

April 17, 1945.

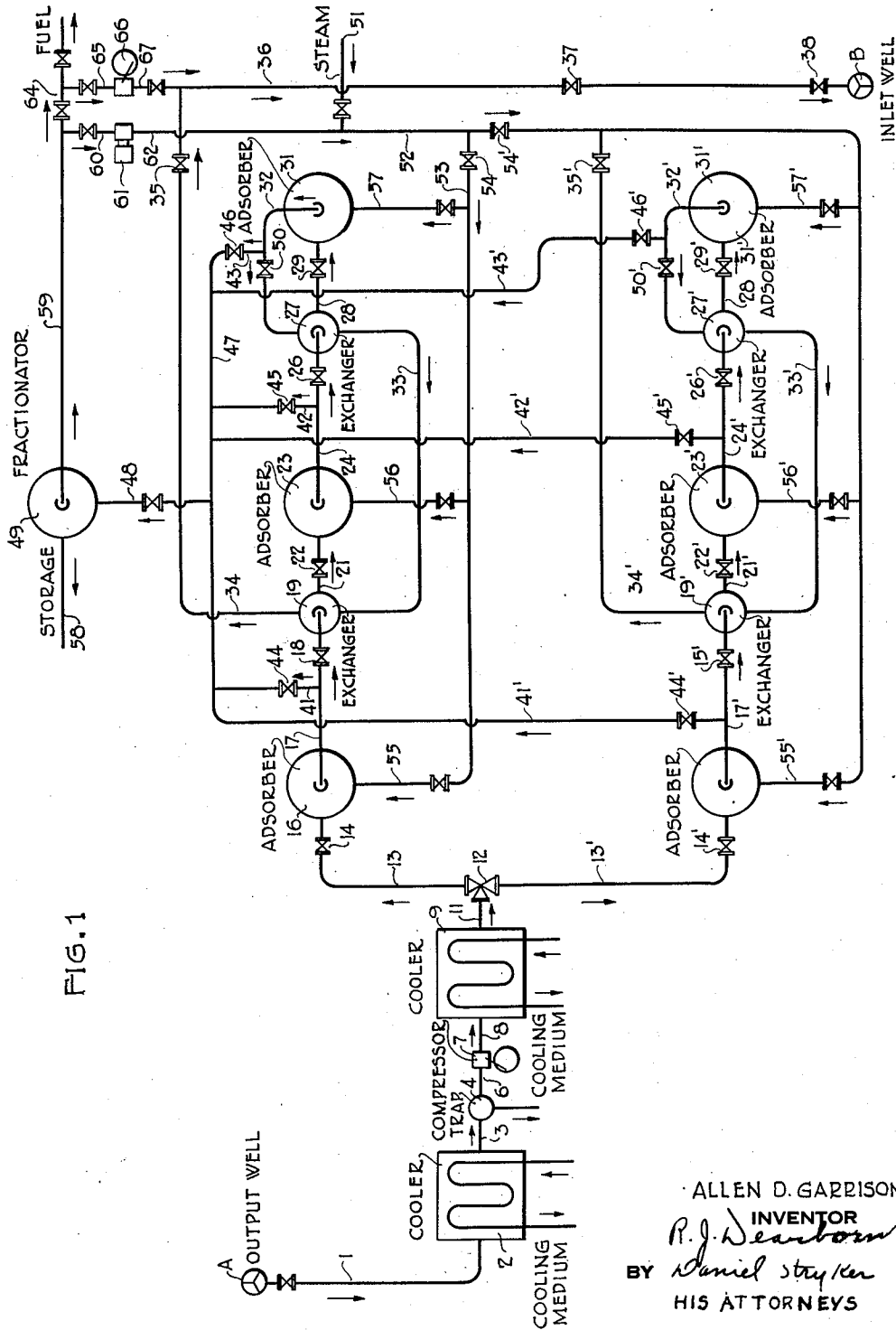
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2,374,091

RECOVERY OF HYDROCARBONS FROM HIGH PRESSURE FLUIDS

Filed July 10, 1941

2 Sheets-Sheet 1



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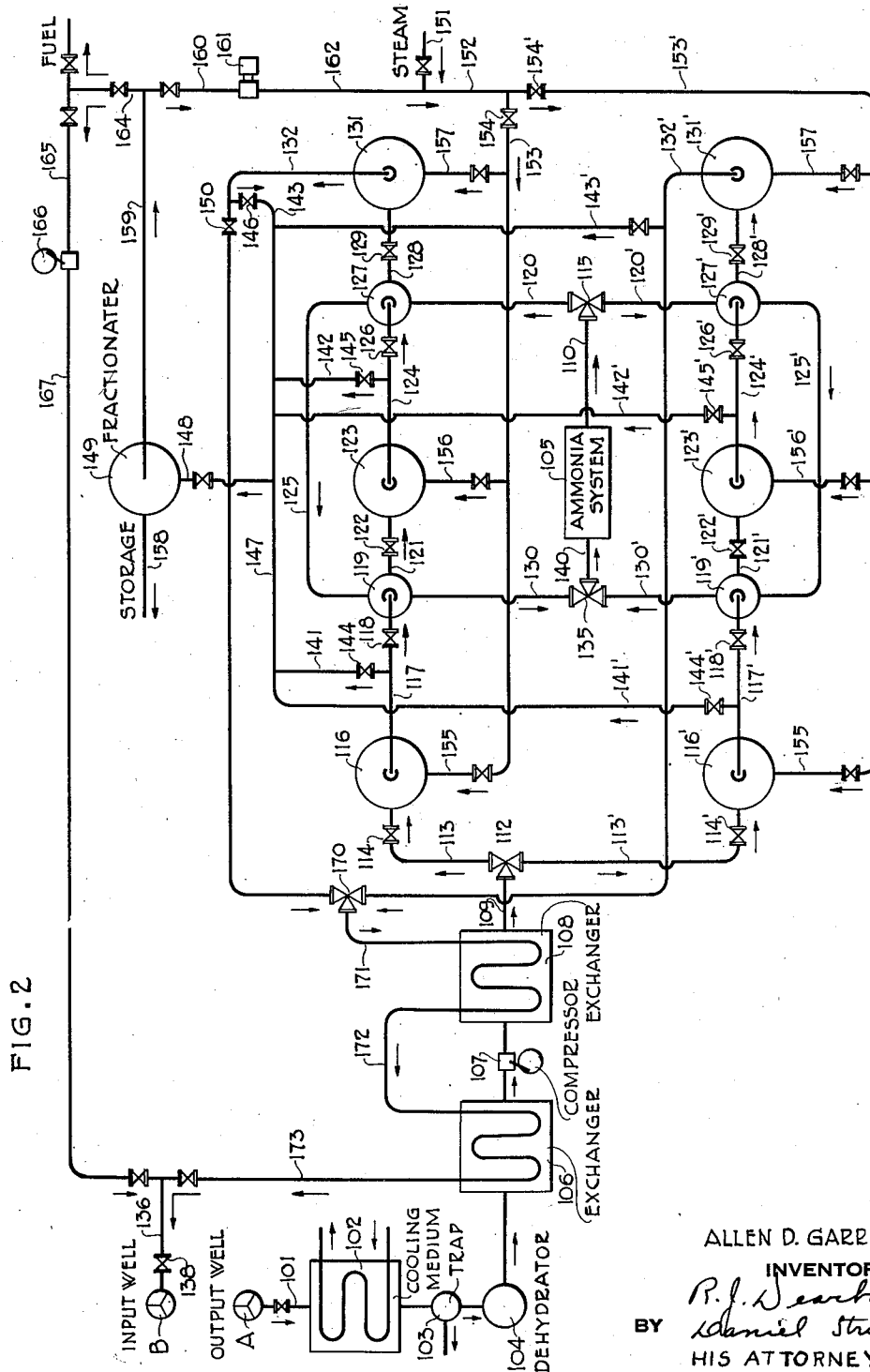
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2 Sheets-Sheet 2



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2,374,091

RECOVERY OF HYDROCARBONS FROM
HIGH-PRESSURE FLUIDS

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Application July 10, 1941, Serial No. 401,801

12 Claims. (Cl. 62—175.5)

- This invention relates to processes for the production of distillate reservoirs wherein liquefiable hydrocarbons (i. e., normally liquid hydrocarbons) are recovered from the fluid flowed from a well tapping a reservoir of this type and residual gases are preferably returned to the same or a different distillate reservoir for the purpose of maintaining formation pressures. The invention especially relates to an adsorption process for the recovery of liquefiable hydrocarbons from distillate fluids.

It is an object of the invention to provide an efficient process for the production of distillate reservoirs which is characterized by its low energy requirements and by the fact that relatively small equipment may be used.

Another object of the invention is to provide an adsorption process for the recovery of liquefiable hydrocarbons from distillate fluids in which a reduced amount of adsorbent is used and the desorption operation is simplified.

Other objects of the invention in part will be obvious and in part will appear hereinafter.

In the production of hydrocarbons from a distillate reservoir, it is recognized that in order to prevent the condensation of liquefiable hydrocarbons in the reservoir itself, which results in permanent loss of hydrocarbons, the residual gas should be returned to the reservoir so as to avoid as far as possible any drop in pressure in the formation. The fluid flowed from a well tapping a distillate reservoir is under such conditions of temperature and pressure that the fluid exists substantially at a homogeneous gas phase. The temperature of typical distillate fluids at the well head are of the order of 125 to 175° F. and the pressures are of the order of 1500 to 5000 pounds per square inch or above. A reduction in the pressure of this fluid causes condensation of hydrocarbons. Accordingly, most of the processes which have been employed for the recovery of hydrocarbons from distillate fluids have involved as an essential feature materially reducing the initial pressure of the fluid.

Because of the necessity of returning the residual gas to the formation under pressures exceeding the formation pressures, the reduction in pressure above ground has added materially to the costs of the processes. Absorption processes using a relatively heavy absorption oil have also been employed. These processes have involved a single stage oil absorption in which after cooling the distillate fluid from its initial temperature to a suitable tem-

perature for absorption, and after reducing the pressure on the fluid to less than 2000 pounds per square inch, the fluid is passed into contact with a cool absorption oil to absorb normally liquid hydrocarbons and yield a residual gas which is compressed and returned to the formation. All of these processes are characterized by the fact that the pressure and/or temperature of the distillate fluid is adjusted so that the conditions under which the separation of normally liquid hydrocarbons is carried out are such as to convert the distillate fluid to a two-phase product. In other words, in these processes the conditions of temperature and pressure of the fluid are adjusted so as to be well within the two-phase boundary on the temperature-pressure plane for the original well fluid.

In considering the conditions under which processes for the recovery of normally liquid hydrocarbons from distillate fluids are carried out, it is of advantage to keep in mind the phase relations of the fluids. For a discussion of phase relations see the article, "Retrograde condensation," by Dr. D. L. Katz and F. Kurata, Industrial and Engineering Chemistry, vol. 32, No. 6, June 1940, pages 817-827. In the reservoir a distillate fluid is considered to exist as a single phase and, as noted above, the conditions at which the fluid is flowed from a well may be without, and in any event are not substantially within the two-phase boundary. Thus, the temperatures in the reservoir and at which the fluid is flowed from the well may be above the temperature at the critical point for the fluid, and the pressures on the fluid in the reservoir and when the fluid is flowed from the well may be above and sometimes are not substantially below the pressure of the two-phase boundary at the existing temperature. It will be understood that where the conditions of temperature and pressure of a distillate fluid are near the two-phase boundary in the critical area, raising the pressure serves to move the conditions away from the two-phase region; i. e., away from conditions at which condensation of liquid takes place.

In accordance with the present invention the production of normally liquid hydrocarbons from a distillate reservoir is carried out by flowing the distillate fluid from an output well, recovering the normally liquid hydrocarbons therefrom, and preferably returning a substantial part of the residual gas to a distillate reservoir at a pressure sufficiently high to pre-

vent substantial drop of reservoir pressure. The invention is in the nature of an improvement of the process described in my application Serial No. 269,472, filed April 22, 1939. The invention comprises the several features described below and the relation of one or more of the features to each of the others.

In the present process the recovery of liquefiable hydrocarbons from a distillate fluid is accomplished by passing the fluid through an adsorbent such as activated charcoal or silica gel in stages wherein the conditions are controlled so as to result in maximum recovery of hydrocarbons. During the adsorption procedure the pressure is maintained above well head pressure; preferably the pressure on the fluid is raised prior to adsorption to a point sufficiently high to yield at the end of the operation a residual gas at a pressure adapted for injection into the reservoir through an input well. The distillate fluid prior to adsorption and also between adsorption stages is subjected to cooling. The invention also involves the feature of returning the residual gas to the reservoir at a temperature substantially below the temperature at which the distillate fluid was flowed from the output well.

Thus the recovery of liquefiable hydrocarbons from a distillate fluid in accordance with the invention may be carried out by raising the pressure of a fluid flowed from a well tapping a distillate reservoir substantially above well head pressure and then passing the fluid at the raised pressure into the first of a plurality of adsorbers. The fluid is preferably cooled prior to entering the compressor and, if this cooling causes the formation of a small amount of liquid phase, the cool fluid may be passed through a trap to remove the liquid. The fluid after leaving the compressor is also cooled at least sufficiently to remove the heat of compression. Accordingly, the fluid entering the first adsorber will be at a pressure considerably above well head pressure and at a relatively low temperature. The conditions of temperature and pressure at which the fluid enters the first adsorber will be in the critical area and such that the fluid exists as a single homogeneous phase. Under these conditions it is passed through the first adsorber wherein the most easily adsorbed hydrocarbons are adsorbed. The remaining fluid is then cooled and passed into a second adsorber. Since a reduction in temperature favors adsorption, hydrocarbons more difficult to condense are removed in the second adsorber. Ordinarily, the process will employ at least three adsorbers and prior to passing the fluid to a third adsorber additional cooling is carried out. Where three adsorbers are used, for example, the temperature of the fluid prior to entering the third adsorber is reduced to a point sufficiently low that the remaining liquefiable hydrocarbons are adsorbed in this stage.

The residual gas leaving the last adsorber is preferably at a pressure sufficiently high to adapt it for return to the reservoir through an input well and is at a low temperature. This cold residual gas will preferably be employed either for cooling the distillate fluid between adsorption stages or for assisting in the cooling of the fluid accomplished before introducing the fluid into the adsorbers. However, these heat exchanging operations are carried out so that the temperature of the residual gas is not raised to a temperature of the order of that of the fluid leaving

the output well. The residual gas, therefore, leaves the system at a low temperature and is preferably introduced into the reservoir in relatively cold condition.

By proceeding as described above, several advantages are obtained. One of the important expenses involved in the installation of equipment for the treatment of distillate fluids is based upon the fact that relatively large volumes of gases are required to be handled. By compressing the gases prior to the recovery step the size of the equipment is materially reduced. Since adsorption is not dependent upon the condensation of liquid, it may be carried out with relatively high pressures which remove the conditions from the neighborhood of the conditions defined by the two-phase boundary.

At least two advantageous results flow from cooling the distillate fluid before adsorption. The volume of fluid to be handled is further reduced and the temperature of the fluid is brought to that temperature most desirable for the first adsorption stage.

With respect to carrying out the adsorption in a plurality of stages with cooling between stages, it is pointed out that this operation can be accomplished with advantage even where the pressure of the distillate fluid is not raised prior to bringing it into contact with the adsorbent. A distillate fluid contains liquefiable hydrocarbons of varying types ranging from butane to hexane and heavier. Where the adsorption is carried out in a single stage it is necessary to adjust the conditions in this stage so as to remove substantially all of these hydrocarbons. This means that the temperature should be reduced to a relatively low point, and, in order to effect the desorption, the adsorbent must be heated to a high temperature in relation to the preferred adsorption temperature. By carrying out the adsorption in stages the temperature of the distillate fluid in the first stage is reduced only to the point sufficient for effective adsorption of the more easily adsorbed hydrocarbons. Thus, in effecting desorption of the adsorbent in the first stage the rise in temperature required is relatively small. The same thing is true in regard to the later stages since it is ordinarily not necessary to heat the adsorbent in the last stage during desorption to as high a temperature as would be required were the entire operation carried out in a single stage. Not only is the amount of heating required reduced but the time of desorption is also smaller since in any case only the last stage involves the slow desorption cycle employing the widest temperature fluctuation between adsorption and desorption.

By returning the residual gas to the formation at a relatively low temperature the volume of the gas required to be handled and the dissipation of energy between the output and input well are kept at a minimum. This gas is preferably returned to a distillate reservoir at a temperature below 75° F. and especially below 50° F. Inasmuch as the gas on entering the reservoir will take up heat from the earth and expand so as to occupy the same volume as it would if it had been introduced at a high temperature, the cold gas will be effective in maintaining formation pressures.

It will be understood that the present process may be operated in various ways. In accordance with one manner of proceeding the distillate fluid flowed from the output well is cooled prior to being compressed. This cooling may be suf-

ficient to reduce the temperature to the point desired for carrying out the first adsorption step. Any liquid that is formed due to cooling may be removed at this point and then the pressure on the fluid is raised. The high pressure fluid is then cooled at least sufficiently to remove the heat of compression and then flows to the first adsorber. In accordance with this embodiment of the invention, prior to entering the first adsorber, the fluid is passed through a pressure reducing valve whereby additional cooling of the fluid is effected. In the first adsorber the more easily adsorbed hydrocarbons are removed and the remaining fluid then passes through a heat exchanger and into the second adsorber. As in the case of the first adsorber the pressure is again reduced so as to effect additional cooling. Thus the temperature in the second adsorber is materially below the temperature in the first and more difficultly adsorbed hydrocarbons are removed. This operation is repeated for the number of adsorption stages desired. For accomplishing cooling between the adsorption stages the relatively cold residual gases leaving the last adsorption stage may be employed.

In passing through the several adsorbers the pressure of the fluid is preferably controlled so as to obtain a residual gas at a sufficiently high pressure to adapt it for return to a distillate reservoir.

Thus it will be seen that in this case a part of the cooling through the adsorption system is accomplished by reducing the pressure of the distillate fluid. However, since the pressure has been raised in advance, and the residual gas is obtained at a pressure above well head pressure, the conditions maintained during adsorption are outside of the two-phase boundary for the fluid and no true condensation of liquid results.

The invention may be practiced in accordance with another manner of proceeding by initially reducing the temperature of the distillate fluid to a relatively low point and maintaining the pressure substantially constant throughout the adsorption. In this case, instead of employing the residual gas for cooling between adsorption stages, this gas is employed for cooling the distillate fluid prior to adsorption. The cooling of the gases between adsorption stages is preferably accomplished with the use of an artificial refrigerant such as a normally gaseous material, particularly ammonia.

In removing the adsorbed hydrocarbons from the adsorbent in the several stages in accordance with the invention advantage is taken of the fact that at the completion of the adsorption the adsorbers are under relatively high pressure. Accordingly, an important proportion of the hydrocarbons are removed by releasing the pressure on the adsorbers and flashing off the hydrocarbons. The desorption is also preferably carried out by heating the adsorbent and passing steam there-through. To remove the last vestiges of steam, or water condensed therefrom, the light gases removed from the fractionator or accumulator to which the hydrocarbons are passed from the adsorbers may be used.

In order that the invention may be understood more fully reference should be had to the accompanying drawings in which Figure 1 is a flow sheet illustrating one embodiment of the invention and Figure 2 is a similar flow sheet illustrating another embodiment.

Referring first to Figure 1, the operation in this case will be described in connection with a dis-

tillate fluid obtained at a well head pressure of 3000 pounds per square inch and a temperature of 150° F. The distillate fluid is removed from output well A through valved line 1 leading to a cooler 2. In passing through cooler 2, which may be an exchanger utilizing a cooling medium such as water, the temperature of the fluid is preferably reduced to about 85° F. This reduction in temperature normally causes condensation of a small amount of liquid and to remove this liquid the fluid is passed through line 3 and trap 4. It then passes through line 6 to a compressor 7 where the pressure is preferably raised to 3800 pounds per square inch and the heat of compression is sufficient to raise the temperature to about 150° F. From the compressor the fluid passes through line 8 to a cooler 9, which may be similar to cooler 2, wherein the temperature of the fluid is again reduced to about 85° F.

The fluid leaving this cooler passes into line 11 leading to valve 12, which is operated in the manner described below, and then into line 13 provided with valve 14. The valve 14 is operated as a pressure reducing valve and the pressure of the fluid is reduced sufficiently to cause additional cooling of the fluid but not to a sufficiently low point to cause the formation of hydrates. For example, the pressure may be reduced to 3600 pounds to bring the temperature of the fluid to about 70° F. Under these conditions the fluid is passed upwardly through adsorber 16. In this adsorber the water in the fluid and the heavier liquefiable hydrocarbons (e. g., the octanes and heavier) are adsorbed. From the top of the adsorber 16 the remaining fluid passes through line 17 provided with valve 18 leading to exchanger 19 wherein it is brought into direct heat exchange relationship with cold residual gas. In this exchanger the temperature is preferably reduced to about 40° F. From the exchanger the fluid flows through line 21 provided with pressure reducing valve 22. Valve 22 is operated so as to reduce the pressure of the fluid to about 3400 pounds resulting in a drop in temperature to about 30° F., under which conditions the fluid is passed upwardly through adsorber 23. In this adsorber the hydrocarbons intermediate with respect to ease of adsorption (e. g., hexanes to octanes) are adsorbed.

The remaining fluid leaves adsorber 23 through line 24 having a valve 26 and thence through exchanger 27. In this exchanger the fluid again comes in indirect contact with cold residual gases and the temperature is preferably reduced to about 10° F. The fluid leaves exchanger 27 through line 28 provided with pressure reducing valve 29. In passing through this valve the pressure is reduced to about 3200 pounds per square inch and the temperature to about 0° F. At this low temperature the most difficultly adsorbed liquefiable hydrocarbons (e. g., butanes to hexanes) are removed from the fluid. The remaining unadsorbed gas, which is substantially free from liquefiable hydrocarbons, leaves the top of adsorber 31 at a temperature of about 0° F. and a pressure of 3200 pounds per square inch. This gas is then passed through line 32 and exchanger 27 where it is effective to cool the fluid passing from adsorber 23 to adsorber 31. From exchanger 27 it passes into line 33 leading into exchanger 19 where it is employed to reduce the temperature of the fluid passing from adsorber 16 to adsorber 23. The residual gas, which is then at a temperature in the neighborhood of 50° F., passes into line 34 provided with valve

35 and hence into line 36 leading to input well B. As shown, line 36 is provided with valves 37 and 38. It will be noted that the pressure of this residual gas is above the well head pressure at output well A and is at a temperature of about 50° F. On returning this gas to the formation it adsorbs heat from the ground and occupies the same space as if it had been introduced at a higher temperature.

The operation described is carried out until the adsorbent in the adsorbers becomes substantially saturated with liquefiable hydrocarbons. The valve 12 is then turned so as to direct the distillate fluid into line 13' which leads into a second system of adsorbers which is identical with the system just described. In the second system the elements corresponding to those of the first system are identified by the same numbers primed. While the second system is in operation desorption of hydrocarbons from the first system is carried out.

In accomplishing desorption, valves 14, 18, 22, 26 and 29 and a valve 50 in line 32 are closed. As shown, leading from lines 17, 24 and 32 there are lines 41, 42 and 43. Line 41 is provided with valve 44, line 42 with valve 45 and line 43 with valve 46. At the beginning of the desorption operation these valves are opened and a portion of the adsorbed hydrocarbons are flashed off through lines 41, 42 and 43 and into line 47. Leading from line 47 is a valved line 48 which is connected with an accumulator or fractionator 49 into which the hydrocarbons are passed. To remove additional hydrocarbons steam is introduced into the system through line 51 leading into line 52 which is connected with line 53 provided with valve 54. Line 53 is connected with valved lines 55, 56 and 57. The steam passes through these lines and into the adsorbers and accomplishes removal of the remainder of the hydrocarbons.

Fractionator 49 is operated so as to separate the liquefiable hydrocarbons (i. e., the condensate) from light gases. The condensate is removed from the system to storage through line 58. The light gases pass from the fractionator through line 59 and after the steam treatment at least a part are passed into line 60 provided with pump 61. This pump raises the pressure of the gases sufficiently to force them through valved line 62 and thence through lines 52, 53, 55, 56 and 57 and through the adsorbers to remove the remainder of the hydrocarbons and condensed steam. The excess light gases removed from the fractionator pass through valved line 64 and they may be used for fuel or they may be passed into valved line 65 provided with a compressor 66. This compressor is operated so as to raise the pressure of the gases to the pressure of the residual gases removed from the last adsorber; in this instance to a pressure of 3200 pounds per square inch, at which pressure they pass through line 67 and into line 36 for return to the reservoir.

The process illustrated in Figure 2 differs from that just described in several particulars but has many points of similarity, particularly in regard to the desorption operation. The process will be described in connection with the same distillate fluid as the process of Figure 1. Referring to the figure, the fluid is removed from output well A through valved line 101 and enters cooler 102 where it is preferably cooled to about 85° F. Any liquid condensed is removed in trap 103 and the remaining fluid passes through a dehydrator 104. This dehydrator is preferably a calcium

chloride brine circulation system in which the fluid is mixed with the brine, and the brine is concentrated and returned for reuse. In this process it is important to dehydrate before adsorption because the temperature is reduced below the temperature of hydrate formation, as will be described. From the dehydrator the fluid passes into a heat exchanger 106 where it is brought into indirect heat exchange relationship with cold residual gas. This step may reduce the temperature to about 30° F. The pressure of the cold fluid is then raised in compressor 107 to a pressure sufficiently high to force the fluid through the system and yield a residual gas of a pressure high enough for return to a distillate reservoir; for example, to a pressure of 3300 pounds per square inch.

Most of the heat of compression is removed in heat exchanger 108 through which the cold residual gas is also passed. The cold fluid, which will be at a temperature of about 35° F., is passed from this exchanger through line 109 leading to valve 112, which valve is operated in the same way as valve 12 of Figure 1, and into line 113 leading to adsorber 116. The system of adsorbers is structurally similar to that of Figure 1 and will not be described in detail. However, in the present operation the pressure is maintained substantially constant throughout the adsorption procedure (i. e. valves 114, 122 and 129 are not operated as pressure-reducing valves). Also, exchangers 119 and 127 are operated with the use of ammonia from the ammonia system 105. Thus the cold ammonia is passed from the ammonia system through line 110, valve 115, and line 120 leading to exchanger 127. After cooling the fluid at this point, it passes through line 125 and to the exchanger 119, and returns to the ammonia system through lines 130, valve 135, and line 140.

In operating in accordance with the process disclosed in Figure 2, the unadsorbed fluid leaving adsorber 116, which will be at a temperature somewhat above 35° F., for example, 40° F., is passed through exchanger 119 wherein the temperature may be reduced to about 10° F. At this temperature the fluid is passed through adsorber 123 and the residual fluid leaving this adsorber, which may be at a temperature of about 15° F., is passed through exchanger 127 and cooled to about 0° F. In adsorber 131 the most difficultly adsorbed hydrocarbons are removed and the cold residual gas leaves this adsorber through line 132 provided with valve 150. The cold gas, which may be at a temperature of 5° F., passes through valve 170 and line 171 leading into heat exchanger 108 and then through line 172 leading into heat exchanger 106. These exchanging operations may be carried out so as to yield a residual gas at a temperature of about 70° F., at which temperature the gas is passed through valved lines 173 and 136 and into input well B for maintaining formation pressures.

The desorption operation involved in the process illustrated in Figure 2 is carried out in the same way as that described in connection with Figure 1 and corresponding elements are identified by the same symbols plus 100. Thus, prior to desorption, the incoming fluid would be directed into the second system by manipulation of valve 112, valves 114, 118, 122, 126, 129 and 150 would be closed, and valves 144, 145, and 146 would be open. Also, steam would enter the adsorbers through lines 151, 152, 153, and lines 155, 156 and 157 leading into the adsorbers. Light gases removed from the accumulator may be introduced

through lines 159 and 160, pump 161 and line 162 which leads into line 152. The remainder of these light gases may be passed through line 164 and thence to fuel, or through line 165, compressor 166, where the pressure is raised to about 3200 pounds per square inch, and line 167 leading into line 136 for return to the reservoir through input well B.

It will be understood that the conditions of temperature and pressure specifically mentioned above are illustrative and that the conditions will vary depending upon the initial temperature and pressure and composition of the fluid. Thus, the conditions are best described by reference to the phase relations.

In the appended claims the terms "distillate fluid" and "fluid" are employed to denote not only the fluid as removed from the well but also this fluid after the removal of a portion of the hydrocarbons and/or the moisture. Thus, the fluid passing through the system is regarded as the same unitary body subjected to various treatments.

Since changes may be made in the processes described above without departing from the scope of the invention, it is intended that the above description shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. The process of recovering liquefiable hydrocarbons from the well fluid of a well tapping a distillate reservoir which comprises contacting said fluid with an adsorbent in a plurality of stages, the temperature and pressure conditions of said fluid entering the first stage being in the critical area and such that the fluid exists substantially as a homogeneous phase and is subject to retrograde condensation upon a reduction in pressure, and reducing the pressure on the fluid in its flow between stages while maintaining the fluid substantially in a single homogeneous phase, whereby the more easily adsorbed hydrocarbons are adsorbed in the first stage and difficultly adsorbed hydrocarbons are adsorbed in a subsequent stage.

2. The process of recovering liquefiable hydrocarbons from the well fluid of a well tapping a distillate reservoir which comprises contacting said fluid with an adsorbent in a plurality of stages, the temperature and pressure conditions of the fluid entering the first stage being in the critical area and such that the fluid exists substantially as a homogeneous phase and is subject to retrograde condensation upon a reduction in pressure, and cooling the fluid and reducing the pressure on the fluid in its flow between stages to reduce the temperature of the fluid entering a subsequent stage to a temperature below that of the fluid entering a preceding stage while maintaining the fluid substantially in a single homogeneous phase, whereby the more easily adsorbed hydrocarbons are adsorbed in the first stage and difficultly adsorbed hydrocarbons are adsorbed in a subsequent stage.

3. The process of recovering liquefiable hydrocarbons from a distillate fluid obtained from a well tapping a distillate reservoir, which comprises raising the pressure on said distillate fluid to a pressure above well-head pressure, introducing said distillate fluid at said raised pressure into the first stage of a plurality of adsorption stages, the temperature and pressure conditions of said distillate fluid entering the first stage being in the critical area and such that said fluid

exists substantially as a single homogeneous phase and is subject to retrograde condensation upon a reduction in pressure, and cooling the fluid in its flow between stages to reduce the temperature of the fluid entering a subsequent stage to a temperature below that of the fluid entering a preceding stage while maintaining the fluid substantially in a single homogeneous phase, whereby the more easily adsorbed hydrocarbons are adsorbed in the first stage, difficultly adsorbed hydrocarbons are adsorbed in a subsequent stage, and residual gases are obtained substantially free from liquefiable hydrocarbons.

4. The process of recovering liquefiable hydrocarbons from a distillate fluid obtained from a well tapping a distillate reservoir, which comprises raising the pressure on said distillate fluid to a pressure above well-head pressure, introducing said distillate fluid at said raised pressure into the first stage of a plurality of adsorption stages, the temperature and pressure conditions of said distillate fluid entering the first stage being in the critical area and such that said fluid exists substantially as a single homogeneous phase and is subject to retrograde condensation upon a reduction in pressure, and cooling the fluid and reducing the pressure on the fluid in its flow between stages to reduce the temperature of the fluid entering a subsequent stage to a temperature below that of the fluid entering a preceding stage while maintaining the fluid substantially in a single homogeneous phase, whereby the more easily adsorbed hydrocarbons are adsorbed in the first stage, difficultly adsorbed hydrocarbons are adsorbed in a subsequent stage, and residual gases are obtained substantially free from liquefiable hydrocarbons.

5. The process of recovering liquefiable hydrocarbons from a distillate fluid obtained from a well tapping a distillate reservoir, which comprises raising the pressure on the fluid to a pressure substantially in excess of the pressure at which the fluid was flowed from the well, introducing the fluid at the raised pressure into the first stage of a plurality of adsorption stages, the temperature and pressure conditions of the fluid entering the first stage being in the critical area and such that the fluid exists substantially as a single homogeneous phase and is subject to retrograde condensation upon a reduction in pressure, and cooling the fluid and reducing the pressure on the fluid in its flow between stages to reduce the temperature of the fluid entering a subsequent stage to a temperature below that of the fluid entering a preceding stage while maintaining the fluid substantially in a single homogeneous phase and at all times at a pressure above the pressure at which the fluid was flowed from the well tapping the distillate reservoir, whereby the more easily adsorbed hydrocarbons are adsorbed in the first stage, difficultly adsorbed hydrocarbons are adsorbed in a subsequent stage, and residual gases are obtained substantially free from liquefiable hydrocarbons and at a pressure above the pressure at which the fluid was flowed from the well tapping the distillate reservoir.

6. The process of recovering liquefiable hydrocarbons from a distillate fluid obtained from a well tapping a distillate reservoir, which comprises raising the pressure on the fluid to a pressure in excess of the pressure at which the fluid was flowed from the well tapping the reservoir, cooling the fluid, introducing the fluid at the raised pressure and lowered temperature into

the first stage of a plurality of adsorption stages, the temperature and pressure conditions of the fluid entering the first stage being in the critical area and such that the fluid exists substantially as a single homogeneous phase and is subject to retrograde condensation upon a reduction in pressure, and cooling the fluid in its flow between stages to reduce the temperature of the fluid entering a subsequent stage to a temperature below that of the fluid entering a preceding stage while maintaining the fluid substantially in a single homogeneous phase and at all times at a substantially constant pressure above the pressure at which the fluid was flowed from the well tapping the distillate reservoir, whereby the more easily adsorbed hydrocarbons are adsorbed in the first stage, difficultly adsorbed hydrocarbons are adsorbed in a subsequent stage, and residual gases are obtained substantially free from liquefiable hydrocarbons and at a pressure above the pressure at which the fluid was flowed from the well tapping the reservoir.

7. The process of recovering liquefiable hydrocarbons from a distillate fluid obtained from a well tapping a distillate reservoir, which comprises raising the pressure on said distillate fluid to a pressure above well-head pressure and at least sufficiently high for returning residual gases to a distillate reservoir, cooling said distillate fluid to a temperature substantially below the temperature at which said distillate fluid is flowed from said well, said raised pressure and said lowered temperature being in the critical area for said distillate fluid and such that said fluid exists substantially as a single homogeneous phase and is subject to retrograde condensation upon a reduction in pressure, introducing said distillate fluid at said raised pressure and said lowered temperature into the first stage of a plurality of adsorption stages, passing the fluid from said first stage to a subsequent stage, and cooling the fluid in its flow between stages to reduce the temperature of the fluid entering a subsequent stage to a temperature below that of the fluid entering a preceding stage while maintaining the fluid substantially in a single homogeneous phase, whereby the more easily adsorbed hydrocarbons are adsorbed in the first stage, difficultly adsorbed hydrocarbons are adsorbed in a subsequent stage, and cold residual gases are obtained substantially free from liquefiable hydrocarbons and at a pressure sufficiently high for return to a distillate reservoir, and utilizing said cold residual gases for effecting said cooling of said fluid in its flow between adsorption stages.

8. The process of recovering liquefiable hydrocarbons from a distillate fluid obtained from a well tapping a distillate reservoir, which comprises raising the pressure on said distillate fluid to a pressure above well-head pressure and above the pressure required for returning residual gases to said distillate reservoir, cooling said distillate fluid to a temperature substantially below the temperature at which said distillate fluid is flowed from said well, said raised pressure and said lowered temperature being in the critical area for said distillate fluid and such that said fluid exists substantially as a single homogeneous phase and is subject to retrograde condensation upon a reduction in pressure, introducing said distillate fluid at said raised pressure and said lowered temperature into the first stage of a plurality of adsorption stages, passing the fluid from said first stage to a subsequent stage, and cooling the fluid

and reducing the pressure on the fluid in its flow between stages to reduce the temperature of the fluid entering a subsequent stage to a temperature below that of the fluid entering a preceding stage while maintaining the fluid substantially in a single homogeneous phase, whereby the more easily adsorbed hydrocarbons are adsorbed in the first stage, difficultly adsorbed hydrocarbons are adsorbed in a subsequent stage, and cold residual gases are obtained substantially free from liquefiable hydrocarbons and at a pressure sufficiently high for return to a distillate reservoir, and utilizing said cold residual gases for effecting said cooling of said fluid in its flow between adsorption stages.

9. The process of recovering liquefiable hydrocarbons from a distillate fluid obtained from a well tapping a distillate reservoir, which comprises cooling said distillate fluid and removing any condensed hydrocarbons, raising the pressure on the cooled fluid to a pressure at least sufficiently high for returning residual gases to a distillate reservoir, cooling the fluid at said raised pressure to a temperature substantially below the temperature at which said distillate fluid is flowed from said well, said raised pressure and said lowered temperature being in the critical area for said fluid and such that said fluid exists substantially as a single homogeneous phase and is subject to retrograde condensation upon a reduction in pressure, introducing said fluid at said raised pressure and said lowered temperature into the first stage of a plurality of adsorption stages, passing the fluid from said first stage to a subsequent stage, and cooling the fluid in its flow between stages to reduce the temperature of the fluid entering a subsequent stage to a temperature below that of the fluid entering a preceding stage while maintaining the fluid substantially in a single homogeneous phase, whereby the more easily adsorbed hydrocarbons are adsorbed in the first stage, difficultly adsorbed hydrocarbons are adsorbed in a subsequent stage, and cold residual gases are obtained substantially free from liquefiable hydrocarbons and at a pressure sufficiently high for return to a distillate reservoir.

10. The process of recovering liquefiable hydrocarbons from a distillate fluid obtained from a well tapping a distillate reservoir, which comprises cooling said distillate fluid and removing any condensed hydrocarbons, raising the pressure on the cooled fluid to a pressure above the pressure required for returning residual gases to said distillate reservoir, cooling the fluid at said raised pressure to a temperature substantially below the temperature at which said distillate fluid is flowed from said well, said raised pressure and said lowered temperature being in the critical area for said fluid and such that said fluid exists substantially as a single homogeneous phase and is subject to retrograde condensation upon a reduction in pressure, introducing said fluid at said raised pressure and said lowered temperature into the first stage of a plurality of adsorption stages, passing the fluid from said first stage to a subsequent stage, and cooling the fluid and reducing the pressure on the fluid in its flow between stages to reduce the temperature of the fluid entering a subsequent stage to a temperature below that of the fluid entering a preceding stage while maintaining the fluid substantially in a single homogeneous phase, whereby the more easily adsorbed hydrocarbons are adsorbed in the first stage, difficultly adsorbed hydrocarbons are adsorbed in a subsequent stage, and cold residual

gases are obtained substantially free from liquefiable hydrocarbons and at a pressure sufficiently high for return to a distillate reservoir, and utilizing said cold residual gases for effecting said cooling of said fluid in its flow between adsorption stages.

11. The process of recovering liquefiable hydrocarbons from a distillate fluid obtained from a well tapping a distillate reservoir, which comprises cooling said distillate fluid and removing any condensed hydrocarbons, raising the pressure on the cooled fluid to a pressure at least sufficiently high for returning residual gases to a distillate reservoir, cooling the fluid at said raised pressure to a temperature substantially below the temperature at which said distillate fluid is flowed from said well, said raised pressure and said lowered temperature being in the critical area for said fluid and such that said fluid exists substantially as a single homogeneous phase and is subject to retrograde condensation upon a reduction in pressure, introducing said fluid at said raised pressure and said lowered temperature into the first stage of a plurality of adsorption stages, passing the fluid from said first stage to a subsequent stage, and cooling the fluid in its flow between stages by passing the fluid in indirect heat exchange relationship with an artificial refrigerant to reduce the temperature of the fluid entering a subsequent stage to a temperature below that of the fluid entering a preceding stage while maintaining the fluid substantially in a single homogeneous phase, whereby the more easily adsorbed hydrocarbons are adsorbed in the first stage, difficultly adsorbed hydrocarbons are adsorbed in a subsequent stage, and cold residual

gases are obtained substantially free from liquefiable hydrocarbons and at a pressure sufficiently high for return to a distillate reservoir, and utilizing said cold residual gases for cooling said distillate fluid prior to introducing said fluid into the first adsorption stage.

12. The process of recovering liquefiable hydrocarbons from a distillate fluid obtained from a well tapping a distillate reservoir, which comprises raising the pressure on the fluid to a pressure substantially in excess of the pressure at which the fluid was flowed from the well, cooling the fluid, then passing the fluid into the first stage of a plurality of adsorption stages, the temperature and pressure conditions of the fluid entering the first stage being in the critical area and such that the fluid exists substantially as a single homogeneous phase and is subject to retrograde condensation upon a reduction in pressure, cooling the fluid in its flow between stages to reduce the temperature of the fluid entering a subsequent stage to a temperature below that of the fluid entering a preceding stage while maintaining the fluid substantially in a single homogeneous phase and at all times at a pressure above the pressure at which the fluid was flowed from the distillate reservoir, whereby the more easily adsorbed hydrocarbons are adsorbed in the first stage, difficultly adsorbed hydrocarbons are adsorbed in a subsequent stage, and residual gases are obtained substantially free from liquefiable hydrocarbons and at a pressure above the pressure at which the fluid was flowed from the well tapping the distillate reservoir.

ALLEN D. GARRISON.

CERTIFICATE OF CORRECTION.

Patent No. 2,374,091.

April 17, 1945.

ALLEN D. GARRISON.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 1, first column, line 35, for "temperature" read --temperatures--; and second column, line 25, for "condensation" read --Condensation--; page 2, first column, line 47, for "existes" read --exists--; page 3, second column, line 37, for "direct" read --indirect--; page 4, second column, line 46, for "temperture" read --temperature--; page 6, second column, line 33, claim 9, for "adsorbtion" read --adsorption--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 7th day of August, A. D. 1945.

Leslie Frazer

(Seal)

Acting Commissioner of Patents.