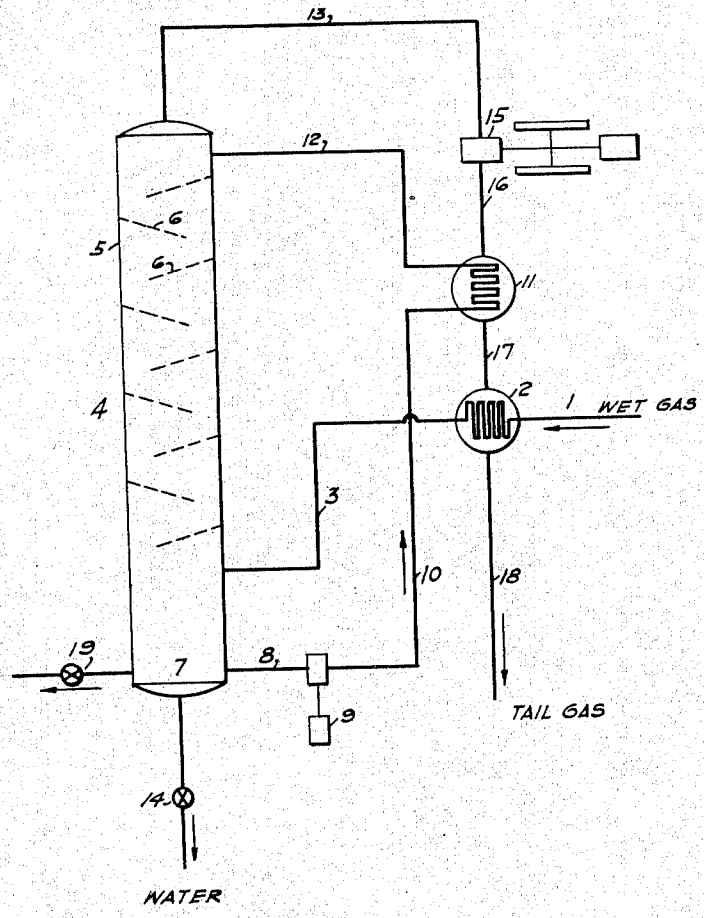
Nov. 1, 1938. O. C. BREWSTER 2,134,701

SEPARATION OF HYDROCARBONS

Filed Sept. 29, 1936



INVENTOR
Oswald C. Brewster
BY Kenyon & Kenyon
ATTORNEYS.

Patented Nov. 1, 1938

2,134,701

UNITED STATES PATENT OFFICE

2,134,701

SEPARATION OF HYDROCARBONS

Oswald C. Brewster, Litchfield, Conn., assignor to Refinery Engineers, Inc., New York, N. Y., a corporation of Missouri

Application September 29, 1936, Serial No. 103,123

2 Claims. (Cl. 62—175.5)

This invention relates to the recovery of liquefiable components from hydrocarbon gas and more particularly to improvemnts in the low temperature recovery of such components wherein trouble due to the freezing of water and water vapor associated with the gas is avoided and at the same time more efficient heat exchange is effected.

In a copending application, Serial No. 103,121 filed September 29, 1936, a novel method for the recovery of valuable liquid components of hydrocarbon gas has been fully disclosed. The method disclosed therein comprises the steps of expanding gas, from which the liquefiable components have been stripped, through an engine, thereby performing work and cooling the gas to a low temperature according to well-known thermodynamic principles. The cold dry gas then serves as the cooling medium in heat exchangers for chilling the incoming wet feed gas at substantial pressure and condensing therefrom its liquefiable components. The unliquefied residual gas then serves as the gas which is expanded and chilled in the engine. The power generated by the expanding gas in the engine is converted into heat and is utilized to stabilize the condensate recovered.

In another copending application, Serial No. 103,122 filed September 29, 1936, a modification of the above described method is disclosed wherein the power developed by the engine is utilized not only to furnish heat to the stabilizer but to compress the feed gas or a portion thereof to a higher pressure than that at which it is originally available.

In the practice of the methods disclosed in the above named copending applications, temperatures well below the freezing point of water are attained and when, as often occurs, appreciable quantities of water vapor are associated with the feed gas difficulties are encountered due to the formation of ice in the heat exchangers and pipes. The formation of ice coatings on the heat conducting surfaces of heat exchangers results in lowered rates of heat transfer and when the accumulation is sufficiently great may even cause a serious stoppage in the flow of gas.

Furthermore, in the practice of the methods disclosed use is made of indirect heat exchange between warm gas on one side and cold gas on the other side for the entire transfer of heat in cooling the feed gas. While entirely practical, the rate of heat transfer from gas to gas is low and as a result large heat exchange surface is required.

It is an object of this invention to provide a method and apparatus for the recovery of lighter boiling liquefiable components of hydrocarbon gas, and to provide a method and apparatus which minimizes the deleterious effects of water present in vapor or liquid form in a hydrocarbon mixture, which mixture is in part or wholly in vapor form, on the recovery of liquid hydrocarbons from such mixture by a procedure in which temperatures low enough to freeze the water occur.

According to this invention, water that is so associated with a hydrocarbon mixture, which mixture is partly or wholly in vapor form and from which liquid hydrocarbons are recovered by a procedure in which temperatures low enough to freeze water therein occur, is largely restrained from advancing to a point in the recovery system at which occur temperatures low enough to freeze the water. A further feature of this invention is that such a hydrocarbon mixture, which is extensively cooled in the recovery of liquid hydrocarbons therefrom, is preliminarily cooled sufficiently to condense water therefrom in liquid form to facilitate separation of the water from the hydrocarbons prior to such extensive cooling thereof. A further feature of this invention is that in such preliminary cooling the hydrocarbon mixture containing water is flowed countercurrently in contact with cold liquid hydrocarbons, the gas preferably being flowed upwardly while the liquid flows downwardly, whereby any ice formed is washed back to a zone of higher temperature. Further features of this invention are that in such countercurrent flow hydrocarbons are also condensed; that the condensed hydrocarbons are utilized as the liquid hydrocarbons maintained in countercurrent flow with the gas; that the uncondensed gas is expanded to effect a reduction of temperature thereof; that the residual gases cooled by such expansion are utilized in cooling the liquid hydrocarbons flowing into countercurrent flow with the hydrocarbon gas; that the hydrocarbon gases cooled by expansion are also used for cooling the hydrocarbon mixture fed to the system; and that the condensed water is separated in liquid form from the hydrocarbons and particularly from the liquid hydrocarbons resulting from the cooling caused by the countercurrent flow relation of gas and cold liquid hydrocarbons.

A further feature of this invention resides in the recovery of liquid hydrocarbons from mixtures thereof with more volatile hydrocarbons by passing the vapors of the hydrocarbon mix-

ture in countercurrent contact with cold liquid hydrocarbons to condense hydrocarbons from the mixture, expanding the uncondensed hydrocarbons to reduce the temperature thereof, absorbing in the cold expanded hydrocarbons heat from the liquid hydrocarbons passing into said countercurrent flow, a further feature being the use of condensed hydrocarbons as the liquid hydrocarbons employed in the countercurrent flow.

The invention resides in the separate use or conjoint use of any of the features thereof herein described, and is not limited to simultaneous use of all or any particular number of such features.

The operation of this invention will be fully understood from the following description taken in connection with the accompanying drawing in which the single figure represents diagrammatically a preferred embodiment of the invention.

Referring to the drawing, wet hydrocarbon gas under substantial pressure enters the system through pipe 1 and passes through heat exchanger 2 wherein it is cooled by indirect heat exchange with cold dry gas to a temperature above the freezing point of water. Depending on the amount of cooling and also on the relative degree of saturation of the gas as it enters the system both with respect to liquefiable hydrocarbons and water vapor, a greater or lesser amount of condensate may be formed at this point, the condensate consisting of water or hydrocarbons or both. From heat exchanger 2, the cooled gas and any resultant condensate pass through pipe 3 to cooling tower 4. Cooling tower 4 may be of any suitable type for the performance of the required service. A preferred form for this service consists of a vertical cylindrical shell 5 equipped with staggered baffles 6 around which gas may rise in the tower in a zigzag path countercurrent to a stream of descending condensate cascading from baffle to baffle and providing intimate contact between ascending gas and descending liquid. Reservoir space 7 is provided in the lower part of tower 4 for the accumulation of condensate and the separation therefrom of condensed water.

Condensate, free from water, is withdrawn from reservoir 7 through pipe 8 and is forced by pump 9 through pipe 10 to heat exchanger 11 in which it is chilled to a low temperature by indirect heat exchange with cold dry gas. From heat exchanger 11 the chilled condensate is conducted through pipe 12 to the top of tower 4 through which it descends, cascading over baffles 6 and returning to reservoir 7. The gas entering tower 4 through pipe 3, rises in the tower countercurrent to the descending cold condensate and is chilled thereby, its higher boiling liquefiable components being liquefied and joining the descending stream of condensate. By the time the gas has reached the top of tower 4 it has been chilled to a low temperature and its recoverable liquefiable components have been substantially condensed so that the gas passing from tower 4 through pipe 13 is dry gas. Water vapor contained in the gas as it enters the tower is almost entirely condensed therefrom as the gas is chilled in ascending the tower. Where the temperature becomes lower than the freezing point of water ice crystals form in the condensate stream and are washed down over the baffles to reservoir 7. The condensate stream in descending the tower is progressively warmed by the ascending gas stream and the rate at which condensate is circulated through the tower is regulated so that its temperature, when it reaches reservoir 7, is close to, but slightly above, the freezing point of water. Thus ice crystals formed in the condensate in the colder upper portions of the tower, on being washed down over baffles 6, are melted by the time they reach reservoir 7. The water collects in the bottom of reservoir 7 and may be decanted off through valve controlled pipe 14.

Dry gas passes from the top of tower 4 through pipe 13 to engine 15. In engine 15 the gas expands polytropically, performing mechanical work. In so expanding the gas is chilled to a relatively low temperature according to well known thermodynamic principles. The cold, expanded gas exhausts from engine 15 into pipe 16 and passes through heat exchanger 11, wherein it serves as the cooling medium for chilling the condensate pumped therethrough as already described. In absorbing heat from the condensate in heat exchanger 11 the gas is partially warmed. The partially warmed gas passes from heat exchanger 11 through pipe 17 to heat exchanger 2 wherein it serves as the cooling medium for cooling the wet feed gas passing therethrough. The dry tail gas passes from heat exchanger 2 through pipe 18 to any desired gas disposal system, as for example, a torch where it is burned.

Condensate accumulating in reservoir 7, representing that currently condensed from the wet feed gas, is withdrawn therefrom and further processed as desired to produce the desired product. For example, it may be stabilized to produce a stable motor fuel and a lighter fraction consisting of material of lower boiling range than is desirable as motor fuel.

The operation of the engine has been fully disclosed in the copending applications mentioned hereinbefore. Also the fact that any type of engine utilizing the expansive energy of a gas is suitable is fully explained therein, it being shown that engines of the reciprocating piston type or of the turbine type such as are in common use as steam engines are entirely satisfactory.

The power developed by the engine may, in accordance with this invention, be utilized in any way desired. For example, it may be used to generate electric power, or it may be used for pumping, or it may even be dissipated by means of a brake or other device. In copending application, Serial No. 103,121, cited hereinbefore, the power developed by the engine is converted largely into heat which is used to stabilize the condensate. In copending application, Serial No. 103,122, also cited hereinbefore, the power developed is used to compress the feed gas, or a portion thereof, to a higher pressure than that at which it is originally available in addition to its partial conversion into heat for use in stabilizing the condensate. In the operation of this invention the power may be advantageously used as disclosed in the copending applications cited but its use is not limited thereto.

In accordance with the invention, wet feed gas, containing from one third of a gallon to several gallons of recoverable motor fuel per thousand cubic feet of gas, is introduced into the system in pipe 1 at a substantial pressure. Preferably this pressure is of the order of one hundred pounds per square inch or higher although a pressure as low as fifty pounds per square inch may be used. Depending on temperatures and pressure conditions, and on the degree of saturation, there may be associated with the wet gas as much as two percent by volume of water vapor, amounting to almost one pound of water per thousand cubic

feet of gas as measured at standard temperature and pressure. At higher pressures and lower temperatures the relative amount of water vapor decreases.

In passing through exchanger 2 the wet gas is cooled to a temperature substantially above the freezing point of water, preferably to a temperature higher than 40 degrees Fahrenheit, for example to about 60 degrees Fahrenheit. The gas and any condensate formed, either hydrocarbon or water or both, enter the lower part of cooling tower 4 at this temperature. Condensate being circulated therein is circulated at such a rate that its temperature in reservoir space 7 is close to, but above, the freezing point of water, for example, the temperature should not fall below about 35 degrees Fahrenheit and should preferably be around 40 degrees Fahrenheit to insure the melting of all ice washed down to the bottom of the tower. The rate at which condensate is circulated by pump 9 through exchanger 11 to the top of tower 4 may vary considerably depending upon conditions. Under normal conditions the amount of condensate circulated varies from as little as one half pound of condensate per pound of wet feed gas introduced to several pounds per pound of feed gas. Under preferred conditions in one specific operation the circulating rate is from one to two pounds of condensate per pound of feed gas. The condensate in passing through heat exchanger 11 is chilled to a relatively low temperature, which, depending on conditions, may vary from around 0 degrees Fahrenheit to around —100 degrees Fahrenheit. In one preferred operation of the temperature of the condensate is around —40 degrees Fahrenheit to —50 degrees Fahrenheit and enters the top of cooling tower 4 at that temperature. The wet gas in passing up through tower 4 is cooled by the descending condensate and stripped of its liquefiable components. It is cooled to a temperature approaching, but not equalling, that of the cold condensate. For example, in one case where the condensate enters the tower at —40 degrees Fahrenheit to —50 degrees Fahrenheit the gas is cooled at the top of the tower to —5 degrees Fahrenheit to —10 degrees Fahrenheit at which temperature, under the pressure conditions prevailing, it is substantially stripped of its high boiling components.

The dry gas on leaving the top of tower 4 through pipe 13 enters the intake of engine 15 at substantially the same temperature as that at the top of tower 4. On expanding through engine 15 the temperature of the gas is lowered materially, the amount depending on the expansion ratio, i. e., the ratio of the pressure before expansion to that after expansion. The drop in temperature under practical conditions may vary from eighty degrees or less to one hundred and fifty degrees or more. In a typical operation the gas enters the engine at about —10 degrees Fahrenheit and 110 pounds pressure absolute, and is expanded to about 20 pounds absolute. The temperature of the gas exhausting from the engine is around —120 degrees Fahrenheit to —125 degrees Fahrenheit and passes to exchanger 11 at that temperature and serves to chill the condensate being circulated as described.

Substantially all of the water vapor contained in the gas is condensed in tower 4. Due to the vapor pressure characteristics of water the great majority is condensed before the gas has been cooled to 32 degrees Fahrenheit and the remainder forms as small ice particles in the condensate stream and is washed to the bottom of the tower where it melts and is decanted through pipe 14.

It will be observed that a large portion of the cooling load is borne by heat exchanger 11, the remainder being borne by heat exchanger 2. The heat exchange in exchanger 11 is carried out through the indirect transfer of heat from a liquid to a gas, i. e., heat passes from the liquid to the metal surface confining it and the heat is conducted through this material and transferred to the gas on the other side. The rate of heat transfer per unit of exchanger surface under these conditions is quite favorable, being almost twice that obtained when the transfer is made from gas to gas. This is due to the fact that the rate of heat transfer from a liquid to its confining surface is relatively very high compared with that from gas to its confining surface.

For the purposes of control it is desirable to provide bypasses for a portion of the materials around the heat exchangers. This control, coupled with the temperature control obtained by varying the rate at which condensate is circulated permits the operation of the process to be carried out under steady conditions with the optimum recovery of the desired product.

Other arrangements of the various elements used in carrying out the invention are possible without departing from the scope of this invention which includes all embodiments thereof falling within the meaning of the appended claims. The process disclosed herein is applicable to the recovery of higher boiling components from any type of gas containing such material and may be applied to natural gas, petroleum gas associated with the production of crude petroleum, refinery still gas produced by the distillation, cracking or polymerization of petroleum hydrocarbons, and gas produced in the processing of coal, shale or other bituminous material.

I claim:

1. The method of recovering liquefiable higher boiling components from hydrocarbon gas containing water vapor which comprises cooling incoming hydrocarbon gas containing water vapor under substantial pressure in indirect heat exchange relationship with cool dry hydrocarbon gas at a temperature substantially above 32 degrees Fahrenheit, passing said cooled incoming hydrocarbon gas in countercurrent direct contact relationship with a cyclic stream of cold hydrocarbon liquid to chill said cooled hydrocarbon gas to a temperature substantially below 32 degrees Fahrenheit and to warm said cyclic stream of cold hydrocarbon liquid to a temperature above 32 degrees Fahrenheit whereby the higher boiling liquefiable components and the water vapor of said hydrocarbon gas are substantially condensed and join said cyclic stream of hydrocarbon liquid, expanding the unliquefied dry gas portion of said chilled hydrocarbon gas to perform work and to lower the temperature of said dry gas, passing said warmed cyclic stream of hydrocarbon liquid and conjoined condensed water vapor to a separating zone, separately withdrawing said condensed water vapor, passing warmed water-free hydrocarbon liquid from said separating zone in indirect heat exchange relationship with said cold expanded dry gas to chill said hydrocarbon liquid substantially below 32 degrees Fahrenheit and to partially warm said expanded dry gas, returning said chilled hydrocarbon liquid to said first mentioned cyclic stream of cold hydrocarbon liquid, said partially

warmed expanded dry gas being the dry gas in said first mentioned indirect heat relationship with incoming hydrocarbon gas, and withdrawing hydrocarbon liquid from said separating zone.

2. In apparatus for recovering liquefiable higher boiling components from hydrocarbon gas, a cooling tower for effecting direct countercurrent contact between gas and liquid and having a liquid collecting space at the bottom thereof and having an opening above the liquid collecting space to admit incoming gas, a prime mover of the type for converting the expansive energy of gas into mechanical work, a conduit leading from the top of said tower to the intake thereof, a heat exchanger adapted to receive gas from the exhaust outlet of said prime mover, a second heat exchanger adapted to receive gas from said first named heat exchanger and incoming gas in indirect heat exchange relationship a pump adapted to pass liquid from the collecting space of said tower to said first named heat exchanger, and a conduit leading from the liquid outlet of said first named heat exchanger to the upper part of said cooling tower, and a conduit for incoming gas leading from said second named heat exchanger to said opening.

OSWALD C. BREWSTER.