ABSORPTION-ADSORPTION METHOD

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This invention relates to new and useful improvements in absorption-adsorption methods.

In United States patent application Serial No. 551,816, filed December 8, 1955, now abandoned in favor of United States patent application Serial No. 669,753, filed July 3, 1957, as a continuation-in-part of said application Serial No. 551,816, in the names of Edward E. Dillman and Dan Ringo an adsorption system is disclosed wherein a plurality of adsorber units are adapted to be selectively connected in series for dehumidifying or stripping air or other gases such as petroleum gases. When a petroleum gas such as field gas coming from a gas well is passed through the adsorption system of said application, the field gas is stripped of water and the hydrocarbons therewith which are in a liquid or vapor state.

An object of this invention is to provide in combination with the adsorption method of said patent application, an adsorption method for absorbing hydrocarbons such as gasoline and the lighter hydrocarbons from a gas subjected to both of such methods, whereby a greater recovery of such hydrocarbons is obtained than is possible when the adsorption method and the absorption method are used separately.

A particular object of this invention is to provide a combined absorption-adsorption method wherein an adsorber unit is connected in series with a plurality of adsorber units to increase the recovery of the condensed or liquid products in a gas.

An important object of this invention is to provide a hydrocarbon recovery method wherein a gas having water and hydrocarbons therewith in a liquid or vapor state is first passed through an adsorber unit for removing the water and some of the hydrocarbons therefrom, and wherein such dehydrated and partially stripped gas is then cooled and passed through an absorption unit to remove the hydrocarbons still in the gas such as the butanes and butenes, whereby the gas is substantially completely stripped of all water and hydrocarbon liquids and vapors by said system.

Another object of this invention is to provide an absorption-adsorption method wherein a low molecular weight absorbent is used without requiring a re-adsorption system for absorbent vapors.

A further object of this invention is to provide an absorption-adsorption method for the recovery of gasoline and the so-called "LPG" (liquefied petroleum gases) from field gas containing same.

Still another object of this invention is to provide a hydrocarbon recovery method wherein at least a pair of adsorption units are connected in series for adsorbing hydrocarbons from a gas, and wherein the second of the adsorption units is subsequently connected as the first unit in series with another adsorption unit, whereby the lighter hydrocarbons in said second of the adsorption units are preferentially displaced by the heavier hydrocarbons so that the maximum recovery of the heavier hydrocarbons such as gasoline is obtained with the adsorption units while the lighter hydrocarbons such as the butanes and butenes are passed to an absorption system for recovery.

An additional object of this invention is to provide a new and improved hydrocarbon recovery method wherein a gas having hydrocarbons present therewith as a vapor and/or condensed liquids is successively passed through adsorption and absorption cycles, and wherein refrigeration is utilized to enhance the yield of the condensed hydrocarbons in the absorption cycle, such refrigeration being utilized without creating ice or hydrates due to the adsorption of the water from the gas prior to the absorption cycle.

The preferred embodiment of this invention will be described hereinafter, together with other features thereof, and additional objects will become evident from such description.

The invention will be more readily understood from a reading of the following specification and the preferred embodiment to the accompanying drawings forming a part thereof, wherein an example of the invention is shown, and wherein:

Fig. 1A is a diagrammatic view illustrating the preferred absorption system for use in this invention, such system being used in combination with the adsorption system illustrated in Fig. 1B;

Fig. 1B is a view illustrating the preferred adsorption system of this invention, including suitable controls therefor, which adsorption system is adapted to be used in conjunction with the absorption system of Fig. 1A for completing the hydrocarbon recovery system of this invention;

Fig. 2 is a view illustrating the combined absorption-adsorption system of this invention with a modified valve arrangement for the system as compared to the valve arrangement disclosed in Figs. 1A and 1B;

Fig. 3 is a view partly in elevation and partly in section, illustrating one type of valve which may be used in the combined system of this invention;

Fig. 4 is a sectional view taken on line 4—4 of Fig. 3 to illustrate further details of the preferred type of valve for this combination absorption-adsorption system of this invention.

In the drawings, the numeral 10 designates the main feed pipe or line from the field or other source of field or raw gas which, in the usual case, is natural gas and which is adapted to be fed through such line 10 to adsorption beds B—1, B—2, B—3 and B—4 (Fig. 1B), in a sequence which will be hereinafter explained. The gas coming from line 10 is also directed through an absorber or absorption unit A (Fig. 1A) in a particular sequence with respect to the adsorption units B—1, B—2, B—3 and B—4. A plurality of multi-port valves 11, 12, 13 and 14 are connected with the adsorption beds or units and the absorption bed or unit so as to control the inlet of the gas to such beds or units and to also control the path of the flow through such units, as will be explained. Also, additional multi-port valves 15, 16, 17 and 18 are suitably connected with the adsorption beds and the absorption bed for controlling the outlet of the gas from the various beds and the sequence of the gas flow therethrough, as will be explained hereinafter. Such multi-port valves are preferably of the construction shown in Figs. 3 and 4 hereof, and as more fully disclosed in said application Serial No. 551,816.
is directed through two additional adsorption beds in series and then the gas is discharged for subsequent treatment or for use through discharge line 20. The fourth adsorption bed or unit is reactivated with a reactivation gas which is maintained in a separate cycle or system while the other three adsorption beds or units are adsorbing components such as water and hydrocarbons from the gas passing therethrough. The gas which is discharged from the line 20 is stripped of the water and hydrocarbons, or other components which are adapted to be removed by adsorption. The adsorption beds B-1, B-2, B-3 and B-4 preferably have a selective adsorption therein such as silica gel or activated carbons, or any other provides for material serving the same purpose. The absorbent used in the absorption unit A is a low molecular weight hydrocarbon liquid, such as natural gasoline which is composed principally of pentanes and heavier hydrocarbons, and as will be more evident hereinafter, such absorbent is produced in connection with the adsorption units. The absorption unit A removes an additional amount of the hydrocarbons from the natural or field gas passing therethrough as compared to the hydrocarbons which are recovered by the adsorption units. Principally, the absorption unit A removes the lower molecular weight hydrocarbons which are the butanes and propanes, which are separated from the absorbent with suitable apparatus, an example of which is illustrated in Fig. 1A.

Still speaking generally with regard to the invention hereof, the absorption-adsorption system of this invention has numerous advantages and results which are not possible with either system alone, or with the use of the absorption and the adsorption systems separately on the same gas. Without attempting to enumerate all of the advantages of the absorption-adsorption system of this invention, it should be at least noted at this point that such system provides for the initial removal of water from the incoming field gas as such gases pass through the first of the adsorption beds. Some of the hydrocarbons, principally the pentanes, are removed along with the water in the first of the adsorption beds. The gas then passes to the absorber unit A, and because of the prior removal of the water from the gas, it is possible to refrigerate or cool the gas below a temperature at which water or hydrates would normally form if the gas were not dehydrated. Therefore, an increased recovery of the lower molecular weight hydrocarbons such as the butanes and propanes is obtained in the absorption unit A. Additionally, by reason of the flow of the gas from the absorption unit A back to, and in series with, a second of the adsorption units or beds, a very low molecular weight absorbent can be used in the absorption unit A because any loss of such absorbent is subsequently collected or recovered in the second and third of the adsorption units which have fresh and highly absorbent material therein so that the process is economical and possible even though the extremely low molecular weight absorbent is used in the unit A. It is therefore possible to use the recovered hydrocarbons from the adsorption portion of the system as the absorbent in the absorption unit A, even though such recovered hydrocarbons are relatively low molecular weight hydrocarbons as compared to the absorbents previously used. For example, such recovered hydrocarbons are primarily pentanes but there are some heavier hydrocarbons present in minor quantities. The combined system could function properly even if the recovered hydrocarbons used as the absorbent were entirely pentanes; in fact, if the heaviest hydrocarbon to be absorbed in the absorption unit was propane, then the absorbent could be butane with this system, so that the minimum molecular weight absorbent is possible with the system of this invention. In any event, the use of the low molecular weight absorbent which is supplied from the adsorption portion of the system has definite advantages over the heavier absorbent previously used. For example, the use of the lower molecular weight adsorbent reduces the circulation rates and the accompanying sizes of all equipment through the system almost in proportion to the reduction in the molecular weight of the absorbent oil; also, higher tray efficiencies in the absorber and higher heat transfer rates liquid and gas. These are only a few of the advantages resulting from the use of the low molecular weight absorbent; and since the absorbent oil has the same composition as the composition of the gasoline product, the use of the low molecular weight absorbent from the adsorption portion of the system results in the elimination of a distillation unit or a rich oil still for freeing by absorption from the products of the combined system, whereby a single stabilizer S (Fig. 1A) can be used for both the adsorption and the absorption portions of the combined system. A further advantage of the system and method of this invention resides in the displacement of previously adsorbed hydrocarbons such as the butanes and the propanes by the pentanes and heavier hydrocarbons in the incoming gas. Such preferential displacement of the lighter hydrocarbons occurs when the valves 11 through 18 are manipulated so that the second of the adsorption beds is connected to the liquid knockout chamber K through line 19, and the field gas through the line 10 so that such second of the adsorption beds becomes the first instead of the second adsorption bed in the series. Such manipulation of the valves will be explained in detail hereinafter. Considering the invention now in detail, reference is first made to Figs. 1A and 1B, wherein it can be seen that the gas to be treated, such as natural gas, is initially passed through a liquid knockout or separator device K, which may be of any conventional construction for collecting and separating the condensed or free water and liquid hydrocarbons in the incoming gas. In the usual case, the separated water would be discharged from the knockout chamber K through discharge line 21, the hydrocarbons which are separated from the gas would be discharged through line 22, and the gas from which such water and liquid hydrocarbons have been separated would be discharged from the liquid knockout chamber K through line 23. The feed line 23 from the knockout chamber or unit K is directed to the multi-port valve 11 which has four laterally spaced discharge ports 11a, 11b, 11c and 11d which are connected with the adsorption beds B-1, B-2, B-3 and B-4, respectively. The inlet line 23 to the adsorption beds is in series with the adsorbers, and when it is open, but only one of the outlet or lateral openings 11a, 11b, 11c, 11d is open at any one time. Thus, with the line 11a to the valve 11 open, as indicated by the arrows in Fig. 1B, the gas flows from the inlet line 23 through the valve 11 and then through line 11a to the adsorption bed B-1. Upon the rotation of the valve 11, the openings 11b, 11c and 11d are successively exposed to subsequently switch the flow of the incoming gas from the line 23 to the adsorption beds B-2, B-3, and B-4 successively. With the incoming gas passing through the adsorption bed B-1 first, the gas would discharge from such adsorption bed B-1 and pass to the valve 15 through inlet line 15a, which inlet line is one of four of the inlet lines 15a, 15b, 15c and 15d which are connected with the discharge lines from the adsorption beds B-1, B-2, B-3 and B-4, respectively. It will be noted that one of such lateral openings 15a, 15b, 15c and 15d of the valve 15 is open at any one time. However, the outlet opening 24 from the valve 15 is open at all times so that the gas passing through the valve 15 is discharged or passed into the line 24. The flow line 24 is continued from Fig. 1B to Fig. 1A because such line 24 directs the gas from the first adsorption unit to the absorption unit A.

Thus, as seen in Fig. 1A, the gas passes from line 24 through a heat exchanger 25 which imparts initial cool-
the multi-port valve 17 and outwardly through the discharge line 32. During the initial flow of the gas through the adsorption bed B-3, the reactivation gas is purged from the bed B-3 and is passed back into the reactivation system by flowing through line 33. Such initial purging of the adsorption bed B-3 is accomplished by using a valve 34 in the line 33 and a valve 35 in the line 20. Thus, as will be more fully explained hereinafter, during the initial purging of the adsorption bed B-3 the valve 34 is open and the valve 35 is closed. Therefore, the reactivation gas which is present in the adsorption bed B-3 is forced to flow through the line 34, and is prevented from flowing out through the line 20. However, after all of the reactivation gas has been displaced with the gas being admitted from line 30 to the adsorption bed B-3, then valve 34 is closed and valve 35 is opened so that thereafter the product gas all passes through line 32 to the line 20 for marketing or storage.

While adsorption beds or units B1, B2 and B3 are thus connected for the series flow of gas therethrough and also through the absorber or absorption unit A, the fourth adsorption bed B-4 is being reactivated so as to remove therefrom all previously adsorbed water and hydrocarbons. The reactivation of the adsorption bed B-4 is accomplished in a closed cycle of the reactivation gas. The reactivation gas or the enriched gas is maintained separately from the main gas system because the enriched gas or reactivation gas is heated and is used in the heated condition for the activation stage of the system and, therefore, the system would be less efficient if there was any substantial admixture between the activating gas and the field gas which is being treated. The reactivation gas is directed to a multi-port valve 14 from line 37 for distribution to the particular adsorption bed which is being reactivated. Thus, the multi-port valve has ports or openings 14a, 14b, 14c and 14d, with one port or opening 14d being open in the flow sheet illustrated in Fig. 1B so that the reactivation gas is flowing to the adsorption bed B-4. The multi-port valve 18 is positioned at the discharge end of the adsorption bed B-4 and it has ports or openings 18a, 18b, 18c and 18d formed therewith, one of which is open at a time. In the particular instance illustrated in Fig. 1B, the port 18d is open to the valve 18 and therefore the reactivation gas from the adsorption bed or unit B-4 passes through the line 18d of the valve 18 and is discharged therefrom through the line 39. The line 39 has a branch line 40 which is connected with the inlet line 10. A check valve 41 is provided in the line 40 so as to prevent any return flow of the incoming gas through the line 10 to the line 40. As will be more fully explained, when the adsorption bed B-4 is initially put on the reactivation cycle, the cool lean gas in the bed is first discharged through the line 40 so that such lean gas is not mixed with the reactivation gas. The line 39 is closed by closing valve 42 during the purging of the lean gas from the adsorption bed B-4 so that all of the lean gas passes through line 40 and check valve 41 for the purge period of the reactivation cycle through the adsorption bed B-4. Therefore, as will be more fully explained, the valve 42 is opened and at such time there is not sufficient pressure to still maintain the valve 41 open, whereby the reactivation gas then passes through the valve 42, heat exchanger 43, cooler 44 and into the accumulator 45. The hydrocarbons and water are collected in the accumulator and are removed thereby. Therefore, when water is discharged as desired through outlet line 45a and the liquid hydrocarbons are discharged through line 28 which, as previously explained, flows to the adsorption portion of the system (Fig. 1A). The rich gas or reactivation gas passes from the accumulator 45 through valve 46 and is pumped through the tower 47 by means of the gas reactivation accumulator pump 47. A heat exchange takes place in the heat exchanger 43 and then the gas passes into a heater 49 which may be heated with any suitable fuel such as the stripped gas from line 20 which...
is admitted through line 56 and valve 51. The valve 51 can be regulated with a temperature controller 52 of known construction so that the amount of gas and the admission of the gas through line 50 to the heater 49 is regulated to regulate the temperature of the reaction gas which flows from the heater 49 to the line 37. It should be noted in connection with the reaction portion of the system that the line 33 leading from the adsorption bed B-3 extends to a point between the valve 46 and the pump 47. Therefore, when the valve 34 is open, and the valve 46 is closed, it will be evident that the pump 47 will be pumping the rich purge gas coming from the adsorption bed B-3 for the period of time during which such bed B-3 is on the purge portion of its cycle. Thus, the rich purge gas from the adsorption bed B-3 is readmitted into the reaction portion of the system. As will also be explained, the lean gas in the adsorption bed B-4 is being returned to the inlet line 10 through the line 40 during the time that the rich gas is being returned to the reaction cycle through the line 33.

In order to reduce the volume of the gas passing from the adsorption bed B-2 to the adsorption bed B-3 during the occurrence before the start of the cycle, the multi-port valves 55 (Fig. 1B) is connected from the flow line 30 to the flow line 20. During the purging of the rich gas from the adsorption bed B-3 in the initial part of the cycle, the amount of the gas flowing from line 30 to the adsorption bed B-3 is reduced by opening the valve 25 to its full extent so that substantially all of the gas flows from the line 30 to the product or discharge line 20. Only enough of the gas flows from the line 30 to the adsorption bed B-3 to remove the rich gas therefrom during the purge cycle. The valve 55 is regulated so as to close or partially close same after the purge cycle so that essentially the same or at least a greater portion of the gas passes from the line 30 to the adsorption bed B-3 for the cooling of the adsorbent in the bed B-3 during that portion of the cycle. The operation of the valve 55 can be controlled with numerous devices which are well known, and as illustrated in Fig. 1B a pressure control device 56 is connected from the line 30 to the line 20 so that the pressure differential between the lines 20 and 30 changes, the valve 55 will be manipulated to adjust the valve 55 to regulate the amount of flow therethrough for each phase of the purge and cooling cycle.

The multi-port valves 11-18, and the other valves 34, 35, 42, 46 and 55 could be manipulated by various devices, or conceivably even by hand, but in order to render the system uniform, such valves are preferably controlled by a fluid pressure system which is schematically illustrated in Fig. 1B at the lower portion thereof. Such system is particularly desirable when the valves 11-18 are of the type illustrated in Figs. 3 and 4 of the drawings. The control system includes diaphragms 56-63 and pistons or fluid pressure actuating means 65-72 for the valves 11-18, respectively. The diaphragms are utilized in the unseating of the valve plugs or members when shifting the valves of the type shown in Figs. 3 and 4 of the drawings. The pistons are provided for actuating the valve plugs or members rotate 90°, or some other predetermined amount, for each change which is desired in the adsorption beds. Such diaphragms and pistons may be of various known constructions, an example of which is shown in said patent application, Serial No. 551,816.

A supply of gas or other actuating fluid is introduced at the line 73 for ultimately actuating the diaphragms 56-63 and the pistons 65-72 when it is desired to rotate the valves 11-18. Also such gas or other actuating fluid functions to operate the valves 34, 35, 42, 46, and 55, as will be explained. While the adsorption beds are on a particular cycle, the valves 74, 75 and 76 are closed so as to prevent the admission of the gas or actuating fluid to the pistons and diaphragms until it is desired to operate the valves 11 through 18. Such valves 74, 75 and 76 could of course be manually manipulated to open and close same for the passage of the supply air or gas from the line 73 to the control system, but as shown in Fig. 1B, the valve 74 is controlled by a conventional temperature controller 77 which opens the valve 74 when the temperature of the gas passing through the line 39 reaches a predetermined temperature. In other words, assuming the adsorption bed B-4 is being activated, the gas passing therefrom through line 39 would reach a predetermined temperature in such line 39 when that bed had been fully reactivated for further use, and therefore, the temperature of the gas in the line 39 would cause the temperature controller 77 to act to open the valve 74. Similarly, the valve 75 is opened by another temperature controller 78 which opens when the gas in the line 32 reaches a predetermined temperature. Such gas in the line 32 is the gas coming from the adsorption bed which is being cooled and therefore, it would be actuated when the bed had been cooled sufficiently for subsequent use. Thus, both conditions, namely the activation of the bed under the activation phase and the cooling of the bed under the cooling phase, would have to be present before 74 and 75 were both opened.

When the valves 74 and 75 line are opened, the air or gas supply from the line 73 acts to open the valve 76 and the gas passes through the normally opened valve 80 also for effecting the closing of the valve 81 which is normally opened. Also, the valve 82 which is normally open is closed by the air or gas passing through the line 83 when the valves 74 and 75 are open. The air or gas passing through the line 84 serves to open the normally closed valve 85. When the valve 85 is open, the diaphragms 56-63 are opened to exhaust which allows the valves 11 through 18 to unseat prior to the rotation thereof to a different position, as will be explained. At the same time, supply pressure bleeds through the valve 86 which delays the actuation of the valve 87 to open same after a delayed period so that the air or gas from the supply line 73 is then fed through the line 88 to the pistons 65-72. The pistons are thus actuated to move the valves 11-18 to open a different port on each of said valves, which would be a 90° movement with the valves illustrated in Figs. 3 and 4 of the drawings. Such rotation or turning of the valves shifts the streams of the gas which is being fed to the various beds of the system.

During the admission of the air or gas through the line 88 to the pistons 65-72, a portion of the gas is also passed through a line 89 to a throttling valve 90 which slowly admits pressure to a surge chamber 91 so that after a predetermined time interval from the opening of the valve 87, the pressure in the drum 91 becomes sufficient to actuate the valve 80 to close same. When the valve 80 is closed, then the valve 81 is returned to its normally open position and the valve 85 is returned to its normally closed position. Such action then permits the supply of air or gas to flow through the line 92 to the diaphragms 56-63 so as to again reseat the valves 11-18. The air or gas in the line 92 also passes through the valve 86 and a build-up in pressure in the surge chamber 91 is obtained after a predetermined period of time to close valve 87.

As previously explained, one of the adsorption beds B-1, B-2, B-3 or B-4 is on the purge and cooling phase during a particular cycle, and the purging is accomplished prior to the cooling portion of that phase for each cycle. Thus, in the particular relationship illustrated in Fig. 1B, the bed B-3 is on the purge and cooling phase and is initially purged of the rich activation gas and thereafter is cooled. Also, one of the adsorption beds is on the purge and reactivation phase, and in the particular example illustrated in Fig. 1B, the adsorption bed B-4 is on such phase. In order to manipulate the valves 34, 35, 42 and 46 to first purge the bed on the purge and cooling cycle and to also first purge the bed on the purge and reactivation cycle, the normally open
valve 35 is closed, the normally closed valve 34 is opened and the normally open valves 42 and 46 are closed. Such shifting of the valves 34, 35, 42 and 46 from their normal positions to their purge positions is accomplished at the time the multi-port valves 11 through 18 are shifted to a new position for the shifting of the adsorption beds. For example, when the adsorption beds are indicated in Fig. 1B so that the incoming gas stream is initially directed through the adsorption bed B-1, then it is directed through the absorber A, then is directed through adsorption bed B-2 and is finally directed through bed B-3 for the purging and cooling of same, the adsorption bed B-1 is activated. When the temperature of the adsorption bed B-4 has reached a predetermined point which can be indicated by a temperature controller in the bed B-4 itself, or by the temperature controller 77 connected to the line 39 as shown in Fig. 1B, then the shifting of the valves 11—18 occurs, as previously mentioned. Ordinarily, the temperature controller 78 is actuated prior to the time the temperature controller 77 is actuated so that the valve 75 ordinarily opens prior to the valve 74. In any event, when both temperature controllers 77 and 78 are satisfied, then both the valves 74 and 75 are opened which of course will turn on the recirculation pump as previously explained. Simultaneously with such shifting of the valves 11—18, pressure fluid such as air or gas is admitted through the line 95 to the line 96 which connects with each of the valves 34, 35, 42 and 46. Such air or gas pressure to such valves through the line 96 causes the valve 35 to close, the valve 34 to open, the valves 42 and 46 to close. Therefore, when the valves 11—18 have rotated so as to cause the adsorption bed B-2 to be in the first of the series of the adsorption beds so that it is receiving the inlet gas directly from the valve 11, and the adsorption bed B-3 is then the second in the adsorption series, and the bed B-4 is on the purge and cooling phase, while the bed B-1 is on the reactivation stage, the valves 34, 35, 42 and 46 are shifted to their purge positions so that the rich reactivation gas which had previously collected in the bed B-4 is initially purged and is discharged through the line 33. Simultaneously, the adsorption bed B-1 is purged of its lean gas which had accumulated in the previous adsorption cycle, and such lean gas passes out through line 40. The lean gas coming out through line 39 to line 40 from the adsorption bed B-1 which is on the reactivation stage, lowers the temperature of the temperature controller 77 to a point below which it functions to maintain the valve 74 in an open position. However, to provide a time delay prior to the closing of the valve 74 so as to permit a predetermined period of time for the purging of the beds B-4 and B-1, a throttling valve 98 and a surge drum 99 are positioned in the line leading from the line 39 to the valve 74. The throttling valve 98 limits the pressure fluid reaching the surge drum 99 so that until a predetermined pressure is built up in the drum 99, the valve 74 remains open. The valve 75 likewise remains open during such delay period. Also, the valve 55 may be connected with the line 96 so that it is moved to a fully open position during the purging operation, as previously explained. As soon as sufficient time has elapsed for the pressure build-up in the surge drum 99, the valve 74 closes, and at the same time, due to the fact that the temperature controller 78 reaches a temperature above the temperature at which it functions to open the valve 75. Thereafter, the valve 35 opens to its normal position, the valve 34 closes to its normal position, and the valves 42 and 46 open to their normal positions. Thus, the bed B-4 is then on simply a cooling stage with the gas passing through the line 32 to the line 20. Also, the adsorption bed B-1 is on the reactivation stage or cycle with the reactivation gas then passing through the line 39, exchangers 43 and 44 to the accumulator 45, as previously explained. It will be understood of course that each change in the valves 11—18 produces such a repetition of steps and a switching of the beds successively so that the beds successively change positions insofar as the flow of the gases therethrough is concerned.

It will be noted that regardless of which of the adsorption beds is the first in the series for adsorption, the arrangement of the valves and the connecting lines with the absorber A is such that such absorber A is always in series and intermediate the first and second adsorption beds. The main portion of the equipment illustrated in Fig. 1A is equipment used for circulating the absorbent which is introduced at line 28 from the adsorption portion of the system, and also for separating the absorbed liquid hydrocarbons from the absorbent to yield the various components such as the propanes, butanes, and the pentanes as products.

Line 28 coming from the adsorption portion of the system passes to line 100 (Fig. 1A) where it is mixed with liquid coming from the absorber unit A through line 101. Thus, the absorbed liquids from line 101 are mixed with the adsorbed liquids from line 28 as they pass into line 100 which feeds into a flash tank 102. The flash tank pressure is at a low pressure which is maintained in a relative high pressure system at the inlet line 10 which is a relatively high pressure coming from a well. For example, the pressure of the gas in the absorber unit A will ordinarily be about 400 to 450 pounds per square inch gauge pressure, although it will be understood that such pressure is only given by way of example. The drop in pressure in the flash tank 102 causes the lower molecular weight hydrocarbons such as the methanes and ethanes to flash or evaporate to a gas which passes out of the flash tank 102 through flow line 103. Such flashed gas passing out through line 103 is principally composed of the methanes and the ethanes, but there are some of the heavier hydrocarbons carried therewith, and therefore, in order to recover the heavier hydrocarbons from the flashed gas, such gas is recirculated back to the absorber unit A. The flashed gas passes from line 103 through a heat exchanger 104 to a compressor assembly 105 which boosts the pressure of the gas to the pressure of the gas coming in from line 24 to the absorber unit A. The gas is then pumped from the compressor assembly 105 through a preliminary cooler 106 and then it joins with the incoming gas from the line 24 for further cooling and refrigeration prior to its entry into the absorber unit A.

The liquids from the flash tank 102 flow outwardly through a liquid level control valve 107 into a flow line 108 through which the liquid is directed to heat exchangers 109 and 110 for a preliminary heating of the liquid prior to its flow through line 111 into the deaerator stabilizer S.

The stabilizer S is utilized for removing the undesirable lower hydrocarbons from the liquid entering same, which lower hydrocarbons are the methanes and the ethanes. Some of such methanes and ethanes were removed in the flash tank so as to reduce the load on the stabilizer S, and actually, it is possible to omit the flash tank if a larger load is taken by the stabilizer S. Heat is applied to the stabilizer S by recirculating a portion of the liquid in the stabilizer S through line 112 which is heated with a heating medium from a source 114, as will be understood. The heat in the stabilizer S is sufficient to cause the vaporization of the lower molecular weight hydrocarbons which pass out through line 115 and flow through a refrigeration condenser or heat exchanger 116 for cooling the gas before it leaves the stabilizer S. The temperature to condense most of the higher hydrocarbons which are carried out with the lower hydrocarbons. Such condensed heavier hydrocarbons are collected in an
accumulator 117 and such liquefied hydrocarbons are recirculated back into the stabilizer through the reflux pump 118. The gas passes from the accumulator 117 through line 118 and it joins with the flashed gas from line 103 as they pass together through the heat exchanger 104. The major portion of the liquid which is composed of the higher molecular weight hydrocarbons, passes from the reboiler 112 through a liquid level control 120 and a control valve 121. The valve 121 is preferably connected with a temperature controller 122 which is set to operate the valve 121 for directing a portion, or all, of the fluid from the reboiler through line 123 to the heat exchanger 110, or is set to direct a portion thereof through line 124 which by-passes the heat exchanger 110. The warm liquid from the reboiler 112 is utilized to heat the incoming liquid from the flash tank as it passes through the heat exchanger 110, but ultimately all of the warm liquid, whether it flows directly from the reboiler 112 or partly from the heat exchanger 110, passes through line 124 to a debutanizer 125 which is of known construction. The debutanizer 125 separates the propane and butanes which pass off as vapors through line 126 while the heavier hydrocarbons, which includes the pentanes and heavier hydrocarbons pass as liquids from the bottom of the debutanizer 125 through line 127.

The propane and butanes passing from line 126 enter a fractionator 128 which separates the propanes and the butanes so that the propanes are discharged as a gas from the upper end thereof and then pass out of the fractionator 128 through line 130. Preferably the propanes are cooled in a cooler 131 and are stored in a storage tank 132 in a liquefied state for subsequent use or marketing. Similarly, the butanes are taken from the fractionator 128 through line 135 and is cooled in a cooler 136 and is subsequently stored in a storage tank 137 for subsequent use or storage. It will of course be recognized that in some instances it will not be desirable or necessary to separate the propanes and butanes from each other, in which case, the combined gas coming from the line 132 can be sent directly to a storage tank for storage or use without passing through the fractionation step provided by the fractionator 128.

The natural gasoline which is composed of the pentanes and the heavier hydrocarbons coming from line 127 is also passed through a cooler 138 and is then sent to a storage tank 140. Such natural gasoline and the desired products and it is taken off at line 141 for marketing or other storage. Some of the gasoline is circulated back into the system with an absorbent pump 142 which circulates the gasoline through line 143. A portion of the natural gasoline in line 143 is diverted through line 144 to initially cool same in the heat exchanger 145 and then such gasoline flows through line 145 to the refrigeration condenser 116 for additional cooling. The majority of the natural gasoline from line 143 passes through line 146 to a heat exchanger 109 for an initial cooling of such absorbent and then through line 147 to a refrigeration exchanger 150. From the exchanger 150, the cooled gasoline passes into the absorbent unit A where it functions as the absorbent for picking up or absorbing the components in the gas which are flowing counter-currently therewith through the absorbent unit A. As previously pointed out, it is possible to use the relatively low molecular weight absorbent, namely the natural gasoline, in this system because any of the absorbent which may be lost will pass back to the particular adsorber which is second in the adsorption series through line 138. Also, it should be emphasized that the temperature of the absorbent is extremely low due to the fact that the water has been removed prior to the time that the gas from line 24 is admitted into the absorbent unit A. For example, the refrigeration unit 26 can satisfactorily lower the temperature of the entering gas to about 25° F., and likewise the entering absorbent liquid passing through the refrigerating exchanger 150 can have its temperature lowered to about 25° F. by such refrigeration so that actually the temperature in the absorbent unit A can be well below 0° F. Such temperature is of course below the freezing point of water, but since the water has been previously removed, there is no danger of forming ice or hydrates in the system.

The operation of the system of Figs. 1A and IB is believed evident from the foregoing description, but a brief summary of such operation is now given to further clarify same. The inlet gas enters through flow line 10 and passes first to the liquid knock-out unit K. It will be understood that this invention is primarily concerned with the system and method wherein a gas having components which are capable of being adsorbed and also absorbed is introduced through the flow line 10. Preferably, such gas will be the usual gas coming from a well and it will have water and hydrocarbons therein, and the system of this invention functions to remove and separate certain desired hydrocarbons such as the propanes, butanes and the natural gasoline which is composed of the pentanes and the higher hydrocarbons. The liquid knock-out chamber K serves to remove any condensed or free liquids from the gas such as water and liquefied hydrocarbons.

The gas then flows to the first multi-port valve A through line 23. With the valves in the position indicated so that the flow occurs in accordance with the arrows shown in Figs. 1A and 1B, the line 11a from the valve 11 is open so that the flow of the incoming gas passes to the adsorption bed B-1, water vapor and some of the hydrocarbons are adsorbed by the absorbent therein. The gas then passes through the valve 15 to line 24 for flow through the cooling and refrigeration exchangers 25 and 26 and then into the absorbent A. In the absorbent unit, the entering gas from the line 24 flows counter-currently with respect to the absorbent from the hot section of the absorbent B and absorption of the hydrocarbons in the gas which are in the liquid and vapor phases as the result of the cooling in the exchangers 25 and 26, and it particularly absorbs the lower molecular weight hydrocarbons such as the butanes and the propanes. As previously mentioned, the absorbent is the natural gasoline itself which is recovered in the adsorption portion of the system and which has been stabilized and introduced into the absorbent A through line 143. The gas from the absorbent unit A flows through line 29 and back to the adsorption portion of the system. The absorbent with the natural gasoline is again sent to the line 12b to the second adsorption bed B-2. It will thus be evident that the adsorption beds B-1 and B-2 are in series with each other and also the absorbent unit A is in series with such adsorption units and is interposed intermediate the two adsorption units B-1 and B-2 which are on the adsorption cycle. The adsorption unit B-2 recovers hydrocarbons and in particular, any of the absorbent which comes from the absorbent unit A. Since the adsorption unit B-2 is the bed which had previously been purged and cooled, it is capable of adsorbing all of the absorbent plus additional hydrocarbons which enter that bed. Therefore, there is no danger of losing the valuable absorbent, which is the natural gasoline, which renders the process of this invention economical and practical.

The gas leaving the adsorption bed B-2 is substantially completely stripped of all of the recoverable hydrocarbons and water, and such stripped gas passes out through the multi-port valve 16, with the major portion of such gas flowing through valve 55 during the initial purge stage of bed B-3 for discharge through line 28 to storage or use. A portion of the gas from line 50 passes to the adsorption bed B-3 for initially purging same of the previously used reactivation gas, and then all, or an increased amount, of the gas is directed to the bed B-3 for cooling such adsorption bed B-3 to render it fresh and in condition for subsequent adsorption. At the same time, the adsorption bed B-4 is on a reactivation cycle with the
reactivation gas circulating in a separate phase or system from the gas which is being stripped. The bed B-4 is initially purged of the so-called "lean" gas which is actually the gas which is passed through the beds during the adsorption cycle, and then, the reactivation gas flows through the adsorption bed B-4 to desorb the bed of the previously adsorbed hydrocarbons so that such hydrocarbons are removed by the reaction gas from the adsorption bed B-4. The removal is made possible because the reactivation gas entering the adsorption bed B-4 has a low saturation by reason of its prior heating or otherwise and is therefore capable of removing large amounts of the hydrocarbons and other liquids such as water from the adsorbed gases. The hydrocarbons which are thus collected or picked up by the reactivation gas are condensed in condenser 44 and are then separated from the reactivation gas in the accumulator 45. Such separated liquid in the accumulator 45 is principally formed of the natural gasoline, which is the liquid used as the absorbent in the absorption portion of the system illustrated in Fig. 1A.

Although the form of the invention shown in Figs. 1A and 1B is the preferred form, it should be clearly understood that this invention is not limited to the particular type of adsorption system disclosed and illustrated in Figs. 1B and 2. The invention could be made up of moving bed absorbers which are well known wherein the absorbent moves counter-currently with respect to the gas being stripped. Also, the particular arrangement of the valves and the number of the adsorption units, the three absorber units, and the third adsorption unit being on the reactivation cycle. Of course, if the moving beds are utilized for the adsorption, it is conceivable that the system could function with only two adsorption sections and the absorber. In Fig. 2 of the drawings, another arrangement of valves is illustrated to further show variations in the valve arrangement. The parts or units of Fig. 2 which are identical, or substantially the same as, the parts or units of Figs. 1A and B. There are the same or similar designations. Since the main difference between the system of Figs. 1A and B is the number and the arrangement of the valves for the system, the valves of the system of Fig. 2 are identified by different numerals, namely, 201, 202, 203, 204, 206 and 206, all of which are multi-port valves which preferably are constructed as illustrated in Figs. 2. Also, in the drawings and as will be explained more fully hereinafter. In addition to such multi-port valves, the system of Fig. 2 also includes one-way valves 207, 208, 209 and 210. Also, three-way valves 211 and 212 are utilized.

Generally, speaking, the valves 201 and 202 control the flow of the gas to the adsorption beds for the adsorption portion of the system, the valves 203 and 204 control the flow of the reactivation gas to the particular adsorption bed which is being reactivated. The valves 205 and 206 control the flow of the gas from the adsorption portion of the system to the absorber portion of the system and the valves 201 from the absorber portion of the system to the adsorption portion of the system. The other valves 207, 208, 209, 210, 211 and 212 function in conjunction with the multi-port valves for effecting such flow of the gases.

Thus, the incoming gas flows in through line 10 and passes through the liquid knockout unit K to the valve 201 which directs the gas from the valve 201 to the particular one of the adsorption beds which is on the adsorption cycle and which is the first in the series. In the case illustrated in Fig. 2, the adsorption bed B-1 is the first adsorption bed in series and therefore the gas passes from the valve 201 to the adsorption bed B-1. The hydrocarbons, water and other components are removed in the bed B-1 and then the gas is discharged through the line 220 which flows to the valve 206 due to the fact that the valve 206 is closed. The valve 206 directs the gas to the absorber unit A where the absorption takes place as previously explained. The gas then returns from the absorber unit A through the valve 205 and passes into the adsorption bed B-2 as indicated by the arrows in Fig. 2. The gas from the adsorption bed B-2 then flows through line 221 and valve 209 to the adsorption bed B-3 for cooling and purging same, as previously explained in connection with Figs. 1A and B. The valve 209 is therefore open to permit such flow as indicated by the arrows in Fig. 2. The product gas discharges from the adsorption bed B-3 through line 222 for flow through the valve 202 to the output line 223 where the gas is discharged to storage or use. The valve 211 may be suitably manipulated so that a portion of the outgoing gas is circulated through a condenser 224 if desired. During such flow of the gas through the adsorption beds and the absorber unit A, one of the adsorption beds, in this instance bed B-4, is on the reactivation phase or cycle. The reactivation gas is admitted into the adsorption bed B-4 through line 225 leading from valve 204. The gas discharges from bed B-4 through line 226 to valve 203 and then through line 227 to the reactivation system or section which is, for all practical purposes identical with that illustrated in Fig. 1B. The three-way valve 212 may be utilized for directing a portion of the gas from the bed B-4 to the line 230 during the purging of such vessel B-4. Suitable temperature and pressure controls are utilized for regulating the valve 212 to change same during the purge and reactivation phases. Thus, after the gas has passed through the reactivation section and the gasoline is removed in the accumulator 45, the gas passes back to the adsorption bed B-4 through line 231 which connects with the valve 204 and thence through line 225 to the bed B-4. The controls for the manipulation of the various valves utilized in the form of the invention shown in Fig. 2 are not illustrated but are simply identified as being located in a control box C which could be of any conventional construction and which would ordinarily follow the same type of control system disclosed in connection with Fig. 1B. It will be understood that the beds are successively shifted as they are in connection with Figs. 1B and 1A. Thus, on the shifting of the valves, the bed B-2 will become the first in the series for adsorption, the bed B-3 will become the second in the series for adsorption, with the absorber unit A being connected in between the beds B-2 and B-3 for flow therethrough. Also, the gas be on the purge and cooling cycle, and the bed B-1 will be on the reactivation cycle. Such successive change continues so that ultimately the bed B-3 will be the first in the adsorption series and then thereafter the bed B-4 will be the first in the adsorption series, which of course is the same successive changes as are made in connection with Figs. 1A and 1B. Therefore, it can be seen that the same advantages are present in the system disclosed in Fig. 2, except that certain rearrangements have been made so that it is evident that various valving combinations can be utilized within the scope of this invention.

The preferred type of multi-port valve which is used in connection with the adsorption system or portion of the system of this invention, is fully disclosed and described in said patent application, Serial No. 551,816, and for purposes of illustration, one type of such valve is shown in Figs. 3 and 4 hereof. The valve includes a valve body 250 which has a plurality of passageways 254, 250 and 250 from the valve body 250 and communicate with a central axial bore or passage 250. Thus, the openings 250a, 250b, 250c and 250d would correspond with the openings 11a, 11b, 11c and 11d, respectively of the valve 11 illustrated in Fig. 1B. Similarly, the inlet opening 25e would correspond with the inlet opening 23 of Fig. 1B. The same
relationship will be evident with respect to each of the other multi-port valves shown in Fig. 15 and in Fig. 2.

The body 250 of the valve illustrated in Figs. 3 and 4 is provided with a plurality of threaded openings or recesses 251 which are adapted to receive studs for connecting pipes or conduit (not shown) to the valve body 250 for conducting fluid or gas to or from the openings 250a—250c. A valve seat 252 which is preferably annular in shape and which has an internal inclined or tapered surface 252x therein is positioned in the bore 250e with one end thereof welded at the annular well 253 to the interior of the body 250. The other end of the valve seat 252 is welded to an annular ring or sleeve 254 which is threaded into the bore 250e. Such weld is indicated at 255 for connecting the sleeve 252 with the ring 254. Such removable valve seat 252 could, of course, be formed or made in one piece with the body 250, but the separate valve seat 252 facilitates the assembly and replacement thereof.

The valve seat 252 has openings 252a, 252b, 252c and 252d which correspond with the openings 250a, 250b, 250c and 250d respectively. A valve member 258 is positioned within the valve seat 252 and is the form of a tapered sleeve with an opening 258a extending laterally therethrough for successively establishing fluid communication between the interior or bore 258b of the valve member 258 and the openings 250a—250d of the valve body 250. The external surface 258c of the valve member 258 is tapered or inclined at the same, or substantially the same, inclination as the inclined seating surface 252x of the valve seat 252, so that when the valve member 258 is properly positioned in the valve seat 252, there is a metal-to-metal seating contact between the surfaces 252x and 258c to prevent fluid passage therebetween.

At the right-hand end (Fig. 3) of the valve member 258, a nut 260 having an internal threaded opening 260a therethrough is mounted. Such mounting may be accomplished in any number of ways, but as illustrated, the nut 260 has flanges 260d formed thereon through which one or more screws 261 extend for connecting the nut 260 to a right-hand end of the valve member 258. Alignment pins 262 are also preferably used at spaced intervals with respect to the screw or screws 261. Such nut 260 could, of course, be made integral with the valve member 258, if so desired. The nut 260 is provided on the valve member 258 for connection to an operating shaft 264 thereto by means of the interengagement of the nut 260 with the internal threads 264d on the internal bore 264b of the valve member 258. Thus, the valve member 258 is connected to the shaft 264 for longitudinal or axial movement together.

A shaft support housing 265 which is annular in shape surrounds the shaft 264 and is provided with axial passage 265a therethrough for supporting the shaft 264 during longitudinal or rotational movement thereof relative to the housing 265. Such housing 265 is connected to the valve body 250 by threaded pins or studs 266 which have nuts 267 threaded thereon. A fluid-tight seal 270 is provided in the housing 265 for contact with the external surface of the shaft 264 so as to prevent any fluid leakage past such point. As shown in the drawing, the seal 270 is formed with a chevron-type packing, but the invention is not limited thereto. The packing is maintained under compression for providing an adequate seal by means of a packing gland 271 which is annular in shape and which is connected to the housing 265 by screws 272 or any similar adjustable connecting means.

The housing 265 has an enlarged diameter portion 265b which serves as the bearing housing and which may be formed separately, but as shown is formed as an integral part of the housing 265. The bearing support ring 275 is threaded within the housing portion 265b and the ball bearings 276 and 277 are mounted on the bearing support 275 and in contact with the external surface of the reduced diameter portion 264b of the shaft 264. A collar 278 surrounds the reduced diameter shaft portion 264b to the left of the ball bearing 276, and its right-hand end 278c is spaced from the left-hand end 278a of the ball bearing 276 so as to leave an adjustable annular space therebetween the wear ring 279 and the ball bearing 276 when the valve member 258 is fully seated, as will be more fully explained, whereby the valve member 258 can move longitudinally until the surfaces 278a and 276a contact each other so as to partially unseat or disengage the surfaces 258c from the seats 252c. At such time, it will be seen that the shaft 264 is normally urged to the right (Fig. 3) so as to tend to move the valve member 258 to an unseated position with respect to the valve seating surface 252c, by means of a coil spring 268 which engages an annular plate or washer 281 in contact with the bearing 277 and also engages a flange 282a of a retaining collar 282 which is threaded to the shaft 264 at the threads 264c. In other words, the coil spring 268 is under compression and it acts to move the retaining collar 282 to the right (Fig. 3) because one portion thereof acts against the fixed washer 281 and the other portion thereof acts against the shaft 264. Such tendency to move the collar 282 to the right is transmitted to the shaft 264 and ultimately to the valve member 258.

For overcoming the tendency of the spring 268 to unseat the valve 258, a diaphragm (not shown) which is operated by air or gas under pressure, and which may be of any conventional construction, but preferably is of the type shown in said patent application, Serial No. 531,816, acts to urge the shaft 264 to the left (Fig. 3). Normally, the air pressure acting on the diaphragm and the shaft 264 is of sufficient amount to overcome the opposite force of the spring 268. However, when it is desired to unseat the valve member 258 for effecting the turning of same relative to the valve body 250, the fluid pressure acting on the shaft 264 is relieved so that the spring 268 then acts to unseat the valve member 258. When the valve member 258 is unseated by its movement to the right (Fig. 3), rotation is imparted to the shaft 264 and therefore to the valve member 258 to turn same to position. The opening 258e of the valve member 258 is in alignment with the next successive opening in the valve body 250. For example, with the opening 258a in the position illustrated in Fig. 4, that is, in alignment with the lateral opening 250b, the valve member 258 would be rotated through the opening 258a and the opening 250c. At such time, it will be evident that only one valve opening 250c is in fluid communication with the interior of the valve member 258, so that upon a re-seating of the valve member 258 in contact with the valve seat 250 by a suitable amount of fluid pressure acting thereon, the fluid is controlled in its flow from the central interior passage 250d to the opening 250c which is then in alignment with the passage or opening 258a. The shaft 264 is always rotated in the same direction and each turning is preferably the same amount so that the openings 250a—250d are successively opened. During the re-seating of the valve member 258, the air pressure or other fluid pressure acting on the shaft 264 and the valve member 258 is reduced so that the spring 268 unseats the valve member 258 from its valve seat 252, and upon the valve member 258 reaching its new position in alignment with the next opening of the valve member 258, the fluid pressure is again increased to overcome the spring pressure of the spring 268 so that the valve is fully seated again.

It will be appreciated that other types of valves and controls for the valves could be utilized, but it has been found that the valve construction illustrated in Figs. 3 and 4 is preferable for use with the system of this invention.
It should be pointed out that although the term "field gas" and similar terminology is generally used throughout this description in referring to the gas being treated, any gas may be used regardless of its source so long as it has components therewith capable of being adsorbed by the adsorption portion of the system or absorbed by the absorbed portion of the system. It will also be understood that the particular adsorbent material and the absorbent material may be varied if necessary or desirable for the particular gas being treated. It will also be evident to those skilled in the art that this invention is not limited to the use of a gas for controlling operation of the multi-port valves disclosed in connection with the foregoing description, but as will be appreciated, electric or electronic controls of various types, and other types of controls may be employed.

The foregoing disclosure and description of the invention is illustrative and explanatory thereof and various changes in the size, shape and materials, as well as in the details of the illustrated construction, may be made within the scope of the appended claims without departing from the spirit of the invention.

What is claimed is:

1. The method of stripping components from a gas which includes a hydrocarbon component having from 5 to 10 carbon atoms and another hydrocarbon component having less than five carbon atoms, comprising the steps of, initially passing said gas through a first adsorption bed to remove substantially all water and a substantial portion of the hydrocarbon component having from 5 to 10 carbon atoms, then passing the gas from said first adsorption bed to an absorber for removing a portion of said another hydrocarbon component having less than five carbon atoms, then passing the gas from the absorber through a second adsorption bed to remove substantially all of the hydrocarbon component having from 5 to 10 carbon atoms from the gas, regenerating said first adsorption bed to remove the adsorbed hydrocarbon component and the water therefrom, separating water from the adsorbed hydrocarbon component which was removed from the first adsorption bed, and then utilizing at least some of said adsorbed hydrocarbon component as the absorbent in said absorber.

2. The method of stripping components from a gas which includes a hydrocarbon component having from 5 to 10 carbon atoms and another hydrocarbon component having less than five carbon atoms, comprising the steps of, initially passing said gas through a first adsorption bed to remove substantially all water and a substantial portion of the hydrocarbon component having from 5 to 10 carbon atoms, then passing the gas from said first adsorption bed to an absorber for removing a portion of said another hydrocarbon component having less than five carbon atoms, then passing the gas from the absorber through a second adsorption bed to remove substantially all of the hydrocarbon component having from 5 to 10 carbon atoms from the gas, regenerating a third adsorption bed which has previously adsorbed water and said hydrocarbon component having from 5 to 10 carbon atoms to remove such water and said hydrocarbon component therefrom, separating the water from the adsorbed hydrocarbon component obtained from said third adsorption bed by the regeneration, and circulating at least some of said adsorbed hydrocarbon component having from 5 to 10 carbon atoms through the absorber as the absorbent for the gas from said first adsorption bed.

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