the pump or by a separate electric heater. Some of these means have ensured a substantially dry running nozzle, but their success in reducing backstreaming was limited because they had no significant effect on boundary layer formation.

One or two workers recognising that random vapour was still emerging from the region of the nozzle lip, have attempted to trap it by interposing cooled condensing surfaces between the nozzle lip and the cooled pump wall, the best practice being to provide one of the condensing surfaces quite near the nozzle lip but spaced from it, extending a little below the nozzle lip and extending up to enclose the nozzle cap. This feature is illustrated in Figure 1 in which the nozzle is shown provided with a cover 5 the lower edge of which is surrounded by a cooling tube 6.

In copending application Ser. No. 531,049 filed August 21, 1955, there are described means for removing from the jet most, if not all, the vapour molecules which have a velocity component opposed to the direction of pumping, said means preferably taking the form of a cooled

ring surrounding the nozzle of the jet. The ring serves to intercept and condense vapour molecules evaporating backwards from the exterior or lip of the nozzle and vapour molecules migrating backwards as a result of collision with other molecules in the vicinity of the nozzle, the undesired backstreaming being thus reduced or eliminated.

A cooled backstreaming trap covering the nozzle cap is effective in preventing backstreaming from the source being considered, but it suffers from certain disadvantages.

Firstly, the trap must be spaced from the jet cap for if they should touch, the jet cap which is usually made of good heat conducting material, would be so much cooled that copious condensation inside it would cause liquid to flow down onto the lower parts of the hot jet assembly—causing a serious disturbance to the pumping action. The cooled cover must therefore be considerably larger than the nozzle so that, on small and medium sized pumps, it occupies together with its support enough of the pumping area to reduce the pumping speed considerably more than the removal of the backstreaming vapour has increased it.

Secondly, boundary layer within the nozzle cap is still permitted to form and grow to full thickness—the random molecules being trapped only after emerging from under the cap. The boundary layer therefore occupies space in the nozzle and may in some cases occupy very considerable space which would otherwise be available for the controlled expansion of the main vapour stream or for making the nozzle more compact. Moreover, the random collision of boundary layer molecules with molecules on the fringes of the main vapour stream rob the stream of energy and transfer still more molecules to the boundary layer. Referring again to the practice general in designing nozzles for low pressure wind tunnels, it is common practice to allow for the growth of a boundary layer and to modify the nozzle contours so as to enlarge it to provide space for the boundary layer to form—but it is recognized that it would be preferable to suck away the boundary layer through slots progressively as it formed, and in spite of the complexity of the extra apparatus required, this solution has been used by some workers. It is similarly desirable that the boundary layer formed in the nozzle of a vapor vacuum pump be as nearly as possible eliminated progressively as it is formed so that all the nozzle space is all the time available for the proper expansion of the vapour stream and so that no random molecules emerge from the lip of the vapour nozzle.

The objects of the present invention are to render innocuous from the backstreaming point of view, any liquid film formed on the inside walls of a nozzle in a vapour vacuum pump before the liquid reaches the lip, to initiate removal of any vapour boundary layer as soon as it begins to form and completely or substantially to remove any vapour boundary layer formed before it emerges from the nozzle lip.

According to the present invention, in apparatus including a nozzle through which condensable vapour flows under conditions such that an undesirable vapour boundary layer occurs or tends to occur, a temperature gradient is established along a wall of the nozzle from the entry region, or from a region intermediate the entry and exit regions, to the exit region thereof, the temperature gradient being such that vapour molecules, traveling in the vicinity of the interior of the said wall tending to form a boundary layer and which in the absence of suitable temperature control of the said wall would issue from the nozzle in a random manner, are condensed, the resulting liquid being sufficiently cooled by the time it emerges on to the nozzle lip to have too low a vapour pressure to emit random vapour at a significant rate. In applying the invention to a vacuum vapour pump, the temperature gradient referred to is established along the wall of the

nozzle from the vapour entry region to the lip and the cooling effect produced is such that the condensed liquid is sufficiently cool by the time it emerges on to the nozzle lip that it has too low a vapour pressure to contribute significantly to backstreaming from the pump.

Further according to the invention, a pumping stage of a vapour vacuum pump comprises a nozzle or nozzles with a cooled lip at the mouth, a vapour entry portion operable at or near the normal operating temperature in conventional vapour vacuum pumps and a middle or connecting portion of selected and not necessarily uniform thermal conductivity chosen so that a temperature gradient is established along it, such that any vapour boundary layer formed inside the nozzle wall is progressively condensed away as the lip of the nozzle is approached and is substantially completely eliminated when the cooled nozzle lip is reached. Preferably, the cooling effect is such that liquid travelling along the inside of the nozzle wall, whether condensate from the boundary layer or from any other source, is cooled progressively as it approaches and arrives at the nozzle lip, with the result that the emergence of random and backstreaming vapour particles from the main vapour stream of the working fluid is reduced or eliminated.

In particular forms of vapour pump embodying the invention, the nozzle is constructed so that, in operation of the pump, the upper part of the nozzle is substantially at the vapour inlet temperature and the lower part of the nozzle is at a significantly lower temperature, the temperature along the lower part of the nozzle decreasing towards the lip of the nozzle.

Alternative forms of pump constructed to operate in accordance with the invention will now be described in greater detail by way of example with reference to Figures 2 to 9 of the accompanying drawings in which:

Figure 2 shows diagrammatically in cross-section those portions of a vapour vacuum pump requisite to an understanding of the invention.

Figure 3 is an explanatory diagram; and

Figures 4 to 9 each show a modification of pump nozzle cooling means embodying the invention.

Referring to Figure 2 of the drawings, pumping fluid vapour from a boiler, not shown, passes up a vapour tube 10 to the nozzle entry 11 beyond which it expands and accelerates through the throat 12 and on through the nozzle 13, the main vapour stream performing its pumping function whilst travelling across to the pump wall 14 cooled by pipes 15. The main vapour stream is condensed on the wall 14 from which the condensate returns to the boiler.

The nozzle lip 16, which is of robust section and has reasonably high thermal conductivity, is conveniently in the form of a copper ring and is deliberately and effectively cooled by conduction along webs or struts 17 of high thermal conductivity fixed by clamping, screwing or other means to the cooled pump wall 14, the webs or struts serving rigidly to support the nozzle. In the construction shown the webs 17 are attached to a band 18 which is firmly secured to the wall 14. Instead of indirect cooling of the nozzle lip 16, direct water cooling may be used and whatever means are adopted, the nozzle lip should be cooled to a temperature such that the vapour pressure of any liquid running over it is not high enough to give rise to backstreaming, and it is found that temperatures lower than about 30 to 40° C. are desirable, although even somewhat higher temperatures give a considerable degree of backstreaming control. The middle region 19 of the nozzle which, as shown in Figure 2, although not necessarily in every case, has the form of a truncated cone, is made of a thin material of suitably low thermal conductivity, for example stainless steel, and is joined to the nozzle lip 16 and to the nozzle crown 20 by any convenient method such as brazing.

The nozzle crown 20 may be made of any convenient section and of any appropriate material. As the crown

is washed by the main vapour stream and thermally insulated from the cooled nozzle lip by the low conductivity middle section of the nozzle, it will normally attain a temperature not much lower than that of the main vapour stream probably 180 to 220° C. but varying considerably according to the particular pumping fluid and the operating boiler pressure.

A nozzle constructed as described will have, when operating, a cooled lip and a hot crown or vapour entry region and a region in between along which the shape of the temperature gradient can be varied by varying the thermal conductivity of the middle section of the nozzle or by selecting its length, its shape and proportions. It is possible by varying the design to exercise a great deal of control over the rate of heat extraction from the outer boundary of the vapour stream throughout the greater part of its travel through the nozzle and finally to ensure that any liquid condensed or liquid from other sources arriving at the nozzle lip is cooled by the time it arrives at a temperature such that its vapour pressure is too low to be objectionable.

It is apparent that the construction described provides control of a boundary layer as it arises. There is no need, as in the case of a low pressure gas nozzle, to consider extracting the boundary layer through slots at great inconvenience. By departing from past teaching and practice under which it has been considered that nozzles must be run hot, the boundary layer can be removed by condensation which is the most powerful method of pumping vapours.

Ideally the boundary layer would be just completely condensed as it arises throughout the whole length of the nozzle, and refinements to be referred to later may make possible an approximate approach to that ideal. In practice sufficiently good results are likely to be obtained if the boundary layer is allowed to grow a little during the early part of the expansion, where the resistance to heat flow down the middle section of the nozzle to the cool lip is highest, and is rather more than completely condensed towards the end of the expansion in the nozzle, where the heat path to the cool lip is direct. Some of the main vapour stream is then condensed towards the end of the expansion in the nozzle but the amount can be made insignificant from the point of view of pumping efficiency.

Measurements of boundary layer are not easily made but Figure 3 considered in conjunction with Figure 1 illustrates qualitatively the effect on the boundary layer of the application of the invention along the lines described. Thus it will be seen in Figure 3 that the boundary layer tending to be built up at 21, instead of issuing from the nozzle as a cloud as does the boundary layer in Figure 1, is dispersed in the form of condensation drops 22 after forming a film of liquid 23. The condensation drops 22 travel with the main vapour stream across to the cooled wall of the pump.

By dispersing the boundary layer as it forms the invention achieves the control of backstreaming from the nozzle lip without the need for condensing surfaces between the nozzle and the pump cooled wall arranged to stop backstreaming vapour from the nozzle, without the need for a cooled cap over the nozzle and without the need for a spray arrester in the vapour path between the boiler and the nozzle.

Further advantages provided by the invention include the feature that the progressive removal of the boundary layer permits adequate expansion of the vapour stream in a nozzle of reduced outside diameter, thus leaving more free area for the entrainment of gases being pumped, or in other words providing a greater pump speed for a given size. The construction of pump described provides a simple and economical means of clamping the interior assembly into the pump body.

It will be appreciated that variations and extensions of the particular embodiments of the invention described are possible. For example, more complete control of

the temperature gradient down the nozzle can be obtained in various ways and for instance the thickness and therefore the thermal conductivity of the middle region of the nozzle can be varied. Alternatively, further heat extraction rings around the nozzle may be provided, each such ring being connected to the main cooling system by heat conductors of any desired conductivity. In Figure 4 one such additional ring 24 is shown in heat conducting relation with a main web or strut 17 by a connecting strip 25. Again, temperature control may be effected by introducing a virtual temperature discontinuity by the use of a band of very low thermal conductivity, for example polytetrafluoroethylene at any desired section of the nozzle.

The invention may be applied to the inner boundary wall of an annular nozzle in the same manner as to the outer as shown, for example, in Figure 5 which illustrates a pump having an inner condensing wall 26 as well as an outer condensing wall 14. The annular nozzle 27 is shown provided with cooling rings 28, 29 the inner ring 29 being joined to the inner condensing wall 26 by a connecting member 30.

A construction alternative to that shown in Figure 2 is illustrated in Figure 6 in which the nozzle 32 itself is not provided with a separately formed lip and is composed of, for example, stainless steel. The lower edge of a copper ring or band 33 is brazed to the lower edge of the nozzle 32 and supporting struts 34 of which only one is shown, are in turn secured, conveniently by brazing, to the copper ring or band 18 shown in Figure 2 but not shown in Figure 6. In this manner a local contact is obtained between the nozzle lip and the cooling means.

In Figure 7 is shown a nozzle assembly having an inner wall 35 which provides control for part of the expansion of the vapour stream, there being a significant temperature drop between the lower edge of the inner wall 35 and the adjacent region of the outer wall 32. The inner wall 35 is uncooled so that controlled condensation takes place only during the later stages of expansion of the vapour stream. If desired, more than one inner wall may be provided. The boundary layer is least troublesome and is least thick towards the upper end of the nozzle where expansion of the vapour stream is only commencing and a construction using an inner wall or walls corresponding to 35 affords the advantage that excessive condensation may be avoided without the use of an inconveniently thin nozzle wall.

In the further method of effecting nozzle temperature control shown in Figure 8, the nozzle wall itself is formed with a re-entrant portion 36 to provide a considerably lengthened conducting path. Also in the case as in Figure 7, there is a temperature discontinuity along the interior of the nozzle wall, there being a significant temperature drop between the lower edge of the re-entrant portion and the adjacent region of the nozzle.

It will be appreciated that drops of liquid pumping fluid are continually becoming detached from the cool lip of the nozzle when a pump constructed in accordance with the invention is being operated. It is desirable that these drops be carried across to the cold pump walls by the main vapour stream so that they do not drop on the hot lower parts of the pump jet assembly and interfere with the pump performance as they re-evaporate. If the drops are too large, as might be the case were the nozzle lip not quite level so that drops tended all to form towards one side of it, they may drop through the vapour stream on to the lower part of the jet assembly. Accordingly it may be desirable to serrate the cool lip of the nozzle to promote the formation of many small drops which are more easily carried by the vapour stream than are larger and heavier drops. Alternately, leadaways for the liquid on the nozzle lip, such as a spider of wires, may be attached to the lip to carry the liquid downwards and

outwards to fall outside any hot lower parts it should not be allowed to reach.

The robust and rigid supporting of the top nozzle cap of a vapour pump from the cool upper parts of the pump body has usually been avoided in the past because the heat loss from the cap along the supports has always been considered highly undesirable in the light of the design considerations that have been accepted hitherto. The present invention so completely reverses conventional design concepts that heat loss from the cap becomes most desirable and the same means that provide paths for heat loss can most rigidly support the cap in the desired position. The cap in turn can be used to retain the rest of the interior assembly without any resort to the tie rods from the pump base, or other means conventionally employed.

Figure 2 illustrates one possible arrangement, a spring 31 being provided to permit the expansion and contraction of the interior as it is heated and cooled. Another similar arrangement is shown in Figure 9 in which a conducting strut 37 supporting the nozzle via the band 33 is rigidly secured by screws 38 to a block 39 mounted within the cooled wall of the pump.

The invention may be applied to any or all of the pumping stages of all forms of vapour vacuum pumps where vapour nozzles are used, and to any or all the nozzles of a pumping stage where multiple or composite nozzles are used in a single stage. A nozzle incorporating the invention may be of any desired shape and contour and not necessarily of the mainly conical shape and contour described and illustrated.

I claim:

1. In a vapour vacuum pump, in combination, a pump wall having means for cooling the same, a vapour nozzle having an inlet and an outlet and a nozzle wall therebetween, and positioned relative to said pump wall to discharge vapour toward and along said pump wall, a tube connected to the inlet of said nozzle for supplying condensable vapour thereto, and cooling means thermally connected with said nozzle for establishing a temperature gradient along said nozzle wall from the vicinity of said inlet to the vicinity of said outlet for condensing a portion of said vapour flowing adjacent said nozzle wall and thereby reducing flow from said outlet of vapour molecules having random direction of flow caused by rebound thereof from said nozzle wall, said temperature gradient being sufficient to cool the condensate so that when it emerges from the outlet of said nozzle it has too low a vapour pressure to contribute significantly to backstreaming from the pump.

2. In a vapour vacuum pump, in combination, a pump wall having means for cooling the same, a vapour nozzle having an inlet and an outlet and a nozzle wall therebetween, and positioned relative to said pump wall to discharge vapour toward and along said pump wall, a tube connected to the inlet of said nozzle for supplying condensable vapour thereto, and cooling means thermally connected with said nozzle for establishing a temperature gradient along said nozzle wall from a region intermediate said inlet and outlet to the vicinity of said outlet for condensing a portion of said vapour flowing adjacent said nozzle wall and thereby reducing flow from said outlet of vapour molecules having random direction of flow caused by rebound thereof from said nozzle wall, said temperature gradient being sufficient to cool the condensate so that when it emerges from the outlet of said nozzle it has too low a vapour pressure to contribute significantly to backstreaming from the pump.

3. The combination of claim 2, said nozzle having a lip at its outlet and an entry portion adjacent its inlet operable at a vapour maintaining temperature, said cooling means being thermally connected with said nozzle lip for thermally cooling the same, and said nozzle wall comprising a connecting portion connecting said entry portion and said lip, said connecting portion being of se-

lected and not necessarily uniform thermal conductivity chosen so that a temperature gradient is established along it for progressively condensing away boundary layer vapour as the lip of said nozzle is approached thereby, thereby substantially eliminating flow from said outlet of vapour molecules having random motion resulting from rebound from said connecting portion and lip.

4. The combination of claim 3, said cooling means having enough cooling capacity to cool the condensed liquid travelling to said lip to a temperature considerably below that of the vapour stream issuing from said outlet so that said liquid has a low vapour pressure and does not itself produce any significant backstreaming from the pump.

5. The combination of claim 3, said connecting portion being composed of thin material of low thermal conductivity, for example stainless steel.

6. The combination of claim 3, said nozzle lip being of heavier cross section than said connecting portion, and being of higher thermal conductivity than said connecting portion.

7. The combination of claim 6, said nozzle lip being constituted by a ring of metal secured in thermal conducting relation with said connecting portion.

8. The combination of claim 2, said cooling means comprising members of high thermal conductivity connecting a portion of said nozzle to said pump wall.

9. The combination of claim 8, said members comprising a common connecting member rigidly attached to said pump wall, and strut members one end of each of which is secured to said nozzle, and the other end of each of which is secured to said common connecting member.

10. The combination of claim 2, said nozzle being annular and having inner and outer boundary walls, and said pump comprising two of said cooled pump walls spaced from each other, one of said cooled pump walls being an outer pump wall and the other being an inner pump wall surrounding said vapour tube, a portion of the

outer boundary wall of said annular nozzle being in good heat conducting connection with said cooled outer pump wall, and a portion of the inner boundary wall of said annular nozzle being in good heat conducting connection with said cooled inner pump wall.

11. The combination of claim 1, said nozzle being composed of metal of low thermal conductivity, for example stainless steel, and having a lip at its outlet, and said cooling means comprising a metal band of high thermal conductivity, said nozzle being secured in good thermal conducting relation with said band, and said band being secured in good thermal conducting relation with said cooled pump wall.

12. The combination of claim 2, said nozzle having an uncooled inner wall extending from the vicinity of its inlet to said intermediate region.

13. The combination of claim 2, in which the conducting path of said nozzle is extended without increasing the overall depth of the nozzle by forming said nozzle with a re-entrant portion.

14. In a vapour vacuum pump, in combination, a vapour nozzle having an inlet, an outlet and a boundary wall therebetween; means connected to said inlet for supplying condensible vapour thereto for passage through said nozzle and from said outlet; and cooling means thermally connected with said boundary wall for cooling the same at least adjacent said outlet for condensing the boundary layer of the condensible vapour passing through said nozzle and thereby reducing flow from said outlet of vapour molecules having random direction of flow caused by rebound from said boundary wall.

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