July 2, 1940. K. C. D. HICKMAN 2,206,093

VACUUM PUMP

Filed Jan. 4, 1939

Fig. 1.

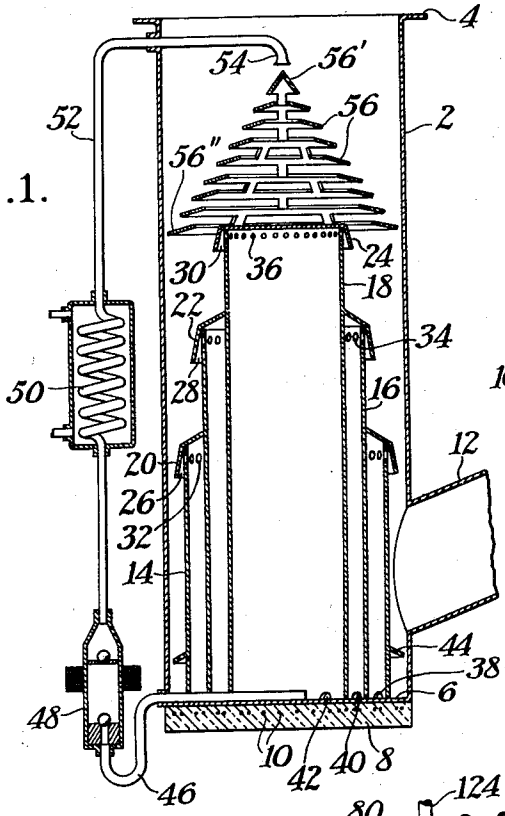


Fig. 3.

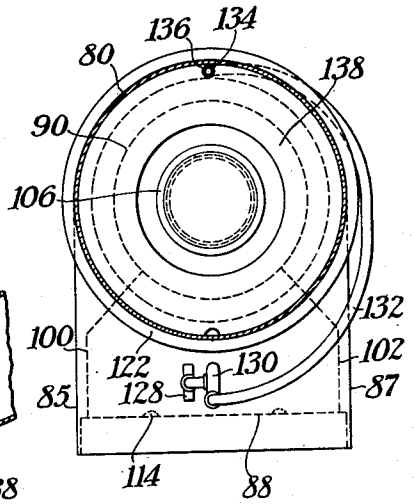
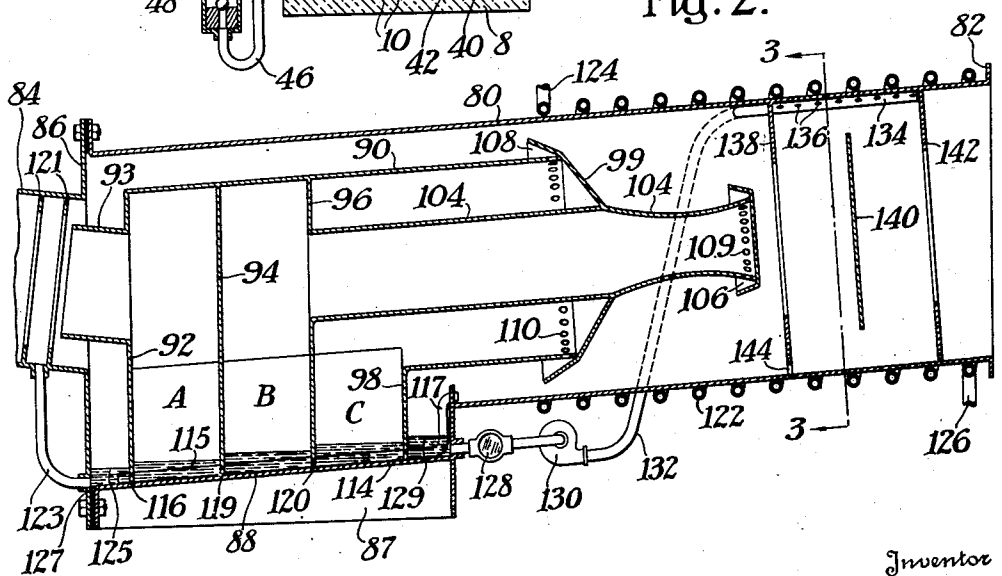


Fig. 2.



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VACUUM PUMP

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10 Claims. (Cl. 230—101)

This invention relates to improved methods and apparatus for high vacuum production.

In my U. S. Patent 2,080,421 I have described fractionating condensation pumps. These pumps operate in the same manner as the ordinary condensation pump, but are provided with means for fractionating the organic pumping fluid into constituents of different vapor pressure and passing the low vapor pressure constituents to the jet operating in the low pressure end of the pump and passing the high vapor pressure constituents to the jet operating in the high pressure end of the pump. This is accomplished in the most useful form by passing the pump fluid in sequence through a series of boilers supplying vapors to the series of jets. The high vapor pressure constituents are vaporized in the boilers supplying vapors to the jets operating at the high pressure end of the pump. Unvolatilized components of the pump fluid then pass in sequence through the various boilers and finally the lowest vapor pressure constituents are vaporized and supplied to the boiler supplying vapors to the jets at the low pressure end of the pump. Since these pumps were described by me to the public they have been extensively used and various modifications have been devised. The principles upon which the pump operates are therefore well known and need not be further described.

This invention has for its object to improve the degree of vacuum and/or the rate of vacuum production obtainable by means of fractionating condensation pumps. Other objects will appear hereinafter.

These and other objects are acomplished in accordance with my invention which includes means for withdrawing pump fluid from one of the boilers toward the low pressure end of the pump and circulating it over a surface or surfaces in contact with gases or vapors present in the low pressure end of the pump.

During the operation of the kind of vacuum pump employing a vapor stream, the low pressure side of the pump becomes filled with a gas composed of pump oil molecules. This gas exerts the saturation pressure of the liquid pump fluid at the temperature existing in this part of the pump. The saturation pressure of the best pump fluids in a suitable fractionating pump may be extremely low, for instance, 10^{-9} mm. of mercury at 20° C. While such a pressure is amply low enough for most academic or industrial operations, nevertheless a saturated vapor at this pressure can, over long periods of time, deposit a film of pump fluid on the walls and parts of the vessel that is being evacuated. Difficulties with poorer types of pump fluids would be much greater.

It is well known that the saturation pressure can be reduced by placing between the apparatus and the pump a cold trap or sink. I have found that the saturation pressure can be effectively reduced by circulating those constituents of the pump fluid, which have failed to evaporate during heating in the pump, over the low pressure zones or the intake side of the pump. During its circulation this liquid absorbs parts of the gases and vapors, and reduces their pressure below the saturation point at the prevailing temperature.

In order to clearly illustrate the operation of my invention, I have shown in the accompanying drawing two of the preferred embodiments thereof wherein:

Fig. 1 is a vertical section of a vertical condensation pump constructed of a plurality of concentric tubes, the base of which form a plurality of boiler compartments and the upper ends of which terminate in pumping jets;

Fig. 2 is a vertical section of a preferred form of horizontal pump; and

Fig. 3 is a horizontal section taken on line 3—3 of Fig. 2.

Referring to Fig. 1, numeral 2 designates a tubular outer casing provided with a flange 4 at the top thereof which is to assist in connecting to the receptacle which is to be evacuated. Numeral 6 designates a plate which serves to close the base of the tube 2 and is integral therewith. Numeral 8 designates a heating unit within which is disposed resistance heating wires 10. Toward the lower end of the casing 2 is an integral conduit 12 which serves to connect the high pressure end of the pump to a backing pump (not shown). Numerals 14, 16 and 18 designate concentric tubes, the base of each of which rests in close contact with base plate 6. Numerals 20, 22, and 24, designate annular shaped elements which close the top end of each tubular element 14, 16 and 18, respectively, and which cooperate therewith to form jet nozzles 26, 28, and 30. A plurality of holes 32, 34 and 36 permit the flow of vapors from inside of each tubular element into the respective jet nozzles. The base of each tubular element 14, 16 and 18 is provided with a series of small holes 38, 40 and 42 which are of restricted areas. Numeral 44 designates a collar integral with tubular element 14 which extends into close proximity with walls of cas-

ing 2. Numeral 46 designates a conduit which terminates near the center of the central tubular element 18 and which serves to withdraw fluid therefrom and convey it into pump 48 which, in turn, serves to pump the fluid through cooler 50, conduit 52 and into the distributing head 54. Numeral 56 designates a plurality of superimposed annular disks so constructed that they will shed fluid from one to the next lowest disk by gravity, much in the same way that shingles on a roof, shed rainwater. Numeral 56' designates the first such element upon which the pump fluid first flows as it falls from the distributing head 54. 56'' designates the last disk of the series, the lower edge of which is in close proximity to the inner wall of casing 2.

Referring to Figs. 2 and 3, numeral 80 designates a cylindrical pump casing which is adapted to be connected at the low pressure end by flange 82 to the chamber to be exhausted, and at the high pressure end by conduit 84 to a backing pump (not shown). The high pressure end of 80 is closed by a plate 86 integral with conduit 84. The base of cylinder 80 in the vicinity of the high pressure end is cut away and the extended walls 85 and 87, closed by a base plate 88 so as to form a recessed pump fluid boiler. A similarly shaped cylinder 90 is located within the main casing 80 and more or less concentric therewith. The portion of this cylinder adjacent the high pressure end of the pump is cut away and provided with an extension corresponding to that of the pump liquid boiler. The end of the cylinder 90 is closed by a plate 92 which is integral with a conduit 93 which extends slightly into conduit 84 as illustrated. Plate 92 extends to the base plate 88 of the boiler. A similarly shaped plate 94 located inside the cylinder 90 extends from the top inside wall of the cylinder to the base plate 88. Plate 96 is similarly shaped and likewise extends to the base plate 88. Plate 98 is integral with the lower wall of cylinder 90 and extends to the base plate 88 of the boiler. Two bent plates 100 and 102 integral with the lower wall of the cylinder 90, extend transversely to plates 92, 94, 96 and 98 and are integral therewith. They serve to segregate the pump liquid boiler into a plurality of compartments, A, B, and C. Cylinder 90 is truncated at 99 and the truncated portion is extended to, and becomes integral with conduit 104. Jet nozzle 106 is mounted at the high vacuum end of conduit 104. Jet nozzle 108 is similarly located at the end of cylinder 90. Holes 109 and 110 provide a passageway for working vapors to issue into jets 106 and 108 respectively.

Numeral 114 designates a semi-circular opening in the base of plate 98. It is sufficiently small that it is well covered by pump fluid. These openings are two in number. Numerals 116, 119 and 120 designate similar openings in the base of plates 92, 94 and 96 respectively. Numeral 115 designates a conduit which extends along the base of the boiler through openings in the various partition plates. These openings are preferably small so that a tight fit results. Conduit 115 is bent upward at 117 and terminates at the bottom central portion of the casing 80. The other end of the conduit terminates at the low pressure end of the boiler.

Numeral 121 designates a series of fractionating rings integral with the wall of conduit 84. Conduit 123 connects the space between the last two rings 121 with the low pressure portion of the boiler. Numeral 122 designates a cooling coil integral with the external wall of the pump casing. Cooling fluid is introduced at 124 and withdrawn at 126. Numeral 128 designates a sight-glass whereby the level of the pump fluid can be readily determined.

Numeral 130 designates a pump connected to the sight-glass 128 which is in turn connected to a conduit 132 which terminates in a distributing device 134 located at the top of pump casing 80. Distributing device 134 is provided with a plurality of small holes 136 which project in an upward direction. Numerals 138, 140 and 142 designate a plurality of baffles located in the intake end or low pressure end of the pump. Numeral 144 designates a hole at the base of baffle 138.

In operation employing the apparatus illustrated in Fig. 1, pump fluid, such as di-2-ethyl hexyl phthalate is introduced into the pump to a height sufficient to cover the tops of openings 38—42. A height half way between collar 44 and base 6 would be sufficient. Flange 4 is connected to the system to be evacuated and conduit 12 is connected to the backing pump which is put into operation. Heating element 8 is then started. Pump fluid is vaporized at the base of tubular element 18 and the vapors rise, pass through openings 36, jet 30 and are condensed on the walls of casing 2. The condensate flows down the walls between casing wall 2 and collar 44 and thence into the boiler enclosed by tubular element 14. Here the high vapor pressure constituents are vaporized, pass through openings 32 and out through jet 26. Condensate accumulating upon the walls of casing 2 flows back into the boiler past collar 44 and through openings 38.

Pump fluid not vaporized in the boiler of tubular element 14 flows through openings 40 into the boiler of tubular element 16. Here the next vapor pressure constituents are vaporized and the vapors passed through openings 34, through jet 28 and are condensed on the walls and returned to the boiler as described previously. It is seen that pump fluid which is vaporized in the boiler at the base of tubular element 18 is that which was not vaporized in the other two boiler compartments and which, therefore, is the lowest vapor pressure component of the pump fluid. During the pumping action secondary pump 48 is put into operation and this low vapor pressure pump fluid in the boiler 18 is withdrawn through conduit 46, circulated through cooler 50 and conduit 52 and finally introduced onto the top of flange 56'. The fluid follows over the series of flanges 56 until it reaches the lowest flange 56'' from which it flows onto the inner surface of casing 2. It then flows by gravity down to the boiler at the base of the pump where it goes through the fractionating operation previously described.

Pump 48 should be run at a speed sufficient to keep a thin film of liquid on the flanges 56. However, it should not be run so fast that the supply of fluid in the boiler at the base of tubular element 18 is depleted. In other words, a body of fluid should always be retained in this boiler.

Gases entering the top casing 2 pass through the spaces between flanges 56. However, in doing so they suffer at least one collision therewith. Various gases and vapors are thus absorbed in the liquid film which is then delivered to the low pressure end of the pump. The absorbed gases and vapors are driven off in the boiler at the base of tubular element 14 and pass out throug

jet 28 and are eventually removed by the backing pump connected to conduit 12.

In operating the apparatus illustrated in Figs. 2 and 3, pump fluid is introduced into the boiler compartments A, B and C. The pump fluid is indicated at 125 and is shown as it would be retained by the boiler during operation of the pump. It will be noted that the pump casing 80 and the base of the boiler 88 slant upwardly toward the high vacuum end. This is to cause the pump liquid to flow back into the boiler compartments. Flange 82 is connected to the chamber to be evacuated and conduit 84 is connected to any suitable backing pump. The boiler containing the pump fluid is heated in any suitable manner, such as by gas. The lowest vapor pressure pump fluid constituents vaporize and pass into compartment A and thence through jet nozzle 93. The jet of vapors passes into conduit 84 where it is condensed and entrained gases removed by the backing pump connected thereto. The condensed pump liquid flows back over fractionating rings 121 and is returned to the boiler by conduit 123. High vapor pressure constituents having no utility are retained by the fractionating rings 121 and may be intermittently removed therefrom by a suitably located conduit.

Components which are not vaporized in section A flow into B. Although compartment B is at a higher elevation than compartment A, compartment A is at a somewhat higher pressure so that the pump fluid is caused to flow more or less uphill into compartment B. In compartment B the intermediate fraction representing the most useful components of the pump fluid is vaporized and passes into conduit 104 and thence to jet 106. Vapors from this jet condense on the cooled walls of 80 and flow to the base and into conduit 115. They then flow through conduit 115 to the lowest portion of the boiler as indicated at 127. The lowest vapor pressure constituents are not vaporized in compartment B, but flow into compartment C. Here the low vapor pressure, decomposable substances are vaporized and issue through the intermediate jet 108. Vapors from this jet condense on the walls of casing 80 and flow by gravity back into conduit 115 and eventually return to compartment 127.

Pump fluid accumulating in section 129 and sight-glass 128 is pumped by pump 130 through conduit 132 into distributing device 134 from which the pump fluid is ejected in a plurality of small streams against the inside wall of casing 80. This pump fluid flows down the walls of the casing in a thin film and thence flows through opening 144 at the base of baffle 138 along the bottom of casing 80 and into conduit 117 and 115 by which it is delivered to the boiler at the high pressure end of the pump. Gases being pumped and which diffuse into the intake end of the pump are caused to pass into contact with the film of liquid on the inside of casing 80 by baffles 138, 140 and 142. Volatiles and gases are thus taken up and are conveyed by the pump fluid to the high pressure end of the pump where they are boiled off and removed by the backing pump.

The pump fluid which is circulated to the low pressure end of the pump and over the baffles may be taken from any of the lower vapor pressure boilers. It is obvious that the lowest vapor pressure components are the best for circulation since they will not give off volatiles or will give off less volatiles than other components. Pump fluid from the boiler supplying vapor to the lowest pressure jet is usually to be preferred. Heavy residues from the pump or boiler in which they are accumulated are also very useful. In order to have a circulation liquid of very low vapor pressure accumulate in the low pressure boiler or in the pump for the low volatiles it is in some cases advantageous to add to the pump fluid a very low vapor pressure component for this particular purpose. Examples of such particularly low vapor pressure substances which could be added to the ordinary pumping fluids are purified castor oil, di-ethyl phenyl phthalate and nonyl selacate and the like. When such substances are withdrawn and circulated over the baffles they have the advantage that they have a lower vapor pressure than any of the components issuing from the jets. Therefore they are able to quite effectively absorb vapors of the latter when they diffuse back into contact with the baffles.

Various modifications can be made in the apparatus described without departing from the spirit or scope of my invention. For instance, it would be desirable to prevent exposure of the circulated liquid to the action of the hot vapors issuing from the various jets since this might possibly drive off some volatiles. This could be avoided by collecting the circulated liquid after it has adbsorbed gases and vapors in a closed conduit and directly conveying it to a boiler at or near the high pressure end of the pump. Although I have illustrated conveying the circulated liquid containing absorbed gases to the boiler at the high pressure end of the pump, it could be circulated to an intermediate boiler without losing the advantages of my invention. In some cases this will adversely affect the results to a slight extent and is not preferred, however, it will give substantially better results than if no circulating expedient is employed and is contemplated as being part of my invention.

It is preferable to cool the circulated liquid as illustrated in Fig. 1. This materially reduces the vapors present to well below the saturation point so that there is little chance of their precipitating or condensing. Warm circulating liquid or the intermediate fractions may be used since they have the necessary effect of reducing the saturation pressure although not as efficiently as the lower vapor pressure fractions and lower temperatures.

This application is a continuation in part of my U. S. Patent #2,153,189, April 4, 1939.

I claim:

1. A condensation pump adapted to employ an organic working fluid, characterized by means, located at the high vacuum end, or intake side of the pump, for introducing a low vapor pressure organic liquid and intimately contacting it with vapors present, whereby harmful vapor constituents which would interfere with the production of low pressures are removed.

2. A fractionating condensation pump adapted to employ an organic working fluid characterized by means for withdrawing pump fluid from the boiler containing lower vapor pressure constituents and circulating it into contact with gases or vapors entering the lower pressure side of the pump.

3. A multi-stage fractionating condensation pump adapted to employ a mixed organic liquid as a pumping fluid and in operation to segregate the components thereof so that the low

vapor pressure components exert their pumping action toward the low pressure side and the high vapor pressure components toward the high pressure side of the pump, characterized by means for circulating a low vapor pressure constituent of the pump fluid segregated in the pump over the interior of the intake end of the pump.

4. A multi-stage fractionating condensation pump adapted to employ a mixed organic pumping fluid and in operation to segregate the components thereof in a plurality of boilers so that the low vapor pressure components exert their pumping action toward the low pressure side and the high pressure components toward the high pressure side of the pump, characterized by means, connected to a boiler containing the lowest vapor pressure components for withdrawing pump fluid therefrom and circulating it over a surface located in the low pressure or intake end of the pump.

5. A multi-stage fractionating condensation pump adapted to employ a mixed organic pumping fluid and in operation to segregrate the components thereof in a plurality of boilers so that the low vapor pressure components are vaporized in the boiler or boilers supplying working vapors to the low pressure side of the pump and the high vapor pressure components are vaporized in the boiler or boilers supplying working vapors to the high pressure side of the pump characterized by means connected to a boiler supplying vapors to the low pressure side of the pump for withdrawing pump fluid therefrom and circulating it in a thin film over a relatively large surface exposed to gases or vapors entering the pump and means for collecting the circulated fluid and conveying it to a boiler at the high pressure end of the pump.

6. A multi-stage fractionating condensation pump adapted to employ a mixed organic pumping fluid and in operation to segregate the components thereof in a plurality of boilers so that the low vapor pressure components are vaporized in the boiler or boilers supplying working vapors to the low pressure side of the pump and the high vapor pressure components are vaporized in the boiler or boilers supplying working vapors to the high pressure side of the pump characterized by means connected to a boiler containing low vapor pressure components for withdrawing pump fluid therefrom and circulating it over a surface located in the intake end of the pump.

7. A multi-stage fractionating condensation pump adapted to employ a mixed organic pumping fluid and in operation to segregate the components thereof in a plurality of boilers so that the low vapor pressure components are vaporized in the boiler or boilers supplying working vapors to the low pressure side of the pump and the high vapor pressure components are vaporized in the boiler or boilers supplying working vapors to the high pressure side of the pump characterized by a secondary pump the intake side of which is connected to the boiler which contains the lowest vapor pressure components and the discharge side of which is connected to a distributing or spreading device located in the low pressure end of the condensation pump, and means for collecting the thus circulated liquid and conveying it to a boiler located at the high pressure side of the pump.

8. A multi-stage fractionating condensation pump adapted to employ a mixed organic liquid as a pumping fluid and in operation to segregate the components thereof so that the low vapor pressure components exert their pumping action toward the low pressure side and the high vapor pressure components toward the high pressure side of the pump, characterized by means for cooling and circulating a low vapor pressure constituent of the pump fluid segregated in the pump, over the interior of the intake end of the pump.

9. A multi-stage fractionating condensation pump adapted to employ a mixed organic pumping fluid and in operation to segregate the components thereof in a plurality of boilers so that the low vapor pressure components exert their pumping action toward the low pressure side and the high vapor pressure components toward the high pressure side of the pump, characterized by means, connected to a boiler containing the lowest vapor pressure components for withdrawing pump fluid therefrom, cooling means for the withdrawn liquid and means for circulating the cooled liquid over a surface located in the low pressure or intake end of the pump.

10. A multi-stage fractionating condensation pump adapted to employ a mixed organic pumping fluid and in operation to segregate the components thereof in a plurality of boilers so that the vapor pressure components are vaporized in the boiler or boilers supplying working vapors to the low pressure side of the pump and the high vapor pressure components are vaporized in the boiler or boilers supplying working vapors to the high pressure side of the pump characterized by means connected to a boiler supplying vapors to the low pressure side of the pump for withdrawing pump fluid therefrom, means for cooling this liquid, means for circulating it in a thin film over a relatively large surface exposed to gases or vapors entering the pump and means for collecting the circulated fluid and conveying it to a boiler at the high pressure end of the pump.

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