PROCESS OF SELECTIVELY RECOVERING DESIRABLE CONSTITUENTS OF NATURAL GAS
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This invention relates to a process of selectively recovering desirable constituents of natural gas and wet natural gas. In a more particular sense the invention relates to an improved type of fractionation of naturally occurring mixtures of hydrocarbon gases and vapors to separate and to recover certain heavy constituents as liquids while retaining the more volatile constituents in a gaseous state.

In the past many methods have been proposed for effecting the separation of hydrocarbon liquids from natural and artificial hydrocarbon gas mixtures. Such a separation does not present any great difficulty at relatively low pressures, i.e., up to about 700 to 800 lbs. However, at more elevated pressures fractionation becomes very difficult. In order to obviate the difficulties inherent in such high pressure fractionation, it has been the practice to initially reduce the pressure and then to proceed with fractionation at such reduced pressure range.

Such a method of procedure is a distinct disadvantage in many types of operation as for example, in cyclic processes in which natural or casinghead gas is withdrawn from a well for extraction of certain constituents and the residue gas is returned to the producing horizon. In the past when the operating pressure on the well was high it was felt necessary to reduce the pressure in order to secure the desired fractionation. A natural concomitant of the drop in pressure was a marked expansion of the gas thus requiring greater volumetric capacities in the treating apparatus and a larger expenditure of power in recompressing the gas for repressurizing the well.

It has been discovered that eminently satisfactory fractionation of these hydrocarbon mixtures may be effected under any pressure up to several thousand pounds per square inch and without any reduction in pressure of the gas other than that which is an incident of the static resistance of the treating system.

The striking advantages of such a method of operation will at once be apparent. With such a high pressure fractionation it becomes possible, in most instances, to directly return the residue back to the producing horizon with but little if any compression, thus effecting large savings in power costs. Such a system operating at substantially well pressure permits the use of compact apparatus of small volumetric capacity as compared to earlier systems.

The novel method of fractionation described herein, is to be distinguished as well from the earlier methods which involved a preliminary reduction in pressure as from the more recent methods which utilize the so-called "retrograde condensation." In this latter method a decided pressure reduction is effected but under such circumstances that the concomitant expansion and drop in temperature is utilized to condense some of the heavier constituents. As will be seen, the method of the present invention involves a substantially isosteric system in which the separation of the different constituents is effected by thermal distillation and fractional condensation.

In order to enable a more ready comprehension of the principles of the invention a typical operation will be described in conjunction with the illustrative apparatus shown in the accompanying drawing. It will be understood, that this is given didactically to explain the new method and not as the exclusive manner of effectuating it. In the drawing Figure 1 is an elevation view of fractionating tower and associated units and Figure 2 is an enlarged detail of the reboiler unit of Figure 1.

As shown in the drawing, the essential elements of the apparatus include a fractionating tower A, a reboiler unit B, connected with the base of the tower and a preheater unit C. The fractionating tower A may be of any suitable size and in the illustrative embodiment comprises a tower about 53 ft. high and about 6 in. in diameter. This tower preferably is packed with iron Raschig rings and is adapted to be maintained under pressure and, in conjunction with the preheater and reboiler serves to fractionate the incoming gases under substantially the pressure obtaining in the well. The unit may be connected to a well through the line 1. As shown in the drawing this line enters the heat exchanger 2 and is connected at its discharge end to the gas line 3 which communicates with the tower A at a low point and below baffle 4. The gases passing through the line 1 are adapted to be preheated in the heat exchanger 2 by hot fluids circulated to and from the reboiler unit.

Positioned adjacent the base of the tower is a reboiler system including the inclined reboiler tank 5 and the upper communicating tank 6. Tank 5 preferably is of the shell and tube type and is provided internally with a bank of tubes to heat the condensate passing therethrough. The unit 5 is connected at its lower end through the line 7 to the bottom or intake of the tower A, and at its upper end through line 8 to the tank 6. The reboiler tank 5 is also connected...
to the tank 8 through the branch line 9. As will be
seen more fully hereafter, the reboiler units,
including tanks 5 and 6 with their circuit con-
nections 8 and 9, form a closed thermal circula-
tion circuit through which the liquid product
collecting in the base of the tower is heated and
circulated. This unit comprises, in a sense, a
fractional distillation zone. Lighter constituents
which are evolved in the circuit, notably methane
and ethane, pass overhead from tank 6 through
the line 10 and are introduced into the tower A
at an intermediate point, preferably about 20 ft.
up from the base of the tower.

The reboiler system is interconnected with
the heat exchanger 2. For this purpose line 11
is connected with the upper section of line 8 at
one end and to the shell of heat exchanger 2 at
the other. Preferably the elevating box 12 is
interposed in the circuit. Hot fluids introduced
into the heat exchanger 2 are withdrawn through
the line 13 controlled by valve 15'. A portion
of these fluids is passed through the line 14 and
pressure control valve 15 into the upper cooling
section of the tower. The remainder of the hot
products in the heat exchanger is passed through
branch 16, pump 17 and line 18 into an interme-
tiate section of the tower A to serve as a reflux liquid. It is particularly to be ob-
served that the inlet for the reflux liquid is posi-
tioned below the inlet of gas line 10.

The upper section of the tower A comprises
the serially arranged coolers 20 and 21. These
are preferably of the internal tube type. Con-
ected to the cooler 20 are the inlet and outlet
lines 22 and 23 respectively, through which the
cooling medium, such as water, is introduced and
withdrawn. In operation, gases which pass
upwardly through the tubes of the condenser 20,
are cooled by indirect contact with the cooling
medium and the gaseous products are then dis-
charged into the communicating cooler 21. Con-
densate from the cooler may be fed back through
line 24, controlled by valve 24' to the upper sec-
tion of tower A as shown.

The gases and vapors which are preliminarily
cooled in the cooler 20 pass outwardly from this
cooler through line 25 and are introduced into
the top of the cooler 21. In passing downwardly
through the interior tubes of this cooler the
gases are further cooled by indirect heat ex-
change with an expanded and cooled fraction
from the preheater introduced through the ex-
pansion valve 15. Expansion of the liquid prod-
ucts passing through line 14 commensurately
reduces the temperature to give a refrigeration
cooling.

The condensate and vapors formed in the
cooler 21 as a result of this expansion and cool-
ing are withdrawn through line 30 and passed
through a suitable stabilizer (not shown) to re-
cover the valuable constituents, as for example
a natural gasoline fraction.

The cooled gases, consisting largely of methane
and ethane, are withdrawn from the lower end
of the tubes in cooler 21 and discharged from the
system through line 31. Pressure may be main-
tained on this line by valve 32.

In one method of operation, high pressure
natural gases from line 34 may be discharged directly
into a residue well. When it is desired to in-
crease the pressure on these gasses, prior to de-
elivery to a well, line 34 may be connected to the
intake side of compressor 35 and the gas at any
desired higher pressure may be forced into a well
through line 34. During the operation of the

system, the excess of the liquid fraction accu-
mulating in the reboiler system may intermittently
or continuously be removed through line 35
controlled by valve 35 and subjected to any
desired type of treatment. It may for example be passed to a stabilization unit or to a unit for
the production of polymer gasoline.

It will be appreciated that the described ap-
paratus enables the operation of a novel and
highly effective process. This process may be
employed for treating natural gas for the recov-
ery of heavier valuable constituents, e.g. propane
or butane and the like, and repressuring a pro-
ducing horizon; similarly the system may be
employed for processing a wet gas to recover a
casinghead gasoline fraction as well as other
valuable heavy constituents of the raw gas and the
residue reintroduced into the producing
horizon. It will be understood that when the
process is utilized for treating casinghead gases
a separator is interposed between the well and
tower to remove the heavy oil prior to frac-
tionation of the gases.

The operation, in sharp contradiction to
prior methods, is carried out at well pressure (or
if desired at higher than well pressure). In
accompanying the process, the tower A is first
charged with a mixture of butane, propane and
pentane introduced through line 40. Raw gas
from a primary source, such as a gas well, and,
in a typical case, at a pressure of substantially
2700 lbs., and a temperature of approximately
80° F, is conveyed through line 1 and thence
through the internal tubes in the heat exchanger
2. During passage through the heat exchanger
the gas is preheated and is then discharged
through line 3 at a temperature of substantially
140° F into the lower portion of the tower below
the baffle 4. In the tower the upwardly flowing
gases are contacted with a countercurrent flow
of scrubbing liquid which is continuously intro-
duced into the tower through line 18. Due to
such direct contact, the liquid refluxing medium
largely condenses the heavier constituents of the
gas and returns these to the base of the tower.

The heavier condensed hydrocarbons accumu-
lating in the base of the tower flow by gravity
into the rebolier 5 through line 7. In the
reboiler the condensate is heated by indirect con-
tact with the steam and the temperature of the
condensate is raised to the order of 250° F. Due
to the increase of temperature and to the expan-
sion of occluded gases, thermal circulation is
initiated and the heated liquid flows upwardly
through line 3 into the demuder tank 6 and back
to the rebolier through line 7. During this cycle
a predetermined portion of the circulating stream
is withdrawn through line 11 and passed to the
preheater 2. In the manner described, the
quantity which is introduced into the preheater
2 is equivalent to that withdrawn from lines 20
and 35.

It will be appreciated that this method of split
or double fractionation is as unique as it is
effective. It will be observed that the liquid prod-
ucts from the base of the tower pass through the
restricted areas of the tubes of rebolier 5 and
after receiving a considerable increment of heat
are passed into the relatively large area in de-
numer tank 6. The velocity of the stream is
therefore diminished in tank 6 and the lighter
constituents of the mixture, principally methane
and ethane, rapidly evolve and pass upwardly
through line 10 into the tower A. This rebolier
unit, therefore, comprises a special type of ther-
mal distillation unit in which condensate from the bottom of the tower is fractionally distilled under the prevailing pressure of the system to remove the lighter ends and these lighter ends are introduced into the tower at a point spaced from the primary fractional condensation zone.

The reboiler unit also serves to add a considerable amount of heat to the condensate for the purpose of preheating the incoming raw gas.

In the operation thus far described, it will be seen that the lower section of the system comprises two concurrently operating fractionating systems. In the first, in the lower part of the tower itself the raw gas enters at well pressure and at a definite preheat. This stream of raw gas is thermally expanded gas is refluxed for a predetermined portion of its travel during which constituents heavier than ethane are largely removed by fractional condensation. Thereupon the condensate is subjected to a segregated and special fractionation, namely a high pressure fractional distillation in which the more volatile components, largely methane and ethane, are removed and reintroduced into the tower above the primary or condensation zone and the condensate itself is heated for the purpose of preheating the raw gas.

In the intermediate and upper sections of the tower the gas from both fractionation zones passes upwardly and is cooled and densified by direct contact with a cooling liquid introduced into the upper end of the tower through line 14. In this intermediate section the temperature of the high pressure gases is reduced to the order of about 60°F. In further passage through the cooler 20 the temperature of the gas is again reduced with resulting knock-back of heavier entrained constituents.

In the final stage of cooling the gases passing downwardly through line 25 and the tubes in cooler 21 are subjected to refrigeration cooling. The cooled gas consisting essentially of methane is thus reduced to a temperature of approximately −5° F. and is discharged through line 31 for utilization as previously described. The condensate and vapors formed in cooler 21 as a result of the expansion and cooling of liquid from preheater 2, and at a temperature of substantially −5° F., are withdrawn through line 30 and treated as desired, for example by passage through a preheater and to a suitable stabilization unit whereby desirable products such as pentane, gasoline, propane, butane and the like are separated out.

A striking feature of the present process of fractionation at high pressures is the exceedingly large capacity of a plant of the present as compared with that of earlier methods. Thus a unit of the type described is capable of processing two million cu. ft. of gas per day. This great capacity is established by the unique fractionation. As explained, in the present method the entire system is held at substantially well pressure. On entering the raw gas is immediately preheated and consequently expanded and then reintroduced into the primary condensation zone with a continuously circulating stream of reflux liquid from which liquid the lighter constituents, especially methane, are largely removed before recycling. In these circumstances the recirculating stream of reflux liquid not only serves as a condensing medium but also in a sense, as a methane demudding or scavenging medium.

Another salient advantage of the present method resides in the physical character of the efflu-
without substantially reducing the pressure of the gas, heating the gas in transit to the zone, contacting the gas in the lower portion of the zone with a recirculating stream of reflux liquid consisting of liquefiable components of the gas, withdrawing the condensate from the zone, heating such condensate, abstracting lighter gases from the condensate and introducing such gases to an upper portion of the zone, passing the heated condensate in indirect heat exchange relationship to the incoming raw gas and then returning the condensate to the said zone to scrub the preheated raw gas.

6. The process of treating natural gas to recover liquefiable constituents thereof which comprises passing the gas to a fractionating tower in which the gas is maintained under substantially well pressure, heating the gas prior to introduction to the tower, scrubbing the preheated gas in the lower section of the tower with a recirculating stream of reflux liquid to condense heavier constituents of the raw gas, withdrawing liquid products from the bottom of the tower, heating such products and separating lighter gaseous constituents, introducing such gaseous constituents into the tower at a point above the point of introduction of the stream of reflux liquid, utilizing the said heated condensate to preheat incoming raw gas and then passing said condensate into the tower to scrub incoming preheated gases.

7. A process of recovering liquefiable constituents from natural gas which comprises, passing gas directly from a well to a fractionating zone which is maintained under substantially well pressure, heating the gas in transit to the zone, contacting the gas in a lower section of said zone with a reflux liquid consisting of liquefiable heavier constituents of the gas substantially free from methane, withdrawing a liquid fraction consisting of the heavier liquefiable constituents from the lower section of said zone and withdrawing uncondensable gases from another section of said zone.

8. In the treatment of natural gas to separately recover the liquefiable constituents and uncondensable gases that improvement which comprises passing the gas at well pressure to a fractionating zone and while maintaining substantially the initial pressure on the gas in said zone heating the raw gas to effect expansion thereof and immediately contacting the whole of the heated gas with a counter current stream of a reflux condensate comprised of the heavier liquefiable constituents of the gas.

9. A process of recovering liquefiable constituents from natural gas which is at a well pressure above 700 lbs. per sq. in. which comprises, continuously heating a stream of the gas, passing the preheated gas to a fractionating zone which is maintained at substantially well pressure and contacting the high pressure gas in said zone with a heated reflux liquid to condense the liquefiable components of the raw gas and continuously withdrawing a liquefied fraction from one section of the zone and a gas fraction consisting essentially of methane from another section of the zone.

10. A process of treating natural gas to recover valuable fractions therefrom which comprises, passing gas from a high pressure well to a fractionating zone maintained under substantially well pressure, heating the gas in transit to said zone, contacting the heated gas, in the lower section of the zone with a reflux liquid consisting of the heavier constituents of the gas and thereby condensing the heavier constituents of the incoming gas, passing condensate collecting in the lower section of the zone to a separate heating zone to raise the temperature of the condensate and to largely evolve the contained methane, introducing the evolved methane into an upper section of the zone, cooling the gases in the upper section of the zone by indirect heat exchange with expanded and cooled reflux liquid and separately withdrawing from the zone a hot condensate and a cold gas.

11. A process of treating natural gas to recover valuable fractions therefrom which comprises passing gas from a high pressure well to a fractionating zone maintained under substantially well pressure, heating the gas in transit to said zone, contacting the heated gas, in the lower section of the zone, with a reflux liquid consisting of the heavier constituents of the gas and thereby condensing the heavier constituents of the incoming gas, passing condensate collecting in the lower section of the zone to a separate heating zone to raise the temperature of the condensate and to largely evolve the contained methane, introducing the evolved methane into an upper section of the zone, cooling the gases in the upper section of the zone by indirect heat exchange with expanded and cooled reflux liquid and separately withdrawing from the fractionating zone a hot liquid condensate and a cold gas fraction.

12. The process of treating natural gas to recover liquefiable constituents thereof which comprises passing the gas to a fractionating zone without substantially reducing the pressure of the gas, heating the gas in transit to the zone, contacting the gas in the lower portion of the zone with a recirculating stream of reflux liquid consisting of liquefiable components of the gas, withdrawing the condensate from the zone, heating such condensate, abstracting lighter gases from the heated condensate and introducing such gases to an upper section of the zone and returning the condensate to the zone to scrub the preheated raw gas.

13. The process of treating natural gas to recover liquefiable constituents thereof which comprises passing the gas to fractionating tower in which the gas is maintained under substantially well pressure, heating the gas prior to introduction to the tower, scrubbing the preheated gas in the lower section of the tower with a recirculating stream of reflux liquid to condense heavier constituents of the raw gas, withdrawing liquid products from the bottom of the tower, heating such products and separating lighter gaseous constituents therefrom, introducing such separated gaseous constituents into the tower at a point above the point of introduction of the stream of reflux liquid and passing condensate, denuded of such lighter constituents, into the tower to scrub incoming gases.