May 26, 1953 R. W. HEATH 2,640,018

METHOD OF STEAM DISTILLATION

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Fig. 1.

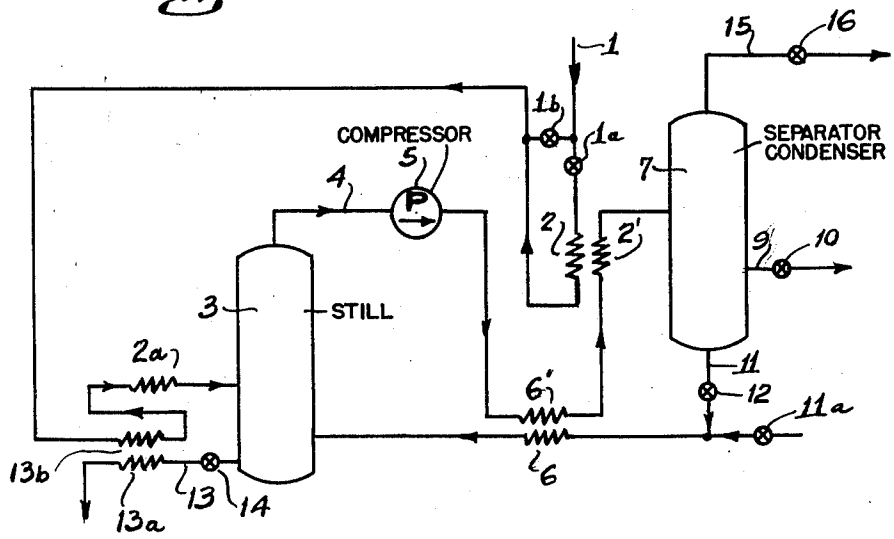
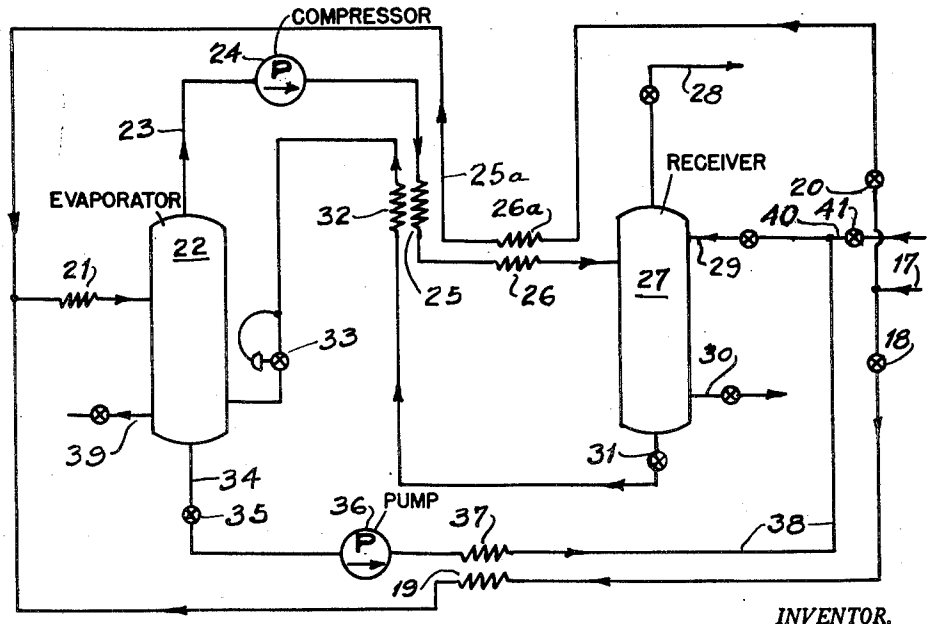


Fig. 2.



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METHOD OF STEAM DISTILLATION

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Fig. 3.

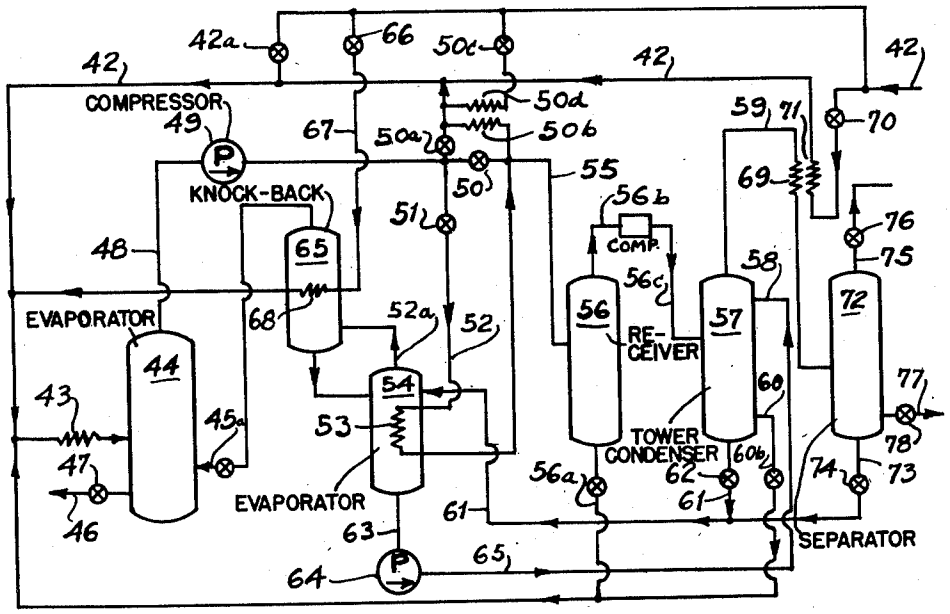
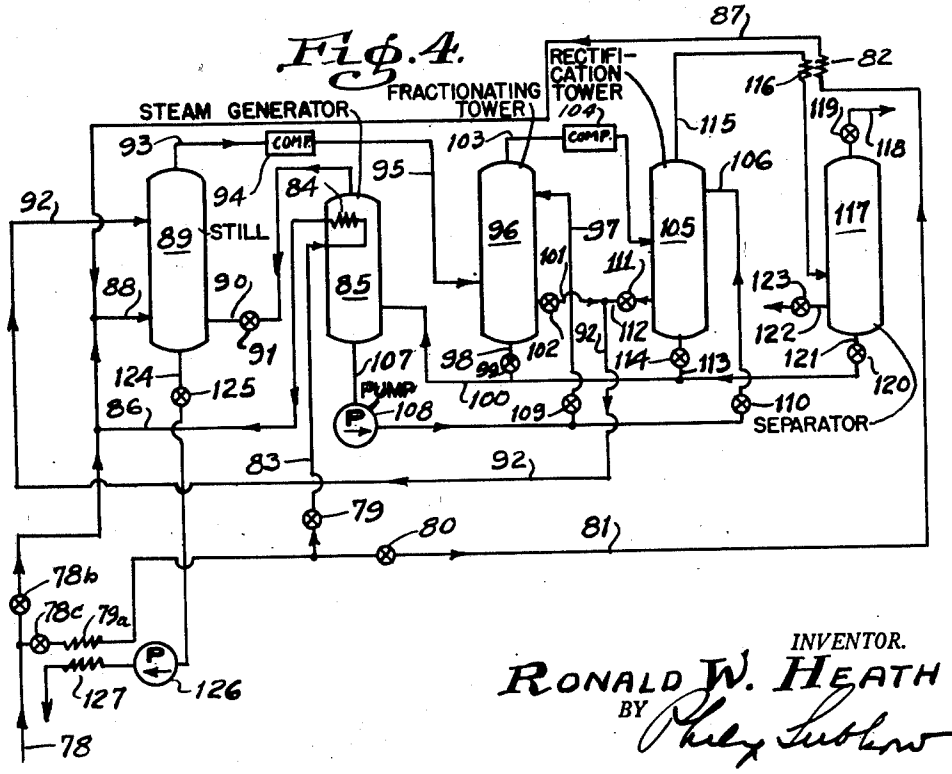


Fig. 4.



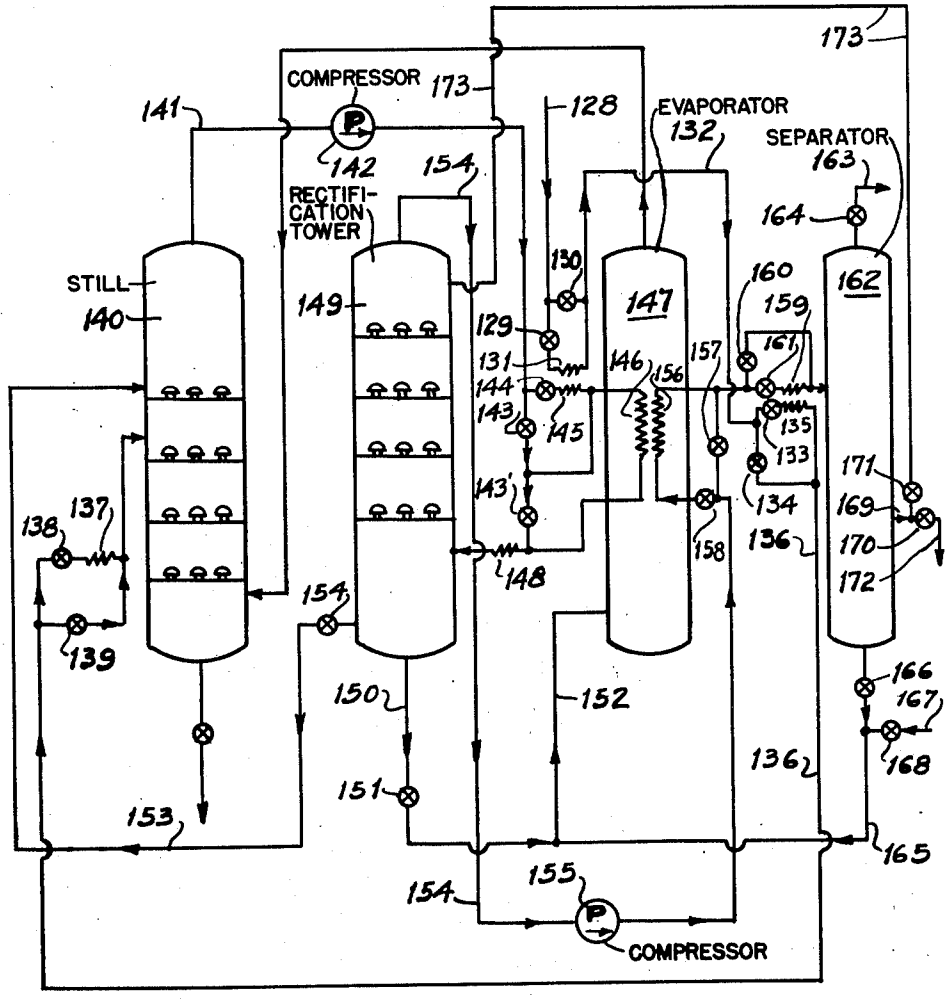
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METHOD OF STEAM DISTILLATION

Filed July 25, 1949 3 Sheets-Sheet 3

Fig. 5.



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2,640,018

METHOD OF STEAM DISTILLATION

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Application July 25, 1949, Serial No. 106,622

18 Claims. (Cl. 202—46)

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This invention may be summarized as follows: It relates to a process of steam distillation in which steam is commingled with a material to be distilled with said steam at a pressure, at or lower than the saturation pressure of the steam at the temperature of distillation, to produce a vapor composed of steam and vapor from the material undergoing distillation. The mixed vapors are compressed and thus heated by the work done in the compression. The superheat and the latent heat of condensation of the compressed vapors are removed to produce a water condensate at the said higher pressure. The water condensate is then passed into a zone of lower pressure, but at a pressure as high or higher than the distillation zone but less than the pressure of the condensation zone and the water is vaporized and the steam employed for said steam distillation. In a modification of the invention the latent heat of vaporization of the steam may be in part supplied by the heat in the compressed vapors passing to the steam condensation stage, previously referred to. There is thus a transference of the latent heat of condensation of steam at high pressure to supply the latent heat of vaporization of the steam at lower pressure. In addition, because the water undergoing vaporization, as steam is vaporized at a temperature lower than the temperature of the water at which the water condenses from the compressed vapors, the water undergoing vaporization to make steam may be circulated as cooling medium in the condensation step, and the water thus heated may be recirculated to the steam forming stage. In addition the heat of the compressed vapors may also be transferred to the incoming material to be distilled by heat exchange between this feed and the high temperature vapor or liquid streams.

Thus, the heat of compression of the vapors is employed as the course of heat for the vaporization steps and by maintaining proper pressure levels, the unvaporized liquid residue from the vaporization step may act as condensation or absorption medium for vapors or gases which are at a higher temperature than the residue.

In addition to the efficiencies attained by this procedure, and in addition to the simplification of apparatus obtained by employing this cycle, I also obtain an economy in cooling water and fuel and in water for generation of process steam, and avoid the construction and operation of separate process steam equipment. The water is employed in cycles of operation and the water requirement is reduced to a minimum. This is particularly important in desert or waste areas such as are found in many oil fields throughout

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the world. In refineries or natural gas plants where steam distillation is required or may be economically employed, the problem of water supply is a primary consideration. In such areas the economy of water utilization obtained by my system and process is an important consideration in making such process possible in such localities.

These and other objects of my invention will be clear to those skilled in this art from the following description taken together with the drawings, in which

Fig. 1 is a flow sheet of one form of the process of my invention;

Fig. 2 is a flow sheet of another form of the process of my invention;

Fig. 3 is a flow sheet of another form of the process of my invention;

Fig. 4 is a flow sheet of another form of the process of my invention; and

Fig. 5 is a flow sheet of another form of the process of my invention.

Referring to Fig. 1, the material to be distilled is passed through the line 1, heat exchange coil 2 (or by-passed in part or whole by control of valves 1*a* and 1*b*) through heat exchange coil 13*b* and heater 2*a* into the still 3 where a portion is vaporized and the unvaporized material withdrawn through line 13 by controller valve 14 and through the heat exchange coil 13*a* in heat exchange with coil 13*b*. The vapors exit through 4 and are compressed by compressor 5 and passed through heat exchange coil 6′ in heat exchange with coil 6 and through heat exchange coil 2′ in heat exchange with coil 2, and then into the separator-condenser 7. Condensate is collected in 7 and the water withdrawn through line 11 and the remaining condensate, if lighter than water, withdrawn through 9 under the control of valve 10. The water passes under its own pressure through line 11 through pressure reduction valve 12 with any water desired to be added through 11*a*, heat exchange coil 6 in exchange with compressed gas in 6′, into the chamber 3. The uncondensed material in 7 is withdrawn through line 15 under the control of valve 16 for other operations or disposal, and the unvaporized material in 3 is withdrawn through line 13 under the control of valve 14.

It will be observed that in order for the water entering by valve 12 to vaporize in 3, the pressure in still 3 must be not above at the vapor pressure of the water at the temperature attained in 3. Exchange of heat in 6 and 6′ may be and probably will always be sufficient to vaporize all of the water passing through valve 12. The compressor 5 will compress the vapors to a high pres-

sure in 6' and the temperature will rise as the result of the heat of compression. Due to the increase in pressure, the temperature at which the vapors will condense is increased. If the drop in temperature as a result of imparting the latent heat of distillation to the liquid passing via 12 is insufficient to drop the temperature to the desired temperature in 7, the compressed vapors must be cooled. This may be attained by heat exchange with the circulating water in 11 in heat exchange coils 6 and 6', and if necessary by heat exchange with the incoming material by a proper setting of valves 1a and 1b in the by-pass line. If this is not enough cooling, extraneous air or water cooling may be resorted to. The heat exchange in 6 and 6' provides nearly all and usually all of the latent heat or vaporization of the water entering into 3. Because of the heat content of the non-steam vapors, the heat available in the compressed vapors may be more than enough to vaporize the water. If needed, additional heat may be added to the feed by exchanger 13b and heater 2a.

The following examples may be given as an illustration of the principles of the operation of my processes and not as a limitation thereof, and, as will be understood by those skilled in this art, the illustrated applications of this principle, shown as applied to distillation of a petroleum oil, is equally applicable to any distillation process in which a phase separation between the water condensate and the remaining distillate may be effected.

Example 1

In Fig. 1 the feed may be a hydrocarbon gas oil or fuel oil fraction containing 8.6 mol per cent of hydrocarbons in the gasoline range. Still 3 is operated at a pressure of 10 pounds gage and a temperature of 260° F. The steam rate in still 3 is about 1.4 mols of steam per mol of such lighter hydrocarbon material. The condenser separator 7 is operated at a pressure of 30 pounds gage and a temperature of 260° F. The 260° F. vapor passing through 4 is compressed by pump 5 to 30 pounds gage plus, i. e., to a pressure sufficiently above the pressure in 7 to permit flow through the lines between the compressor and the separator. For all practical purposes this pressure drop may be ignored. The heat of compression will raise the temperature to about 350° F. In passing through the heat exchange coils 6', it is cooled to 280° F. and cooled down to about 260° F. in the exchanger 2'. At this temperature and pressure (giving effect to the partial pressure of the gasoline hydrocarbons), the gasoline hydrocarbons will condense and the residual water vapor will also condense. The condensation temperature of the water vapor at 30 pounds gage is 274° F., and at 260° F. substantially all of the water vapor will condense, as will the hydrocarbons of this example, leaving some uncondensed fixed gases and vapors passing through 15.

The water separates from the condensed hydrocarbons and is withdrawn under its own pressure of 30 pounds gage, reduced in pressure through valve 12 to 10 pounds gage, and passed through the exchanger 6 where it is heated in heat exchange with the hot vapors to a temperature of 300° F. The water is thus vaporized and superheated, since the boiling point of water at 10 pounds gage is 239.4° F.

Example 2

The same principle applies when steam distilling in vacuum, but higher compression ratios are obtainable on the compressed vapors.

The still 3 is operated at a pressure of 3 pounds per square inch absolute (p. s. i. a.) and at a temperature of 145° F., using the same feed and steam rate as in the previous example. The vapors are compressed to produce a pressure of about 14.7 p. s. i. a. in 7, i. e., atmospheric pressure, and raised to a temperature of about 400° F. In passing through heat exchanger 6' the vapors are reduced in temperature to about 180° F. and then cooled in exchanger 2' to a temperature of about 100° F., and condensate is separated in 7. The water separated at 100° F. is passed through valve 12, reduced in pressure to a pressure of 3 p. s. i. a., and passed through heat exchanger 6 wherein it is vaporized and superheated to a temperature of 300° F.

It will be observed that in both of the above examples the water travels in a closed cycle and therefore, assuming a constant flow rate of oil entering 3, the circulation of the water to keep a constant level in 7 will thus control the volume of steam at the partial pressure of steam in 3. The only loss of water will be that lost in the vapor exiting through 15 or lost by entrainment in 13 or 9. These losses will be insignificant. It will also be observed that all heat exchange operations are at relatively high temperatures and that none of the vapor or liquid streams require cooling water at atmospheric temperature. Thus, the water requirements are reduced to a minimum.

In the cycle illustrated in Fig. 2, the temperature of condensation of the steam is higher than the temperature of the distillation, and water is circulated from the still to act as a condensing medium. The material to be distilled enters through 17, passes through valve 18 and the heat exchange coil 19 in exchange with coil 37, with additional material passing through the valved by-pass line 20, through heat exchange coil 26a in heat exchange with coil 26 and the combined streams then pass through the heater 21 into the evaporator 22. The vapors pass through 23 and through compressor 24 pumped through exchange coils 25 and 26 into the distillate collector 27, and the uncondensed vapors removed from 28 for further processing. Any condensate lighter than water is removed from 30 and the water is withdrawn through line 31, passed through heat exchange coil 32 by the pressure reduction control valve 33, into the evaporator 22. Residue lighter than water is withdrawn through 39 and water is withdrawn through line 34 by valve 35 and pumped by pump 36 and heat exchange coil 37, line 38, into the line 29. Any additional water, if desired, may be passed through line 40 under control of valve 41.

In this cycle the vapors generated in low pressure still 22 are compressed and heated by heat of compression by pump 24 and passed through coil 25 into the condensate receiver 27. The heated compressed vapors are cooled and the latent heat of condensation of the water and distillate vapors are withdrawn in exchangers 32 and 26a.

The water circulating from the evaporator 22 by way of pump 36 is at a lower temperature than the operating temperature in 27 and thus acts as a cooling and condensing medium 27. Additionally, it may be cooled by heat exchange with the incoming material to be distilled. The circulating water thus acts to further condense steam and condensate in 27. The water thus

being heated again to a temperature obtaining in the receiver 27. The temperature of the water passing by valve 33 is above the equilibrium temperature at the pressures in 22. The heat in the water entering via 33 is insufficient to evaporate all of the water by pressure drop through valve 33, nor is the heat in the stream entering from 21 sufficient when added to the heat of the water sufficient to vaporize all of the water entering through valve 33. Only part of the water is evaporated and the remaining water is removed through 34. The control of the amount of water evaporated, and therefore the partial pressure of the steam in 22, is by the rate of recirculation of the water through the valve 33, and by control of the temperature of the material passing through 21 into 22.

Fig. 3 shows a similar cycle in which the hot water from the condenser-separator is passed to an evaporator-cooler and steam still for generation of the steam and the cooling of the water, instead of directly into the main still where these functions are combined with the distillation of the incoming feed material.

In the cycle illustrated in Fig. 3, the steam generation step is in a unit separate from the still but operating at substantially the pressure of the still, i. e., at some higher pressure than the still, determined by the back pressure of the vapor lines connecting the two units. Thus, material to be distilled may be introduced through line 42 and a portion or all of the stream may be passed via valve 42*a* and heater 43 into the evaporator 44 where it meets steam entering through 45. The unvaporized material is withdrawn through line 46 under the control of valve 47. The vapors including steam are withdrawn through line 48 by compressor 49 and may be passed either by means of valve 50 directly into receiver 56 and/or by-passed through line 52 by means of valve 51 and passed through the heat exchange coil 53 or by means of valve 50*a* and heat exchange coil 50*b* in exchange with a portion of the incoming feed material by-passed through valve 50*c* and heat exchange coil 50*d* back into line 55.

The partially cooled vapors in 55 pass into the condensate receiver 56 where any condensate may be separated, and since it will be materially higher boiling than water (if there be any such present) it may be withdrawn through the valved line 56*a* and returned to the still. The vapors then pass through the compressor 56*b* and line 56*c* into the tower 57. The vapors are washed with water entering through 58 and the uncondensed vapors are withdrawn through 59. The condensate lighter than water is withdrawn through 60 and by control of valve 60*b* returned to line 42 and the hot water is withdrawn through 61 under control of valve 62 and pased into the evaporator 54.

Steam is withdrawn from the evaporator through 52*a* and cooled water is withdrawn through line 63 by means of pump 64 passed to the line 65 and then to line 56. The steam passes through knock-back 65 wherein a portion may be recondensed by exchange with a portion of the incoming feed by-passed via valve 66, line 67, heat exchange coil 68 back to line 42. The steam condensate collecting in 65 returns to 54 by gravity and the uncondensed steam passes via line 45 and valve 45*a* into still 44.

Returning to the uncondensed distillate vapors in 59, it is passed through heat exchange coil 69 in heat exchange with a portion of the feed from 42 by-passed through valve 70 and heat exchange coil 71. The cooled vapors pass into separator 72, wherein the water is separated and withdrawn via line 73 and valve 74 and returned to 54. The condensate, if lighter than water, is withdrawn via line 77 and valve 78 and the uncondensed vapors are withdrawn via line 75 and valve 76.

It will be observed that the evaporator 54 is at the pressure of the still 44 or somewhat higher, depending upon the back pressure in line 45, knock-back 65, and the connecting lines. The material passing through 48 is heated by the heat of compression by means of compressor 49 and has its temperature raised above that in 44 or 54. The material in passing through 53 is condensed at pressures in excess of the pressures and temperatures maintained in 54. The latent heat of condensation at this higher pressure is transferred to supply the latent heat of vaporization of the water at the lower pressure in 54. The temperature of the condensate in 57, due to the higher pressures in 57 than obtains in 54, will be higher than the temperature of the hot water in 54 and this hot water may then circulate through line 63 to aid in the condensation of steam and other vapors in 57. The water then exiting from 57 via 61 is at a higher temperature than the equilibrium temperature of the water in 54 and when it enters 54 will vaporize. Only a fraction of this water is vaporized, the fraction depending upon the temperature of the water passing through 61 and the heat imparted by coils 53 and temperature and pressures maintained. This then controls also the volume of steam entering through 45. Because this vaporization rate may be excessive for the steam rate required in 44 some of the steam is condensed in 65 and the resultant condensation of the steam holds and controls the steam rate in 44.

Example 3

The following example, which relates to the flow sheet of Fig. 3, will also be pertinent in illustrating the fundamental relationships of the flow sheet of Fig. 2. For purposes of illustration, as explained in connection with Examples 1 and 2, I will use the same feed material and the same steam rate as in Examples 1 and 2.

In Fig. 3, the still 44 is maintained at a temperature of 145° F. and a pressure of 3 p. s. i. a. The inlet temperature of the feed into 44 is 155° F. Assume for purposes of illustration the material entering line 42 passes through coil 71 and coil 68, valves 50*c* and 42*a* are closed. The evaporator 54 and knock-back 65 are maintained at about 6 p. s. i. a. by the proper setting of valve 45*a*. The vapors are compressed in compressor 49 to a pressure sufficient to maintain a pressure of 15 p. s. i. a. in 56 and are heated to a temperature of about 400° F. by compression. In passing through the coil 53, valves 50 and 50*a*, being closed, the vapors are reduced in temperature to about 185° F. Normally no water would condense due to the partial pressure of the hydrocarbons present, but if there be any high boiling oil fractions, they may be condensed and returned to the still. The vapors withdrawn from 56 are further compressed in a second stage of compression by means of compressor 56*b* to a pressure sufficient to maintain 60 pounds gage in 57 and the vapors are heated by compression to a temperature of about 435° F. and introduced into the separator 57. Relatively cool water withdrawn from evaporator-cooler 54 at a tempera-

ture of about 170° F. is passed by pump 64 into 57 and by heat exchange with the hot vapors is heated to a temperature of about 200° F., cooling the vapors to approximately this temperature.

The hot water is then passed into the evaporator-cooler steam still 54. At the circulation rate of the water passing to the separator 57, because of the temperature of the water and the heat in the vapors passing through the coil 53, an excessive vaporization of the water in 54 results which is in excess of the steam rate desired in 44. This has the effect of cooling the water in 54 to the desired low temperature. The fraction in excess of the desired steam rate is condensed in 65 by exchange with the oil passing through 68 and the condensation of the steam fraction in 65 controls the volume of steam passed to still 44, and therefore the steam rate. At the steam rates indicated, about ⅓ of the steam generated in 54 is condensed in 65.

The vapors exiting through 59 are cooled by exchange with the incoming feed to reduce them to a temperature of about 85° F. and the preheated oil passing through the coil 68 is heated to a temperature of 155° F., the initial temperature of the feed being adjusted to obtain the desired temperature of 155° F. The heater 43 is then not used, or if it is to be used, the initial temperature of the feed may be lower.

The water condensate is withdrawn via line 73 and valve 74 and returned to 54. The hydrocarbons are withdrawn via line 77 and valve 78 and the uncondensed gas withdrawn via line 73 and valve 76.

In the previous examples as illustrated by Figs. 1, 2 and 3, the latent heat of evaporation of the steam was supplied in part by indirect heat transfer from the heat of the compressed vapors. Where the pressures and temperatures are favorable, the steam generation may be made by flash evaporation. The heat necessary to generate the steam vapors is obtained by compressing the steam vapors and washing the compressed steam with the water cooled by the evaporation in generating the steam. This is illustrated by flow sheet of Fig. 4.

The incoming material to be distilled passes through line 78 and heat exchange coil 79*a* (in exchange with coil 127) via valve 78*c* and heat exchange coil 82 (in exchange with coil 116) and line 87, or by-passed in whole or in part via valve 78*b* into line 88 and may be apportioned by setting of valves 79 and 80, part to be passed through coil 82 and line 87 and part through line 83, coil 84, and line 86 and combined with line 88 and introduced into the still 89.

The vapors from 89 pass via line 93 and are compressed by compressor 94 and the compressed and heated vapors enter the fractionating tower 96 in which they are separated into fractions by aid of the recirculated relatively cool water added through 97. Condensate, if of lower specific gravity than water, is separated via line 101 and valve 102 and introduced into line 92 whereby it is introduced as a reflux in still 89. The relatively hot water is passed through line 98 and valve 99 into line 100 from which it passes into the steam generator 85. Steam vapors separated from the water in 85 are in part condensed by the heat exchange coil 84 and the uncondensed fraction passes via valve 91 and line 90 to enter the steam still 89.

The unevaporated relatively cool water is withdrawn from 85 via line 107 and pumped by pump 108 into lines 97 and 106 by proper control of valves 109 and 110. The uncondensed fraction of water and distillate vapors are withdrawn from 96 via line 103 and compressed to a higher pressure by compressor 104 and introduced into rectification tower 105 in which separation of fractions occurs by aid of the relatively cool water introduced via 106.

The uncondensed fractions pass via line 115 and coil 116 in heat exchange with coil 82 and are introduced into the separator 117. The water condensate in 105 is withdrawn via line 113 and valve 114 and introduced into line 100. The condensed distillate fraction, if lighter than water, is withdrawn via line 111 and valve 112 and passes into line 92.

In the separator 117, the lightest fraction, if lighter than water, is withdrawn via line 122 and valve 123 and passed to storage or other disposal. The water condensate is withdrawn via line 121 and valve 120 and passed into line 100. The uncondensed vapors and gases are withdrawn via line 118 and valve 119. The residue withdrawn from still 89 via line 124 and valve 125 and pump 126 is passed through coil 127 in heat exchange with incoming material via line 78.

To illustrate the operation of this cycle and for purposes of comparison with the other cycles, the steam distillation of the material employed to illustrate the operation of the cycles of Figs. 1–3, inclusive, may be employed, employing also the same steam rate.

Example 4

The oil entering via line 88 may be at a temperature of 155° F., the still being operated at a temperature of 145° F. at 3 p. s. i. a. in the presence of steam introduced via 90. The residue is withdrawn at a temperature of 145° F. and may, if desired, be used to preheat part of the feed which is introduced at the desired initial temperature.

The vapors via 93 are compressed from 3 p. s. i. a. to 15 p. s. i. a. in 96 and are thus heated to a temperature of about 400° F. They are reduced in temperature to about 185° F. by heat exchange in 96 (at 15 p. s. i. a.) with water circulated from 85 at a temperature of about 170° F. The water condensate is withdrawn from 96 and introduced into the evaporator cooler 85 in which it is reduced in temperature to about 170° F. by evaporation in 85 at a pressure of 6 p. s. i. a.

The uncondensed vapors from 96 are further compressed to obtain a pressure of 60 pounds per square inch gage (p. s. i. g.) in 105 and are thus superheated to a temperature of about 435° F. and are introduced into rectifying tower 105 at about this pressure in which they meet a stream of water at about 170° F. circulating from 85.

The condensed water is withdrawn via line 113 and valve 114 and recirculated to the flash evaporator 85. The oil condensates in 96 and 105 are withdrawn via lines 101 and 112, respectively, and recirculated as reflux to the still 89 via line 92.

The vapors and gases passing at about 200° F. via line 115 are reduced in temperature in exchanger 116 to a temperature of 85° F. and separated in separator 117 at substantially 60 p. s. i. g. The water condensate is withdrawn via line 120 and valve 121 and introduced into line 100.

Returning to the flash evaporator 85, the heat in the stream entering 85 is such that at the

pressure in 85 the amount of water vaporized is in excess of the steam rate desired. The excess is separated by condensing the undesired fraction, i. e., about 36% of the generated steam. The latent heat of condensation thus withdrawn is used to add heat to the feed passing to the still 89. Thus the steam rate is controlled without raising the pressure or temperature in still 85.

In the previous flow sheets 2, 3, and 4, the water circulated was in excess of the water needed for steam generation for use in the steam still. In Fig. 5 is illustrated a system in which the water circulated is equal to the steam requirement. The feed passes through line 128 and by control of the valves 129 and 130 may be passed in whole or in part through heat exchange coil 131 and line 132 and then by control of the valves 133 and 134 may be passed in whole or in part through heat exchange coils 135 and if necessary through the heating coil 137 by proper control of valves 138 and 139 into still 140.

The vapors from still 140 pass via line 141 and compressor 142 and by control of valves 143 and 144 and 143' may pass via heat exchange coil 145 in heat exchange with coil 131 and through coil 146 in evaporator 147 and through cooling coil 148 into the rectifying tower 149 or directly (valve 143' and 143 being opened and 144 closed) through cooler 148 into still 149. The water condensate passes out of the tower via line 150 under control of valve 151 to be introduced via line 152 into the water evaporator 147. The condensate, if lighter than water, passes via line 153 controlled by valve 154 to be introduced as a reflux in still 140.

The overhead vapors from 149 pass via line 154 and are compressed by compressor 155 and may pass in whole or in part through coils 156 in evaporator 147, by control of valves 157 and 158, and then in part or in whole through coil 159 in heat exchange with coils 135 by proper control of valves 161 and 160. The vapors are then introduced into the separator 162. The uncondensed gases are withdrawn via 163 by control of valve 164. The water condensate, if any, is withdrawn via line 165 and valve 166 to pass with any make-up water as desired introduced via line 167 and valve 168 to pass into line 152.

Condensate lighter than water is withdrawn via line 169 and by control of valves 170 and 171 may be passed in part to storage via 172 and in part via 173 to be introduced as reflux into rectifier 149.

The operation of this cycle may be illustrated and compared with the other cycles by employing the feed material and steam rate of the other examples.

Example 5

The still 140 is operated at a temperature of about 145° F. and a pressure of 3 p. s. i. a. The vapors are compressed in 142 to a pressure sufficient to obtain 15 p. s. i. a. in 149 and heated to a temperature of about 400° F. The vapors from the compressor 155 are compressed from a temperature of about 185° F. and pressure of 15 p. s. i. a. to a pressure of 60 p. s. i. g. in 162. The gases are heated by this compression to a temperature of 435° F. The available heat in the hot gases will be, in the case of the example given, in excess of that necessary to generate the steam. In fact, only a portion of the heat is necessary for this purpose. The remaining heat may be dissipated by heat exchange with the incoming feed. The coils may thus be by-passed in part or whole to limit the heat required to vaporize all the water entering via 152 to maintain an initial constant level of water in 147.

While I have for purposes of illustration referred the application of my system to the distillation of petroleum oil containing hydrocarbons in the gasoline range, my invention is not so limited and may be employed for the steam distillation of any liquids or solids where the vaporization temperature and pressure of the still are such that at such pressure and temperature steam may be generated from liquid. Numerous examples will suggest themselves to those skilled in this art as a result of the teachings of this application.

While I have described a particular embodiment of my invention for the purpose of illustration, it should be understood that various modifications and adaptations thereof may be made within the spirit of the invention as set forth in the appended claims.

I claim:

1. A method for steam distillation, which comprises passing steam into a material undergoing distillation in a distillation zone at a distillation temperature, removing the vapors containing steam from the undistilled residue, compressing the mixed vapors above the pressure at which distillation occurred, heating said mixed vapors by such compression above the temperature of distillation, cooling said mixed vapors to condense water from said vapors at said higher pressure, reducing the pressure on said water to substantially the pressure of said distillation and passing said water in heat exchange with the compressed vapor thus cooling said vapors, vaporizing a portion of said water at said lower pressure to form steam, leaving some water unvaporized, introducing said steam into said distillation zone, passing said unvaporized water in direct contact with said compressed vapors at a higher pressure than said lower steam forming pressure, and cooling said compressed vapors by heat exchange between said vapors and said water by said direct contact at said higher pressure.

2. A method for steam distillation, which comprises passing steam into a material undergoing distillation in a distillation zone at a distillation temperature, removing vapors containing steam from the undistilled residue, compressing said mixed vapors above the pressure at which said distillation occurred, heating said mixed vapors by such compression above the temperature of distillation, cooling said mixed vapors by indirect heat exchange with a water maintained in a vaporizing zone at a pressure substantially that of said distillation zone, vaporizing said water to form steam, introducing said steam into said distillation zone, condensing water from said cooled vapors at a pressure and temperature substantially higher than is maintained in said water vaporizing zone, separating said condensed water, reducing the pressure on said water, introducing said water into said water vaporizing zone at said reduced pressure, removing water from said water vaporizing zone, introducing said removed water into contact with the compressed vapors at a pressure substantially higher than said water vaporizing zone, and condensing said compressed vapors at said higher pressure.

3. A method for steam distillation, which comprises passing steam into a material undergoing distillation in a distillation zone at a distillation temperature, removing vapors containing steam from the undistilled residue, compressing said

mixed vapors above the pressure at which distillation occurred, heating said mixed vapors by such compression above the temperature of distillation, cooling said mixed vapors by indirect heat exchange with a water maintained in a vaporizing zone at a pressure substantially that of said distillation zone, vaporizing said water to form steam, partially condensing said steam, separating the uncondensed steam from the steam condensate, introducing the uncondensed steam vapors into said distillation zone, commingling the steam condensate with the water in said water vaporizing zone, condensing water from said cooled vapors at a pressure substantially higher than is maintained in said water vaporizing zone, separating said condensed water, reducing the pressure on said water, and introducing said water into said water vaporizing zone.

4. A method for steam distillation which comprises passing steam into a material undergoing distillation in a distillation zone at a distillation temperature, removing vapors containing steam from the undistilled residue, compressing said mixed vapors above the pressure at which distillation occurred, heating said mixed vapors by such compression above the temperature of distillation, cooling said mixed vapors by indirect heat exchange with a water maintained in a vaporizing zone at a pressure substantially that of said distillation zone, and vaporizing said water to form steam, condensing water from said cooled vapors at a pressure and temperature substantially higher than is maintained in said water vaporizing zone, separating said condensed water, reducing the pressure on said water, introducing said water into said water vaporizing zone, removing water from said water vaporizing zone, introducing said removed water into contact with the compressed vapors at a pressure substantially higher than said water vaporizing zone, cooling said compressed vapors by contact between the vapors and the water, and condensing said compressed vapors at said higher pressure.

5. A method for steam distillation, which comprises passing steam into a material undergoing distillation in a distillation zone at a distillation temperature and pressure, removing vapors of said material mixed with water vapors from the unvaporized residue, compressing the mixed vapors to a pressure substantially higher than the pressure in said vaporizing zone, heating the vapors by such compression, passing the compressed vapors in heat exchange with water in a water vaporizing zone maintained at a pressure substantially that of the distillation zone to cool the vapors and to supply latent heat of vaporization of the water, condensing a portion of the compressed vapors, separating condensate from the uncondensed vapors at such higher pressure, further compressing said uncondensed vapors to a higher pressure and thus further heating said vapors by such compression, passing said further compressed vapors in heat exchange with said water in said vaporizing zone to further supply latent heat of vaporization of said water in said vaporizing zone and to cool the further compressed vapors, condensing water from said further compressed vapors at such higher pressure, separating such water condensate from the uncondensed vapors at such higher pressure, reducing the pressure on said water condensate, and introducing such water at such reduced pressure into said water vaporizing zone.

6. A method for steam distillation, which comprises passing steam into a material undergoing distillation in a distillation zone at a distillation temperature and pressure, removing vapors of said material mixed with water vapors from the unvaporized residue, compressing the mixed vapors to a pressure substantially higher than the pressure in said vaporizing zone, heating the vapors by such compression, passing the compressed vapors in heat exchange with water in a water vaporizing zone maintained at a pressure substantially that of the distillation zone to cool the vapors and to supply latent heat of vaporization of the water, condensing a portion of the compressed vapors, separating condensate from the uncondensed vapors at such higher pressure, further compressing said uncondensed vapors to a higher pressure and thus further heating said vapors by such compression, passing said further compressed vapors in heat exchange with said water in said vaporizing zone to further supply latent heat of vaporization of said water in said vaporizing zone and to cool the further compressed vapors, separating water from said water vaporizing zone, commingling said water with the further compressed vapors at a pressure substantially higher than the vaporizing zone, and cooling the compressed vapors at said higher pressure, condensing water from said further compressed vapors at such higher pressure, separating such water condensate from the uncondensed vapors at such higher pressure, reducing the pressure on said water condensate, and introducing such water at such reduced pressure into said water vaporizing zone.

7. A method for steam distillation, which comprises passing steam into a material undergoing distillation in a distillation zone at a distillation temperature and pressure, removing vapors of said material mixed with water vapors from the unvaporized residue, compressing the mixed vapors to a pressure substantially higher than the pressure in said vaporizing zone, heating the vapors by such compression, passing the compressed vapors in heat exchange with water in a water vaporizing zone maintained at a pressure substantially that of the distillation zone to cool the vapors and to supply latent heat of vaporization of the water, condensing a portion of the compressed vapors, separating condensate from the uncondensed vapors at such higher pressure, further compressing said uncondensed vapors to a higher pressure and thus further heating said vapors by such compression, separating water from said water vaporizing zone, commingling said water with the further compressed vapors to cool the same, condensing water from said further compressed vapors at such higher pressure, separating such water condensate from the uncondensed vapors at such higher pressure, reducing the pressure on said water condensate, and introducing such water at such reduced pressure into said water vaporizing zone.

8. A method for steam distillation, which comprises passing steam into a material undergoing distillation in a distillation zone at a distillation temperature, removing the vapors containing steam from the undistilled residue, compressing the mixed vapors above the pressure at which distillation occurred, heating said mixed vapors by such compression above the temperature of distillation, cooling said mixed vapors to condense water from said vapors at said higher pressure, reducing the pressure on said water to substantially the pressure of said distillation, vaporizing a portion of said water at said lower

pressure to form steam, leaving some water unvaporized, introducing said steam into said distillation zone, passing said unvaporized water in contact with said compressed vapors at a pressure substantially higher than the pressure in the vaporizing zone, and cooling said compressed vapors by direct heat exchange between said water and said compressed vapors at said higher pressure.

9. A method for steam distillation, which comprises passing steam into a material undergoing distillation in a distillation zone at a distillation temperature, removing vapors containing steam from the undistilled residue, compressing said mixed vapors above the pressure at which distillation occurred, heating said mixed vapors by such compression above the temperature of distillation, cooling said mixed vapors, condensing water, separating said condensed water, reducing the pressure on said water, introducing said water into a water vaporizing zone, vaporizing said water to form steam, introducing said steam into said distillation zone, removing water from said water vaporizing zone, and introducing said removed water into contact with the compressed vapors undergoing condensation at a pressure substantially higher than the pressure in said water vaporizing zone.

10. A method for steam distillation, which comprises passing steam into a material undergoing distillation in a distillation zone at a distillation temperature, removing vapors containing steam from the undistilled residue, compressing said mixed vapors above the pressure at which distillation occurred, heating said mixed vapors by such compression above the temperature of distillation, cooling said mixed vapors, condensing water, separating said condensed water, reducing the pressure on said water, introducing said water into a water vaporizing zone, vaporizing said water to form steam in said vaporizing zone, partially condensing said steam, separating the uncondensed steam from the steam condensate, introducing the uncondensed steam vapors into said distillation zone, and commingling the steam condensate with the water in said water vaporizing zone.

11. A process of steam distillation, which comprises generating steam in a steam generation zone, introducing heated material into a distillation zone, said material being heated sufficiently to supply heat of vaporization of said material in said distillation zone, introducing said steam into the distillation zone, removing mixed vapors containing steam from said distillation zone, compressing said vapors above the pressure of said distillation zone and said steam generation zone, thus heating the mixed vapors by said compression, transferring a portion only of the heat of the compressed vapors to the steam passing to said vaporization zone, separately removing the remaining portion of the heat added by compression to the compressed vapors, further cooling said compressed vapors, condensing the water in said compressed mixed vapors at an elevated pressure higher than said distillation pressure, removing water of condensation, reducing the pressure on said water, and introducing said water into said steam generation zone, whereby the latent heat of vaporization of water vaporized in said steam generation zone is supplied solely by the heat added to the water by said compressed vapors.

12. A method of steam distillation, which comprises vaporizing water in a water vaporizing zone and passing steam so generated into a material undergoing distillation in a distillation zone, heating said material sufficiently to supply heat of vaporization of said material, removing vapors containing steam and vaporized material from the undistilled residue in the distillation zone, compressing the mixed vapors to a pressure in excess of the said distillation pressure and in excess of the pressure maintained in said water vaporizing zone, heating said vapors to a temperature in excess of the temperature maintained in said distillation zone, partially cooling the compressed vapors by heat exchange with water undergoing vaporization in the water vaporizing zone, increasing the heat content of the water undergoing vaporization and generated steam by an amount less than the heat of compression, additionally cooling the compressed vapors, by a heat exchange in addition to said aforementioned heat exchange, and thereby removing the heat of compression and latent heat of condensation of the steam in said compressed mixed vapors and thus condensing steam at said higher pressure, removing the condensed steam, reducing the pressure on said steam condensate, and introducing said condensate into the water vaporizing zone wherein the water is vaporized, the latent heat of vaporization of water being supplied solely by the heat added to said water by said compressed vapors.

13. A method for steam distillation, which comprises passing steam into a material undergoing distillation in a distillation zone at a distillation temperature and pressure, removing vapors of said material mixed with water vapors from the unvaporized residue, compressing the mixed vapors to a pressure substantially higher than the pressure in said vaporizing zone, heating the vapors by such compression, passing the compressed vapors in heat exchange with water in a water vaporizing zone maintained at a pressure substantially that of the distillation zone to cool the vapors and to supply latent heat of vaporization of the water, condensing a portion of the compressed vapors of the vaporized material and of the compressed water vapor, separating condensate from the uncondensed vapors at such higher pressure, further compressing said uncondensed vapors to a higher pressure and thus further heating said vapors by such compression, passing said further compressed vapors in heat exchange with said water in said vaporizing zone to further supply latent heat of vaporization of said water in said vaporizing zone and to cool the further compressed vapors, condensing water and said vaporized material from said further compressed vapors at such higher pressure, separating such water condensate from the uncondensed vapors at such higher pressure, reducing the pressure on said water condensate, and introducing such water at such reduced pressure into said water vaporizing zone.

14. A method for steam distillation, which comprises passing steam into a material undergoing distillation in a distillation zone at a distillation temperature and pressure, removing vapors of said material mixed with water vapors from the unvaporized residue, compressing the mixed vapors to a pressure substantially higher than the pressure in said vaporizing zone, heating the vapors by such compression, passing the compressed vapors in heat exchange with water in a water vaporizing zone maintained at a pressure substantially that of the distillation zone to cool the vapors and to supply latent heat of vaporization

of the water, condensing a portion of the compressed vapors of the vaporized material and of the compressed water vapor, separating condensate from the uncondensed vapors at such higher pressure, further compressing said uncondensed vapors to a higher pressure and thus further heating said vapors by such compression, passing said further compressed vapors in heat exchange with said water in said vaporizing zone to further supply latent heat of vaporization of said water in said vaporizing zone and to cool the further compressed vapors, separating water from said water vaporizing zone, commingling said water with the further compressed vapors at a pressure substantially higher than the vaporizing zone and cooling said vapors at said higher pressure, condensing water and said vaporized material from said further compressed vapors at such higher pressure, separating such water condensate from the uncondensed vapors at such higher pressure, reducing the pressure on said water condensate, and introducing such water at such reduced pressure into said water vaporizing zone.

15. A method for steam distillation, which comprises passing steam into a material undergoing distillation in a distillation zone at a distillation temperature and pressure, removing vapors of said material mixed with water vapors from the unvaporized residue, compressing the mixed vapors to a pressure substantially higher than the pressure in said vaporizing zone, heating the vapors by such compression, passing the compressed vapors in heat exchange with water in a water vaporizing zone maintained at a pressure substantially that of the distillation zone to cool the vapors and to supply latent heat of vaporization of the water, condensing a portion of the compressed vapors of the vaporized material and of the compressed water vapor, separating condensate from the uncondensed vapors at such higher pressure, further compressing said uncondensed vapors to a higher pressure and thus further heating said vapors by such compression, separating water from said water vaporizing zone, commingling said water with the further compressed vapors to cool the same, condensing water and said vaporized material from said further compressed vapors at such higher pressure, separating such water condensate from the uncondensed vapors at such higher pressure, reducing the pressure on said water condensate, and introducing such water at such reduced pressure into said water vaporizing zone.

16. A process of steam distillation, which comprises passing steam through a material undergoing distillation in a distillation zone heating said material sufficiently to supply the heat of vaporization of said material, removing mixed vapors of water and the vaporized material from said distillation zone, compressing the mixed vapors to a pressure substantially higher than the distillation pressure and thus heating the mixed vapors to a temperature substantially higher than the distillation temperature, passing said compressed vapors in heat exchange with water and thus heating said water to a temperature sufficient to vaporize said water at a pressure substantially lower than the pressure of said compressed vapors but below the boiling point of the water at the pressure of the compressed vapors in heat exchange with the water, vaporizing the heated water at a pressure substantially lower than the said pressure of said compressed vapors the latent heat of vaporization of water having been added solely by said heat exchange with the compressed vapors, introducing the resultant steam into the still, cooling the compressed vapors separately and independently from the aforesaid heat exchange between said water and the compressed vapors, condensing vapors of said material vaporized by said distillation in a condensation zone at a pressure substantially higher than said distillation pressure, and removing condensate from said condensation zone.

17. A process of steam distillation, which comprises passing steam through a material undergoing distillation in a distillation zone, heating said material sufficiently to supply the heat of vaporization of said material, removing mixed vapors of steam and vaporized material from the distillation zone, compressing the mixed vapors to a pressure substantially higher than the distillation pressure, condensing water at said higher pressure, separating the condensed water from uncondensed vaporous material, heating said water by heat exchange with said compressed gases to partially cool said compressed gases, vaporizing said heated water in a vaporizing zone at a vaporizing pressure substantially lower than the pressure of said uncondensed vaporous material the latent heat of vaporization of water having been added solely by the heat exchange with said compressed vapors, introducing the resultant steam into the distillation zone, and further and separately cooling the uncondensed vaporous material at a pressure substantially higher than the vaporizing pressure of the water in said vaporizing zone.

18. A process of steam distillation, which comprises passing steam through a material undergoing distillation in a distillation zone at a distillation temperature and pressure, removing mixed vapors of steam and vaporized material from the distillation zone, compressing the mixed vapors to a pressure substantially higher than the distillation pressure and thus heating the compressed gases to a temperature substantially higher than the distillation pressure, partially heat exchanging said compressed vapors with relatively cool water and partially condensing said vapors to form a water condensate in a condensation zone, separately removing the water from the condensed compressed vapors, reducing the pressure on said water condensate and vaporizing steam and thus cooling the water to a temperature substantially below the temperature of condensation of said water, passing such relatively cool water in said heat exchange with said compressed vapors, further and separately cooling the uncondensed compressed vapors in a separate condensation zone at a pressure substantially higher than the pressure in the vaporization zone to condense distilled material, and removing the condensate from the material from said higher pressure condensation zone.

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References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
849,579	Siebel	Apr. 9, 1907
1,200,996	Soderlund	Oct. 10, 1916
1,425,005	Genucke	Aug. 8, 1922
1,489,009	Rohmer et al.	Apr. 1, 1924
1,822,455	Ricard et al.	Sept. 8, 1931
2,327,643	Houghland	Aug. 24, 1943