Aug. 13, 1940. K. C. D. HICKMAN 2,211,329

HIGH VACUUM PUMP

Filed Aug. 9, 1938 2 Sheets-Sheet 1

FIG. 1.

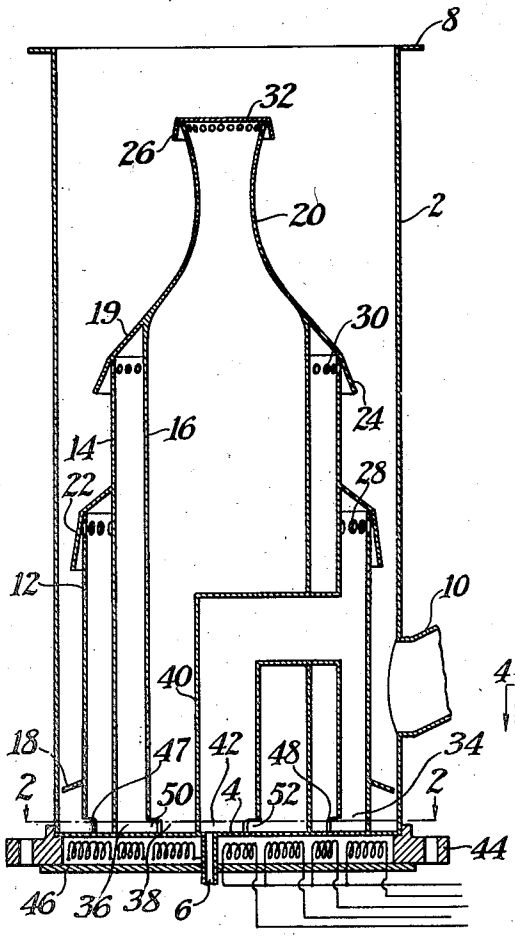


FIG. 3.

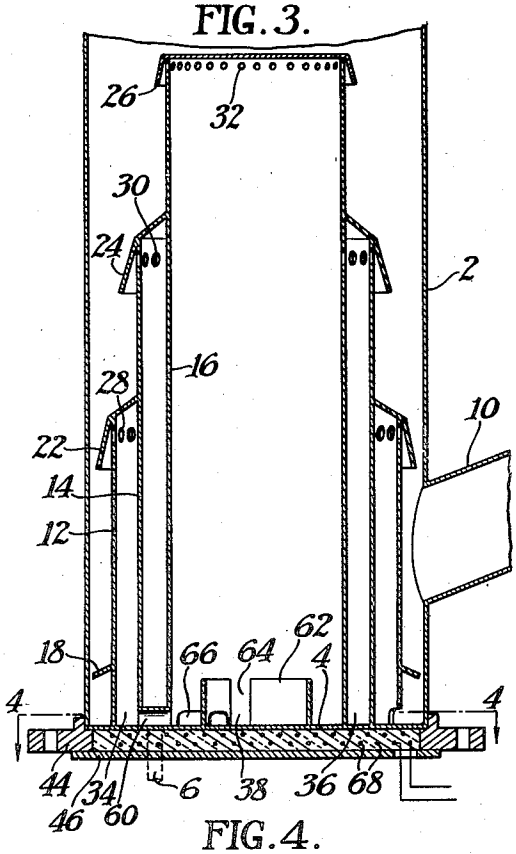


FIG. 2.

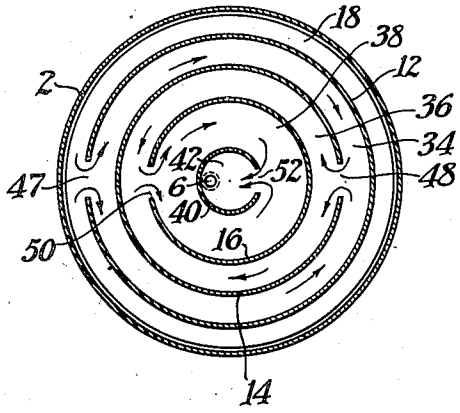
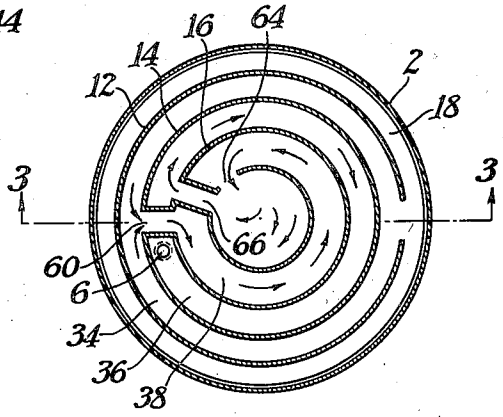


FIG. 4.



KENNETH C.D. HICKMAN
INVENTOR

BY Warren H. Cannon
ATTORNEYS

Aug. 13, 1940. K. C. D. HICKMAN 2,211,329

HIGH VACUUM PUMP

Filed Aug. 9, 1938 2 Sheets-Sheet 2

FIG. 5.

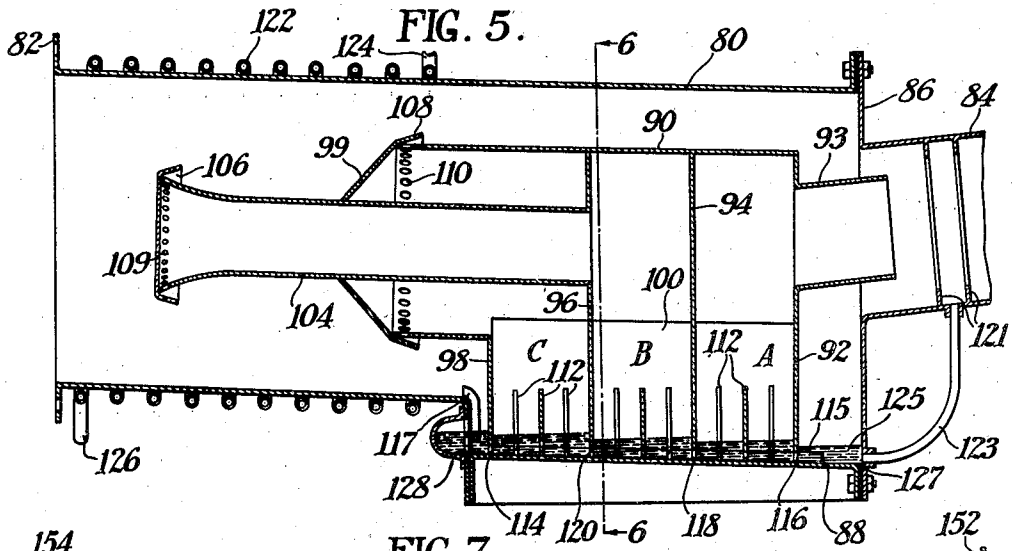


FIG. 7.

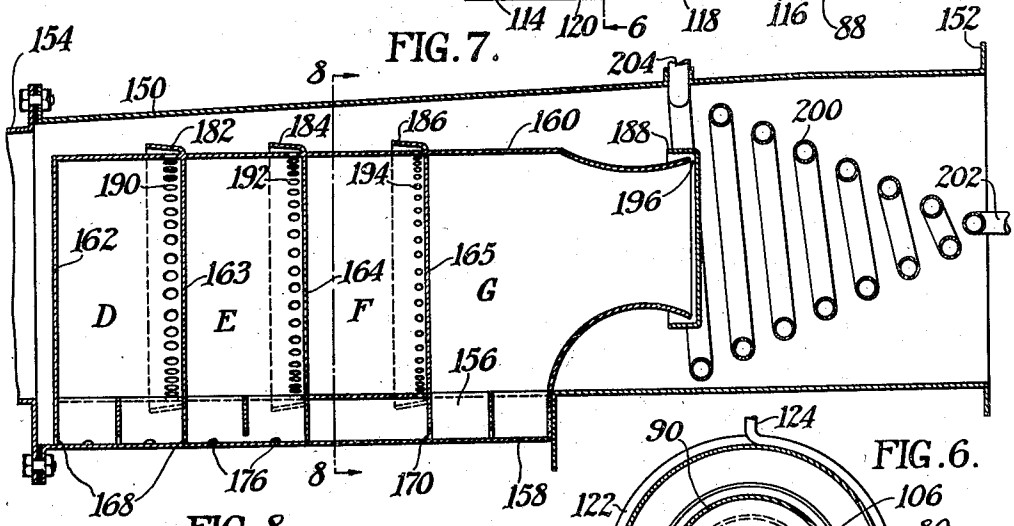


FIG. 8.

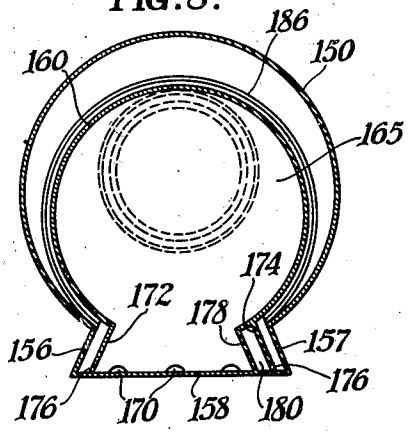
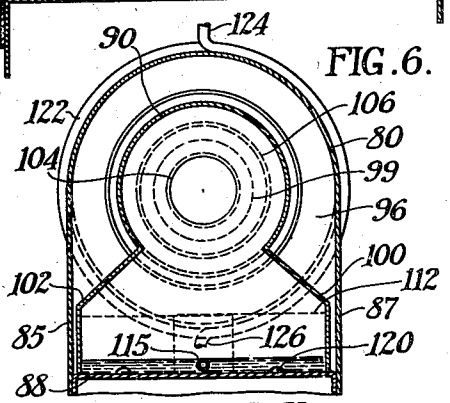


FIG. 6.



KENNETH C.D. HICKMAN
INVENTOR

BY Warren H. Cannon
ATTORNEYS

Patented Aug. 13, 1940

2,211,329

UNITED STATES PATENT OFFICE

2,211,329

HIGH VACUUM PUMP

Kenneth C. D. Hickman, Rochester, N. Y., assignor to Distillation Products Inc., Rochester, N. Y., a corporation of Delaware

Application August 9, 1938, Serial No. 223,925

8 Claims. (Cl. 230—101)

This invention relates to improved apparatus for producing high vacua and in particular relates to improved condensation or diffusion pumps.

In my U. S. Patent 2,080,421 I have described improved condensation pumps adapted to employ an organic working fluid. These pumps are adapted to fractionate the organic pump fluid during use and deliver the vapors of the various fractions to appropriate jets in the pump. The pumps described in this patent are a big improvement over pumps of the prior art. However, even with the fractionating features, these pumps do not give pressure reductions corresponding to theory. This has been found to be particularly true in connection with vertical fractionating pumps wherein a plurality of boiler compartments are formed in the base by concentric tubes which deliver vapors to appropriately located jets at the upper ends of the concentric tubes.

An object of my invention is to provide improved fractionating condensation or diffusion pumps. A further object is to provide improved fractionating condensation pumps of the vertical concentric tube type. A still further object is to provide fractionating condensation pumps which will yield pressure reductions corresponding to theory. A still further object is to provide condensation pumps which will yield pressure reductions approximately as low as the vapor pressure of the lowest vapor pressure constituents of the pump fluid which can be vaporized without decomposition. Other objects will appear hereinafter.

These and other objects are accomplished by my invention which in general comprises arranging the boiler compartments or the vapor conduits between the boiler compartments and the jet nozzles so that the lowest vapor pressure components of the pump fluid, which cannot be vaporized without decomposition, are delivered to a jet nozzle at least once removed from the highest vacuum jet nozzle so that the next lowest vapor pressure components, which can be vaporized without appreciable decomposition, are delivered to the highest vacuum jet.

The reason why theoretical pressure reductions were not obtained in the earlier constructions has been found to be due to the fact that the lowest vapor pressure constituents cannot be vaporized without at least partial thermal decomposition. Heretofore, the vapors from the lowest vapor pressure constituents were delivered to the highest vacuum jet. Therefore, these volatile decomposition products were released at a point in the pump where they could do most harm. By bypassing these harmful constituents to a low vacuum or intermediate vacuum jet they are prevented from exerting their harmful action and are, in fact, caused to perform useful pumping action.

In the following description I have given numerous examples of the preferred embodiments of my invention. However, it is to be understood that these are given for the purpose of illustration and not as limitations thereof.

In the accompanying drawings:

Fig. 1 is an elevation in section of a vertical concentric pump embodying the principles of my invention wherein vapors from the lowest vapor pressure constituents are by-passed to the lowest vacuum jet;

Fig. 2 is a horizontal section on line 2—2 of Fig. 1;

Fig. 3 is an elevation in section of a vertical concentric pump wherein the lowest vapor pressure constituents of the pump liquid are bypassed from the boiler supplying the high vacuum jet to the boiler supplying vapors to a jet operating against an intermediate vacuum;

Fig. 4 is a horizontal section on line 4—4 of Fig. 3;

Fig. 5 is a sectional elevation of a horizontal fractionating pump wherein the vapors are bypassed;

Fig. 6 is a vertical section on line 6—6 of Fig. 5 and is shown on a slightly reduced scale;

Fig. 7 illustrates in sectional elevation a modified horizontal fractionating pump wherein the lowest vapor pressure constituents are by-passed in liquid form from the lowest vapor pressure boiler to an intermediate boiler supplying vapors to the next lowest vacuum jet;

Fig. 8 is a vertical section on line 8—8 of Fig. 7.

Referring to Fig. 1, numeral 2 designates a cylindrical pump casing, the base of which is closed by an integral plate 4, the center of which is connected to a withdrawal conduit 6. The top of the casing 2 is provided with a flange 8 which facilitates connection to the system which is to be evacuated. The upper end, therefore, represents the high vacuum or intake side of the pump. The low vacuum side, or exhaust side of the pump is indicated by conduit 10 which connects to the backing pump (not shown). Numerals 12, 14 and 16 designate approximately concentric cylinders, the base of each of which is in close, and preferably liquid-tight contact with the base plate 4. Concentric cylinder 12 is provided with a collar 18 at its base which extends into close proximity

to the inner wall of pump casing 2. Cylinder 12 is truncated at the top and the truncated portion is extended to, and integral with, concentric cylinder 14. Concentric cylinder 14 is similarly truncated at 19. Cylinder 16 is truncated at 20 as illustrated in order to form a chimney for vapors passing to the highest vacuum jet.

Numerals 22, 24 and 26 designate annular jet lips integral with the periphery of cylinders 12, 14 and 16 respectively, so as to form low, intermediate and high vacuum jet nozzles. Numerals 28, 30 and 32 designate openings through which vapors issue into the jet nozzles from the spaces between the concentric cylinders. Numeral 34 designates the annular boiler formed at the base by concentric cylinders 12 and 14 which supplies working vapor to jet nozzle 22. Numeral 36 designates an annular boiler which supplies working vapor to jet nozzle 24. Numeral 38 designates an annular boiler which supplies working vapor to jet nozzle 26. Numeral 40 designates a conduit, the lower end of which is integral with and penetrates through concentric cylinders 14 and 16. This conduit covers a circular central portion 42 which serves as a boiler for the lowest vapor pressure constituents.

Numeral 44 designates a collar which supports the entire pump assembly and which provides a circular space, closed by plate 46 within which is mounted a plurality of heating units as illustrated. Each of these heating units is adapted to heat the boiler compartments 34, 36, 38 and 42 to separate and independent temperatures.

Referring particularly to Fig. 2, numeral 47 designates an opening in the base of concentric cylinder 12. This opening is sufficiently low that its upper portion is well covered by the pump liquid in the boiler. Numeral 48 designates a similar opening in the base of cylinder 14. Numeral 50 designates a small opening in the base of concentric cylinder 16. Numeral 52 designates a similar opening in the base of cylinder 40.

Referring to Figs. 3 and 4, concentric cylinders 12, 14 and 16 are mounted within the main cylindrical casing as described in connection with Figs. 1 and 2. These cylinders are in liquid-tight contact with the base 4 and cylinders 12 and 14 are truncated as previously described. However, cylinder 16 extends, without constriction directly to the high vacuum jet 26. Numeral 60 designates a conduit integral with concentric cylinders 14 and 16 which provides a passageway for the flow of pump liquid from boiler compartment 34 into boiler compartment 38. A baffle 62 in the shape of an annular ring is located in the boiler 38 and is split at 64 as indicated. Passage 60 is sufficiently low that its top portion is well covered by pump liquid. A similar passageway 66 connects the inside of baffle 62 with boiler compartment 36. An electrical heating element 68 is mounted in the base. It is not shown as being controllable so as to heat each boiler compartment to an independent temperature. However, the amount of heat supplied to each boiler compartment can be regulated by varying the proportion of heating unit placed under each compartment.

Referring to Figs. 5 and 6, numeral 80 designates a cylindrical pump casing which is adapted to be connected at the high vacuum end by flange 82 to the chamber to be exhausted, and at the low vacuum end by conduit 84 to a backing pump (not shown). The low vacuum end of 80 is closed by a plate 86 integral with conduit 84. The base of cylinder 80 in the vicinity of the low vacuum 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 low vacuum 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 112 designates a series of staggered baffles which are located in the various boiler compartments. They cause the pump fluid to flow in a tortuous path or at a slow rate in passing through the boiler compartments.

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, 118 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 baffle and 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.

Referring to Figs. 7 and 8, numeral 150 designates an approximately cylindrical pump casing, the high vacuum end of which is provided with a flange 152 which is adapted to be connected to the chamber to be evacuated and the low vacuum end of which is shown is connected to a conduit 154 which is in turn connected to a backing pump (not shown). The base of pump casing 150 is cut out at a point beginning at the central portion to the low vacuum end. The walls of the base near the cut out area are extended to form an elongated reservoir having walls 156 and 157 and base 158. A cylindrical element 160 is located inside the pump casing

and has its base cut away in a position corresponding to the location of the reservoir in the base of casing 150. Internal cylindrical element 160 is divided into a plurality of compartments D, E, F and G by partitions 162, 163, 164 and 165 which extend to the base plate 158 of the boiler. The boiler is therefore separated into a corresponding series of compartments by these partitions. Each such compartment directly communicates with sections D, E, F and G. Partitions 162 and 163 are provided with a plurality of small notches 168 which are well below the level of the pump liquid in the boiler. Partition 164 extends entirely to the base plate 158 and makes substantially liquid-tight contact therewith. Partition 165 is provided at its base with a plurality of notches 170. The walls of cylindrical element 160 are extended to the base of the boiler at 172 and 174 which are at a sufficient distance from walls 156 and 157 to just permit pump liquid to flow therebetween. Numeral 176 designates a plurality of minute notches, in walls 172 and 174 which permit pump liquid to flow back into the boiler compartments.

Referring particularly to Fig. 8, it will be noticed that partitions 164 and 165 do not extend to wall 174. They are shortened, as shown, and are connected by a plate 178 so as to form a passageway 180 from the boiler of compartment E directly into the boiler of compartment G.

Reference numerals 182, 184, 186 and 188 designate jet nozzles which communicate with compartments D, E, F, and G by openings 190, 192, 194 and throat 196, respectively. Numeral 200 designates a baffle constructed of a metal conduit wound in the form of a helix. Cooling fluid is supplied to this baffle by introduction at 202 and withdrawal at 204.

In operating the apparatus illustrated in Fig. 1, an organic pump fluid is introduced into the pump. It should be filled to a height sufficient to at least cover the openings 48, 50 and 52. Flange 8 is connected to the system to be evacuated and conduit 10 is connected to a backing pump in the usual manner. Conduit 6 is closed or is connected to a small air-tight sump. The base of the pump is then heated by the electrical heating element. It is best that the temperature uniformly increase toward the center of the pump. Vapor produced in boiler section 34 rises in the annular space between concentric tubes 12 and 14 and passes through holes 28 and issues from jet nozzle 22. The jet entrains gases in known manner which are removed by the backing pump through conduit 10. The jet vapors condense on the walls of casing 2, flow by gravity into the space between 18 and 2 and arrive back into the boiler compartment 34 from which they were derived by way of opening 47. The unvaporized liquid in compartment 34 flows in a circular path to opening 48 and into boiler compartment 36. When the liquid arrives in compartment 36 it has traveled in a tortuous path through boiler 34 and has, therefore, been thoroughly deprived of high vapor pressure constituents before passing through opening 48.

In compartment 36 the next lowest, below the high vapor pressure constituents are vaporized and pass upwards between concentric cylinders 14 and 16. These vapors issue through openings 30 and pass out through jet nozzle 24. Vapors are condensed on the inside wall of casing 2 and the condensed liquid flows back into boiler compartment 34. The pump fluid which is not vaporized in compartment 36 passes in a circular or tortuous path to passage 50 and into boiler compartment 38. Here the next lowest, to the lowest vapor pressure components are vaporized and rise and issue through openings 32 and pass from jet nozzle 26. Jet 26 is the highest vacuum jet and it is desirable that it be supplied with the best portion of the pump fluid vapors. Vapors issuing from jet 26 are condensed on the walls of casing 2 and flow by gravity back into boiler 34.

Pump fluid which is not vaporized in boiler compartment 38 then flows through opening 52 into boiler compartment 42. These pump fluid constituents are the lowest vapor pressure components. However, they have such a low vapor pressure that they cannot be efficiently vaporized without some thermal decomposition. The vapors derived therefrom are, therefore, not suitable for delivery to the high vacuum jet 26. These vapors rise through L-shaped conduit 40 and pass into the annular space between concentric tubes 12 and 14 and eventually pass out through jet 22.

It is apparent that efficient fractionation of the pump fluid takes place in the operation of this apparatus. The pump fluid is segregated into components of gradually increasing vapor pressure as in prior constructions but the lowest vapor pressure component is segregated and is not permitted to be vaporized and delivered to the highest vacuum jet. The harmful effects of its decomposition products are thereby avoided.

A further feature of novelty which also adds to the efficient operation of the vertical concentric fractionating pump is illustrated in Figs. 1 and 2. It will be noted that the boiler area in boiler compartment 38 is increased so that it is approximately the same as the boiler areas in each of the other compartments. This permits effective vaporization of pump fluid in ample quantities for operation of the high vacuum jet without overheating.

The feature of causing the pump fluid to pass in a tortuous path through each boiler compartment is also of decided advantage and can be used in fractionating pumps of all types. If the pump fluid is permitted to flow too quickly from one compartment to another it is not efficiently stripped of its lighter constituents and these will be vaporized at a point where they may adversely affect the pumping action. By causing liquid to pass in a tortuous path removal of all volatile constituents before it reaches the next boiler compartment is assured.

During operation of the apparatus illustrated in Figs. 3 and 4, fractionation and the action of the jet is similar to that of the apparatus illustrated in Fig. 1. However, the pump liquid in boiler 34 flows directly into boiler compartment 38 through conduit 60. The highest vapor pressure constituents are, therefore, vaporized in compartment 34 and issue through jet 22. The intermediate vapor pressure constituents are vaporized in boiler compartment 38 and in the area within ring 62. These vapors rise and issue through high vacuum jet 26. The lowest vapor pressure constituents remain unvaporized and pass through passageway 66 into intermediate boiler compartment 36. Here the lowest vapor pressure components which undergo more or less decomposition are vaporized and the vapors delivered to jet 24 which operates against a lower vacuum.

In both concentric pumps illustrated in Figs. 1 and 3 non-volatile residues and tars will accu-

mulate. These can intermittently be withdrawn by suitably located conduits such as conduit 6.

In operating the apparatus illustrated in Figs. 5 and 6, pump fluid is introduced into the boiler compartment. 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 highest 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 up-hill 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.

The staggered baffles 112 in each of the boiler compartments cause the pump fluid to pass in a tortuous path as explained above. Sight-glass 128 permits accurate determination of the level of the pump fluid in the boiler.

It will be noted that in the apparatus illustrated in Figs. 1, 3 and 5 the conduit conveying vapors to the highest vacuum jet is more or less completely surrounded by heated vapors which pass to an intermediate jet. This effectively prevents the low vapor pressure constituents passing to the highest vacuum jet from condensing before they reach the jet. The efficiency of the jet is thereby increased.

In operating the apparatus illustrated in Figs. 7 and 8 conduit 154 is connected to a backing pump and flange 152 is connected to a receptacle to be evacuated. The boiler compartments are filled with an appropriate pump fluid to a level well above the top of openings 170 and 176, etc. In the boiler of compartment D, the highest vapor pressure constituents are vaporized, rise through compartment D, pass through openings 190 and issue from jet 182. The vapors condense on the wall of casing 150, flow by gravity into the space between wall 156 and wall 172 and thence through openings 176 back into the boiler compartment. Liquid which is not vaporized in compartment D then flows through openings 168 in partition 163 and are vaporized in compartment E and issue from jet nozzle 184. The remaining unvaporized liquid then by-passes compartment F through passage 180 and directly flows into the boiler of compartment G. Here the most useful vapor pressure constituents for the high vacuum jet nozzle 188 are vaporized and pass through that jet. Unvaporized residue then passes backwards through openings 170 in the base of partition 165 and into the boiler of compartment F. Here non-volatile residues accumulate and low vapor pressure constituents which cannot be vaporized without decomposition are vaporized and delivered to jet nozzle 86 where they perform useful pumping action. Vapors from each of the jets are returned to the boiler compartments in the same manner described in connection with compartment D.

Any vapors which might diffuse backwards into the zone under evacuation are condensed upon baffle 200. This baffle may be constructed in other ways well known in the art but the shape shown has been found to have high efficiency. A baffle should present as little resistance to the flow of gases into the pump as is possible.

The apparatus illustrated in Figs. 7 and 8 may be provided with a tilting device so that the level of the pump fluid in the various boilers may be appropriately controlled. The base of the boiler may likewise be slanted as illustrated in connection with Fig. 5.

The apparatus illustrated may be constructed of any suitable materials. Any of the apparatus illustrated may be constructed entirely of metal. The apparatus of Figs. 1 and 3 can be conveniently constructed partly of glass so that the operation of the pump can be observed. The jet nozzles can be conveniently spun from aluminum and the standpipes and other parts can also be constructed of this metal, although steel, iron, copper, etc., may be used.

This application is a continuation in part of my U. S. application 143,305 filed May 18, 1937, now Patent 2,153,189, granted April 4, 1939.

What I claim is:

1. In a multi-stage fractionating vacuum pump provided with a plurality of jet nozzles adapted to operate in series and a plurality of boiler compartments adapted in operation to arrange the low vapor pressure components of the pump fluid so that they exert their pumping action toward the high vacuum side and the high vapor pressure components toward the low vacuum side, the improvement which comprises a vapor passage conduit connecting the boiler compartment containing the lowest vapor pressure components to a jet nozzle intermediate the lowest and highest vacuum jet nozzles, and a vapor passage conduit connecting the boiler compartment containing the next lowest to the lowest vapor pressure components to the highest vacuum jet, whereby the lowest vapor pressure components of the pump fluid are not vaporized and passed to the highest vacuum jet where they would do harm but instead are utilized in a lower vacuum jet where they do not exert harmful effects.

2. In a multi-stage fractionating vacuum pump provided with a plurality of jet nozzles adapted to operate in series and a plurality of boiler compartments adapted in operation to arrange the low vapor pressure components of the pump fluid so that they exert their pumping action toward

the high vacuum side and the high vapor pressure components toward the low vacuum side, the improvement which comprises a restricted pump liquid passage directly connecting the boiler compartment supplying working vapors to the high vacuum jet with the boiler compartment supplying vapors to a jet at least once removed from the high vacuum jet, and a restricted pump liquid passage between the boiler compartment supplying the high vacuum jet with working vapors, and the boiler compartment supplying working vapors to the jet next to the high vacuum jet whereby the lowest vapor pressure components of the pump fluid are not vaporized and passed to the highest vacuum jet where they would do harm, but instead are utilized in a lower vacuum jet where they do not exert harmful effects.

3. In a multi-stage fractionating vacuum pump provided with a plurality of jet nozzles adapted to operate in series and a plurality of boiler compartments adapted in operation to arrange the low vapor pressure components of the pump fluid so that they exert their pumping action toward the high vacuum side and the high vapor pressure components toward the low vacuum side the improvement which comprises a vapor passage conduit connecting the boiler compartment containing the lowest vapor pressure components to a jet nozzle intermediate the lowest and highest vacuum jet nozzle and a vapor passage conduit connecting the boiler compartment containing the next lowest vapor pressure components with the highest vacuum jet whereby the lowest vapor pressure components of the pump fluid are not vaporized and passed to the highest vacuum jet where they would do harm, but instead are utilized in a lower vacuum jet where they do not exert harmful effects.

4. In a multi-stage fractionating vacuum pump provided with a plurality of jet nozzles adapted to operate in series and a plurality of boiler compartments adapted in operation to arrange the low vapor pressure components of the pump fluid so that they exert their pumping action toward the high vacuum side and the high vapor pressure components toward the low vacuum side the improvement which comprises a vapor passage conduit connecting the boiler compartment containing the lowest vapor pressure components to a jet nozzle at least once removed from the highest vacuum jet nozzle, and a vapor passage conduit connecting the boiler compartment containing the next lowest vapor pressure component with the highest vacuum jet whereby the lowest vapor pressure components of the pump fluid are not vaporized and passed to the highest vacuum jet where they would do harm, but instead are utilized in a lower vacuum jet where they do not exert harmful effects.

5. A multi-stage fractionating vacuum pump adapted in operation to arrange the components of the pump fluid so that the low vapor pressure components exert their pumping action toward the high vacuum side and the high vapor pressure components toward the low vacuum side of the pump, comprising in combination a tubular chamber with an outlet port near the lower end and an inlet port above the outlet port, means to heat the base of the tubular chamber, a plurality of nozzles in series from the high vacuum to the low vacuum side mounted one above the other between said ports and directed toward the outlet port, a plurality of approximately concentric conduits each communicating at the upper end with one of said nozzles and terminating at the bottom of the chamber to form a plurality of boiler compartments in the chamber below the outlet port, restricted passages in sequence between adjoining boiler compartments, except those supplying vapors to the two highest vacuum jets, a restricted pump liquid passage between the boiler compartment supplying working vapors to the high vacuum jet and the boiler compartment supplying vapors to a jet at least once removed from the highest vacuum jet and a restricted pump liquid passage from the boiler compartment supplying the high vacuum jet with working vapors to the boiler compartment supplying working vapors to the jet next in the series to the high vacuum jet whereby the lowest vapor pressure components of the pump fluid are not vaporized and passed to the highest vacuum jet where they would do harm, but instead are utilized in a lower vacuum jet where they do not exert harmful effects.

6. A multi-stage fractionating vacuum pump adapted in operation to arrange the components of the pump fluid so that the low vapor pressure components exert their pumping action toward the high vacuum side and the high vapor pressure components toward the low vacuum side of the pump, comprising in combination a tubular chamber with an outlet port near the lower end and an inlet port above the outlet port, means to heat the base of the tubular chamber, a plurality of nozzles in sequence from the high vacuum to the low vacuum side mounted one above the other between said ports and directed toward the outlet port, a plurality of approximately concentric conduits each communicating at the upper end with one of said nozzles and terminating at the bottom of the chamber to form a plurality of boiler compartments in the chamber below the outlet port, restricted fluid passages between the adjoining compartments, a vapor passage conduit connecting the boiler compartment containing, in operation the lowest vapor pressure components, to a jet nozzle at least once removed from the highest vacuum jet nozzle and a vapor passage from the boiler compartment containing the next lowest to the lowest vapor pressure components to the highest vacuum jet whereby the lowest vapor pressure components of the pump fluid are not vaporized and passed to the highest vacuum jet where they would do harm, but instead are utilized in a lower vacuum jet where they do not exert harmful effects.

7. In a multi-stage fractionating vacuum pump provided with a plurality of jet nozzles arranged in horizontal series and adapted to operate in series and a horizontal boiler divided into a plurality of compartments by approximately vertical partitions and adapted in operation to arrange the low vapor pressure components of the pump fluid so that they exert their pumping action toward the high vacuum side and the high vapor pressure components toward the low vacuum side, the improvement which comprises a vapor passage conduit connecting the boiler compartment containing the lowest vapor pressure components to a jet nozzle intermediate the lowest and highest vacuum jet nozzles and a vapor passage conduit connecting the boiler compartment containing the next lowest to the lowest vapor pressure component with the highest vacuum jet whereby the lowest vapor pressure components of the pump fluid are not vaporized and passed to the highest vacuum jet where they would do harm, but instead are utilized in a low-

er vacuum jet where they do not exert harmful effects.

8. A multi-stage fractionating vacuum pump adapted in operation to arrange the components of the pump fluid so that the low vapor pressure components exert their pumping action toward the high vacuum side and the high vapor pressure components toward the low vacuum side of the pump, comprising in combination a tubular chamber with an outlet port near the lower end and an inlet port above the outlet port, means to heat the base of the tubular chamber, a plurality of nozzles mounted one above the other between said ports and directed toward the outlet port, and a plurality of approximately concentric conduits each communicating on the upper end with one of said nozzles and terminating at the bottom of the chamber to form a plurality of boiler compartments in the chamber below the outlet port, the concentric conduits being of such diameter that approximately the same area of the bottom of the chamber is enclosed between each pair of conduits.

KENNETH C. D. HICKMAN.