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METHOD AND APPARATUS FOR TREATMENT OF HIGH-PRESSURE NATURAL GAS STREAMS

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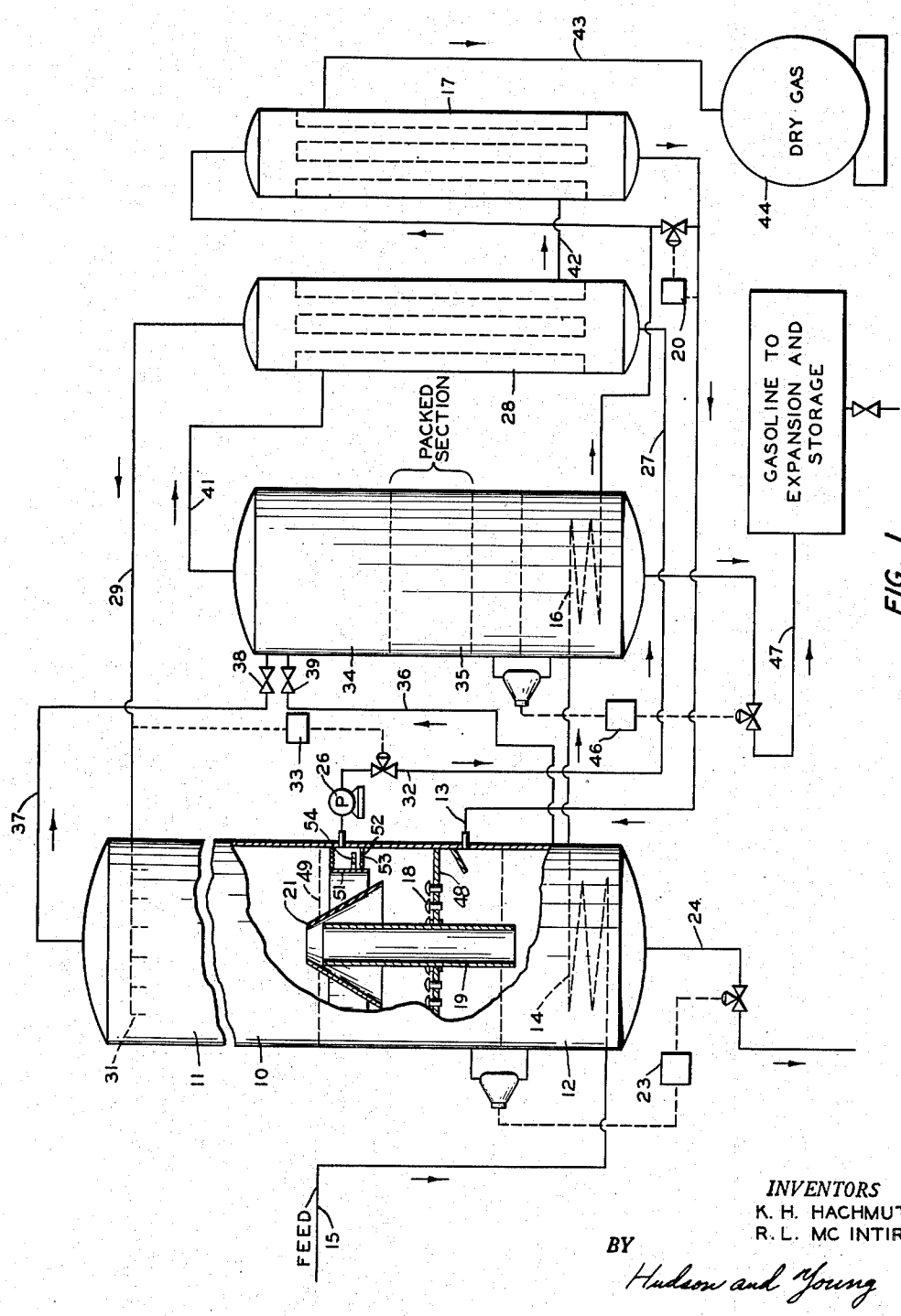


FIG. 1

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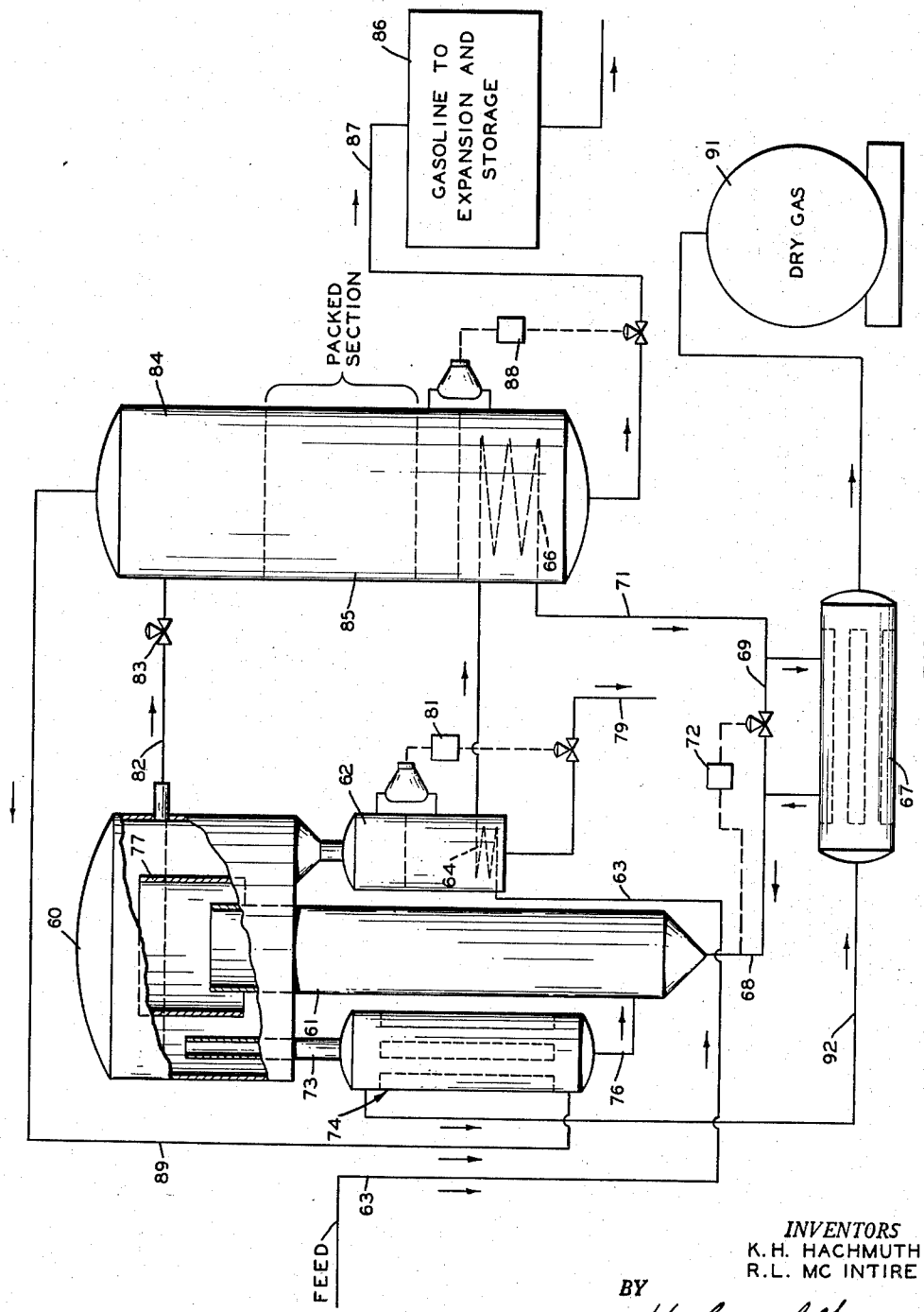


FIG. 2

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METHOD AND APPARATUS FOR TREATMENT OF HIGH-PRESSURE NATURAL GAS STREAMS

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10 Claims. (Cl. 260—676)

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This invention relates to a new and useful method of and apparatus for treatment of gas streams. In one of its more specific aspects, it relates to dehydration of a high pressure natural gas stream. In another of its more specific aspects, it relates to the separation of natural gasoline from said stream.

In gas streams as they are produced at the well, there exists a considerable quantity of water, water vapor, condensable hydrocarbons and normally gaseous hydrocarbons. The temperatures in these wells are usually fairly high, and very little condensation takes place before the gas arrives at the surface of the well. However, when this gas stream is passed into the transmission lines, which are often operated at substantially lower pressures, the condensable components are likely to condense. The liquid water resulting from this condensation reacts with the hydrocarbons forming solid hydrates. For instance, when operating with natural gas streams in the neighborhood of 2,000 p. s. i., hydrate formation becomes troublesome in normal apparatus at temperatures of 60° F. and lower. These hydrates tend to form on relatively cold surfaces, and are particularly troublesome where the gas stream is passed though valves. Shut downs are often necessary because these valves have been plugged.

By the various aspects of this invention, one or more of the following objects will be obtained.

It is an object of this invention to treat the gas to eliminate these problems.

Another object of this invention relates to a method of and apparatus for dehydrating high pressure natural gas streams.

A still further object of this invention relates to the removal of condensable hydrocarbons from a gas stream.

Another important object of this invention relates to a method of recovering a dry natural gas and liquid hydrocarbon products from a gas stream by means of a self-refrigerating system.

A further object of this invention relates to recovery of dehydrated gas and natural gasoline from a high pressure well in which the gas, following hydrate formation and separation, is further expanded in order to cool the circulating refrigerant which is utilized in the dehydration step.

Still further objects will be apparent to one skilled in the art.

The construction designed to carry out our invention will be hereinafter described together with other features thereof.

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

Figure 1 is a diagrammatic view of an apparatus, constructed in accordance with the invention, for practicing the improved method; and

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Figure 2 is a diagrammatic view of a modified form of this invention.

This invention will be described as applied to the main flow line or pipe which extends from a high pressure gas well but, it will be understood that it may be applied to any high pressure gas line.

Referring now to the drawings in detail, in Figure 1, 10 designates the hydrate formation and separation chamber. This vessel contains two zones, a cold zone, or hydrate forming zone 11, and a warm zone, or hydrate melting zone 12. The gas stream inlet 13 enters chamber 10 below the hydrate forming zone 11, after passing through heat exchange coils 14 and 16, heat exchanger 17 and connecting conduits. Temperature control 20 regulates the flow of gas through heat exchanger 17 so that the feed gas entering column 10 will be cooled to a temperature just above that at which hydrates will form. Bubble caps 18 are provided to permit the flow of gas up into the liquid in the cold zone. In order to direct the hydrates from 11 into the conduit 19 baffle 21 is provided. The level of the liquid in the hydrate melting zone 12 is regulated by the liquid level control 23 which permits the withdrawal of water through line 24.

A liquid level is maintained above tray 48 which contains bubble caps 18, the upper level of this liquid being indicated by the dotted line 49. Ring 51, which is positioned at the level of the conduit leading to pump 26, is provided with a bottom plate 52 having perforations 53 therein. Baffle 54 is positioned a short distance above section 52 in order to provide for turbulent flow through the holes 53.

Baffle 21 functions to direct the flow of gas from bubble caps 18 into the space between baffle 21 and conduit 19. Solid hydrates, which are formed in zone 11 as the gas contacts the refrigerant introduced through nozzles 31, fall into the liquid above bubble tray 48, where they descend until they are picked up by the rising gas bubbles and are carried into the space between baffle 21 and conduit 19. Due to the frothing action produced by the gas, these hydrates and some liquid spill over into conduit 19 and descend therethrough into the liquid in hydrate melting zone 12.

Of course, a small portion of the hydrates may fall directly into conduit 19 from that portion of zone 11 immediately thereabove, but this constitutes only a small portion of the total area below the hydrate forming zone. The action of the feed gas flowing through bubble caps 18 and then through the space between 19 and 21 results in a substantial separation of the hydrates from the liquid phase, thereby concentrating the hydrates

in zone 12. The liquid level 49 is maintained by the action of conduit 19 serving as an overflow pipe. The upper end of conduit 19 is, of course, above the level at which pump 26 takes suction.

The formation of hydrates is brought about in zone 11 by means of a circulating refrigerant, which is circulated by means of pump 26. This refrigerant is a liquid hydrocarbon product of the process. From this pump the refrigerant flows through pipe 27, into heat exchanger 28, to line 29, from which it is released into chamber 11 by means of spray head 31. This refrigerant is withdrawn from chamber 11 through line 32, the rate of circulation being controlled by temperature control 33. Refrigerant is a portion of the hydrocarbons condensed in 10.

From chamber 10 the hydrocarbon products pass to expansion chamber 34, the liquid hydrocarbons passing through conduit 36 and the gaseous hydrocarbons through line 37. Chamber 34 is provided with packed section 35. Positioned at, or near, the expansion chamber 34 are expansion valves 38 and 39. As a result of the expansion and cooling of the gas, a further liquid hydrocarbon fraction is condensed and goes to the bottom of this chamber. The overhead, or gaseous fraction, passes through line 41 into heat exchanger 28. From heat exchanger 28 this gas is passed through line 42 into heat exchanger 17, and from heat exchanger 17 through line 43 into storage 44 or transmission line.

By means of liquid level control 46 the flow of liquid hydrocarbons to storage through line 47 is regulated.

In Figure 2, a modification of the form shown in Figure 1 is illustrated wherein the entering gas lifts the refrigerant to the top of the hydrate formation column and the need for a pump, as used in Figure 1, is eliminated. In this modification the liquid and gaseous separation zone is designated 60. Included are a hydrate forming zone 61 and a hydrate melting zone 62. From the well, or other high pressure source, the gas passes through line 63, heat transfer coils 64 and 66, heat exchanger 67, and connecting conduits, before passing through line 68 into the hydrate forming zone 61. By-pass 69 is located in line 71 so that a portion of the feed may be passed around heat exchanger 67. This is necessary in order that the temperature in line 68 be maintained above that at which hydrates will be formed. The amount of feed thus by-passed is controlled by temperature control 72.

The circulating refrigerant for this system is withdrawn from the liquid in the upper portion of the separating chamber 60 by means of conduit 73. This refrigerant is cooled in heat exchanger 74 by means of expanded product gas, which will be hereinafter described, and returned to the lower part of zone 61 through line 76.

Hydrates which are conveyed to the upper portion of separator 60 by means of the gas stream, fall by gravity into hydrate melting zone 62, this flow being aided by means of baffle 77. The hydrates are melted in zone 62 by heat exchange with the hot gas passing through coil 64, and the water is removed through line 79, this rate of removal being regulated by interface level control 81. Gaseous and liquid hydrocarbon products from the upper portion of separation zone 60 flow through line 82, and are expanded by means of expansion valve 83 before entering expansion chamber 84, said column being provided with packed section 85. The expansion and cooling of the gaseous portion results in an additional fraction of the gas being condensed. The liquid portion is withdrawn to gasoline storage 86 through line 87, said withdrawal being controlled by liquid level control 88. The gaseous fraction, cooled as a result of this expansion, serves as a refrigerant in heat exchanger 74, being conveyed to said heat exchanger by line 89. Said gas is then passed to the gas storage 91 or transmission line by means of line 92. As the gas in line 92 is still cool with respect to the entering gas, it is further heat exchanged with the entering gas in heat exchanger 67.

In the operation of our invention, gas is conveyed from the well to chamber 10, Figure 1, through line 15. Generally, this gas is considerably above the temperature at which hydrate formation occurs. For this reason, various indirect heat exchange steps are shown. However, this cooling should be continued only to a point near that at which hydrates will form. This temperature will depend upon the pressure of the gas, which may vary from a few hundred pounds to several thousand pounds. For instance, at 2,000 p. s. i. hydrates begin to form in the neighborhood of 60° F. That is to say if the temperature of the gas stream, at the pressure at which it issues from the earth, is near the hydrate formation point it will not be necessary to use all the heat exchange steps shown in Figure 1.

The natural gas stream enters column 10 through line 13 and bubbles up through the bubble caps 18. In the upper part of chamber 10 it contacts the circulating refrigerant, and is cooled so that the hydrates are formed in this region. As a general rule, there will be no appreciable pressure drop as the gas enters this chamber. Condensation that occurs will be the result of the lowered temperature. This reduction in temperature is brought about by means of the circulating refrigerant hereinafter described. Hydrates and hydrocarbons which are condensed collect in the lower section of cold zone 11 and flow therefrom through conduit 19 into the hydrate melting zone 12. In zone 12 the hydrates are heat exchanged with the original hydrocarbon stream. This hydrocarbon stream will be warm enough to melt the hydrates formed in the upper part of separator 10. The water condensed and that resulting from the decomposition of the hydrates is removed through line 24. At least a portion of the products from chamber 10 are introduced into expansion chamber 34 by means of lines 36 and 37. Here they are expanded until a low temperature is reached, and further condensable hydrocarbons are collected. The liquid fraction is taken off to storage and the gaseous fraction is also taken off to storage or transmission after being indirectly heat exchanged with the circulating refrigerant in exchanger 28 and the feed gas stream in exchanger 17. As the hydrocarbons in the lower portion of chamber 34 have been cooled as a result of this expansion, they are available for further cooling of the original gas stream flowing through coil 18 if this is necessary. The apparatus shown in Figure 1 is adaptable under a wide variety of operating conditions. For instance, the pressure of the natural gas in the field may vary widely. We now believe, but do not wish to be restricted thereto, that this invention will find its widest application when used with natural gas pressures of 1,500 to 3,500 p. s. i. The temperatures can likewise vary over wide ranges. As the only heating necessary is that required to melt the hydrates, a temperature a few degrees above that of hydrate forma-

tion results in practical operation. The expansion in chamber 34 is governed by two considerations. The first of these is that it is desired to keep this gas under a pressure sufficient for transmission and use without further compression. Such lines normally operate in the range of 600 to 1,400 p. s. i. Secondly the expansion should be great enough to provide the necessary cooling for the circulating refrigerant.

In order that this invention may be more fully understood, certain illustrative temperatures and pressures will be given. On a natural gas line carrying gas at 2,000 p. s. i. and 100° F. the hydrate formation temperature will be about 60° F. Then, in the apparatus of Figure 1, this gas will be heat exchanged down to a point just above incipient hydrate formation. At 65° F. this gas enters the column and is allowed to bubble up through the liquid phase and is cooled by contact with a liquid refrigerant supplied at a temperature of 0° F. The circulated refrigerant is drawn off above the bubble caps and is cooled in heat exchanger 28 to a temperature of —10° F. by indirect heat exchange with the expanded gas. The hydrates and liquid hydrocarbons flow into the bottom of separator 10 wherein the hydrate is decomposed. The overhead gas is expanded from the initial 2,000 p. s. i. to 860 p. s. i. and this results in a cooling to —50° F. This gas is then cool enough to cool the circulating refrigerant.

The modification of Figure 2 shows different apparatus for carrying out the method of our invention. In this modification we have eliminated the necessity for a refrigerant circulating pump. The gas entering the bottom of column 61 causes the flow of the refrigerant up through this column. Hydrates formed in this column are also carried upward and, when they reach the upper part of the column, fall by gravity into the hydrate melting zone 62. The hydrates are melted by indirect heat exchange with the field gas and the water is withdrawn through line 79. Part of the condensable hydrocarbons are withdrawn through line 73, and are cooled in heat exchanger 74 before being returned to column 61 through line 76.

Gaseous and liquid hydrocarbons pass into expansion column 84 wherein they are cooled. Expansion valve 83 is located in line 82 in order to provide for expansion of this hydrocarbon stream. The gaseous fraction passes through heat exchangers 74 and 67 to the storage chamber 91 or transmission line (not shown), while the liquid hydrocarbons pass into gasoline storage through line 87, said liquid hydrocarbon withdrawal being controlled by liquid level control 88.

This apparatus can be used for the separation of the same type of gas streams which are discussed in connection with Figure 1. We have found that the temperature in the upper part of separation chamber 60 will be in the range of 30° to 50° F., with 40° F. as an average temperature. If the hydrocarbon products are expanded to about 860 p. s. i., the temperature in the upper part of column 84 will be about —8° F., and this temperature will be low enough to cool the circulating refrigerant.

The example temperatures and pressures which are given in connection with the operation of Figures 1 and 2 are not to be considered as limiting conditions but are only set forth in order that this invention may be more fully understood.

As many possible embodiments may be made of this invention without departing from the scope thereof, it is to be understood that all matter herein set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

We claim:

1. A method for the continuous dehydration and recovery of condensable hydrocarbons of a high pressure natural gas stream comprising cooling said stream to a temperature just above that of hydrate formation; contacting said stream with a hydrocarbon refrigerant cooled solely by expanded product gas, thereby forming hydrates in the liquid phase; contacting said hydrates indirectly with warm field gas to decompose the hydrates; removing the resultant water; conducting at least a portion of the hydrocarbons so treated to an expansion zone and condensing an additional liquid fraction therein; and separating and removing the resultant gaseous and liquid hydrocarbon streams.

2. A method for the continuous dehydration and recovery of condensable hydrocarbons of a high pressure natural gas stream comprising cooling said stream to a temperature just above that of hydrate formation; contacting said stream with a hydrocarbon refrigerant cooled solely by expanded product gas, thereby forming hydrates in the liquid phase; contacting said hydrates indirectly with warm field gas to decompose the hydrates; removing the resultant water; conducting at least a portion of the hydrocarbons so treated to an expansion zone and condensing an additional liquid fraction therein; cooling said refrigerant by heat exchange with the expanded gaseous hydrocarbon stream; and separating and removing the resultant gaseous and liquid hydrocarbon streams.

3. A process for separating liquids from a high pressure natural gas stream including cooling said stream as hereinafter described; conveying said stream to a hydrate forming zone; countercurrently contacting said stream with a refrigerant, thereby condensing a portion of said stream and forming hydrates therein; passing the condensed liquid and hydrates into a hydrate melting zone; melting the hydrates by means of indirect heat exchange with said original stream; removing the resulting liquid water; conducting the liquid and gaseous stream removed from said hydrate forming zone to an expansion zone in order to condense a further liquid fraction; utilizing the resultant cooled gaseous hydrocarbon stream to cool the refrigerant; and utilizing the resultant cooled liquid hydrocarbon stream to cool the original natural gas stream.

4. A process for separating liquids from a high pressure natural gas stream including cooling said stream as hereinafter described, conveying said stream to a hydrate forming zone; concurrently contacting said stream with a refrigerant, thereby condensing a portion of said stream and forming hydrates therein; passing the condensed liquid and hydrates into a hydrate melting zone; melting the hydrates by means of indirect heat exchange with said original stream; removing the resulting liquid water; conducting the liquid and gaseous stream removed from said hydrate forming zone to an expansion zone in order to condense a further liquid fraction; utilizing the resultant cooled gaseous hydrocarbon stream to cool the refrigerant; and utilizing the resultant cooled liquid hydrocarbon stream to cool the original natural gas stream.

5. Apparatus for removing water and liquid hydrocarbons from gaseous streams comprising an elongated upright gas-liquid contacting cham-

ber; a hydrate melting chamber in communication with said contacting chamber; a feed gas conduit communicating with the lower portion of said contacting chamber; a refrigerant supply conduit extending into and communicating with said contacting chamber; a heat exchanger in said hydrate melting chamber; a water removal conduit extending from the lower portion of said hydrate melting chamber; a liquid hydrocarbon removal conduit extending from said hydrate melting chamber from a point above said water removal conduit; a gas removal conduit extending from the upper portion of said contacting chamber; and a liquid hydrocarbon conduit extending from said contacting chamber.

6. Apparatus for removing water and liquid hydrocarbons from gaseous streams comprising an elongated upright gas-liquid contacting chamber; a hydrate melting chamber in communication with said contacting chamber; a feed gas conduit communicating with the lower portion of said contacting chamber; a refrigerant supply conduit extending into and communicating with said contacting chamber; a heat exchanger in said hydrate melting chamber; a water removal conduit extending from the lower portion of said hydrate melting chamber; a liquid hydrocarbon removal conduit extending from said hydrate melting chamber from a point above said water removal conduit; a gas removal conduit extending from the upper portion of said contacting chamber; a liquid hydrocarbon conduit extending from said contacting chamber and a heat exchanger connecting said conduit with said refrigerant supply conduit.

7. Apparatus for removing water and gasoline from natural gas streams comprising a closed separating vessel having a hydrate forming zone and a hydrate melting zone; a first conduit extending from said melting zone; a closed expansion chamber; a first heat exchanger; a second conduit extending through the melting zone of said separating vessel, said expansion chamber, and communicating through said first heat exchanger with the lower portion of the hydrate forming zone of said separating vessel; a third conduit extending from the upper portion of the separating vessel to the expansion chamber; a fourth conduit extending from the hydrate melting zone to the expansion chamber; a second heat exchanger; a fifth conduit extending from the upper portion of the expansion chamber, and communicating through said first and second heat exchangers with a product outlet; a sixth conduit extending from the hydrate forming zone to said second heat exchanger; a seventh conduit extending from said second heat exchanger to the top of the hydrate forming zone of said separating vessel; and an eighth conduit extending from the lower portion of the expansion chamber to a product outlet.

8. Apparatus for removing water and gasoline from natural gas streams comprising a closed separating vessel having a hydrate forming zone and a hydrate melting zone; a first conduit extending from said melting zone; a closed expansion chamber; a first heat exchanger; a second conduit extending through the melting zone of said separating vessel, said expansion chamber, and communicating through said first heat exchanger with the lower portion of the hydrate forming zone of said separating vessel; a third conduit extending from the upper portion of the separating vessel to the expansion chamber; a fourth conduit extending from the hydrate melting zone to the expansion chamber; a second heat exchanger; a fifth conduit extending from the upper portion of the expansion chamber, and communicating through said first and second heat exchangers with a product outlet; a sixth conduit extending from the hydrate forming zone to said second heat exchanger, a pump in said conduit; a seventh conduit extending from said second heat exchanger to the hydrate forming zone of said separating vessel, and an eighth conduit extending from the lower portion of the expansion chamber to a product outlet.

9. Apparatus for removing water and gasoline from natural gas streams comprising a closed separating vessel having a hydrate forming zone and a hydrate melting zone; a first conduit extending from said melting zone; a closed expansion chamber; a first heat exchanger; a second conduit extending through the melting zone of said separating vessel, said expansion chamber, and communicating through said first heat exchanger with the lower portion of the hydrate forming zone of said separating vessel; a third conduit extending from the upper portion of the separating vessel to the expansion chamber; a fourth conduit extending from the hydrate melting zone to the expansion chamber; a second heat exchanger; a fifth conduit extending from the upper portion of the expansion chamber, and communicating through said first and second heat exchangers with a product outlet; a sixth conduit extending from the hydrate forming zone to said second heat exchanger; a seventh conduit extending from said second heat exchanger to the lower portion of the hydrate forming zone of said separating vessel; and an eighth conduit extending from the lower portion of the expansion chamber to a product outlet.

10. Apparatus for removing water and gasoline from gas streams comprising a closed separating vessel having a hydrate forming zone and a hydrate melting zone; a first conduit extending from said melting zone; a closed expansion chamber; a first heat exchanger; a second conduit extending through the melting zone of said separating vessel, said expansion chamber, and communicating through said first heat exchanger with the lower portion of the hydrate forming zone of said separating vessel; at least one hydrocarbon conduit extending from the separating vessel to the expansion chamber; a second heat exchanger; a third conduit extending from the upper portion of the expansion chamber, and communicating through said first and second heat exchangers with a product outlet; a fourth conduit extending from the hydrate forming zone to said second heat exchanger; a fifth conduit extending from said second heat exchanger to the hydrate forming zone of said separating vessel; and a sixth conduit extending from the lower portion of the expansion chamber to a product outlet.

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