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METHOD OF TREATING NATURAL GAS

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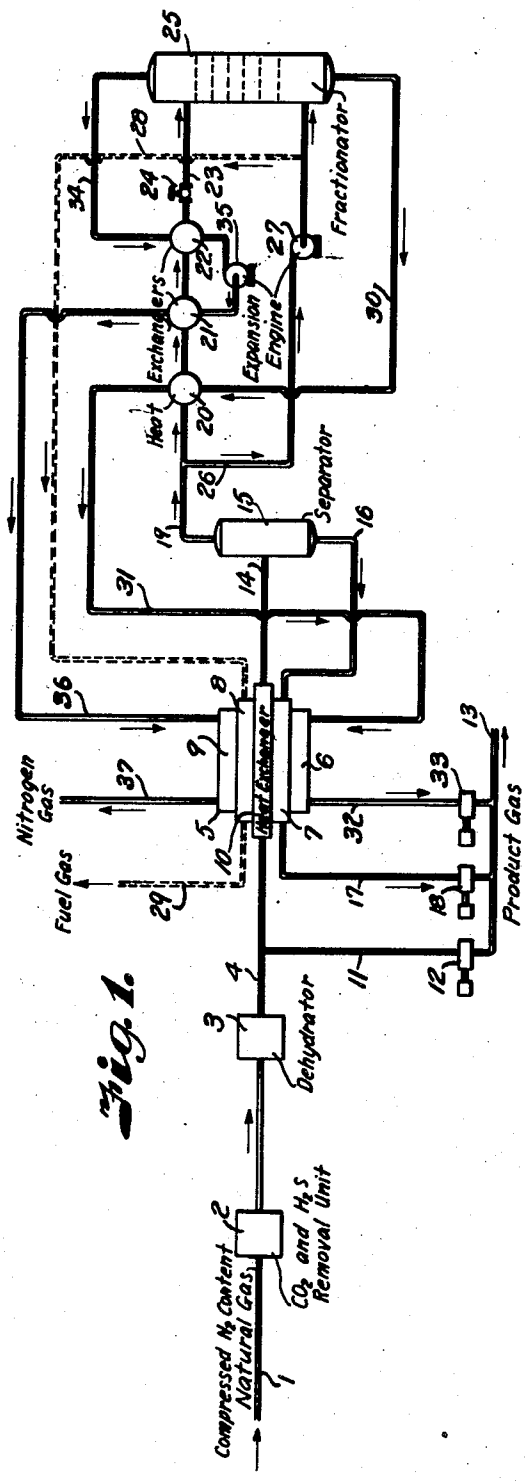


Fig. 1.

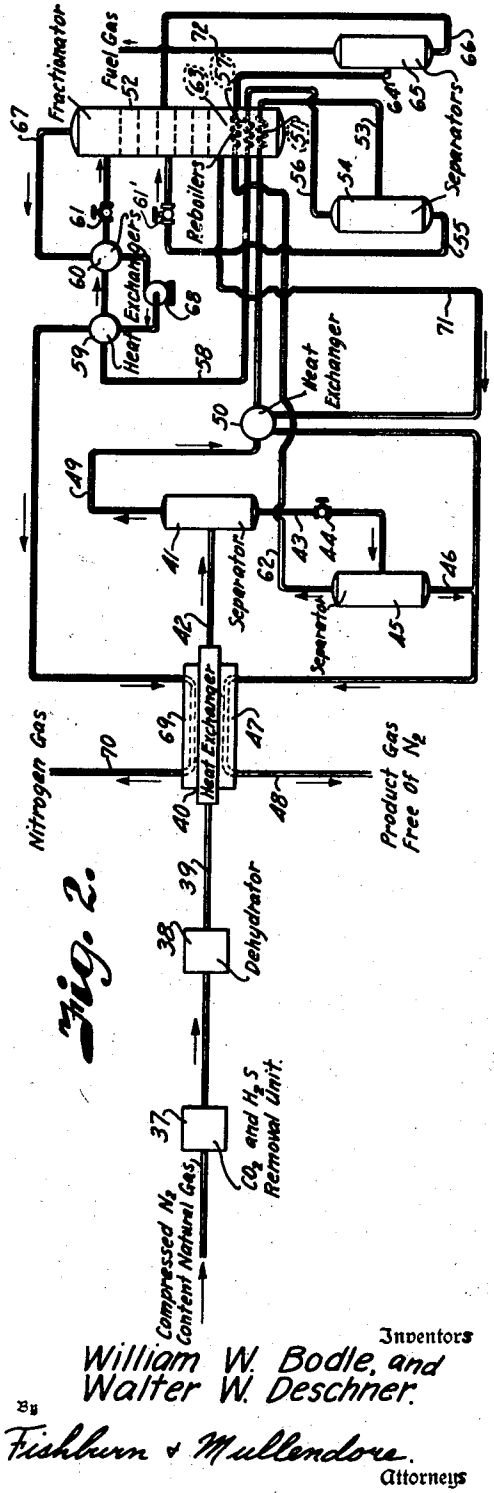


Fig. 2.

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METHOD OF TREATING NATURAL GAS

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This invention relates to a method for removing inert constituents, particularly nitrogen, from natural gas, and has for its principal object to provide an economical method for removing nitrogen by low temperature liquefaction and fractionation of the natural gas and thereby providing a product relatively free of nitrogen and a waste gas relatively free of hydrocarbons.

Other objects of the invention are to provide for the low temperatures necessary to liquefy the gas through heat exchange of the entrained gas with processed factions which carry low temperatures effected through expansion in low temperature expansion engines, and to utilize as far as practicable power of the expansion engines for operating equipment required in processing of the gas.

In accomplishing these and other objects of the invention, we have provided an improved process and apparatus for practicing the process illustrated in the accompanying drawing wherein:

Fig. 1 is a flow diagram of a form of the invention for removing the nitrogen in sufficient amount from natural gas to provide a product gas of a certain B. t. u. value.

Fig. 2 is a similar flow diagram of an apparatus wherewith substantially the entire nitrogen content of the natural gas may be removed.

Referring more in detail to Fig. 1 of the drawing:

1 designates a pipe line through which the natural gas to be processed is transported from a source of supply to a processing apparatus embodying the present invention. The gas processing apparatus includes a carbon dioxide and hydrogen sulfide removal unit designated 2 and a dehydrating unit 3 through which the natural gas is conducted preparatory for liquefaction of the gas.

The gas is conducted from the dehydrator 3 through a pipe 4 leading to a heat exchanger 5 wherein it is cooled to low temperature by heat exchange with effluent streams of low temperature gas fractions leaving the treating apparatus through passages 6, 7, 8 and 9 arranged in heat exchange relation with the passageway 10 through which the incoming gas passes, the gas being cooled to a temperature that a phase separation into liquid and vapor takes place in the feed.

Attention is here directed to the fact that the temperatures and pressures carried on in the process are dependent upon the chemical composition of the gas, and consequently, are variable and it is to be understood that the temperatures and pressures specified are illustrative for one type of natural gas to facilitate better understanding of the process. Therefore, it will be considered that 56,636,000 s. c. f. d. (standard cubic feet per day) of natural gas is delivered through pipe 1 at 90° F. and at a pressure of 215 pounds per square inch absolute, that the gas contains 17 per cent nitrogen, and that the gas has 965 B. t. u. per cubic foot higher heating value at 60° F. A standard cubic foot of natural gas is one cubic foot of natural gas at 14.7 pounds per square inch absolute at 60° F. It may also be assumed that 50,000,000 s. c. f. d. product gas is to be delivered from the system at 615 p. s. i. a. having a higher heat value at 60° F. of 1055 B. t. u. per cubic foot, and which contains 9.6 per cent nitrogen. Since it is desired to raise the heating value, it is necessary to treat only that portion of the flow so that when the treated gas is mixed with the untreated portion a product gas of the desired B. t. u. value will result. To accomplish the result, the portion of the untreated gas may be figured at 17,836,000 s. c. f. d., which portion of the flow is diverted from the pipe 4 through a pipe 11 to a compression unit indicated at 12 whereby gas is raised to the delivery pressure and discharged into the delivery pipe line 13 for mixture with treated gas to give a product gas having the above specifications. The remaining portions of the flow or 38,800,000 s. c. f. d. at a temperature of approximately 90° F. is to be treated and is delivered to the passageway 10 of the heat exchanger 5. The gas is cooled in the heat exchanger to approximately —200° F. while the pressure is maintained at approximately 200 p. s. i. a.

The highly cooled gas flow passes on through a pipe 14 into a separator 15 wherein it separates into a liquid phase containing 7.3 per cent nitrogen and a gas phase containing 41.7 per cent nitrogen. The liquid phase drops to the bottom of the separator and is carried off through a pipe 16 leading to the heat exchanger passage 7 where it gives up its cold by countercurrent heat exchange with the incoming gas traveling through the passage 10 so that it becomes a gas low in nitrogen and which is usable in making up the product gas. Therefore, the gas is discharged from the heat exchanger and conducted through a pipe 17 leading to compression units indicated at 18 for delivery to the pipe line 13 at the required pressure to mix with the untreated portion of the gas flow.

The gas carrying the major portion of nitrogen contains a substantial quantity of methane which is also usable in making up the product gas. Therefore, a portion of the high nitrogen content gas is discharged from the top of the separator 15 through a pipe 19 leading through heat exchangers 20, 21 and 22 at a pressure of 200 p. s. i. a.

and a temperature of −200° F. Upon flow through the heat exchangers the gas is liquefied and fed through a pipe 23 under control of a throttle valve 24 into the top of a fractionating tower 25 at a temperature of −292° F. and pressure of 50 p. s. i. a.

The remainder of the gas in vapor phase is diverted through a pipe 26 and is delivered to an expansion engine 27. In passing through the expansion engine 27, the gas is cooled essentially to its liquefaction temperature and is delivered to the bottom of the fractionator 25 at a temperature of −258° F. and a pressure of 50 p. s. i. a. If desired, a portion of the discharge from the expansion engine 27 may be taken off through a pipe 28 for flow through the passageway 8 of the heat exchanger to assist in maintaining the desired low temperature of the incoming gas. After absorbing heat in the passageway 8, the gas is discharged through a pipe 29 and may be used as fuel gas to operate the compressors.

The fluid passing into the top of the fractionator tower from the heat exchangers 20, 21 and 22 assumes a temperature of −292° F. and enters the top of the fractionator at a pressure of 50 p. s. i. a. and passes downwardly through the tower in countercurrent flow with upwardly rising vapors. A liquid methane product leaves the tower through a pipe 30 and is conducted thereby to the heat exchanger 20 at a temperature of −260° F. and pressure of 50 p. s. i. a. for heat exchange relation with the fluid being delivered to the fractionating tower through the pipe 19 to assist in obtaining the ultimate temperature of the fluid delivered to the fractionator, and effect evaporation of the liquid methane product.

From the heat exchanger 20 the cold methane is delivered through a pipe 31 to the passageway 6 to further assist in maintaining the desired temperature of the gas delivered to the separator 15. The methane is discharged as a gas from the heat exchanger through a pipe 32 that connects with a compressor 33 which raises the pressure for mixture with the gas discharged from the other compressor units to complete make-up of the product gas.

If low pressure product gas is desired the compressors, of course, may be omitted from the system since their only purpose is to impart the desired delivery pressure of product gas.

The nitrogen separated in the tower 25 leaves the top of the tower through a pipe 34 and passes through the heat exchanger 22 in heat exchange relation with the incoming liquid to the fractionating tower. After passing through the heat exchanger the nitrogen has considerable pressure and the temperature may be further reduced by passing it through an expansion engine 35 whereby it is expanded down to assume a temperature of −305° F. and then passed through the heat exchanger 21 where it gives up its cold to the incoming liquid, after which it is discharged through a pipe 36 into the heat exchange passageway 9 of the heat exchanger 5 so as to assist in maintaining the liquefaction temperature of the incoming gas traveling through the passageway 10. After absorbing heat within the heat exchanger, the nitrogen is discharged through a pipe 37 as waste gas.

The form of the invention illustrated by the flow diagram in Fig. 2 is designed to remove more or all of the nitrogen. In this system all of the gas after passing through the carbon dioxide and hydrogen sulfide removal and dehydrator units 37 and 38 respectively is passed through a pipe

39 to a heat exchanger 40 where the temperature is reduced to partial liquefaction point at the pressure of the gas and is passed to a separator 41 through a pipe 42 where the liquid and vapors separate.

The liquid phase is taken from the bottom of the separator 41 through a pipe 43 having a throttle valve 44 therein and is passed to a second stage separator 45 wherein the pressure is held low enough so that the liquid leaving the bottom thereof by way of a pipe 46 contains practically no nitrogen. The cold is recovered from the liquid by flowing it through a passageway 47 of the heat exchanger 40 and is discharged therefrom through a pipe 48 as a part of the product gas.

The vapor phase in the separator 41 which contains the nitrogen leaves the top of the separator through a pipe 49 and is conducted through a heat exchanger 50 and then through a reboiler 51 located in the base of the fractionating column or tower 52 and is therein partially condensed. The partially condensed flow is then conducted through a pipe 53 into a separator 54 wherein the liquid portion of the flow drops to the bottom and is removed through a pipe 55 and introduced into the mid portion of the fractionating tower 52. The pipe 55 is provided with a pressure reducing valve 61′ so that the flow therethrough may be admitted at a pressure corresponding with the pressure in the fractionator 52. The vapor portion is removed from the top of the separator 54 through a pipe 56 and conducted through a reboiler 57 for total condensation. The condensate is conducted from the reboiler 57 by a pipe 58 through heat exchangers 59 and 60 for subcooling and then flow is throttled by a valve 61 and discharged into the upper end of the fractionating tower 52 for counterflow with gases rising in the tower.

Separated gas is removed from the top of the separator 45 through a pipe 62 and is conducted through a reboiler 63 in fractionating tower 52 for partial condensation and the partially condensed flow continues through a pipe 64 into a separator 65. The liquid component separates and is removed from the bottom through a pipe 66 and discharged at a mid point of the fractionating column. The nitrogen released in the fractionating tower 52 is carried off through a pipe 67 for use as a cooling medium in the heat exchangers 59 and 60. By expanding the nitrogen in an expansion engine 68, located intermediate the heat exchangers 59 and 60, the temperature of the coolant is further reduced to maintain lower temperatures in the exchanger 59 required to maintain liquefaction temperature of the flow into the top of the fractionating tower. The nitrogen still retaining substantial refrigeration is passed through a passage 69 of the heat exchanger 40 and removed through a pipe 70 to be discharged as waste gas. The cold methane vapor is discharged from the bottom of the fractionating tower 52 through a pipe 71 that leads the cold vapor to the heat exchanger 50 for exchange with the gas conducted through the pipe 49. Continuing from the heat exchanger 50, the fluid is united with the flow in the pipe 46 and flows therewith through the passage 47 and pipe 48 to complete make-up of the product gas.

If desired, the vapor may be removed from the separator 65 and discharged through the pipe 72 for use as fuel.

From the foregoing it is obvious that we have provided an economic method for removing nitro-

gen from natural gas by low temperature liquefaction and fractionation, the low temperatures necessary for liquefaction being maintained through heat exchange of the natural gas with the processed fractions.

What we claim and desire to secure by Letters Patent is:

1. The method of treating natural gas influent for producing a product gas having a higher B. t. u. value including cooling the natural gas for effecting partial liquefaction of the natural gas, separating the gaseous portion from the liquefied portion, partially condensing the gaseous portion in a reboiler, separating the condensate from the vapors, passing the vapors through a second reboiler to effect condensation of said vapors, subcooling said condensate, fractionating the subcooled condensate to separate nitrogen and a product gas having a high B. t. u. value, mixing the product gas with the first separated liquefied portion, vaporizing the mixture by passing said mixture in heat exchange relation with the incoming natural gas to assist in maintaining said liquefaction temperature of the incoming natural gas, and passing the nitrogen from the fractionating zone in heat exchange relation with the incoming natural gas.

2. The method of treating natural gas for producing a product gas having a higher B. t. u. value including cooling an incoming stream of natural gas for effecting partial liquefaction of said stream, subcooling the portion of the stream remaining in gaseous state, passing the subcooled portion through a reboiler stage to effect partial condensation, passing the uncondensed portion from the reboiler through a second reboiler stage to effect substantially complete condensation, subcooling said last named condensate, fractionating all of said condensate into a nitrogenous gas fraction and a gaseous fraction having a high B. t. u. value, expanding and performing work with the nitrogenous fraction for reducing temperature of the nitrogenous fraction to that required for subcooling said condensate, passing the cooled nitrogenous fraction in heat exchange relation with said condensate for maintaining said subcooling temperature of said condensate, passing the nitrogenous gas fraction from said heat exchange relation to heat exchange relation with the incoming natural gas for assisting in maintaining said partial liquefaction temperature, passing the liquefied portion of the natural gas in heat exchange relation with the stream remaining in gaseous state, mixing the liquefied portion of the natural gas with the portion liquefied in said first step, and passing said mixture and said gaseous fraction separately in heat exchange relation with the stream of incoming natural gas to assist in maintaining said partial liquefaction temperature and for vaporizing said liquefied portion.

3. The method of treating a natural gas influent for producing a product gas having a higher B. t. u. value including cooling the natural gas for effecting partial liquefaction of the natural gas, separating the gaseous portion from the liquefied portion, partially condensing the gaseous portion in a reboiler, separating the condensate from the vapors, passing the vapors through a second reboiler to effect condensation of said vapors, subcooling said condensate, fractionating the subcooled condensate to separate nitrogen and a gaseous fraction having a high B. t. u. value, uniting the fraction high in B. t. u. value with said previously liquefied portion of the

natural gas, and vaporizing the mixture to make up the product gas.

4. The method of treating a natural gas influent for producing a product gas having a higher B. t. u. value including cooling the natural gas for effecting partial liquefaction of the natural gas, separating the gaseous portion from the liquefied portion, partially condensing the gaseous portion in a reboiler, separating the condensate from the vapors, passing the vapors through a second reboiler to effect condensation of said vapors, subcooling said last named condensate, throttling flow of the liquefied portion, separating vapors from the liquefied portion, passing said vapors through a third reboiler for partial condensation, discharging the vapors from said third reboiler, fractionating the subcooled condensate together with the other condensate to separate nitrogen and a fraction having a high B. t. u. value, uniting said previously liquefied portion of the natural gas with the fraction high in B. t. u. value and vaporizing the mixture to make up the product gas.

5. The method of treating natural gas for producing a product gas having a higher B. t. u. value including cooling an incoming stream of natural gas for effecting partial liquefaction of said stream, again cooling the portion of the stream remaining in gaseous state, passing the cooled portion through a reboiler stage to effect partial condensation, passing the uncondensed portion from the reboiler through a second reboiler stage to effect substantially complete condensation, subcooling said last named condensate, throttling flow of said liquefied portion, separating vapors from the throttled liquefied portion, passing said vapors from the throttled liquefied portion through a reboiler stage to effect partial condensation, discharging the vapors from the condensate resulting in said last named reboiler stage, fractionating all of said condensate into a nitrogenous fraction and a gaseous fraction having a high B. t. u. value, expanding and performing work with the nitrogenous fraction for reducing temperature of the nitrogenous fraction to that required for said subcooling temperature, passing the cooled nitrogenous fraction in heat exchange relation with said condensate which is sub-cooled for maintaining said subcooling temperature, passing the nitrogenous gas fraction from said heat exchange relation to heat exchange relation with the incoming natural gas for assisting in maintaining said partial liquefaction temperature, mixing the liquefied portion of the natural gas and said gaseous fraction, and passing said mixture in heat exchange relation with the stream of incoming natural gas to assist further in maintaining said partial liquefaction temperature and for vaporizing said mixture to make up the product gas.

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