

Feb. 20, 1940.

W. GAEDE

2,191,345

METHOD OF AND APPARATUS FOR DRAWING GASEOUS FLUIDS FROM RECEPTACLES

Filed Dec. 21, 1936

3 Sheets-Sheet 1

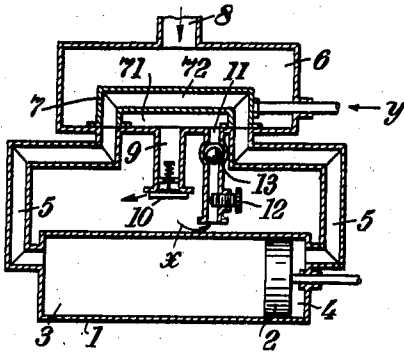


Fig. 1

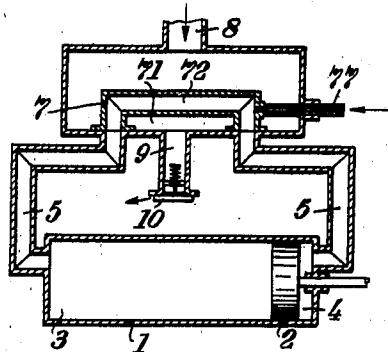


Fig. 1a

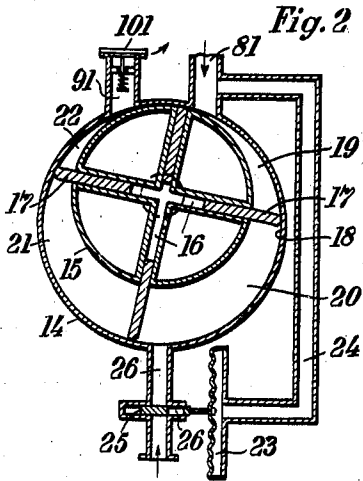


Fig. 2

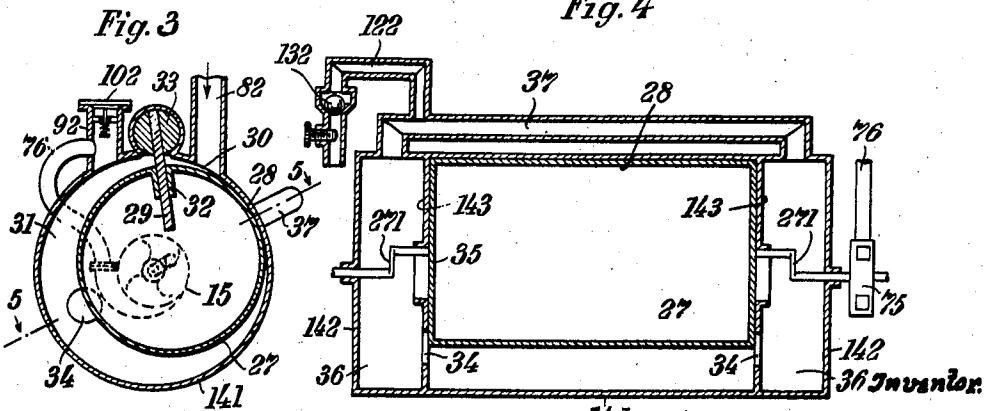


Fig. 3

Fig. 4

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3 Sheets-Sheet 2

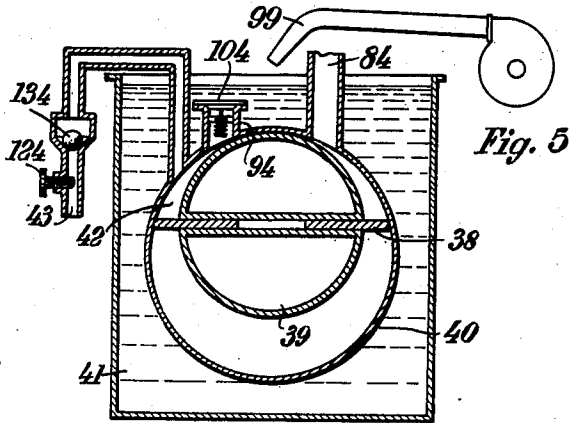


Fig. 5

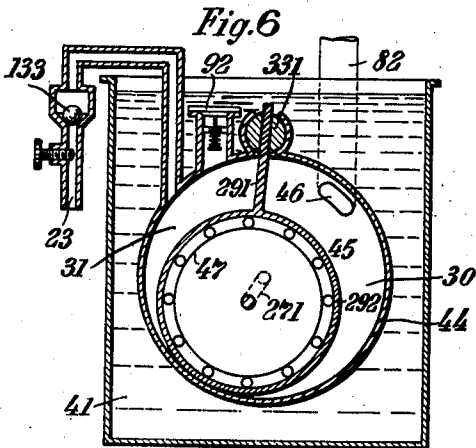


Fig. 6

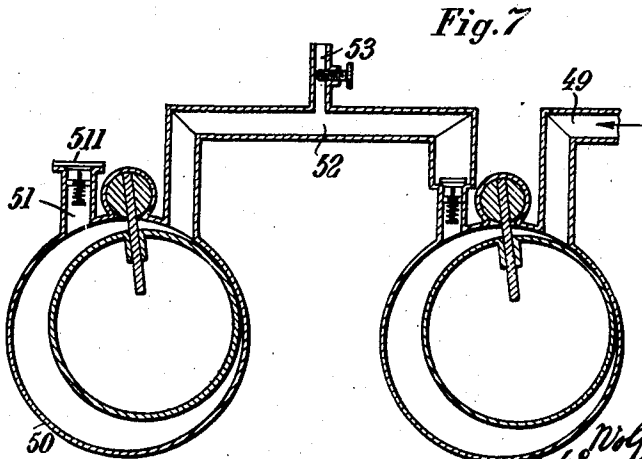


Fig. 7

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3 Sheets-Sheet 3

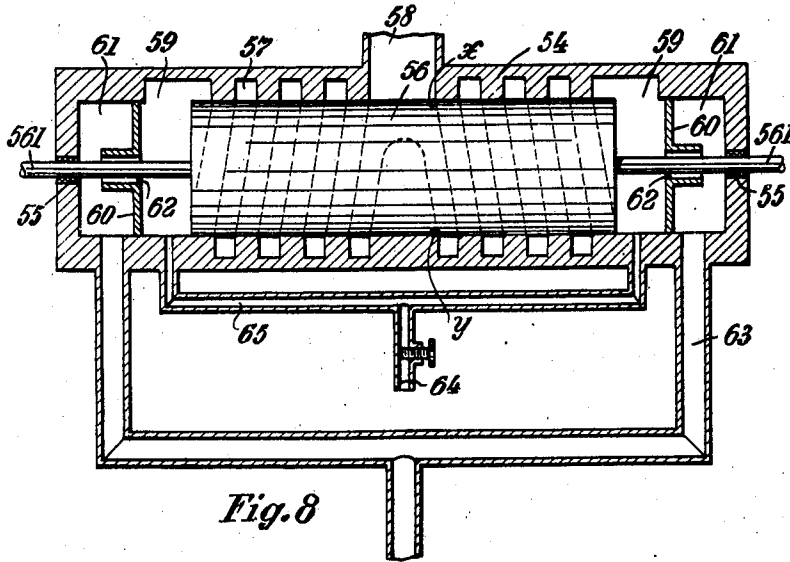


Fig. 8

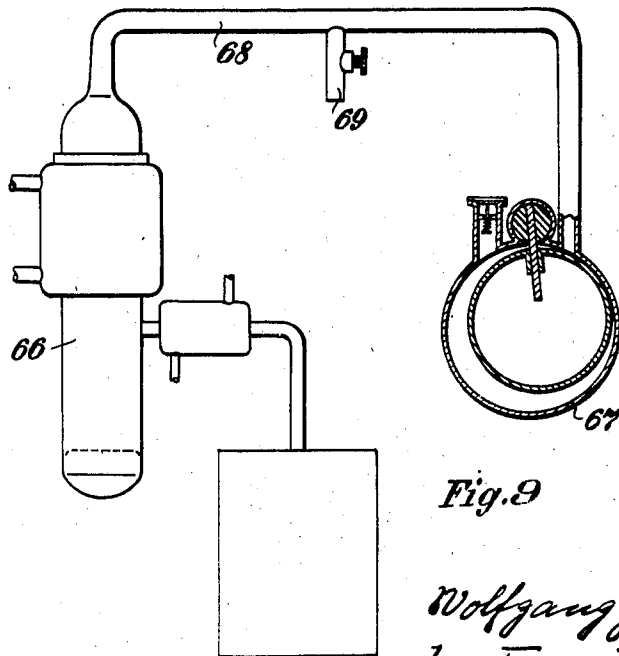


Fig. 9

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UNITED STATES PATENT OFFICE

2,191,345

METHOD OF AND APPARATUS FOR DRAWING GASEOUS FLUIDS FROM RECEPTACLES

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Application December 21, 1936, Serial No. 117,021
In Germany December 21, 1935

8 Claims. (Cl. 230-1)

My invention relates to improvements in high vacuum pumps, and more particularly in high vacuum pumps for drawing off vapors or mixtures of gas and vapor. In such pumps the vapor or mixture of gas and vapor is subject to condensation, and the precipitated liquid is distributed all through the pump and also gets into the suction conduit or into chambers connected therewith, where it is again vaporized and spoils the vacuum.

The object of the improvements is to provide a pump in which this objection is obviated, and with this object in view my invention consists in supplying a certain amount of gas to the vapor or mixture of gas and vapor which has been drawn off by the pump, the said amount of gas being compressed and expelled from the pump together with the vapor or mixture.

The amount of gas supplied to the vapor may be such that any condensation of vapor is avoided. But in many cases it will be sufficient to supply only so much gas that a certain amount of the vapor is condensed, provided that the said condensed vapor is immediately vaporized when the space containing the same gets into communication with an evacuated chamber which is separated from the suction conduit and in which the condensed vapor is immediately vaporized.

For the purpose of explaining the invention several examples embodying the same have been shown in a diagrammatical way in the accompanying drawings in which the same reference characters have been used in all the views to indicate corresponding parts. In said drawings,

Fig. 1 is a diagrammatic figure, showing in longitudinal section a high-vacuum pump in which the invention is embodied;

Fig. 1a is a similar view, illustrating a modification in the embodiment of the invention;

Fig. 2 is a view in transverse section showing a pump of different type, and an embodiment of the invention with a certain refinement;

Figs. 3 and 4 are views in transverse and longitudinal section of a pump of a third type, having the invention embodied in a somewhat different arrangement of parts;

Fig. 5 is a view in transverse section of a pump of the type shown in Fig. 2, immersed in an oil bath, but having the invention embodied in the structure;

Fig. 6 is a view similar to Fig. 5, in which the type of pump is that shown in Figs. 3 and 4;

Fig. 7 is a view in transverse section of a tandem arrangement of two pumps, severally of the

type shown in Fig. 3, having the invention embodied in the organization;

Fig. 8 is a view in longitudinal section of a pump of yet another type in which also the invention is embodied; and

Fig. 9 is a view corresponding in other respects to Fig. 7, in which the pump that stands first in the tandem succession has been replaced by a pump of another type—of the type, namely, of Fig. 8. This substituted pump is in Fig. 9 shown in elevation and a receptacle to be evacuated is diagrammatically shown, with connection to the pump.

In the example shown in Fig. 1 the pump comprises a cylinder 1 having a piston 2 reciprocating therein. The chambers 3 and 4 are connected by passages 5 with a valve chest 6 in which a slide valve 7 is located, the movement of the said valve being displaced with relation to that of the piston at an angle $\pi/2$. To the valve chest 6 a suction conduit 8 is connected. A pressure or delivery passage 9 including a check valve 10 is connected to a chamber 11 provided by the concave part of the slide valve, the said check valve being automatically opened when sufficient pressure is produced within the chamber 11. The said chamber is provided with a vent 11 including a regulatable throttle valve 12, and between the said vent and the throttle valve 12 there is a check valve 13 which is closed by pressure within the chamber 11. Through the said throttle valve and the vent 11 an additional amount of gas may be supplied to the chamber 11 as is indicated by the arrow x.

In the position of the parts shown in the figure the piston 2 is in its right hand dead center, the chambers 3 and 4 communicate temporarily with each other through the passages 5 and a passage 12, so that the chamber 4 is relieved of pressure. The slide valve 7 moves to the left and in the direction of the arrow y, and it is just in its median position. The chamber 3, which before was in communication with the suction conduit 8 is now disconnected from the said suction conduit by the slide valve 7, and the vapor or mixture of gas and vapor is under low pressure. When the slide valve continues its movement to the left the chamber 11 is connected with the evacuated chamber 3, and the vacuum is transmitted from the chamber 3 to the chamber 11 so that the check valve 13 permits a certain amount of gas to be supplied through the chamber 11 and into the chamber 3. By this supply of gas to the evacuated vapor, condensation by the compression of the charge of the chamber 3

is prevented or reduced so far that no liquid is collected within the pump. By the compression stroke of the piston pressure is produced within the chamber 71, and thereby the check valve 13 is closed and the check valve 10 is opened, so that the whole charge is delivered through the check valve 10.

In the construction shown in Fig. 1 the chamber 3 and the chamber 71 connected therewith provide the evacuated chamber into which the additional gas is supplied, the said chamber being disconnected from the suction conduit. The gas is compressed together with the vapor or mixture of gas and vapor within the chambers 3 and 71. By means of the throttle valve 12 the supply of gas to the said chambers may be regulated at will, the supply being such that either condensation of the vapor is entirely avoided, or that only a slight amount of vapor is condensed which is immediately vaporized again when the chamber 71 gets into connection at the end of the next stroke of the piston 2 with the evacuated chamber 4.

The regulation of the supply of the gas to the vapor or mixture of gas and vapor should be made so as is needed in the various steps of the operation. A large amount of gas is needed at the beginning of the evacuation of a receptacle by the pump and when the vacuum within the pump is comparatively small, and as the vacuum is increased the amount of gas falls off. For this reason it is preferred to provide automatic means for regulating the supply of gas to the pump, the said regulating means acting so that the throttle valve is closed more and more as the pressure within the suction conduit falls off, and that thus the amount of gas supplied to the pump is reduced. This regulation of the supply of gas is desirable because the gas supplied to the pump must be compressed and the energy necessarily to be supplied to the pump is thereby increased.

In Fig. 1a I have shown a modification in which the additional gas or air is supplied to the passage 72 through an axial bore made in the valve rod 77. In this case the said gas or air is supplied only at the moment when chambers 3 and 4 are connected with each other, and it is transmitted to the vapor or mixture of gas and vapor contained in the chamber 3 (or 4).

In Fig. 2 I have shown a modification of the pump in which automatic means are provided for thus regulating the supply of gas to the pump.

The pump is provided with rotary pistons 17 which are slidably mounted in slots 16 made in a rotary cylinder 15 eccentrically mounted in a cylindrical casing 14. The pistons 17 are in contact with the wall of the casing at 18, and they divide the same into chambers 19, 20, 21 and 22 which alternately act as suction and pressure chambers. In the position of the parts shown in the figure the chamber 19 is in communication with the suction conduit 81 and it acts as a suction chamber, the chamber 20 is disconnected from the suction conduit, and it communicates with a vent 26 through which a certain amount of air is supplied to the vapor or mixture confined within the said chamber, the said air or gas being compressed thereafter together with the vapor or mixture, and the chamber 21 contains gas or a mixture of vapor and gas and in addition a certain amount of gas supplied thereto through the vent 26. The compressed mixture is delivered through a pressure passage 91 provided with a check valve 101.

Within the chamber 20 there is no compression of the vapor or mixture, and therefore a check valve may be dispensed with in the vent 26. The vent provides throttling means which are controlled in accordance with the vacuum within the receptacle to be evacuated. As shown, the suction passage 81 is connected through a pipe 24 with an elastic box 23, and the said box is connected with a throttle member 25 having the vent 26 formed therein. At the beginning of the operation, and when evacuation of the receptacle connected with the suction passage 81 has not yet begun, the vent 26 is open, and in the degree as evacuation proceeds the throttle member 25 moves to the right and in a direction for reducing the area of the vent 26. Thus the amount of gas supplied to the chamber 20 is gradually reduced.

The action of the supply of gas to the vapor or mixture of vapor and gas in the manner described with reference to Figs. 1 and 2 will be best understood from the following example:

In the construction shown in Fig. 1 the vapor confined within the chamber 3 is compressed to a pressure a little more than 1 atmosphere, and it is expelled through the check valve 9. It may be assumed that the pump draws in vaporized water of a pressure of 0.1 millimeter mercury column, and that no air is supplied to the chamber 71. Therefore the vapor which is compressed within the said chamber to 1 atmosphere is completely condensed and precipitated on the wall of the pump in the form of water, because the temperature of the said wall is less than the boiling temperature of the vapor at atmospheric pressure, which in case of water is 100° C. It may now be assumed that a certain amount of air is added to the vapor within the chamber 71 which is separate from the suction conduit. The partial pressure of the air which is thus added may be 8 millimeters mercury column, and the partial pressure of the vaporized water 0.1 millimeter mercury column. When now the vapor is again compressed to a little more than 1 atmosphere, the partial pressures rise substantially to hundredfold the original value, and therefore the partial pressure of the air rises to 800 millimeters mercury column and the partial pressure of the vaporized water to 10 millimeters mercury column. With this partial pressure the dew point of the vaporized water is 11° C. Of course, the temperature of the pump is higher than this value, so that condensation of the steam within the pump is impossible, even if the temperature of the mixture of air and water vapor should not rise notwithstanding the compression, by reason of the contact with the wall of the pump.

If it is desired to prevent any condensation of steam within the pump, it is necessary only to add a sufficient amount of air, which amount may be calculated from the above data. However, in many cases it is not necessary to add so much air, and a smaller amount of gas or air may be sufficient, which is desirable because thereby the work of compression of the pump is not unduly increased. It is not necessary in any case to prevent any condensation of vapor within the chamber 71, and it is sufficient to take care that the amount of liquid precipitated within the said chamber by condensation of the vapor is immediately vaporized when communication is established between the chamber 71 and the evacuated chamber 3 or 4 of the cylinder. It must be borne in mind that the liquid which is precipitated by

any compression stroke and again vaporized is mixed with the vapor within the evacuated chamber 3 or 4, and that thereby the amount of liquid precipitated by the next compression is increased. However, when a suitable amount of air is added to the low pressure vapor, after a certain number of operations the precipitated amount of liquid is always vaporized, as appears from the following:

It may be assumed that by each compression a portion a of the vapor contained within the evacuated chamber is precipitated on the wall of the pump, a being a value smaller than 1. The evacuated chamber may contain an amount D of vapor, so that by the first compression the amount of water $W_1 = D \cdot a$ is precipitated. After the first compression, and when the low pressure mixture is delivered into the evacuated chamber 71, the said amount of water W_1 is vaporized, and it is added to the mixture contained within the chamber 71. Therefore after the second compression the amount of water contained in the mixture within the evacuated chamber 71 is $D(1+a)$. By the second compression a part a of the vapor contained in the chamber 71 is again condensed, so that the whole amount of condensed water is $W_2 = D(a+a^2)$. This amount of water W_2 is added to the mixture contained within the chamber 71 which is compressed by the third compression, so that the amount of vapor within the said mixture is $D(1+a+a^2)$. By the third compression the portion a of the vapor is again condensed, and the amount of precipitated water is $(W_3 = D(a+a^2+a^3))$. This process is continuously repeated so that after n compressions the whole amount of precipitated water is

$$W_n = D(a + a^2 + a^3 + \dots + a^n) = aD \frac{1-a^n}{1-a}$$

If a is 1, and if all the vapor is condensed, the amount of the said condensed liquid is

$$W_n = n \cdot D$$

Therefore by each compression the condensed amount of water is increased by the full amount D , and therefore all the water is collected within the pump. This is the case when no air is added.

If however, a is smaller than 1, the amount of water present in the mixture after several compressions approaches the value

$$W = aD \frac{1}{1-a}$$

In this equation $a \cdot D$ is the amount which is precipitated by the first compression. The factor

$$\frac{1}{1-a}$$

shows to what extent the precipitated amount of water is increased after an infinite number of compressions. If for example, the value a is 0.1, the said factor is about 1.1, which indicates that the amount of water which is precipitated after an infinite number of compressions is hardly larger than the amount of water of the first compression. The said amount of water being

$$W = 0.11 \cdot D$$

Thus, after each compression about one tenth of the vapor is precipitated, and this vapor is completely vaporized when it gets into connection with the evacuated chamber 3 or 4. Therefore, by adding a suitable amount of gas a collection of liquid in the pump can be avoided.

In Figs. 3 and 4 I have shown a pump having a gyratory piston 27 which is mounted eccentrically

within a cylinder 141 and on a cranked shaft 271 rotatably mounted in end walls 142 of the cylinder 141, the said piston being in linear contact with the wall of the said cylinder at 28. The space provided between the piston 27 and the cylinder is divided by a plate 29 into chambers 30 and 31 which alternately act as suction and compression chambers. The plate 29 is shiftable in a slot 32 made in the circumferential wall of the piston 27, and it is fixed to a pivotally mounted cylindrical block 33. In the operation of the pump vapor or a mixture of vapor and gas is drawn through a suction passage 82 and into the chamber 30 which at the time acts as a suction chamber, and simultaneously a charge of vapor or mixture which before has been drawn into the chamber 31 is compressed and expelled through a pressure passage 92 and a check valve 102 provided for closing the said passage. Upon further gyration of the piston 27 the line of contact 28 travels around the wall of the cylinder in clockwise direction, and finally it passes first the pressure passage 92 and thereafter the suction passage, whereupon the enlarging chamber 30 is connected with the suction passage, while the diminishing chamber 31 is connected with the pressure passage. To the chamber 31 which is disconnected from the suction passage and connected with the pressure passage a certain amount of gas is supplied through vents 34 made one in each of two partition walls 143 of the cylinder 141, and the end walls 35 of the piston 27 periodically close the said vents 34 in order to prevent the access of the air into the chamber which is in connection with the suction passage, and they open the said vents while the chamber which is connected with the pressure passage is still under a high vacuum.

The vents 34 open into chambers 36 through which the cranked shaft 271 of the cylinder is passed outwardly, and the said chambers 36 are connected by a passage 37 with a vent 122 for the supply of air, which vent may be normally closed by a check valve 132.

In Figs. 5 and 6 I have shown pumps which are similar to the pumps shown in Figs. 3 and 4, which however work within an oil bath.

In pumps of this type the supply of air to the vapor or mixture of vapor is particularly important. In the evacuation of receptacles containing vaporized water the oil which covers the pressure passage is gradually transformed into a dim yellowish emulsion of oil and water, so that the pump is not able any more to produce the same high vacuum as at the beginning of the operation. I have found that by adding gas or air to the vapor in the manner described above this objection may be obviated, as will appear from the following:

The air is expelled through the oil-covered valve, and it produces minute bubbles within the oil. The radius of a bubble may be r , and the pressure of the air within the bubble p . The pressure within the oil around the bubble may be p' , and p' may be smaller than p by the value p'' , p'' being the additional pressure produced by the capillary force of the oil. If α is the capillarity constant, the said additional pressure is

$$p'' = \frac{2\alpha}{r}$$

Between the pressure p within the gas bubble and its volume

$$v = \frac{4}{3}\pi r^3$$

there is the relation $p.v=C$, in which C is a constant, as long as the temperature and the mass are not changed. Thus the pressure within the bubble is

$$p=p'+p''$$

or

$$\frac{C}{\frac{4}{3}\pi r^3}=p'+\frac{2\alpha}{r}$$

From this equation the radius of the bubble under varying outer pressure may be determined. First an air bubble within the oil may be considered, and the following values may be assumed: $\alpha=25$ and $C=1.3$ (absolute measuring system). When the bubble being expelled through the valve of the pump is compressed to atmospheric pressure, and the pressure within the oil is $p'=760$ millimeters mercury column, the following values expressed in technical measuring system are obtained: Diameter of the bubble $d=0.13$ millimeter, capillary pressure $p''=5.5$ millimeters mercury column, pressure within the bubble $p=765.5$ millimeters mercury column. Thus the capillary pressure p'' is immaterial.

When the bubble is not expelled through the valve, but gets into the evacuated space of the pump and rises therein to the surface of the oil, so that there is no liquid column above the same, and, therefore, p' is 0, the following values are obtained: $d=1.6$ millimeters, $p''=p=0.47$ millimeter, mercury column. The bubble which is near the vacuum is not continuously expanded until it bursts but it keeps the diameter 1.6 millimeters, and it is under the pressure $p''=0.47$ millimeter, mercury column which is produced by the capillary force.

When now the pressure rises by reason of the compression within the compression chamber of the pump, say to $p'=54$ millimeters mercury column, the values are changed as follows: $d=0.32$ millimeter, $p''=2.3$ millimeters mercury column and $p=56.3$ millimeters mercury column. The diameter of the bubble falls off as the pressure within the said chamber is increased, and simultaneously the pressure produced within the bubble by the capillary force rises.

Now it may be assumed that the same bubble which so far was assumed to be filled with air, is filled with vaporized water. The temperature of the oil may be 40°C ., and the saturation point of the water vapor at this temperature is 55 millimeters, mercury column. As long as the pressure p within the bubble is less than 55 millimeters, mercury column, the values of d , p and p'' are the same as in case of air bubbles. When however the pressure p rises above the saturation pressure of 55 millimeters, mercury column, as is the case with continued compression, the vapor is condensed to water. When with the pressure of 55 millimeters, mercury column, that is slightly before condensation, the bubble of vapor has the diameter $d=0.32$ millimeter, it shrinks upon condensation to the volume of the liquid, and finally it is transformed into a minute drop of water having a diameter $d=0.12$ millimeter. Now the pressure produced by the capillary forces is $p''=63$ millimeters, mercury column, which pressure is higher than the saturation pressure of 55 millimeters mercury column. The pressure p does not fall below the value permitting vaporization of the drop of water, even when the oil surrounding the same gets again into contact with the evacuated space of the pump and the outer pressure p' is reduced to

zero. Therefore the water remains in a liquid state.

When however gas is added to the vapor within the pump chambers in the manner described above, the bubbles which are formed within the oil contain a mixture of gas and vapor. It is necessary only to add so much gas that the capillary forces become larger than the saturation pressure of the steam and thus prevent re-vaporization.

Therefore it is not only possible to prevent precipitation of liquid within the pump, but also, by adding a certain amount of gas to oil pumps, the oil may be prevented from being gradually transformed into an emulsion of oil and water.

Referring now again to the oil pump illustrated in Fig. 5, it will be seen that the general construction of the pump is similar to the one described with reference to Fig. 2. The pump comprises a cylindrical casing 40 having a rotatable cylinder 39 eccentrically mounted therein, the said cylinder 39 being formed with a diametrical slot in which pistons 38 in the form of plates are shiftable. The cylindrical casing is connected with a suction passage 84 and a pressure passage 94 provided with a check valve 104. The cylindrical casing is located in an oil bath 41 which covers the check valve 104. The pistons 38 divide the space between the cylindrical casing 40 and the cylinder 39 into three chambers. In the position of the parts shown in the figures the chamber 42 communicates with the pressure passage 94, and it has a supply of additional air through a vent 43 including a throttle 124 and a check valve 134. Therefore a mixture of vapor and air is delivered through the passage 94. When the amount of the said additional air is sufficient the bubbles produced in the oil keep the form of air bubbles, and they rise to the surface of the oil and burst after some time, and the transformation of the air bubbles into drops of water, which would spoil the pump and the vacuum, is prevented. Preferably the air at the surface of the oil is continuously regenerated, in order that the liquid contained in the bubbles is immediately vaporized as is indicated by a nozzle 99.

The pump illustrated in Fig. 6 is similar in construction to the pump illustrated in Fig. 3. As distinguished from the pump shown in Fig. 3 the pump shown in Fig. 6 is disposed in an oil bath 41. Further, the suction passage 82 does not open into the pump through the cylindrical wall 44, but through one of the end walls 45, the port having received the reference character 46. Therefore the said port is covered by the end wall of the cylinder 47 when the said cylinder is in its uppermost position, and a connection between the vent 122 and the suction passage 82 is prevented. As far as the action of the air delivered from the pump on the oil is concerned, the function is the same as has been described with reference to Fig. 5.

In the construction shown in Fig. 6, the plate 291 is made integral with a ring 292 rotatably mounted on the piston 47, and it is in sliding engagement with a cylindrical block 331 pivotally mounted in a bore of the casing 44. This construction of piston, ring, and abutment has been shown in the patent of the United States No. 1,997,725 granted to me July 16, 1935.

In Fig. 7 I have shown an embodiment of the invention in a two-stage pump. As shown, the said pump consists of a high vacuum pump 48 and a low vacuum pump 50, which pumps are similar in construction to the pump illustrated

in Fig. 3. The suction conduit 49 of the pump 48 is connected with the container to be evacuated. The delivery passage 51 of the pump 50 includes a check valve 511. The delivery passage of the pump 48 is connected by a pipe 52 with the suction passage of the pump 50, and it comprises a regulatable vent 53 through which an additional amount of air is supplied to the air delivered from the pump 48 and supplied to the pump 50. The amount of air supplied through the said vent is regulated so that by the compression of the vapor drawn from the receptacle by the pump 48 no liquid is collected in the pump 50, so that, in case of a pump disposed in an oil bath, the said oil is not transformed into an emulsion of oil and water.

In the figure the pumps 48 and 50 have been shown one beside the other. But I wish it to be understood that ordinarily the said pumps are mounted on the same axis.

It will be understood that the invention illustrated in Fig. 7 may be embodied in connection with high vacuum pumps of any type. For example, in lieu of the pump 48 a pump based on molecular action may be used. Such a pump has been illustrated in Fig. 8.

As shown in the said figure, the pump comprises a cylindrical casing 54 which is formed internally with helical grooves 57 having oppositely directed pitch. Within the cylindrical casing 54 a cylinder 55 is rotatably mounted. The receptacle to be evacuated is connected to the cylindrical casing at 58, and the mixture of gas and vapor or vapor is delivered at both ends of the casing 54 through a delivery passage 63 which is connected to a vacuum pump such as 50 (Fig. 7) by means of which a vacuum is maintained at the delivery ends of the pump. Under such circumstances vapor or mixture of gas and vapor is drawn from the tubular stud 58 through the helical grooves 57 into chambers 59 provided at either end of the cylinder 56. Preferably, the bearings 55 of the shaft 561 of the cylinder 56 are separated from the chambers 59 by partitions 60, and they are located in separate chambers 61, the shaft passing through concentric openings 62 of the partition walls 60. The chambers 59 are connected with each other by a pipe 65 which is provided with a regulatable vent 64.

The function of the pump may at first be considered without a supply of additional gas through the vent 64. Under such circumstances oil vapors may get from the chambers 61 and 59 and particularly from the lubricated bearings 55 into the receptacle to be evacuated when the pump is at rest. If thereafter the operation of the pump is started the saturated oil vapor is drawn from the receptacle, and by the slightest increase of pressure the oil is precipitated. For example, a mass of oil located at x is transmitted by the rotation of the cylinder 56 to y , and it is condensed at this point by reason of the higher pressure of the gas. By the further rotation of the cylinder 56 the film of oil is again returned to x , and it is vaporized at this point and may flow back into the receptacle to be evacuated. Thus it is not possible to draw the vapor of oil from the receptacle.

If, however, a certain amount of air is supplied to the chambers 59, there is a continuous flow of air from the chambers 59 and through the openings 62 into the chambers 61 and to the pipe 63 and the suction side of the pump 50. Thus, there is a mixture of vapor and air within the chambers 59. By supplying a sufficient

amount of gas or air the partial pressure of the vapors within the chambers 59 may be reduced far below the saturation pressure of the vapors, so that the pressure of the vapors drawn by suction from 58 and flowing through the grooves 57 to the chambers 59 is always below the saturation pressure. Therefore the vapors cannot be condensed any more within the grooves 57. The current of additional gas or air carries the vapors from the chambers 59 through the openings 62 and the chambers 61 through the pressure conduit 63 and the vacuum pump connected therewith. Thus by adding a certain amount of additional air to the gas, not only vapors of any kind, but also oil vapors may be removed from the receptacle, and, further, when hydrogen is drawn off a high vacuum may be produced which would be impossible without the said supply of additional air or gas in view of the high molecular velocity of the hydrogen. The smaller the molecular velocity of the said additional gas or air is, the higher is the vacuum which may be obtained by means of the pump shown in Fig. 8. The continuous flow of air through the passage 62 prevents the oil vapor from flowing from the bearings 55 into the high vacuum pump. The size of the openings 62 must be such that they do not act as diffusion slots, and that therefore the oil vapor is not transmitted by diffusion from the chambers 61 into chambers 59.

Also in the constructions shown in Figs. 7 and 8 the vents 53 and 64 may be provided with automatic regulating means such as have been described in connection with Fig. 2, so that only so much additional air is supplied as is needed for attaining the result aimed at. Thereby an undesirable increase of the power to be supplied to the pump is avoided.

In Fig. 9 I have illustrated the invention as embodied in a diffusion pump. The diffusion pump has been shown in a general way and it has received the reference character 66. The said pump cooperates with a pump 67 which may have the construction shown in Fig. 4. The delivery passage of the diffusion pump 66 is connected by a pipe 68 with the suction passage of the pump 67, and the said pipe 68 is provided with a vent 69 through which additional air may be supplied in the manner described with reference to Fig. 7.

Diffusion pumps such as are shown by way of example in Fig. 9 are known in the art, and I deem it not necessary to describe the same in detail.

In all the embodiments of the invention the mixture of additional air and vapor in the delivery passage of the pump may be mixed with fresh air and flushed thereby from the delivery passage. The current of fresh air may be produced by friction of a rotary plate fixed to the pump shaft or by centrifugal force by means of centrifugal blades carried by the shaft of the pump. An example of this construction has been illustrated diagrammatically in Figs. 4 and 5 in which a propeller 75 is mounted on the shaft of the rotary piston 271, the casing of said propeller being connected by a pipe 76 with the delivery passage 92.

In the claims I refer to gaseous fluids which are drawn from the receptacles, and to a relatively non-condensable gaseous fluid which is supplied to the said gaseous fluid, and I understand the term gaseous fluid drawn from the receptacle to indicate either a vapor, or a mix-

ture of gas and vapor, or a gas which is originally not condensable and to which vapor is added in the operation of the pump, for example vaporized lubricating medium. The term relatively non-condensable gaseous fluid is understood to mean a gas or air which either does not contain any vapor at all, or an amount of vapor which is small as compared to the vapor contained in the gaseous fluid drawn from the receptacle to be evacuated, the said non-condensable gaseous fluid having the function to counteract the tendency of the gaseous fluid drawn from the receptacle to be condensed by pressure.

15 I claim:

1. In the operation of evacuating a vessel by means of a high vacuum pump having a chamber that intermittently and repeatedly is connected with and disconnected from the vessel to be evacuated and that is alternately filled by enlargement and emptied by contraction, the method herein described of preventing condensation of vapor upon the chamber walls that consists in admitting to the chamber after its enlargement and before its contraction is completed an augmenting volume of vapor-absorbing gas.

2. In the production of high-vacuum elements, and in the operation of apparatus that includes, in association with a container whose contents are of vaporous nature, a high-vacuum pump having an expanding and contracting chamber, together with means for establishing intermittent communication between the container and the pump chamber, whereby the isolated and progressively attenuated body of vaporous nature within the container is repeatedly expanded into the pump chamber, and a fraction thereof segregated within the pump chamber and compressed, the method herein described of widening the limit of attainable attenuation which consists in rendering the segregated fraction of attenuated vapor uncondensable under the said compression by adding thereto before compression a volume of vapor-absorbing gas.

3. In the production of high-vacuum elements, and in the operation of apparatus that includes, in association with a container whose contents are of vaporous nature, a high-vacuum pump having an expanding and contracting chamber, together with means for establishing intermittent communication between the container and the pump chamber, whereby the isolated and progressively attenuated body of vaporous nature within the container is repeatedly expanded into the pump chamber, and a fraction thereof segregated within the pump chamber and compressed, the method herein described of widening the limit of attainable attenuation which consists in rendering the segregated fraction of attenuated vapor uncondensable under the said compression by adding thereto before compression a volume of vapor-absorbing gas, the successively added volumes of vapor-absorbing gas, as attenuation increases, being of diminishing magnitude.

4. In high-vacuum apparatus that includes the combination of a receptacle to be evacuated, filled with a gas of vaporous content, a vacuum pump provided with intake and discharge ports and having a chamber that in the progress of operation expands and contracts, and means for establishing intermittent communication from the receptacle through the intake port to the pump chamber and, alternatively, from the pump chamber through the discharge port to the open air, whereby an isolated and progressively atten-

uated body of the gas within the receptacle may be repeatedly expanded into the expanding pump chamber and fractions thereof, of progressively diminishing mass—that is to say, of increasing degree of attenuation,—segregated within the pump chamber, may be expelled under pressure from the contracting pump chamber through the discharge port, the improvement herein described of preventing disturbance of the progress of attenuation which consists in combining with such apparatus means for admitting to each successive segregated fraction of the so-expanded contents of the receptacle a volume of vapor-absorbing gas, whereby the tendency of the vapor to condense under the pressure of expulsion is overcome.

5. In high-vacuum apparatus that includes the combination of a receptacle to be evacuated, filled with a gas of vaporous content, a vacuum pump provided with intake and discharge ports and having a chamber that in the progress of operation expands and contracts, and means for establishing intermittent communication from the receptacle through the intake port to the pump chamber and, alternatively, from the pump chamber through the discharge port to the open air, whereby an isolated and progressively attenuated body of the gas within the receptacle may be repeatedly expanded into the expanding pump chamber and fractions thereof, of progressively diminishing mass—that is to say, of increasing degree of attenuation,—segregated within the pump chamber, may be expelled under pressure from the contracting pump chamber through the discharge port, the improvement herein described of preventing disturbance of the progress of attenuation which consists in combining with such apparatus means for admitting to each successive segregated fraction of the so-expanded contents of the receptacle a volume of atmospheric air, whereby the tendency of the vapor to condense under the pressure of expulsion is overcome, such means including an intake of adjustable effective size open to the air.

6. In high-vacuum apparatus that includes the combination of a receptacle to be evacuated, filled with a gas of vaporous content, a vacuum pump provided with intake and discharge ports and having a chamber that in the progress of operation expands and contracts, and means for establishing intermittent communication from the receptacle through the intake port to the pump chamber and, alternatively, from the pump chamber through the discharge port to the open air, whereby an isolated and progressively attenuated body of the gas within the receptacle may be repeatedly expanded into the expanding pump chamber and fractions thereof, of progressively diminishing mass—that is to say, of increasing degree of attenuation,—segregated within the pump chamber, may be expelled under pressure from the contracting pump chamber through the discharge port, the improvement herein described of preventing disturbance of the progress of attenuation which consists in combining with such apparatus means for admitting under superior pressure to each successive segregated fraction of the so-expanded contents of the receptacle a volume of vapor-absorbing gas, whereby the tendency of the vapor to condense under the pressure of expulsion is overcome, such means including a control element responsive as operation progresses to the diminishing pressure of the progressively attenuated body of gas.

7. In high-vacuum apparatus that includes the

combination of a receptacle to be evacuated, filled with a gas of vaporous content, a vacuum pump provided with intake and discharge ports and having a chamber that in the progress of operation expands and contracts, and means for establishing intermittent communication from the receptacle through the intake port to the pump chamber and, alternatively, from the pump chamber through the discharge port to the open air, whereby an isolated and progressively attenuated body of the gas within the receptacle may be repeatedly expanded into the expanding pump chamber and fractions thereof, of progressively diminishing mass—that is to say, of increasing degree of attenuation,—segregated within the pump chamber, may be expelled under pressure from the contracting pump chamber through the discharge port, the improvement herein described of preventing disturbance of the progress of attenuation which consists in combining with such apparatus means for admitting under superior pressure to each successive segregated fraction of the so-expanded contents of the receptacle a volume of vapor-absorbing gas, whereby the tendency of the vapor to condense under the pressure of expulsion is overcome, such means including an inlet port and fluid-pressure means responsive to the diminishing pressure of the progressively attenuated body of gas that repeatedly expands into the expanding pump chamber for changing the effective size of the inlet port of the gas-admitting means.

8. In high-vacuum apparatus that includes the combination of a receptacle to be evacuated, filled with a gas of vaporous content, a vacuum pump comprising a cylindrical casing, a cylindrical piston of smaller diameter arranged within the casing and adapted to move in gyratory course in linear contact with the casing wall, and a plate pivotally mounted in the casing and engaging the piston with sliding connection, the said casing being provided with a suction passage through which the said receptacle is in communication with the pump, and with a pressure passage through which the pump discharges, whereby as the piston gyrates a chamber within the casing expands and contracts and an isolated and progressively attenuated body of the gas within the receptacle may be repeatedly expanded into the expanding chamber within the pump casing and fractions thereof, of progressively diminishing mass—that is to say, of increasing degree of attenuation,—segregated within the casing, may be expelled under pressure from the contracting chamber through the pressure passage, the improvement herein described of preventing disturbance of the progress of attenuation which consists in combining with such apparatus means for admitting to each successive segregated fraction of the so-expanded contents of the receptacle a volume of vapor-absorbing gas, whereby the tendency of the vapor to condense under the pressure of expulsion is overcome.

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