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(54) HYDROCARBON GAS PROCESSING

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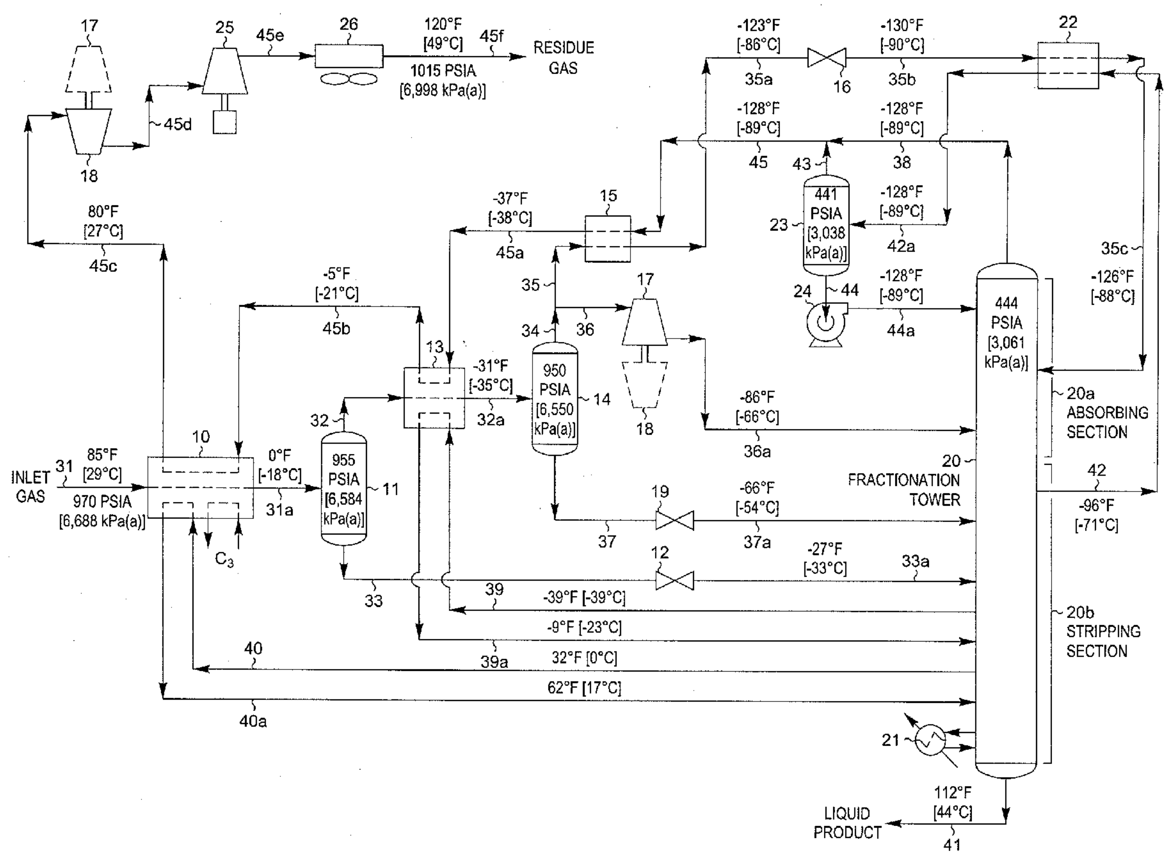
(57) **ABSTRACT**

A process for the recovery of ethane, ethylene, propane, propylene, and heavier hydrocarbon components from a hydrocarbon gas stream is disclosed. The stream is cooled and divided into first and second streams. The first stream is further cooled to condense substantially all of it and is thereafter expanded to the fractionation tower pressure, heated, and supplied to the fractionation tower at an upper mid-column feed position. The second stream is expanded to the tower pressure and is then supplied to the column at a mid-column feed position. A distillation vapor stream is withdrawn from the column above the feed point of the second stream and is then directed into heat exchange relation with the expanded cooled first stream and the tower overhead vapor stream to cool the distillation vapor stream and condense at least a part of it, forming a condensed stream. At least a portion of the condensed stream is directed to the fractionation tower as its top feed. The quantities and temperatures of the feeds to the fractionation tower are effective to maintain the overhead temperature of the fractionation tower at a temperature whereby the major portion of the desired components is recovered.



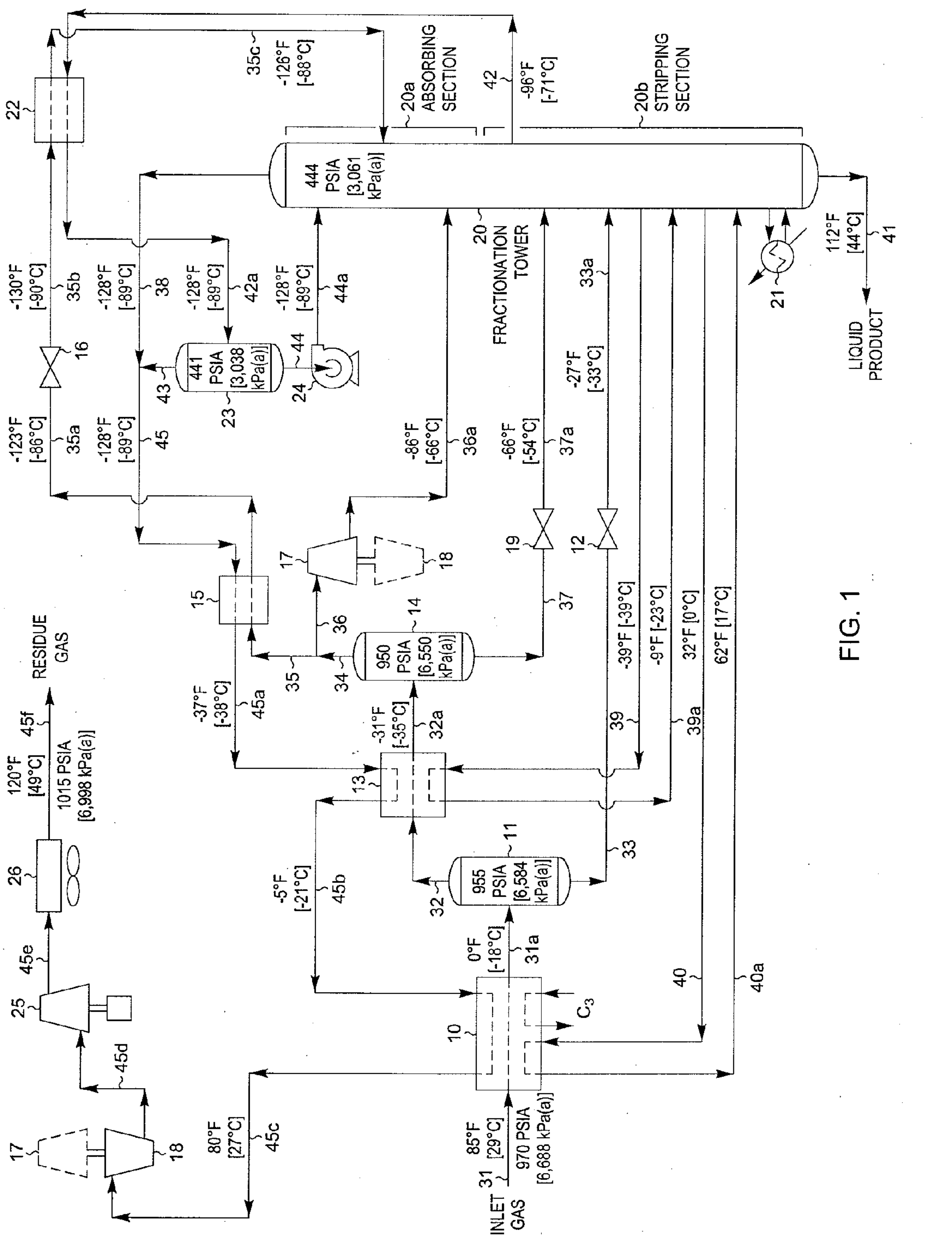
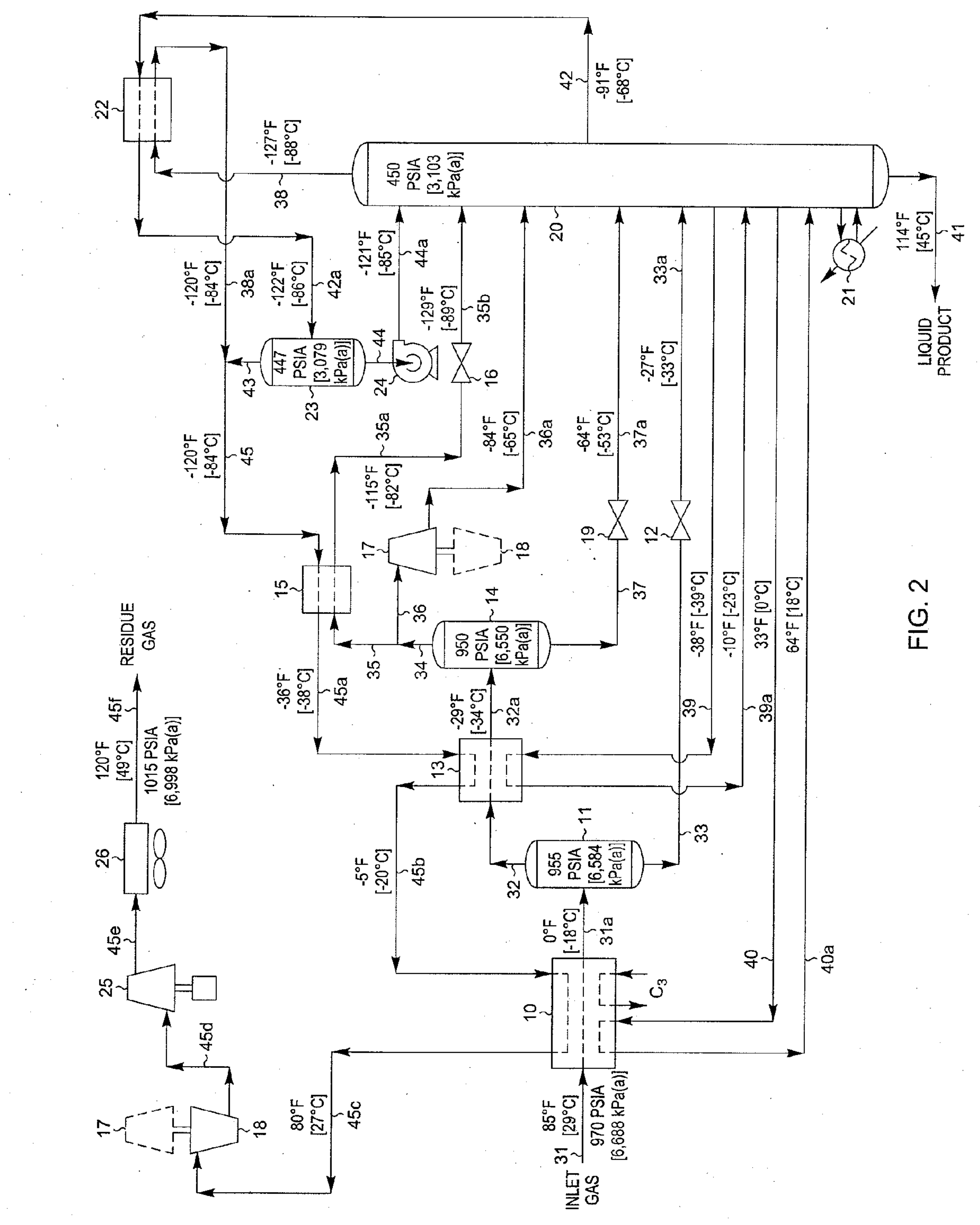

INLET GAS
31
85°F
[29°C]
970 PSIA
[6,688 kPa(a)]
10
C3
31a
0°F
[-18°C]
955
PSIA
[6,584
kPa(a)]
11
32
33
13
32a
-31°F
[-35°C]
950
PSIA
[6,550
kPa(a)]
14
34
35
36
37
15
17
18
19
12
16
35a
-123°F
[-86°C]
35b
-130°F
[-90°C]
35c
-126°F
[-88°C]
22
45
-128°F
[-89°C]
38
42a
44a
441
PSIA
[3,038
kPa(a)]
23
43
44
24
36a
-86°F
[-66°C]
37a
-66°F
[-54°C]
33a
-27°F
[-33°C]
444
PSIA
[3,061
kPa(a)]
20
FRACTIONATION
TOWER
20a
ABSORBING
SECTION
20b
STRIPPING
SECTION
42
-96°F
[-71°C]
21
41
112°F
[44°C]
LIQUID
PRODUCT
39
-39°F [-39°C]
-9°F [-23°C]
39a
32°F [0°C]
40
62°F [17°C]
40a
45a
-37°F
[-38°C]
45b
-5°F
[-21°C]
45c
80°F
[27°C]
45d
25
45e
26
45f
120°F
[49°C]
1015 PSIA
[6,998 kPa(a)]
RESIDUE
GAS

FIG. 1



RESIDUE GAS
INLET GAS
LIQUID PRODUCT
450 PSIA [3,103 kPa(a)]
447 PSIA [3,079 kPa(a)]
950 PSIA [6,550 kPa(a)]
955 PSIA [6,584 kPa(a)]
970 PSIA [6,688 kPa(a)]
1015 PSIA [6,998 kPa(a)]
85°F [29°C]
0°F [-18°C]
-5°F [-20°C]
-29°F [-34°C]
-36°F [-38°C]
-115°F [-82°C]
-84°F [-65°C]
-64°F [-53°C]
-27°F [-33°C]
-38°F [-39°C]
-10°F [-23°C]
33°F [0°C]
64°F [18°C]
-120°F [-84°C]
-122°F [-86°C]
-121°F [-85°C]
-129°F [-89°C]
-127°F [-88°C]
-91°F [-68°C]
114°F [45°C]
80°F [27°C]
120°F [49°C]
C_3

FIG. 2

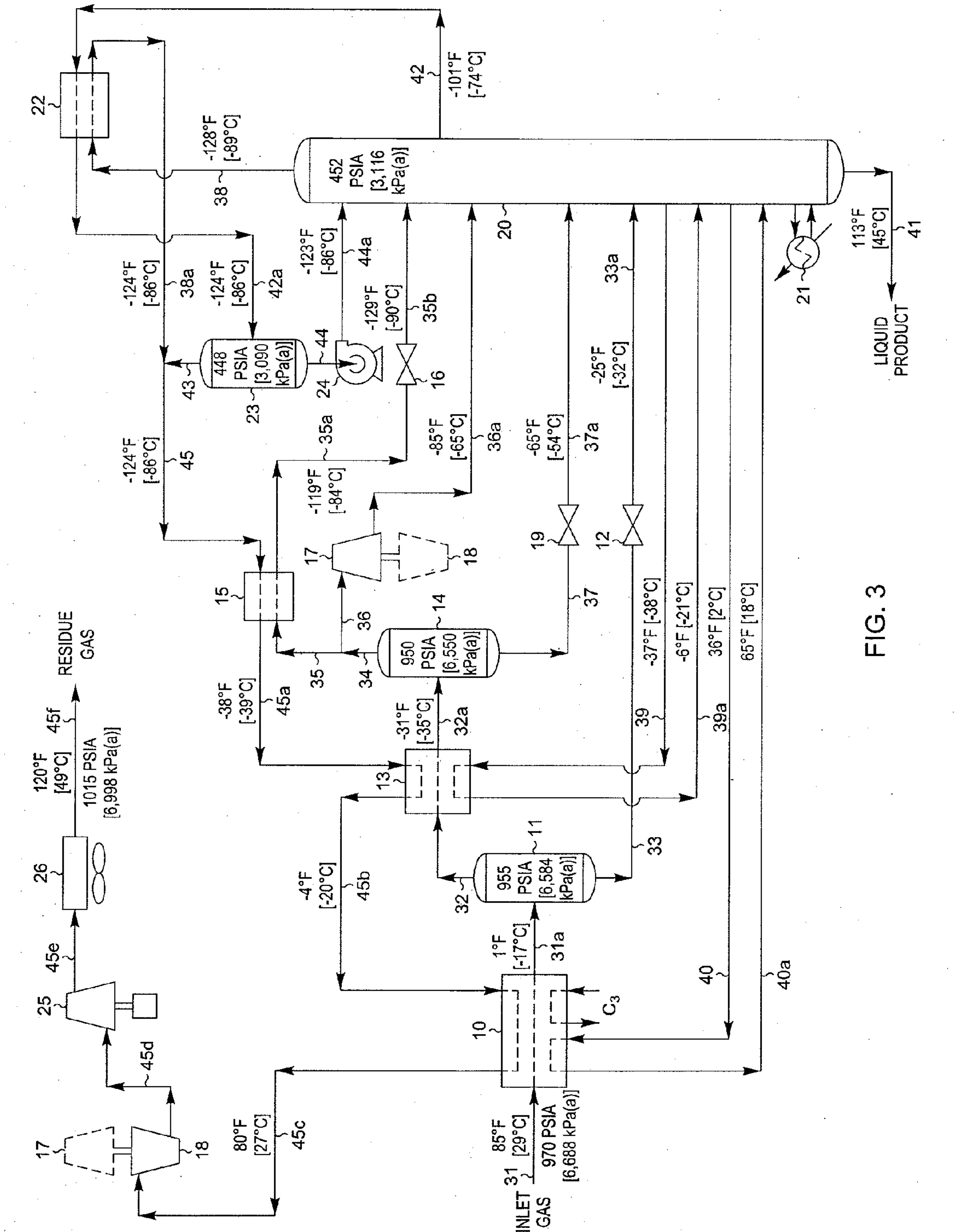

INLET GAS
RESIDUE GAS
LIQUID PRODUCT
85°F [29°C] 970 PSIA [6,688 kPa(a)]
955 PSIA [6,584 kPa(a)]
950 PSIA [6,550 kPa(a)]
452 PSIA [3,116 kPa(a)]
448 PSIA [3,090 kPa(a)]
120°F [49°C] 1015 PSIA [6,998 kPa(a)]
113°F [45°C]
-101°F [-74°C]
-128°F [-89°C]
-124°F [-86°C]
-123°F [-86°C]
-129°F [-90°C]
-119°F [-84°C]
-85°F [-65°C]
-65°F [-54°C]
-25°F [-32°C]
-37°F [-38°C]
-6°F [-21°C]
36°F [2°C]
65°F [18°C]
-38°F [-39°C]
-31°F [-35°C]
-4°F [-20°C]
1°F [-17°C]
80°F [27°C]
C_3

FIG. 3

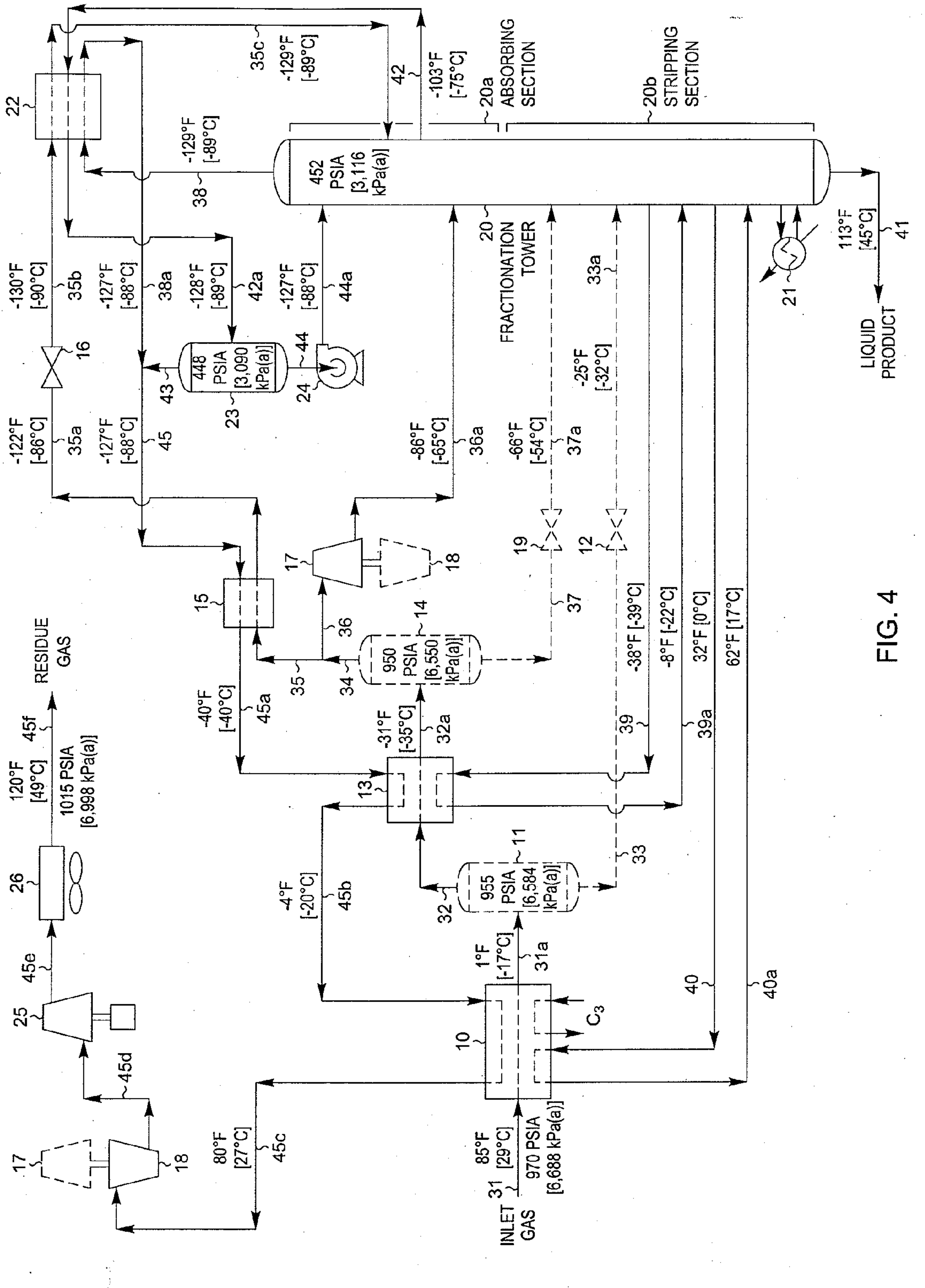

INLET GAS
31
85°F [29°C]
970 PSIA [6,688 kPa(a)]
10
C_3
1°F [-17°C]
31a
955 PSIA [6,584 kPa(a)]
11
32
33
13
-31°F [-35°C]
32a
950 PSIA [6,550 kPa(a)]
14
34
35
36
37
15
17
18
19
12
RESIDUE GAS
45f
120°F [49°C]
1015 PSIA [6,998 kPa(a)]
26
45e
25
45d
80°F [27°C]
45c
-4°F [-20°C]
45b
-40°F [-40°C]
45a
-122°F [-86°C]
35a
-127°F [-88°C]
45
-86°F [-65°C]
36a
-66°F [-54°C]
37a
-25°F [-32°C]
33a
16
-130°F [-90°C]
35b
-127°F [-88°C]
38a
-128°F [-89°C]
42a
-127°F [-88°C]
44a
448 PSIA [3,090 kPa(a)]
23
43
44
24
22
35c
-129°F [-89°C]
-129°F [-89°C]
38
42
-103°F [-75°C]
20a ABSORBING SECTION
20b STRIPPING SECTION
452 PSIA [3,116 kPa(a)]
20 FRACTIONATION TOWER
21
113°F [45°C]
41
LIQUID PRODUCT
-38°F [-39°C]
39
-8°F [-22°C]
39a
32°F [0°C]
40
62°F [17°C]
40a

FIG. 4

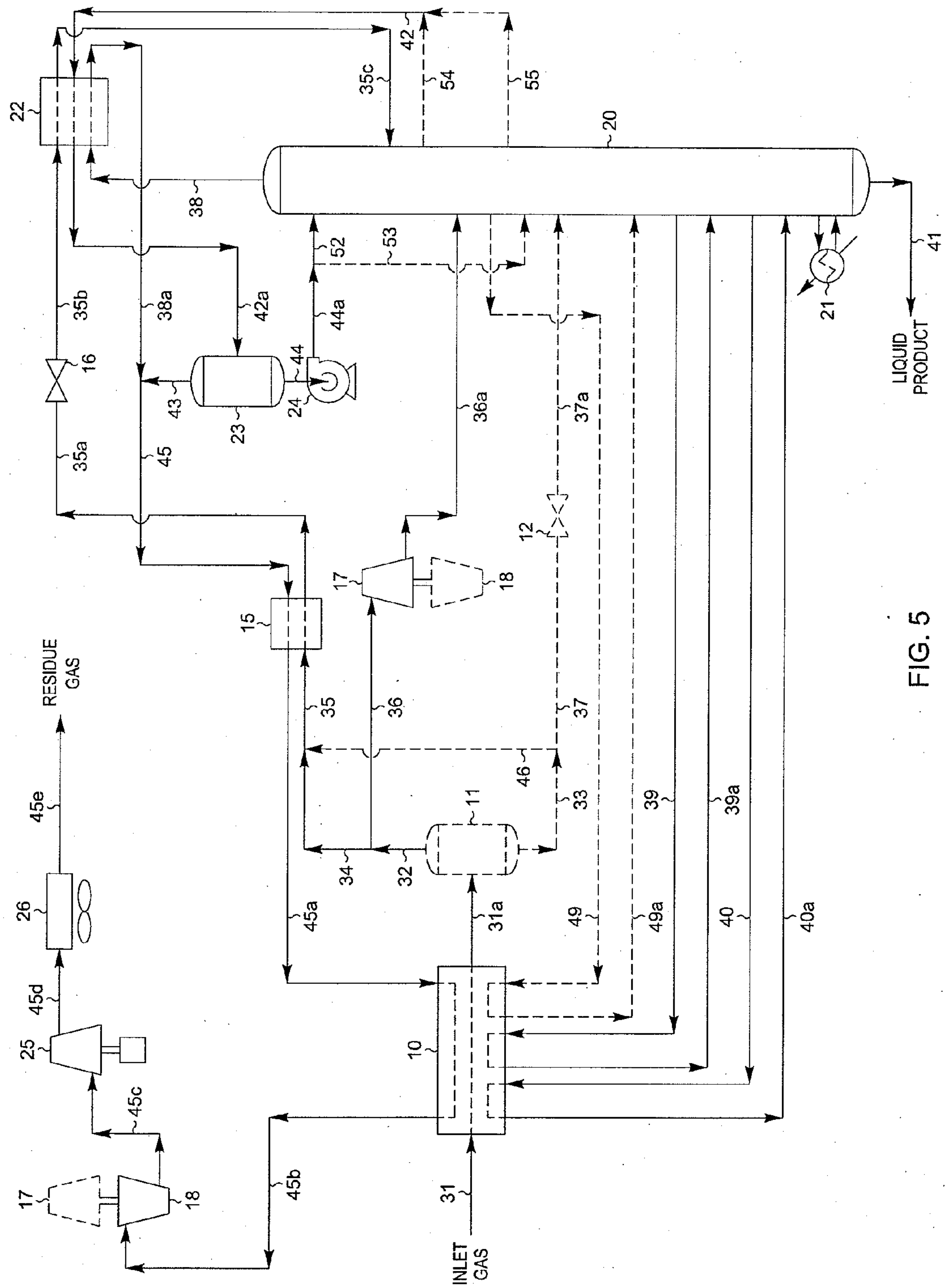

RESIDUE GAS
INLET GAS
LIQUID PRODUCT
10
11
12
15
16
17
18
20
21
22
23
24
25
26
31
31a
32
33
34
35
35a
35b
35c
36
36a
37
37a
38
38a
39
39a
40
40a
41
42
42a
43
44
44a
45
45a
45b
45c
45d
45e
46
49
49a
52
53
54
55

FIG. 5

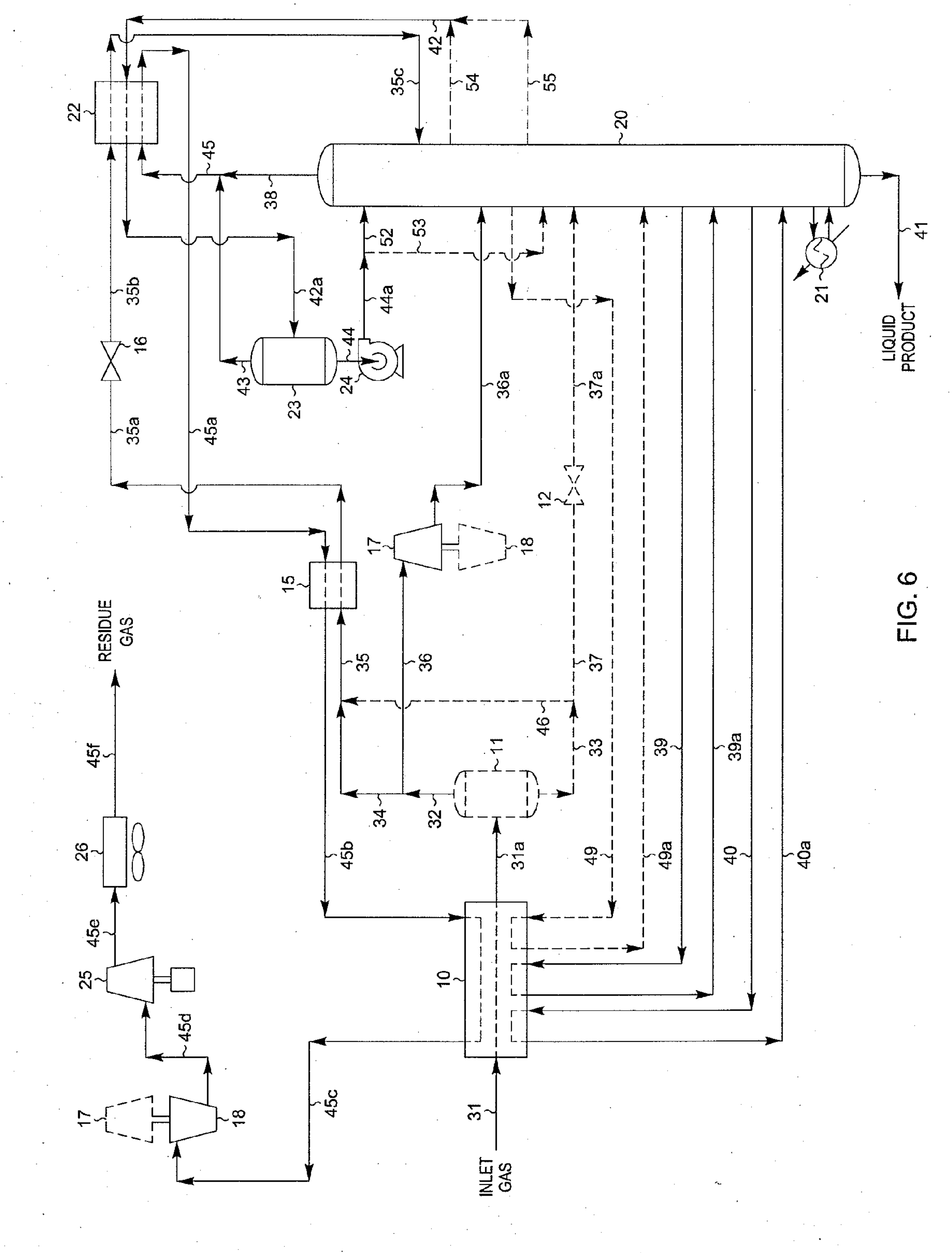


FIG. 6

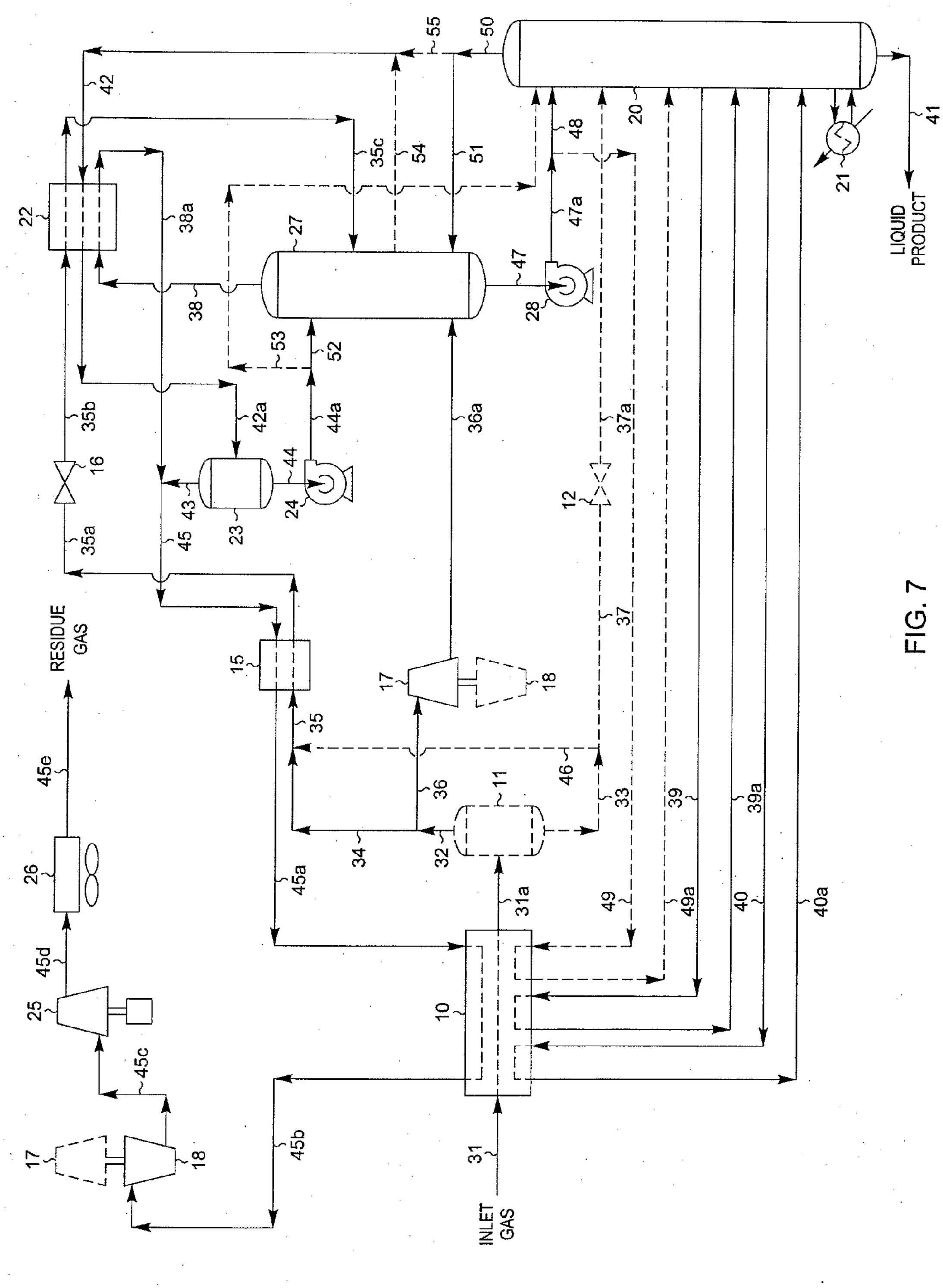

RESIDUE GAS
INLET GAS
LIQUID PRODUCT
10
11
12
15
16
17
18
20
21
22
23
24
25
26
27
28
31
31a
32
33
34
35
35a
35b
35c
36
36a
37
37a
38
38a
39
39a
40
40a
41
42
42a
43
44
44a
45
45a
45b
45c
45d
45e
46
47
47a
48
49
49a
50
51
52
53
54
55

FIG. 7

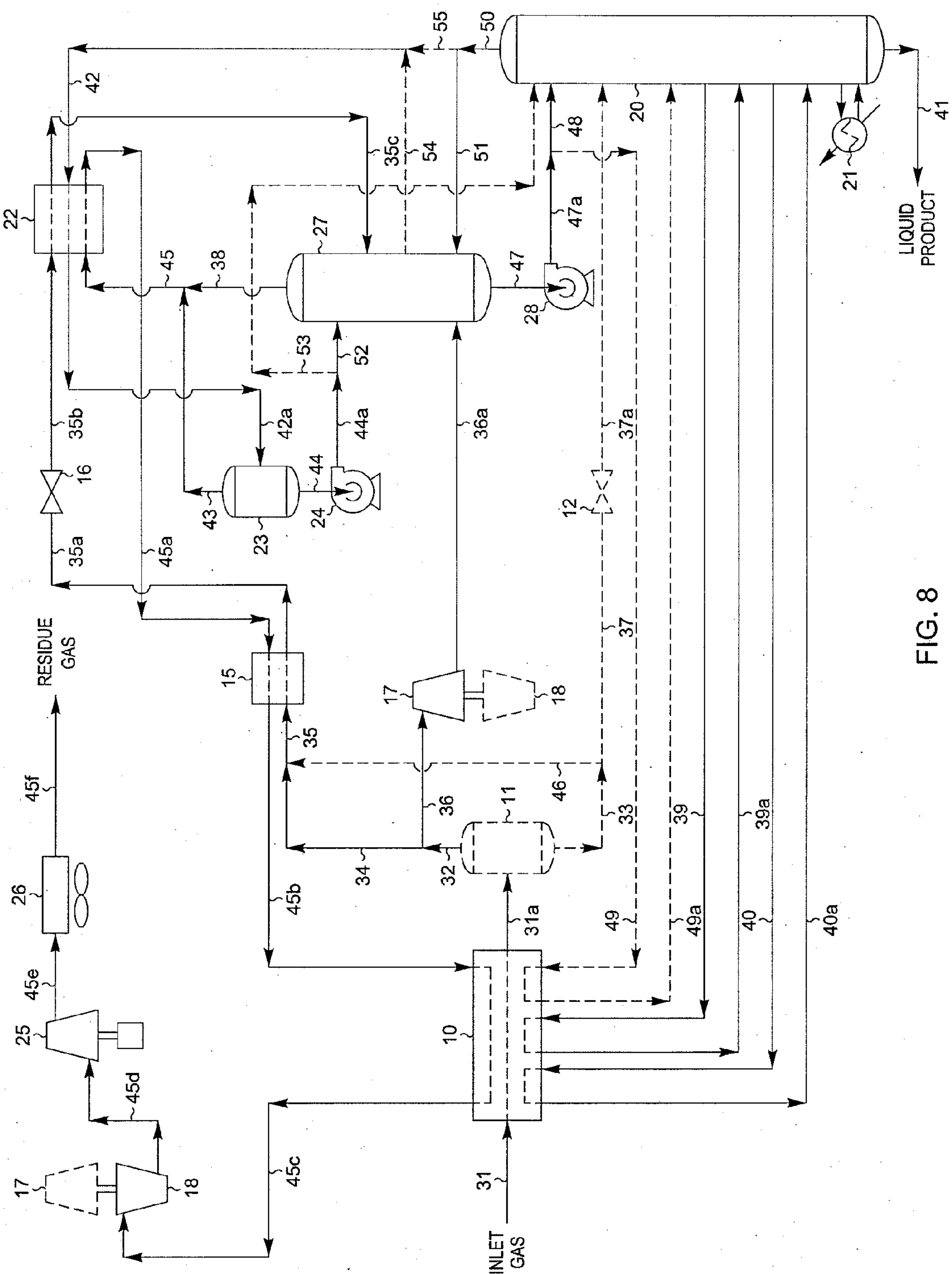

INLET GAS
RESIDUE GAS
LIQUID PRODUCT
10
11
12
15
16
17
18
20
21
22
23
24
25
26
27
28
31
31a
32
33
34
35
35a
35b
35c
36
36a
37
37a
38
39
39a
40
40a
41
42
42a
43
44
44a
45
45a
45b
45c
45d
45e
45f
46
47
47a
48
49
49a
50
51
52
53
54
55

FIG. 8

HYDROCARBON GAS PROCESSING

[0001] This invention relates to a process and an apparatus for the separation of a gas containing hydrocarbons. The applicants claim the benefits under Title 35, United States Code, Section 119(e) of prior U.S. Provisional Applications No. 61/244,181 which was filed on Sep. 21, 2009, No. 61/346,150 which was filed on May 19, 2010, and No. 61/351,045 which was filed on Jun. 3, 2010.

BACKGROUND OF THE INVENTION

[0002] Ethylene, ethane, propylene, propane, and/or heavier hydrocarbons can be recovered from a variety of gases, such as natural gas, refinery gas, and synthetic gas streams obtained from other hydrocarbon materials such as coal, crude oil, naphtha, oil shale, tar sands, and lignite. Natural gas usually has a major proportion of methane and ethane, i.e., methane and ethane together comprise at least 50 mole percent of the gas. The gas also contains relatively lesser amounts of heavier hydrocarbons such as propane, butanes, pentanes, and the like, as well as hydrogen, nitrogen, carbon dioxide, and other gases.

[0003] The present invention is generally concerned with the recovery of ethylene, ethane, propylene, propane and heavier hydrocarbons from such gas streams. A typical analysis of a gas stream to be processed in accordance with this invention would be, in approximate mole percent, 80.8% methane, 9.4% ethane and other C_2 components, 4.7% propane and other C_3 components, 1.2% iso-butane, 2.1% normal butane, and 1.1% pentanes plus, with the balance made up of nitrogen and carbon dioxide. Sulfur containing gases are also sometimes present.

[0004] The historically cyclic fluctuations in the prices of both natural gas and its natural gas liquid (NGL) constituents have at times reduced the incremental value of ethane, ethylene, propane, propylene, and heavier components as liquid products. This has resulted in a demand for processes that can provide more efficient recoveries of these products, for processes that can provide efficient recoveries with lower capital investment, and for processes that can be easily adapted or adjusted to vary the recovery of a specific component over a broad range. Available processes for separating these materials include those based upon cooling and refrigeration of gas, oil absorption, and refrigerated oil absorption. Additionally, cryogenic processes have become popular because of the availability of economical equipment that produces power while simultaneously expanding and extracting heat from the gas being processed. Depending upon the pressure of the gas source, the richness (ethane, ethylene, and heavier hydrocarbons content) of the gas, and the desired end products, each of these processes or a combination thereof may be employed.

[0005] The cryogenic expansion process is now generally preferred for natural gas liquids recovery because it provides maximum simplicity with ease of startup, operating flexibility, good efficiency, safety, and good reliability. U.S. Pat. Nos. 3,292,380; 4,061,481; 4,140,504; 4,157,904; 4,171,964; 4,185,978; 4,251,249; 4,278,457; 4,519,824; 4,617,039; 4,687,499; 4,689,063; 4,690,702; 4,854,955; 4,869,740; 4,889,545; 5,275,005; 5,555,748; 5,566,554; 5,568,737; 5,771,712; 5,799,507; 5,881,569; 5,890,378; 5,983,664; 6,182,469; 6,578,379; 6,712,880; 6,915,662; 7,191,617; 7,219,513; reissue U.S. Pat. No. 33,408; and co-pending application Ser. Nos. 11/430,412; 11/839,693; 11/971,491; 12/206,230; 12/689,616; 12/717,394; 12/750,862; 12/772,472; and 12/781,259 describe relevant processes (although the description of the present invention in some cases is based on different processing conditions than those described in the cited U.S. patents).

[0006] In a typical cryogenic expansion recovery process, a feed gas stream under pressure is cooled by heat exchange with other streams of the process and/or external sources of refrigeration such as a propane compression-refrigeration system. As the gas is cooled, liquids may be condensed and collected in one or more separators as high-pressure liquids containing some of the desired C_2+ components. Depending on the richness of the gas and the amount of liquids formed, the high-pressure liquids may be expanded to a lower pressure and fractionated. The vaporization occurring during expansion of the liquids results in further cooling of the stream. Under some conditions, pre-cooling the high pressure liquids prior to the expansion may be desirable in order to further lower the temperature resulting from the expansion. The expanded stream, comprising a mixture of liquid and vapor, is fractionated in a distillation (demethanizer or deethanizer) column. In the column, the expansion cooled stream(s) is (are) distilled to separate residual methane, nitrogen, and other volatile gases as overhead vapor from the desired C_2 components, C_3 components, and heavier hydrocarbon components as bottom liquid product, or to separate residual methane, C_2 components, nitrogen, and other volatile gases as overhead vapor from the desired C_3 components and heavier hydrocarbon components as bottom liquid product.

[0007] If the feed gas is not totally condensed (typically it is not), the vapor remaining from the partial condensation can be split into two streams. One portion of the vapor is passed through a work expansion machine or engine, or an expansion valve, to a lower pressure at which additional liquids are condensed as a result of further cooling of the stream. The pressure after expansion is essentially the same as the pressure at which the distillation column is operated. The combined vapor-liquid phases resulting from the expansion are supplied as feed to the column.

[0008] The remaining portion of the vapor is cooled to substantial condensation by heat exchange with other process streams, e.g., the cold fractionation tower overhead. Some or all of the high-pressure liquid may be combined with this vapor portion prior to cooling. The resulting cooled stream is then expanded through an appropriate expansion device, such as an expansion valve, to the pressure at which the demethanizer is operated. During expansion, a portion of the liquid will vaporize, resulting in cooling of the total stream. The flash expanded stream is then supplied as top feed to the demethanizer. Typically, the vapor portion of the flash expanded stream and the demethanizer overhead vapor combine in an upper separator section in the fractionation tower as residual methane product gas. Alternatively, the cooled and expanded stream may be supplied to a separator to provide vapor and liquid streams. The vapor is combined with the tower overhead and the liquid is supplied to the column as a top column feed.

[0009] In the ideal operation of such a separation process, the residue gas leaving the process will contain substantially all of the methane in the feed gas with essentially none of the heavier hydrocarbon components, and the bottoms fraction leaving the demethanizer will contain substantially all of the heavier hydrocarbon components with essentially no methane or more volatile components. In practice, however, this ideal situation is not obtained because the conventional demethanizer is operated largely as a stripping column. The methane product of the process, therefore, typically comprises vapors leaving the top fractionation stage of the column, together with vapors not subjected to any rectification step. Considerable losses of C_2, C_3, and C_4+ components occur because the top liquid feed contains substantial quantities of these components and heavier hydrocarbon components, resulting in corresponding equilibrium quantities of C_2 components, C_3 components, C_4 components, and heavier hydrocarbon components in the vapors leaving the top fractionation stage of the demethanizer. The loss of these desirable components could be significantly reduced if the rising vapors could be brought into contact with a significant quantity of liquid (reflux) capable of absorbing the C_2 components, C_3 components, C_4 components, and heavier hydrocarbon components from the vapors.

[0010] In recent years, the preferred processes for hydrocarbon separation use an upper absorber section to provide additional rectification of the rising vapors. The source of the reflux stream for the upper rectification section is typically a recycled stream of residue gas supplied under pressure. The recycled residue gas stream is usually cooled to substantial condensation by heat exchange with other process streams, e.g., the cold fractionation tower overhead. The resulting substantially condensed stream is then expanded through an appropriate expansion device, such as an expansion valve, to the pressure at which the demethanizer is operated. During expansion, a portion of the liquid will usually vaporize, resulting in cooling of the total stream. The flash expanded stream is then supplied as top feed to the demethanizer. Typically, the vapor portion of the expanded stream and the demethanizer overhead vapor combine in an upper separator section in the fractionation tower as residual methane product gas. Alternatively, the cooled and expanded stream may be supplied to a separator to provide vapor and liquid streams, so that thereafter the vapor is combined with the tower overhead and the liquid is supplied to the column as a top column feed. Typical process schemes of this type are disclosed in U.S. Pat. Nos. 4,889,545; 5,568,737; and 5,881,569, assignee's co-pending application Ser. No. 12/717,394, and in Mowrey, E. Ross, "Efficient, High Recovery of Liquids from Natural Gas Utilizing a High Pressure Absorber", Proceedings of the Eighty-First Annual Convention of the Gas Processors Association, Dallas, Tex., Mar. 11-13, 2002. Unfortunately, these processes require the use of a compressor to provide the motive force for recycling the reflux stream to the demethanizer, adding to both the capital cost and the operating cost of facilities using these processes.

[0011] The present invention also employs an upper rectification section (or a separate rectification column if plant size or other factors favor using separate rectification and stripping columns). However, the reflux stream for this rectification section is provided by using a side draw of the vapors rising in a lower portion of the tower. Because of the relatively high concentration of C_2 components in the vapors lower in the tower, a significant quantity of liquid can be condensed in this side draw stream without elevating its pressure, often using only the refrigeration available in the cold vapor leaving the upper rectification section and the flash expanded substantially condensed stream. This condensed liquid, which is predominantly liquid methane, can then be used to absorb C_2 components, C_3 components, C_4 components, and heavier hydrocarbon components from the vapors rising through the upper rectification section and thereby capture these valuable components in the bottom liquid product from the demethanizer.

[0012] Heretofore, such a side draw feature has been employed in C_3+ recovery systems, as illustrated in the assignee's U.S. Pat. No. 5,799,507, as well as in C_2+ recovery systems, as illustrated in the assignee's U.S. Pat. No. 7,191,617 and co-pending application Ser. Nos. 12/206,230 and 12/781,259. Surprisingly, applicants have found that using the flash expanded substantially condensed stream to provide a portion of the cooling of the side draw feature disclosed in assignee's co-pending application Ser. Nos. 12/206,230 and 12/781,259 processes improves the C_2+ recoveries and the system efficiency with no increase in operating cost.

[0013] In accordance with the present invention, it has been found that C_2 recovery in excess of 87% and C_3 and C_4+ recoveries in excess of 99% can be obtained without the need for compression of the reflux stream for the demethanizer. The present invention provides the further advantage of being able to maintain in excess of 99% recovery of the C_3 and C_4+ components as the recovery of C_2 components is adjusted from high to low values. In addition, the present invention makes possible essentially 100% separation of methane and lighter components from the C_2 components and heavier components at the same energy requirements compared to the prior art while increasing the recovery levels. The present invention, although applicable at lower pressures and warmer temperatures, is particularly advantageous when processing feed gases in the range of 400 to 1500 psia [2,758 to 10,342 kPa(a)] or higher under conditions requiring NGL recovery column overhead temperatures of −50° F. [−46° C.] or colder.

[0014] For a better understanding of the present invention, reference is made to the following examples and drawings. Referring to the drawings:

[0015] FIG. **1** is a flow diagram of a prior art natural gas processing plant in accordance with U.S. Pat. No. 5,890,378;

[0016] FIG. **2** is a flow diagram of a prior art natural gas processing plant in accordance with U.S. Pat. No. 7,191,617;

[0017] FIG. **3** is a flow diagram of a prior art natural gas processing plant in accordance with assignee's co-pending application Ser. No. 12/206,230;

[0018] FIG. **4** is a flow diagram of a natural gas processing plant in accordance with the present invention; and

[0019] FIGS. **5** through **8** are flow diagrams illustrating alternative means of application of the present invention to a natural gas stream.

[0020] In the following explanation of the above figures, tables are provided summarizing flow rates calculated for representative process conditions. In the tables appearing herein, the values for flow rates (in moles per hour) have been rounded to the nearest whole number for convenience. The total stream rates shown in the tables include all non-hydrocarbon components and hence are generally larger than the sum of the stream flow rates for the hydrocarbon components. Temperatures indicated are approximate values rounded to the nearest degree. It should also be noted that the process design calculations performed for the purpose of comparing the processes depicted in the figures are based on the assumption of no heat leak from (or to) the surroundings to (or from) the process. The quality of commercially available insulating materials makes this a very reasonable assumption and one that is typically made by those skilled in the art.

[0021] For convenience, process parameters are reported in both the traditional British units and in the units of the Systeme International d'Unités (SI). The molar flow rates given in the tables may be interpreted as either pound moles per hour or kilogram moles per hour. The energy consumptions reported as horsepower (HP) and/or thousand British Thermal Units per hour (MBTU/Hr) correspond to the stated molar flow rates in pound moles per hour. The energy consumptions reported as kilowatts (kW) correspond to the stated molar flow rates in kilogram moles per hour.

DESCRIPTION OF THE PRIOR ART

[0022] FIG. **1** is a process flow diagram showing the design of a processing plant to recover C_2+ components from natural gas using prior art according to U.S. Pat. No. 5,890,378. In this simulation of the process, inlet gas enters the plant at 85° F. [29° C.] and 970 psia [6,688 kPa(a)] as stream **31**. If the inlet gas contains a concentration of sulfur compounds which would prevent the product streams from meeting specifications, the sulfur compounds are removed by appropriate pretreatment of the feed gas (not illustrated). In addition, the feed stream is usually dehydrated to prevent hydrate (ice) formation under cryogenic conditions. Solid desiccant has typically been used for this purpose.

[0023] The feed stream **31** is cooled in heat exchanger **10** by heat exchange with cool residue gas (stream **45***b*), demethanizer lower side reboiler liquids at 32° F. [0° C.] (stream **40**), and propane refrigerant. Note that in all cases exchanger **10** is representative of either a multitude of individual heat exchangers or a single multi-pass heat exchanger, or any combination thereof. (The decision as to whether to use more than one heat exchanger for the indicated cooling services will depend on a number of factors including, but not limited to, inlet gas flow rate, heat exchanger size, stream temperatures, etc.) The cooled stream **31***a* enters separator **11** at 0° F. [−18° C.] and 955 psia [6,584 kPa(a)] where the vapor (stream **32**) is separated from the condensed liquid (stream **33**). The separator liquid (stream **33**) is expanded to the operating pressure (approximately 444 psia [3,061 kPa(a)]) of fractionation tower **20** by expansion valve **12**, cooling stream **33***a* to −27° F. [−33° C.] before it is supplied to fractionation tower **20** at a first lower mid-column feed point.

[0024] The vapor (stream **32**) from separator **11** is further cooled in heat exchanger **13** by heat exchange with cool residue gas (stream **45***a*) and demethanizer upper side reboiler liquids at −39° F. [−39° C.] (stream **39**). The cooled stream **32***a* enters separator **14** at −31° F. [−35° C.] and 950 psia [6,550 kPa(a)] where the vapor (stream **34**) is separated from the condensed liquid (stream **37**). The separator liquid (stream **37**) is expanded to the tower operating pressure by expansion valve **19**, cooling stream **37***a* to −66° F. [−54° C.] before it is supplied to fractionation tower **20** at a second lower mid-column feed point.

[0025] The vapor (stream **34**) from separator **14** is divided into two streams, **35** and **36**. Stream **35**, containing about 39% of the total vapor, passes through heat exchanger **15** in heat exchange relation with the cold residue gas (stream **45**) where it is cooled to substantial condensation. The resulting substantially condensed stream **35***a* at −123° F. [−86° C.] is then flash expanded through expansion valve **16** to slightly above the operating pressure of fractionation tower **20**. During expansion a portion of the stream is vaporized, resulting in cooling of the total stream. In the process illustrated in FIG. **1**, the expanded stream **35***b* leaving expansion valve **16** reaches a temperature of −130° F. [−90° C.]. The expanded stream **35***b* is warmed to −126° F. [−88° C.] and further vaporized in heat exchanger **22** as it provides cooling and partial condensation of distillation vapor stream **42** withdrawn from stripping section **20***b* of fractionation tower **20**. The warmed stream **35***c* is then supplied at an upper mid-column feed point, in absorbing section **20***a* of fractionation tower **20**.

[0026] The remaining 61% of the vapor from separator **14** (stream **36**) enters a work expansion machine **17** in which mechanical energy is extracted from this portion of the high pressure feed. The machine **17** expands the vapor substantially isentropically to the tower operating pressure, with the work expansion cooling the expanded stream **36***a* to a temperature of approximately −86° F. [−66° C.]. The typical commercially available expanders are capable of recovering on the order of 80-85% of the work theoretically available in an ideal isentropic expansion. The work recovered is often used to drive a centrifugal compressor (such as item **18**) that can be used to re-compress the residue gas (stream **45***c*), for example. The partially condensed expanded stream **36***a* is thereafter supplied as feed to fractionation tower **20** at a mid-column feed point.

[0027] The demethanizer in tower **20** is a conventional distillation column containing a plurality of vertically spaced trays, one or more packed beds, or some combination of trays and packing. The demethanizer tower consists of two sections: an upper absorbing (rectification) section **20***a* that contains the trays and/or packing to provide the necessary contact between the vapor portions of the expanded streams **35***c* and **36***a* rising upward and cold liquid falling downward to condense and absorb the C_2 components, C_3 components, and heavier components; and a lower, stripping section **20***b* that contains the trays and/or packing to provide the necessary contact between the liquids falling downward and the vapors rising upward. The demethanizing section **20***b* also includes one or more reboilers (such as reboiler **21** and the side reboilers described previously) which heat and vaporize a portion of the liquids flowing down the column to provide the stripping vapors which flow up the column to strip the liquid product, stream **41**, of methane and lighter components. Stream **36***a* enters demethanizer **20** at an intermediate feed position located in the lower region of absorbing section **20***a* of demethanizer **20**. The liquid portion of the expanded stream **36***a* comingles with liquids falling downward from absorbing section **20***a* and the combined liquid continues downward into stripping section **20***b* of demethanizer **20**. The vapor portion of the expanded stream **36***a* rises upward through absorbing section **20***a* and is contacted with cold liquid falling downward to condense and absorb the C_2 components, C_3 components, and heavier components.

[0028] A portion of the distillation vapor (stream **42**) is withdrawn from the upper region of stripping section **20***b*. This stream is then cooled and partially condensed (stream **42***a*) in exchanger **22** by heat exchange with expanded substantially condensed stream **35***b* as described previously, cooling stream **42** from −96° F. [−71° C.] to about −128° F. [−89° C.] (stream **42***a*). The operating pressure (441 psia [3,038 kPa(a)]) in reflux separator **23** is maintained slightly below the operating pressure of demethanizer **20**. This provides the driving force which causes distillation vapor stream **42** to flow through heat exchanger **22** and thence into the reflux separator **23** where the condensed liquid (stream **44**) is separated from any uncondensed vapor (stream **43**).

[0029] The liquid stream **44** from reflux separator **23** is pumped by pump **24** to a pressure slightly above the operating pressure of demethanizer **20**, and stream **44*a*** is then supplied as cold top column feed (reflux) to demethanizer **20** at −128° F. [−89° C.]. This cold liquid reflux absorbs and condenses the C_3 components and heavier components rising in the upper rectification region of absorbing section **20*a*** of demethanizer **20**.

[0030] The liquid product stream **41** exits the bottom of the tower at 112° F. [44° C.], based on a typical specification of a methane to ethane ratio of 0.025:1 on a molar basis in the bottom product. Cold demethanizer overhead stream **38** exits the top of demethanizer **20** at −128° F. [−89° C.] and combines with vapor stream **43** to form cold residue gas stream **45** at −128° F. [−89° C.]. The cold residue gas stream **45** passes countercurrently to the incoming feed gas in heat exchanger **15** where it is heated to −37° F. [−38° C.] (stream **45*a***), in heat exchanger **13** where it is heated to −5° F. [−21° C.] (stream **45*b***), and in heat exchanger **10** where it is heated to 80° F. [27° C.] (stream **45*c***). The residue gas is then re-compressed in two stages. The first stage is compressor **18** driven by expansion machine **17**. The second stage is compressor **25** driven by a supplemental power source which compresses the residue gas (stream **45*d***) to sales line pressure. After cooling to 120° F. [49° C.] in discharge cooler **26**, the residue gas product (stream **451**) flows to the sales gas pipeline at 1015 psia [6,998 kPa(a)], sufficient to meet line requirements (usually on the order of the inlet pressure).

[0031] A summary of stream flow rates and energy consumption for the process illustrated in FIG. **1** is set forth in the following table:

TABLE I

(FIG. 1)
Stream Flow Summary - Lb. Moles/Hr [kg moles/Hr]

Stream	Methane	Ethane	Propane	Butanes+	Total
31	53,228	6,192	3,070	2,912	65,876
32	49,244	4,670	1,650	815	56,795
33	3,984	1,522	1,420	2,097	9,081
34	47,282	4,037	1,178	405	53,293
37	1,962	633	472	410	3,502
35	18,582	1,587	463	159	20,944
36	28,700	2,450	715	246	32,349
38	44,854	790	11	0	45,920
42	12,398	720	42	3	13,270
43	8,242	135	2	0	8,421
44	4,156	585	40	3	4,849
45	53,096	925	13	0	54,341
41	132	5,267	3,057	2,912	11,535

Recoveries*

Ethane	85.05%
Propane	99.57%
Butanes+	99.99%

Power

Residue Gas Compression	24,134 HP	[39,676 kW]
Refrigerant Compression	7,743 HP	[12,729 kW]
Total Compression	31,877 HP	[52,405 kW]

*(Based on un-rounded flow rates)

[0032] FIG. **2** represents an alternative prior art process according to U.S. Pat. No. 7,191,617. The process of FIG. **2** has been applied to the same feed gas composition and conditions as described above for FIG. **1**. In the simulation of this process, as in the simulation for the process of FIG. **1**, operating conditions were selected to minimize energy consumption for a given recovery level.

[0033] In the simulation of the FIG. **2** process, inlet gas enters the plant as stream **31** and is cooled in heat exchanger **10** by heat exchange with cool residue gas (stream **45*b***), demethanizer lower side reboiler liquids at 33° F. [0° C.] (stream **40**), and propane refrigerant. The cooled stream **31*a*** enters separator **11** at 0° F. [−18° C.] and 955 psia [6,584 kPa(a)] where the vapor (stream **32**) is separated from the condensed liquid (stream **33**). The separator liquid (stream **33**) is expanded to the operating pressure (approximately 450 psia [3,103 kPa(a)]) of fractionation tower **20** by expansion valve **12**, cooling stream **33*a*** to −27° F. [−33° C.] before it is supplied to fractionation tower **20** at a first lower mid-column feed point.

[0034] The vapor (stream **32**) from separator **11** is further cooled in heat exchanger **13** by heat exchange with cool residue gas (stream **45*a***) and demethanizer upper side reboiler liquids at −38° F. [−39° C.] (stream **39**). The cooled stream **32*a*** enters separator **14** at −29° F. [−34° C.] and 950 psia [6,550 kPa(a)] where the vapor (stream **34**) is separated from the condensed liquid (stream **37**). The separator liquid (stream **37**) is expanded to the tower operating pressure by expansion valve **19**, cooling stream **37*a*** to −64° F. [−53° C.] before it is supplied to fractionation tower **20** at a second lower mid-column feed point.

[0035] The vapor (stream **34**) from separator **14** is divided into two streams, **35** and **36**. Stream **35**, containing about 37% of the total vapor, passes through heat exchanger **15** in heat exchange relation with the cold residue gas (stream **45**) where it is cooled to substantial condensation. The resulting substantially condensed stream **35*a*** at −115° F. [−82° C.] is then flash expanded through expansion valve **16** to the operating pressure of fractionation tower **20**. During expansion a portion of the stream is vaporized, resulting in cooling of stream **35*b*** to −129° F. [−89° C.] before it is supplied to fractionation tower **20** at an upper mid-column feed point.

[0036] The remaining 63% of the vapor from separator **14** (stream **36**) enters a work expansion machine **17** in which mechanical energy is extracted from this portion of the high pressure feed. The machine **17** expands the vapor substantially isentropically to the tower operating pressure, with the work expansion cooling the expanded stream **36*a*** to a temperature of approximately −84° F. [−65° C.]. The partially condensed expanded stream **36*a*** is thereafter supplied as feed to fractionation tower **20** at a mid-column feed point.

[0037] A portion of the distillation vapor (stream **42**) is withdrawn from the upper region of the stripping section in fractionation tower **20**. This stream is then cooled from −91° F. [−68° C.] to −122° F. [−86° C.] and partially condensed (stream **42*a***) in heat exchanger **22** by heat exchange with the cold demethanizer overhead stream **38** exiting the top of demethanizer **20** at −127° F. [−88° C.]. The cold demethanizer overhead stream is warmed slightly to −120° F. [−84° C.] (stream **38*a***) as it cools and condenses at least a portion of stream **42**.

[0038] The operating pressure (447 psia [3,079 kPa(a)]) in reflux separator **23** is maintained slightly below the operating pressure of demethanizer **20**. This provides the driving force which causes distillation vapor stream **42** to flow through heat exchanger **22** and thence into the reflux separator **23** where the condensed liquid (stream **44**) is separated from any uncondensed vapor (stream **43**). Stream **43** then combines with the warmed demethanizer overhead stream **38***a* from heat exchanger **22** to form cold residue gas stream **45** at −120° F. [−84° C.].

[0039] The liquid stream **44** from reflux separator **23** is pumped by pump **24** to a pressure slightly above the operating pressure of demethanizer **20**, and stream **44***a* is then supplied as cold top column feed (reflux) to demethanizer **20** at −121° F. [−85° C.]. This cold liquid reflux absorbs and condenses the C_3 components and heavier components rising in the upper rectification region of the absorbing section of demethanizer **20**.

[0040] The liquid product stream **41** exits the bottom of tower **20** at 114° F. [45° C.]. The cold residue gas stream **45** passes countercurrently to the incoming feed gas in heat exchanger **15** where it is heated to −36° F. [−38° C.] (stream **45***a*), in heat exchanger **13** where it is heated to −5° F. [−20° C.] (stream **45***b*), and in heat exchanger **10** where it is heated to 80° F. [27° C.] (stream **45***c*) as it provides cooling as previously described. The residue gas is then re-compressed in two stages, compressor **18** driven by expansion machine **17** and compressor **25** driven by a supplemental power source. After stream **45***e* is cooled to 120° F. [49° C.] in discharge cooler **26**, the residue gas product (stream **45***f*) flows to the sales gas pipeline at 1015 psia [6,998 kPa(a)].

[0041] A summary of stream flow rates and energy consumption for the process illustrated in FIG. **2** is set forth in the following table:

TABLE II

(FIG. 2)
Stream Flow Summary - Lb. Moles/Hr [kg moles/Hr]

Stream	Methane	Ethane	Propane	Butanes+	Total
31	53,228	6,192	3,070	2,912	65,876
32	49,244	4,670	1,650	815	56,795
33	3,984	1,522	1,420	2,097	9,081
34	47,440	4,081	1,204	420	53,536
37	1,804	589	446	395	3,259
35	17,553	1,510	445	155	19,808
36	29,887	2,571	759	265	33,728
38	48,675	811	23	1	49,805
42	5,555	373	22	2	6,000
43	4,421	113	2	0	4,562
44	1,134	260	20	2	1,438
45	53,096	924	25	1	54,367
41	132	5,268	3,045	2,911	11,509

Recoveries*

Ethane	85.08%
Propane	99.20%
Butanes+	99.98%

Power

Residue Gas Compression	23,636 HP	[38,857 kW]
Refrigerant Compression	7,561 HP	[12,430 kW]
Total Compression	31,197 HP	[51,287 kW]

*(Based on un-rounded flow rates)

[0042] A comparison of Tables I and II shows that, compared to the FIG. **1** process, the FIG. **2** process maintains essentially the same ethane recovery (85.08% versus 85.05%) and butanes+recovery (99.98% versus 99.99%), but the propane recovery drops from 99.57% to 99.20%. However, comparison of Tables I and II further shows that the power requirement for the FIG. **2** process is about 2% lower than that of the FIG. **1** process.

[0043] FIG. **3** represents an alternative prior art process according to co-pending application Ser. No. 12/206,230. The process of FIG. **3** has been applied to the same feed gas composition and conditions as described above for FIGS. **1** and **2**. In the simulation of this process, as in the simulation for the process of FIGS. **1** and **2**, operating conditions were selected to minimize energy consumption for a given recovery level.

[0044] In the simulation of the FIG. **3** process, inlet gas enters the plant as stream **31** and is cooled in heat exchanger **10** by heat exchange with cool residue gas (stream **45***b*), demethanizer lower side reboiler liquids at 36° F. [2° C.] (stream **40**), and propane refrigerant. The cooled stream **31***a* enters separator **11** at 1° F. [−17° C.] and 955 psia [6,584 kPa(a)] where the vapor (stream **32**) is separated from the condensed liquid (stream **33**). The separator liquid (stream **33**) is expanded to the operating pressure (approximately 452 psia [3,116 kPa(a)]) of fractionation tower **20** by expansion valve **12**, cooling stream **33***a* to −25° F. [−32° C.] before it is supplied to fractionation tower **20** at a first lower mid-column feed point.

[0045] The vapor (stream **32**) from separator **11** is further cooled in heat exchanger **13** by heat exchange with cool residue gas (stream **45***a*) and demethanizer upper side reboiler liquids at −37° F. [−38° C.] (stream **39**). The cooled stream **32***a* enters separator **14** at −31° F. [−35° C.] and 950 psia [6,550 kPa(a)] where the vapor (stream **34**) is separated from the condensed liquid (stream **37**). The separator liquid (stream **37**) is expanded to the tower operating pressure by expansion valve **19**, cooling stream **37***a* to −65° F. [−54° C.] before it is supplied to fractionation tower **20** at a second lower mid-column feed point.

[0046] The vapor (stream **34**) from separator **14** is divided into two streams, **35** and **36**. Stream **35**, containing about 38% of the total vapor, passes through heat exchanger **15** in heat exchange relation with the cold residue gas (stream **45**) where it is cooled to substantial condensation. The resulting substantially condensed stream **35***a* at −119° F. [−84° C.] is then flash expanded through expansion valve **16** to the operating pressure of fractionation tower **20**. During expansion a portion of the stream is vaporized, resulting in cooling of stream **35***b* to −129° F. [−90° C.] before it is supplied to fractionation tower **20** at an upper mid-column feed point.

[0047] The remaining 62% of the vapor from separator **14** (stream **36**) enters a work expansion machine **17** in which mechanical energy is extracted from this portion of the high pressure feed. The machine **17** expands the vapor substantially isentropically to the tower operating pressure, with the work expansion cooling the expanded stream **36***a* to a temperature of approximately −85° F. [−65° C.]. The partially condensed expanded stream **36***a* is thereafter supplied as feed to fractionation tower **20** at a mid-column feed point.

[0048] A portion of the distillation vapor (stream **42**) is withdrawn from an intermediate region of the absorbing section in fractionation column **20**, above the feed position of expanded stream **36***a* in the lower region of the absorbing section. This distillation vapor stream **42** is then cooled from −101° F. [−74° C.] to −124° F. [−86° C.] and partially condensed (stream **42***a*) in heat exchanger **22** by heat exchange with the cold demethanizer overhead stream **38** exiting the top of demethanizer **20** at −128° F. [−89° C.]. The cold demethanizer overhead stream is warmed slightly to −124° F. [−86° C.] (stream **38***a*) as it cools and condenses at least a portion of stream **42**.

[0049] The operating pressure (448 psia [3,090 kPa(a)]) in reflux separator **23** is maintained slightly below the operating pressure of demethanizer **20**. This provides the driving force which causes distillation vapor stream **42** to flow through heat exchanger **22** and thence into the reflux separator **23** where the condensed liquid (stream **44**) is separated from any uncondensed vapor (stream **43**). Stream **43** then combines with the warmed demethanizer overhead stream **38***a* from heat exchanger **22** to form cold residue gas stream **45** at −124° F. [−86° C.].

[0050] The liquid stream **44** from reflux separator **23** is pumped by pump **24** to a pressure slightly above the operating pressure of demethanizer **20**, and stream **44***a* is then supplied as cold top column feed (reflux) to demethanizer **20** at −123° F. [−86° C.]. This cold liquid reflux absorbs and condenses the C_2 components, C_3 components, and heavier components rising in the upper rectification region of the absorbing section of demethanizer **20**.

[0051] The liquid product stream **41** exits the bottom of tower **20** at 113° F. [45° C.]. The cold residue gas stream **45** passes countercurrently to the incoming feed gas in heat exchanger **15** where it is heated to −38° F. [−39° C.] (stream **45***a*), in heat exchanger **13** where it is heated to −4° F. [−20° C.] (stream **45***b*), and in heat exchanger **10** where it is heated to 80° F. [27° C.] (stream **45***c*) as it provides cooling as previously described. The residue gas is then re-compressed in two stages, compressor **18** driven by expansion machine **17** and compressor **25** driven by a supplemental power source. After stream **45***e* is cooled to 120° F. [49° C.] in discharge cooler **26**, the residue gas product (stream **45***f*) flows to the sales gas pipeline at 1015 psia [6,998 kPa(a)].

[0052] A summary of stream flow rates and energy consumption for the process illustrated in FIG. **3** is set forth in the following table:

TABLE III

(FIG. 3)
Stream Flow Summary - Lb. Moles/Hr [kg moles/Hr]

Stream	Methane	Ethane	Propane	Butanes+	Total
31	53,228	6,192	3,070	2,912	65,876
32	49,340	4,702	1,672	831	56,962
33	3,888	1,490	1,398	2,081	8,914
34	47,289	4,040	1,179	404	53,301
37	2,051	662	493	427	3,661
35	17,828	1,523	444	152	20,094
36	29,461	2,517	735	252	33,207
38	49,103	691	19	0	50,103
42	4,946	285	8	0	5,300
43	3,990	93	1	0	4,119
44	956	192	7	0	1,181
45	53,093	784	20	0	54,222
41	135	5,408	3,050	2,912	11,654

Recoveries*

Ethane	87.33%
Propane	99.36%
Butanes+	99.99%

Power

Residue Gas Compression	23,518 HP	[38,663 kW]
Refrigerant Compression	7,554 HP	[12,419 kW]
Total Compression	31,072 HP	[51,082 kW]

*(Based on un-rounded flow rates)

[0053] A comparison of Tables I, II, and III shows that the FIG. **3** process improves the ethane recovery from 85.05% (for FIG. **1**) and 85.08% (for FIG. **2**) to 87.33%. The propane recovery for the FIG. **3** process (99.36%) is lower than that of the FIG. **1** process (99.57%) but higher than that of the FIG. **2** process (99.20%). The butanes+recovery is essentially the same for all three of these prior art processes. Comparison of Tables I, II, and III further shows that the FIG. **3** process using slightly less power than both prior art processes (more than 2% less than the FIG. **1** process and 0.4% less than the FIG. **2** process).

DESCRIPTION OF THE INVENTION

[0054] FIG. **4** illustrates a flow diagram of a process in accordance with the present invention. The feed gas composition and conditions considered in the process presented in FIG. **4** are the same as those in FIGS. **1**, **2**, and **3**. Accordingly, the FIG. **4** process can be compared with that of the FIGS. **1**, **2**, and **3** processes to illustrate the advantages of the present invention.

[0055] In the simulation of the FIG. **4** process, inlet gas enters the plant at 85° F. [29° C.] and 970 psia [6,688 kPa(a)] as stream **31** and is cooled in heat exchanger **10** by heat exchange with cool residue gas (stream **45***b*), demethanizer lower side reboiler liquids at 32° F. [0° C.] (stream **40**), and propane refrigerant. The cooled stream **31***a* enters separator **11** at 1° F. [−17° C.] and 955 psia [6,584 kPa(a)] where the vapor (stream **32**) is separated from the condensed liquid (stream **33**). The separator liquid (stream **33**) is expanded to the operating pressure (approximately 452 psia [3,116 kPa (a)]) of fractionation tower **20** by expansion valve **12**, cooling stream **33***a* to −25° F. [−32° C.] before it is supplied to fractionation tower **20** at a first lower mid-column feed point (located below the feed point of stream **36***a* described later in paragraph [0058]).

[0056] The vapor (stream **32**) from separator **11** is further cooled in heat exchanger **13** by heat exchange with cool residue gas (stream **45***a*) and demethanizer upper side reboiler liquids at −38° F. [−39° C.] (stream **39**). The cooled stream **32***a* enters separator **14** at −31° F. [−35° C.] and 950 psia [6,550 kPa(a)] where the vapor (stream **34**) is separated from the condensed liquid (stream **37**). The separator liquid (stream **37**) is expanded to the tower operating pressure by expansion valve **19**, cooling stream **37***a* to −66° F. [−54° C.] before it is supplied to fractionation tower **20** at a second lower mid-column feed point (also located below the feed point of stream **36***a*).

[0057] The vapor (stream **34**) from separator **14** is divided into two streams, **35** and **36**. Stream **35**, containing about 38% of the total vapor, passes through heat exchanger **15** in heat exchange relation with the cold residue gas (stream **45**) where it is cooled to substantial condensation. The resulting substantially condensed stream **35***a* at −122° F. [−86° C.] is then flash expanded through expansion valve **16** to slightly above the operating pressure of fractionation tower **20**. During expansion a portion of the stream is vaporized, resulting in cooling of the total stream. In the process illustrated in FIG. **4**, the expanded stream **35***b* leaving expansion valve **16** reaches a temperature of −130° F. [−90° C.]. The expanded stream **35***b* is warmed slightly to −129° F. [−89° C.] and further vaporized in heat exchanger **22** as it provides a portion of the cooling of distillation vapor stream **42**. The warmed stream **35***c* is then supplied at an upper mid-column feed point, in absorbing section **20***a* of fractionation tower **20**.

[0058] The remaining 62% of the vapor from separator **14** (stream **36**) enters a work expansion machine **17** in which mechanical energy is extracted from this portion of the high pressure feed. The machine **17** expands the vapor substantially isentropically to the tower operating pressure, with the work expansion cooling the expanded stream **36***a* to a temperature of approximately −86° F. [−65° C.]. The partially condensed expanded stream **36***a* is thereafter supplied as feed to fractionation tower **20** at a mid-column feed point (located below the feed point of stream **35***c*).

[0059] The demethanizer in tower **20** is a conventional distillation column containing a plurality of vertically spaced trays, one or more packed beds, or some combination of trays and packing. The demethanizer tower consists of two sections: an upper absorbing (rectification) section **20***a* that contains the trays and/or packing to provide the necessary contact between the vapor portions of the expanded streams **35***c* and **36***a* rising upward and cold liquid falling downward to condense and absorb the C_2 components, C_3 components, and heavier components from the vapors rising upward; and a lower, stripping section **20***b* that contains the trays and/or packing to provide the necessary contact between the liquids falling downward and the vapors rising upward. The demethanizing section **20***b* also includes one or more reboilers (such as reboiler **21** and the side reboilers described previously) which heat and vaporize a portion of the liquids flowing down the column to provide the stripping vapors which flow up the column to strip the liquid product, stream **41**, of methane and lighter components. Stream **36***a* enters demethanizer **20** at an intermediate feed position located in the lower region of absorbing section **20***a* of demethanizer **20**. The liquid portion of the expanded stream **36***a* comingles with liquids falling downward from absorbing section **20***a* and the combined liquid continues downward into stripping section **20***b* of demethanizer **20**. The vapor portion of the expanded stream **36***a* rises upward through absorbing section **20***a* and is contacted with cold liquid falling downward to condense and absorb the C_2 components, C_3 components, and heavier components.

[0060] A portion of the distillation vapor (stream **42**) is withdrawn from an intermediate region of absorbing section **20***a* in fractionation column **20**, above the feed position of expanded stream **36***a* in the lower region of absorbing section **20***a*. This distillation vapor stream **42** is then cooled from −103° F. [−75° C.] to −128° F. [−89° C.] and partially condensed (stream **42***a*) in heat exchanger **22** by heat exchange with the cold demethanizer overhead stream **38** exiting the top of demethanizer **20** at −129° F. [−89° C.] and with the expanded substantially condensed stream **35***b* as described previously. The cold demethanizer overhead stream is warmed slightly to −127° F. [−88° C.] (stream **38***a*) as it provides a portion of the cooling of distillation vapor stream **42**.

[0061] The operating pressure (448 psia [3,090 kPa(a)]) in reflux separator **23** is maintained slightly below the operating pressure of demethanizer **20**. This provides the driving force which causes distillation vapor stream **42** to flow through heat exchanger **22** and thence into the reflux separator **23** where the condensed liquid (stream **44**) is separated from any uncondensed vapor (stream **43**). Stream **43** then combines with the warmed demethanizer overhead stream **38***a* from heat exchanger **22** to form cold residue gas stream **45** at −127° F. [−88° C.].

[0062] The liquid stream **44** from reflux separator **23** is pumped by pump **24** to a pressure slightly above the operating pressure of demethanizer **20**, and stream **44***a* is then supplied as cold top column feed (reflux) to demethanizer **20** at −127° F. [−88° C.]. This cold liquid reflux absorbs and condenses the C_2 components, C_3 components, and heavier components rising in the upper rectification region of absorbing section **20***a* of demethanizer **20**.

[0063] In stripping section **20***b* of demethanizer **20**, the feed streams are stripped of their methane and lighter components. The resulting liquid product (stream **41**) exits the bottom of tower **20** at 113° F. [45° C.] (based on a typical specification of a methane to ethane ratio of 0.025:1 on a molar basis in the bottom product). The cold residue gas stream **45** passes countercurrently to the incoming feed gas in heat exchanger **15** where it is heated to −40° F. [−40° C.] (stream **45***a*), in heat exchanger **13** where it is heated to −4° F. [−20° C.] (stream **45***b*), and in heat exchanger **10** where it is heated to 80° F. [27° C.] (stream **45***c*) as it provides cooling as previously described. The residue gas is then re-compressed in two stages, compressor **18** driven by expansion machine **17** and compressor **25** driven by a supplemental power source. After stream **45***e* is cooled to 120° F. [49° C.] in discharge cooler **26**, the residue gas product (stream **45***f*) flows to the sales gas pipeline at 1015 psia [6,998 kPa(a)].

[0064] A summary of stream flow rates and energy consumption for the process illustrated in FIG. **4** is set forth in the following table:

TABLE IV

(FIG. 4)
Stream Flow Summary - Lb. Moles/Hr [kg moles/Hr]

Stream	Methane	Ethane	Propane	Butanes+	Total
31	53,228	6,192	3,070	2,912	65,876
32	49,407	4,712	1,676	832	57,046
33	3,821	1,480	1,394	2,080	8,830
34	47,346	4,041	1,176	401	53,354
37	2,061	671	500	431	3,692
35	17,991	1,536	447	152	20,274
36	29,355	2,505	729	249	33,080
38	49,756	713	14	0	50,779
42	4,688	249	7	0	5,000
43	3,336	57	0	0	3,420
44	1,352	192	7	0	1,580
45	53,092	770	14	0	54,199
41	136	5,422	3,056	2,912	11,677

Recoveries*

Ethane	87.56%
Propane	99.55%
Butanes+	99.99%

Power

Residue Gas Compression	23,552 HP	[38,719 kW]
Refrigerant Compression	7,520 HP	[12,363 kW]
Total Compression	31,072 HP	[51,082 kW]

* (Based on un-rounded flow rates)

[0065] A comparison of Tables I, II, III, and IV shows that, compared to the prior art, the present invention matches or exceeds the propane and butanes+recoveries of all the prior art processes while significantly improving the ethane recovery. The ethane recovery for the present invention (87.56%) is higher than the FIG. **1** process (85.05%), the FIG. **2** process (85.08%), and the FIG. **3** process (87.33%). Comparison of

Tables I, II, III, and IV further shows that the improvement in yields was achieved without using more power than the prior art, and in some cases using significantly less power. In terms of the recovery efficiency (defined by the quantity of ethane recovered per unit of power), the present invention represents an improvement of 5%, 3%, and 0.3%, respectively, over the prior art of the FIG. **1**, FIG. **2**, and FIG. **3** processes. Although the power required for the present invention is essentially the same as that for the prior art FIG. **3** process, the present invention improves both the ethane recovery and the propane recovery by 0.2% compared to the FIG. **3** process without using more power.

[0066] Like the FIGS. **1**, **2**, and **3** prior art processes, the present invention uses the expanded substantially condensed feed stream **35***c* supplied to absorbing section **20***a* of demethanizer **20** to provide bulk recovery of the C_2 components, C_3 components, and heavier hydrocarbon components contained in expanded feed **36***a* and the vapors rising from stripping section **20***b*, and the supplemental rectification provided by reflux stream **44***a* to reduce the amount of C_2 components, C_3 components, and C_4+ components contained in the inlet feed gas that is lost to the residue gas. However, the present invention improves the rectification in absorbing section **20***a* over that of the prior art processes by making more effective use of the refrigeration available in process streams **38** and **35***b* to improve the recoveries and the recovery efficiency.

[0067] Comparing reflux stream **44** in Table I for the FIG. **1** prior art process with that in Table IV for the present invention, it can be seen that although the compositions of the streams are similar, the FIG. **1** process has over 3 times as much supplemental reflux as the present invention. Surprisingly, however, the FIG. **1** process achieves much lower ethane recovery than the present invention despite the much greater quantity of reflux. The better recovery achieved by the present invention can be understood by comparing the condition of the warmed expanded substantially condensed stream **35***c* in the FIG. **1** prior art process with that of the corresponding stream in the FIG. **4** embodiment of the present invention. Although the temperature of this stream is only slightly warmer in the FIG. **1** process, the proportion of this stream that has been vaporized before entering demethanizer **20** is vastly higher than that of the present invention (42% versus 12%). This means that not only is there less cold liquid in stream **35***c* of the FIG. **1** process available for rectification of the vapors rising in absorbing section **20***a*, there is much more vapor in the upper region of absorbing section **20***a* that must be rectified by reflux stream **44***a*. The net result is that reflux stream **44***a* of the FIG. **1** process allows more of the C_2 components to escape to demethanizer overhead stream **38** than the present invention does, reducing both the recovery and the recovery efficiency of the FIG. **1** process compared to the present invention. The key improvement of the present invention over the FIG. **1** prior art process is that the cold demethanizer overhead vapor stream **38** is used to provide a portion of the cooling of distillation vapor stream **42** in heat exchanger **22** so that sufficient methane can be condensed for use as reflux, without adding significant rectification load in absorbing section **20***a* due to the excessive vaporization of stream **35***c* that is inherent in the FIG. **1** prior art process.

[0068] Comparing reflux stream **44** in Tables II and III for the FIGS. **2** and **3** prior art processes with that in Table IV for the present invention, it can be seen that the present invention produces both more reflux and a better reflux stream than these prior art processes. Not only is the quantity of reflux higher (10% higher than the FIG. **2** process and 34% higher than the FIG. **3** process), the concentration of C_2+ components is significantly lower (12.6% for the present invention, versus 19.6% for the FIG. **2** process and 16.9% for the FIG. **3** process). This makes reflux stream **44***a* of the present invention more effective for rectification in absorbing section **20***a* of demethanizer **20**, improving both the recovery and the recovery efficiency of the present invention compared to the FIGS. **2** and **3** prior art processes. The key improvement of the present invention over the FIGS. **2** and **3** prior art processes is that the expanded substantially condensed stream **35***b* (which is predominantly liquid methane) is a better refrigerant medium than demethanizer overhead vapor stream **38** (which is primarily methane vapor), so using stream **35***b* to provide a portion of the cooling of distillation vapor stream **42** in heat exchanger **22** allows more methane to be condensed and used as reflux in the present invention.

Other Embodiments

[0069] In accordance with this invention, it is generally advantageous to design the absorbing (rectification) section of the demethanizer to contain multiple theoretical separation stages. However, the benefits of the present invention can be achieved with as few as two theoretical stages. For instance, all or a part of the pumped condensed liquid (stream **44***a*) from reflux separator **23** and all or a part of the warmed expanded substantially condensed stream **35***c* from heat exchanger **22** can be combined (such as in the piping joining the pump and heat exchanger to the demethanizer) and if thoroughly intermingled, the vapors and liquids will mix together and separate in accordance with the relative volatilities of the various components of the total combined streams. Such comingling of the two streams, combined with contacting at least a portion of expanded stream **36***a*, shall be considered for the purposes of this invention as constituting an absorbing section.

[0070] FIGS. **5** through **8** display other embodiments of the present invention. FIGS. **4** through **6** depict fractionation towers constructed in a single vessel. FIGS. **7** and **8** depict fractionation towers constructed in two vessels, absorber (rectifier) column **27** (a contacting and separating device) and stripper (distillation) column **20**. In such cases, a portion of the distillation vapor (stream **54**) is withdrawn from the lower section of absorber column **27** and routed to reflux condenser **22** to generate reflux for absorber column **27**. The overhead vapor stream **50** from stripper column **20** flows to the lower section of absorber column **27** (via stream **51**) to be contacted by reflux stream **52** and warmed expanded substantially condensed stream **35***c*. Pump **28** is used to route the liquids (stream **47**) from the bottom of absorber column **27** to the top of stripper column **20** so that the two towers effectively function as one distillation system. The decision whether to construct the fractionation tower as a single vessel (such as demethanizer **20** in FIGS. **4** through **6**) or multiple vessels will depend on a number of factors such as plant size, the distance to fabrication facilities, etc.

[0071] Some circumstances may favor withdrawing the distillation vapor stream **42** in FIGS. **5** and **6** from the upper region of stripping section **20***b* in demethanizer **20** (stream **55**). In other cases, it may be advantageous to withdraw a distillation vapor stream **54** from the lower region of absorbing section **20***a* (above the feed point of expanded stream **36***a*), withdraw a distillation vapor stream **55** from the upper region of stripping section **20***b* (below the feed point of expanded stream **36***a*), combine streams **54** and **55** to form combined distillation vapor stream **42**, and direct combined distillation vapor stream **42** to heat exchanger **22** to be cooled and partially condensed. Similarly, in FIGS. **7** and **8** a portion (stream **55**) of overhead vapor stream **50** from stripper column **20** may be directed to heat exchanger **22** (optionally combined with distillation vapor stream **54** withdrawn from the lower section of absorber column **27**), with the remaining portion (stream **51**) flowing to the lower section of absorber column **27**.

[0072] Some circumstances may favor mixing the remaining vapor portion (stream **43**) of cooled distillation vapor stream **42***a* with the fractionation column overhead (stream **38**), then supplying the mixed stream to heat exchanger **22** to provide a portion of the cooling of distillation vapor stream **42** or combined distillation vapor stream **42**. This is shown in FIGS. **6** and **8**, where the mixed stream **45** resulting from combining the reflux separator vapor (stream **43**) with the column overhead (stream **38**) is routed to heat exchanger **22**.

[0073] As described earlier, the distillation vapor stream **42** or the combined distillation vapor stream **42** is partially condensed and the resulting condensate used to absorb valuable C_2 components, C_3 components, and heavier components from the vapors rising through absorbing section **20***a* of demethanizer **20** or through absorber column **27**. However, the present invention is not limited to this embodiment. It may be advantageous, for instance, to treat only a portion of these vapors in this manner, or to use only a portion of the condensate as an absorbent, in cases where other design considerations indicate portions of the vapors or the condensate should bypass absorbing section **20***a* of demethanizer **20** or absorber column **27**. Some circumstances may favor total condensation, rather than partial condensation, of distillation vapor stream **42** or combined distillation vapor stream **42** in heat exchanger **22**. Other circumstances may favor that distillation vapor stream **42** be a total vapor side draw from fractionation column **20** or absorber column **27** rather than a partial vapor side draw. It should also be noted that, depending on the composition of the feed gas stream, it may be advantageous to use external refrigeration to provide partial cooling of distillation vapor stream **42** or combined distillation vapor stream **42** in heat exchanger **22**.

[0074] Feed gas conditions, plant size, available equipment, or other factors may indicate that elimination of work expansion machine **17**, or replacement with an alternate expansion device (such as an expansion valve), is feasible. Although individual stream expansion is depicted in particular expansion devices, alternative expansion means may be employed where appropriate. For example, conditions may warrant work expansion of the substantially condensed portion of the feed stream (stream **35***a*).

[0075] When the inlet gas is leaner, separator **11** in FIG. **4** may not be justified. In such cases, the feed gas cooling accomplished in heat exchangers **10** and **13** in FIG. **4** may be accomplished without an intervening separator as shown in FIGS. **5** through **8**. The decision of whether or not to cool and separate the feed gas in multiple steps will depend on the richness of the feed gas, plant size, available equipment, etc. Depending on the quantity of heavier hydrocarbons in the feed gas and the feed gas pressure, the cooled feed stream **31***a* leaving heat exchanger **10** in FIGS. **4** through **8** and/or the cooled stream **32***a* leaving heat exchanger **13** in FIG. **4** may not contain any liquid (because it is above its dewpoint, or because it is above its cricondenbar), so that separator **11** shown in FIGS. **4** through **8** and/or separator **14** shown in FIG. **4** are not required.

[0076] The high pressure liquid (stream **37** in FIG. **4** and stream **33** in FIGS. **5** through **8**) need not be expanded and fed to a lower mid-column feed point on the distillation column. Instead, all or a portion of it may be combined with the portion of the separator vapor (stream **35** in FIG. **4** and stream **34** in FIGS. **5** through **8**) flowing to heat exchanger **15**. (This is shown by the dashed stream **46** in FIGS. **5** through **8**.) Any remaining portion of the liquid may be expanded through an appropriate expansion device, such as an expansion valve or expansion machine, and fed to a lower mid-column feed point on the distillation column (stream **37***a* in FIGS. **5** through **8**). Stream **33** in FIG. **4** and stream **37** in FIGS. **4** through **8** may also be used for inlet gas cooling or other heat exchange service before or after the expansion step prior to flowing to the demethanizer.

[0077] In accordance with the present invention, the use of external refrigeration to supplement the cooling available to the inlet gas from other process streams may be employed, particularly in the case of a rich inlet gas. The use and distribution of separator liquids and demethanizer side draw liquids for process heat exchange, and the particular arrangement of heat exchangers for inlet gas cooling must be evaluated for each particular application, as well as the choice of process streams for specific heat exchange services.

[0078] Some circumstances may favor using a portion of the cold distillation liquid leaving absorbing section **20***a* or absorber column **27** for heat exchange, such as dashed stream **49** in FIGS. **5** through **8**. Although only a portion of the liquid from absorbing section **20***a* or absorber column **27** can be used for process heat exchange without reducing the ethane recovery in demethanizer **20** or stripper column **20**, more duty can sometimes be obtained from these liquids than with liquids from stripping section **20***b* or stripper column **20**. This is because the liquids in absorbing section **20***a* of demethanizer **20** (or absorber column **27**) are available at a colder temperature level than those in stripping section **20***b* (or stripper column **20**).

[0079] As shown by dashed stream **53** in FIGS. **5** through **8**, in some cases it may be advantageous to split the liquid stream from reflux pump **24** (stream **44***a*) into at least two streams. A portion (stream **53**) can then be supplied to the stripping section of fractionation tower **20** (FIGS. **5** and **6**) or the top of stripper column **20** (FIGS. **7** and **8**) to increase the liquid flow in that part of the distillation system and improve the rectification, thereby reducing the concentration of C_2+ components in stream **42**. In such cases, the remaining portion (stream **52**) is supplied to the top of absorbing section **20***a* (FIGS. **5** and **6**) or absorber column **27** (FIGS. **7** and **8**).

[0080] In accordance with the present invention, the splitting of the vapor feed may be accomplished in several ways. In the processes of FIGS. **4** through **8**, the splitting of vapor occurs following cooling and separation of any liquids which may have been formed. The high pressure gas may be split, however, prior to any cooling of the inlet gas or after the cooling of the gas and prior to any separation stages. In some embodiments, vapor splitting may be effected in a separator.

[0081] It will also be recognized that the relative amount of feed found in each branch of the split vapor feed will depend on several factors, including gas pressure, feed gas composition, the amount of heat which can economically be extracted from the feed, and the quantity of horsepower available. More feed to the top of the column may increase recovery while decreasing power recovered from the expander thereby increasing the recompression horsepower requirements. Increasing feed lower in the column reduces the horsepower consumption but may also reduce product recovery. The relative locations of the mid-column feeds may vary depending on inlet composition or other factors such as desired recovery levels and amount of liquid formed during inlet gas cooling. Moreover, two or more of the feed streams, or portions thereof, may be combined depending on the relative temperatures and quantities of individual streams, and the combined stream then fed to a mid-column feed position.

[0082] The present invention provides improved recovery of C_2 components, C_3 components, and heavier hydrocarbon components or of C_3 components and heavier hydrocarbon components per amount of utility consumption required to operate the process. An improvement in utility consumption required for operating the demethanizer or deethanizer process may appear in the form of reduced power requirements for compression or re-compression, reduced power requirements for external refrigeration, reduced energy requirements for tower reboilers, or a combination thereof.

[0083] While there have been described what are believed to be preferred embodiments of the invention, those skilled in the art will recognize that other and further modifications may be made thereto, e.g. to adapt the invention to various conditions, types of feed, or other requirements without departing from the spirit of the present invention as defined by the following claims.

We claim:

1. In a process for the separation of a gas stream containing methane, C_2 components, C_3 components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C_2 components, C_3 components, and heavier hydrocarbon components or said C_3 components and heavier hydrocarbon components, in which process

(a) said gas stream is cooled under pressure to provide a cooled stream;

(b) said cooled stream is expanded to a lower pressure whereby it is further cooled; and

(c) said further cooled stream is directed into a distillation column and fractionated at said lower pressure whereby the components of said relatively less volatile fraction are recovered;

the improvement wherein following cooling, said cooled stream is divided into first and second streams; and

(1) said first stream is cooled to condense substantially all of it and is thereafter expanded to said lower pressure whereby it is further cooled;

(2) said expanded cooled first stream is heated and is thereafter supplied to said distillation column at an upper mid-column feed position;

(3) said second stream is expanded to said lower pressure and is supplied to said distillation column at a mid-column feed position below said upper mid-column feed position;

(4) an overhead vapor stream is withdrawn from an upper region of said distillation column and heated, thereafter discharging at least a portion of said heated overhead vapor stream as said volatile residue gas fraction;

(5) a distillation vapor stream is withdrawn from a region of said distillation column below said upper mid-column feed position and above said mid-column feed position and is directed into heat exchange relation with said expanded cooled first stream and said overhead vapor stream, whereby said distillation vapor stream is cooled sufficiently to condense at least a part of it and thereby form a residual vapor stream and a condensed stream, thereby supplying at least a portion of the heating of steps (2) and (4);

(6) at least a portion of said condensed stream is supplied to said distillation column at a top feed position; and

(7) the quantities and temperatures of said feed streams to said distillation column are effective to maintain the overhead temperature of said distillation column at a temperature whereby the major portions of the components in said relatively less volatile fraction are recovered.

2. In a process for the separation of a gas stream containing methane, C_2 components, C_3 components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C_2 components, C_3 components, and heavier hydrocarbon components or said C_3 components and heavier hydrocarbon components, in which process

(a) said gas stream is cooled under pressure to provide a cooled stream;

(b) said cooled stream is expanded to a lower pressure whereby it is further cooled; and

(c) said further cooled stream is directed into a distillation column and fractionated at said lower pressure whereby the components of said relatively less volatile fraction are recovered;

the improvement wherein said gas stream is cooled sufficiently to partially condense it; and

(1) said partially condensed gas stream is separated thereby to provide a vapor stream and at least one liquid stream;

(2) said vapor stream is thereafter divided into first and second streams;

(3) said first stream is cooled to condense substantially all of it and is thereafter expanded to said lower pressure whereby it is further cooled;

(4) said expanded cooled first stream is heated and is thereafter supplied to said distillation column at an upper mid-column feed position;

(5) said second stream is expanded to said lower pressure and is supplied to said distillation column at a mid-column feed position below said upper mid-column feed position;

(6) at least a portion of said at least one liquid stream is expanded to said lower pressure and is supplied to said distillation column at a lower mid-column feed position below said mid-column feed position;

(7) an overhead vapor stream is withdrawn from an upper region of said distillation column and heated, thereafter discharging at least a portion of said heated overhead vapor stream as said volatile residue gas fraction;

(8) a distillation vapor stream is withdrawn from a region of said distillation column below said upper mid-column feed position and above said mid-column feed position and is directed into heat exchange relation with said expanded cooled first stream and said overhead vapor stream, whereby said distillation vapor stream is cooled sufficiently to condense at least a part of it and thereby

form a residual vapor stream and a condensed stream, thereby supplying at least a portion of the heating of steps (4) and (7);

(9) at least a portion of said condensed stream is supplied to said distillation column at a top feed position; and

(10) the quantities and temperatures of said feed streams to said distillation column are effective to maintain the overhead temperature of said distillation column at a temperature whereby the major portions of the components in said relatively less volatile fraction are recovered.

3. In a process for the separation of a gas stream containing methane, C_2 components, C_3 components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C_2 components, C_3 components, and heavier hydrocarbon components or said C_3 components and heavier hydrocarbon components, in which process

(a) said gas stream is cooled under pressure to provide a cooled stream;

(b) said cooled stream is expanded to a lower pressure whereby it is further cooled; and

(c) said further cooled stream is directed into a distillation column and fractionated at said lower pressure whereby the components of said relatively less volatile fraction are recovered;

the improvement wherein said gas stream is cooled sufficiently to partially condense it; and

(1) said partially condensed gas stream is separated thereby to provide a vapor stream and at least one liquid stream;

(2) said vapor stream is thereafter divided into first and second streams;

(3) said first stream is combined with at least a portion of said at least one liquid stream to form a combined stream, whereupon said combined stream is cooled to condense substantially all of it and is thereafter expanded to said lower pressure whereby it is further cooled;

(4) said expanded cooled combined stream is heated and is thereafter supplied to said distillation column at an upper mid-column feed position;

(5) said second stream is expanded to said lower pressure and is supplied to said distillation column at a mid-column feed position below said upper mid-column feed position;

(6) any remaining portion of said at least one liquid stream is expanded to said lower pressure and is supplied to said distillation column at a lower mid-column feed position below said mid-column feed position;

(7) an overhead vapor stream is withdrawn from an upper region of said distillation column and heated, thereafter discharging at least a portion of said heated overhead vapor stream as said volatile residue gas fraction;

(8) a distillation vapor stream is withdrawn from a region of said distillation column below said upper mid-column feed position and above said mid-column feed position and is directed into heat exchange relation with said expanded cooled combined stream and said overhead vapor stream, whereby said distillation vapor stream is cooled sufficiently to condense at least a part of it and thereby form a residual vapor stream and a condensed stream, thereby supplying at least a portion of the heating of steps (4) and (7);

(9) at least a portion of said condensed stream is supplied to said distillation column at a top feed position; and

(10) the quantities and temperatures of said feed streams to said distillation column are effective to maintain the overhead temperature of said distillation column at a temperature whereby the major portions of the components in said relatively less volatile fraction are recovered.

4. In a process for the separation of a gas stream containing methane, C_2 components, C_3 components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C_2 components, C_3 components, and heavier hydrocarbon components or said C_3 components and heavier hydrocarbon components, in which process

(a) said gas stream is cooled under pressure to provide a cooled stream;

(b) said cooled stream is expanded to a lower pressure whereby it is further cooled; and

(c) said further cooled stream is directed into a distillation column and fractionated at said lower pressure whereby the components of said relatively less volatile fraction are recovered;

the improvement wherein following cooling, said cooled stream is divided into first and second streams; and

(1) said first stream is cooled to condense substantially all of it and is thereafter expanded to said lower pressure whereby it is further cooled;

(2) said expanded cooled first stream is heated and is thereafter supplied at a mid-column feed position to a contacting and separating device that produces a first overhead vapor stream and a bottom liquid stream, whereupon said bottom liquid stream is supplied to said distillation column;

(3) said second stream is expanded to said lower pressure and is supplied to said contacting and separating device at a first lower column feed position below said mid-column feed position;

(4) a second overhead vapor stream is withdrawn from an upper region of said distillation column and is supplied to said contacting and separating device at a second lower column feed position below said mid-column feed position;

(5) said first overhead vapor stream is heated, thereafter discharging at least a portion of said heated first overhead vapor stream as said volatile residue gas fraction;

(6) a distillation vapor stream is withdrawn from a region of said contacting and separating device below said mid-column feed position and above said first and second lower column feed positions and is directed into heat exchange relation with said expanded cooled first stream and said first overhead vapor stream, whereby said distillation vapor stream is cooled sufficiently to condense at least a part of it and thereby form a residual vapor stream and a condensed stream, thereby supplying at least a portion of the heating of steps (2) and (5);

(7) at least a portion of said condensed stream is supplied to said contacting and separating device at a top feed position; and

(8) the quantities and temperatures of said feed streams to said contacting and separating device are effective to maintain the overhead temperature of said contacting and separating device at a temperature whereby the

major portions of the components in said relatively less volatile fraction are recovered.

5. In a process for the separation of a gas stream containing methane, C_2 components, C_3 components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C_2 components, C_3 components, and heavier hydrocarbon components or said C_3 components and heavier hydrocarbon components, in which process

(a) said gas stream is cooled under pressure to provide a cooled stream;

(b) said cooled stream is expanded to a lower pressure whereby it is further cooled; and

(c) said further cooled stream is directed into a distillation column and fractionated at said lower pressure whereby the components of said relatively less volatile fraction are recovered;

the improvement wherein said gas stream is cooled sufficiently to partially condense it; and

(1) said partially condensed gas stream is separated thereby to provide a vapor stream and at least one liquid stream;

(2) said vapor stream is thereafter divided into first and second streams;

(3) said first stream is cooled to condense substantially all of it and is thereafter expanded to said lower pressure whereby it is further cooled;

(4) said expanded cooled first stream is heated and is thereafter supplied at a mid-column feed position to a contacting and separating device that produces a first overhead vapor stream and a bottom liquid stream, whereupon said bottom liquid stream is supplied to said distillation column;

(5) said second stream is expanded to said lower pressure and is supplied to said contacting and separating device at a first lower column feed position below said mid-column feed position;

(6) at least a portion of said at least one liquid stream is expanded to said lower pressure and is supplied to said distillation column at a mid-column feed position;

(7) a second overhead vapor stream is withdrawn from an upper region of said distillation column and is supplied to said contacting and separating device at a second lower column feed position below said mid-column feed position;

(8) said first overhead vapor stream is heated, thereafter discharging at least a portion of said heated first overhead vapor stream as said volatile residue gas fraction;

(9) a distillation vapor stream is withdrawn from a region of said contacting and separating device below said mid-column feed position and above said first and second lower column feed positions and is directed into heat exchange relation with said expanded cooled first stream and said first overhead vapor stream, whereby said distillation vapor stream is cooled sufficiently to condense at least a part of it and thereby form a residual vapor stream and a condensed stream, thereby supplying at least a portion of the heating of steps (4) and (8);

(10) at least a portion of said condensed stream is supplied to said contacting and separating device at a top feed position; and

(11) the quantities and temperatures of said feed streams to said contacting and separating device are effective to maintain the overhead temperature of said contacting and separating device at a temperature whereby the major portions of the components in said relatively less volatile fraction are recovered.

6. In a process for the separation of a gas stream containing methane, C_2 components, C_3 components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C_2 components, C_3 components, and heavier hydrocarbon components or said C_3 components and heavier hydrocarbon components, in which process

(a) said gas stream is cooled under pressure to provide a cooled stream;

(b) said cooled stream is expanded to a lower pressure whereby it is further cooled; and

(c) said further cooled stream is directed into a distillation column and fractionated at said lower pressure whereby the components of said relatively less volatile fraction are recovered;

the improvement wherein said gas stream is cooled sufficiently to partially condense it; and

(1) said partially condensed gas stream is separated thereby to provide a vapor stream and at least one liquid stream;

(2) said vapor stream is thereafter divided into first and second streams;

(3) said first stream is combined with at least a portion of said at least one liquid stream to form a combined stream, whereupon said combined stream is cooled to condense substantially all of it and is thereafter expanded to said lower pressure whereby it is further cooled;

(4) said expanded cooled combined stream is heated and is thereafter supplied at a mid-column feed position to a contacting and separating device that produces a first overhead vapor stream and a bottom liquid stream, whereupon said bottom liquid stream is supplied to said distillation column;

(5) said second stream is expanded to said lower pressure and is supplied to said contacting and separating device at a first lower column feed position below said mid-column feed position;

(6) any remaining portion of said at least one liquid stream is expanded to said lower pressure and is supplied to said distillation column at a mid-column feed position;

(7) a second overhead vapor stream is withdrawn from an upper region of said distillation column and is supplied to said contacting and separating device at a second lower column feed position below said mid-column feed position;

(8) said first overhead vapor stream is heated, thereafter discharging at least a portion of said heated first overhead vapor stream as said volatile residue gas fraction;

(9) a distillation vapor stream is withdrawn from a region of said contacting and separating device below said mid-column feed position and above said first and second lower column feed positions and is directed into heat exchange relation with said expanded cooled combined stream and said first overhead vapor stream, whereby said distillation vapor stream is cooled sufficiently to condense at least a part of it and thereby form a residual vapor stream and a condensed stream, thereby supplying at least a portion of the heating of steps (4) and (8);

(10) at least a portion of said condensed stream is supplied to said contacting and separating device at a top feed position; and

(11) the quantities and temperatures of said feed streams to said contacting and separating device are effective to maintain the overhead temperature of said contacting and separating device at a temperature whereby the major portions of the components in said relatively less volatile fraction are recovered.

7. The improvement according to claim **1** wherein

(1) said overhead vapor stream is combined with said residual vapor stream to form a combined vapor stream; and

(2) said combined vapor stream is directed into heat exchange relation with said distillation vapor stream and heated, thereby to supply at least a portion of said cooling of said distillation vapor stream, and thereafter discharging at least a portion of said heated combined vapor stream as said volatile residue gas fraction.

8. The improvement according to claim **2** wherein

(1) said overhead vapor stream is combined with said residual vapor stream to form a combined vapor stream; and

(2) said combined vapor stream is directed into heat exchange relation with said distillation vapor stream and heated, thereby to supply at least a portion of said cooling of said distillation vapor stream, and thereafter discharging at least a portion of said heated combined vapor stream as said volatile residue gas fraction.

9. The improvement according to claim **3** wherein

(1) said overhead vapor stream is combined with said residual vapor stream to form a combined vapor stream; and

(2) said combined vapor stream is directed into heat exchange relation with said distillation vapor stream and heated, thereby to supply at least a portion of said cooling of said distillation vapor stream, and thereafter discharging at least a portion of said heated combined vapor stream as said volatile residue gas fraction.

10. The improvement according to claim **4** wherein

(1) said first overhead vapor stream is combined with said residual vapor stream to form a combined vapor stream; and

(2) said combined vapor stream is directed into heat exchange relation with said distillation vapor stream and heated, thereby to supply at least a portion of said cooling of said distillation vapor stream, and thereafter discharging at least a portion of said heated combined vapor stream as said volatile residue gas fraction.

11. The improvement according to claim **5** wherein

(1) said first overhead vapor stream is combined with said residual vapor stream to form a combined vapor stream; and

(2) said combined vapor stream is directed into heat exchange relation with said distillation vapor stream and heated, thereby to supply at least a portion of said cooling of said distillation vapor stream, and thereafter discharging at least a portion of said heated combined vapor stream as said volatile residue gas fraction.

12. The improvement according to claim **6** wherein

(1) said first overhead vapor stream is combined with said residual vapor stream to form a combined vapor stream; and

(2) said combined vapor stream is directed into heat exchange relation with said distillation vapor stream and heated, thereby to supply at least a portion of said cooling of said distillation vapor stream, and thereafter discharging at least a portion of said heated combined vapor stream as said volatile residue gas fraction.

13. The improvement according to claim **1**, **2**, **3**, **7**, **8**, or **9** wherein said distillation vapor stream is withdrawn from a region of said distillation column below said mid-column feed position.

14. The improvement according to claim **1**, **2**, **3**, **7**, **8**, or **9** wherein

(1) a first distillation vapor stream is withdrawn from said region of said distillation column below said upper mid-column feed position and above said mid-column feed position;

(2) a second distillation vapor stream is withdrawn from a region of said distillation column below said mid-column feed position; and

(3) said first distillation vapor stream is combined with said second distillation vapor stream to form said distillation vapor stream.

15. The improvement according to claim **4**, **5**, **6**, **10**, **11**, or **12** wherein said second overhead vapor stream is divided into said distillation vapor stream and a second distillation vapor stream, whereupon said second distillation vapor stream is supplied to said contacting and separating device at said second lower column feed position.

16. The improvement according to claim **4**, **5**, **6**, **10**, **11**, or **12** wherein

(1) a first distillation vapor stream is withdrawn from said region of said contacting and separating device below said mid-column feed position and above said first and second lower column feed positions;

(2) said second overhead vapor stream is divided into a second distillation vapor stream and a third distillation vapor stream, whereupon said second distillation vapor stream is supplied to said contacting and separating device at said second lower column feed position;

(3) said first distillation vapor stream is combined with said third distillation vapor stream to form said distillation vapor stream.

17. The improvement according to claim **1**, **2**, **3**, **7**, **8**, or **9** wherein

(1) said condensed stream is divided into at least a first portion and a second portion;

(2) said first portion is supplied to said distillation column at said top feed position; and

(3) said second portion is supplied to said distillation column at a second mid-column feed position below said mid-column feed position.

18. The improvement according to claim **13** wherein

(1) said condensed stream is divided into at least a first portion and a second portion;

(2) said first portion is supplied to said distillation column at said top feed position; and

(3) said second portion is supplied to said distillation column at a second mid-column feed position below said mid-column feed position.

19. The improvement according to claim **14** wherein

(1) said condensed stream is divided into at least a first portion and a second portion;

(2) said first portion is supplied to said distillation column at said top feed position; and

(3) said second portion is supplied to said distillation column at a second mid-column feed position below said mid-column feed position.

20. The improvement according to claim **4**, **5**, **6**, **10**, **11**, or **12** wherein
(1) said condensed stream is divided into at least a first portion and a second portion;
(2) said first portion is supplied to said contacting and separating device at said top feed position; and
(3) said second portion is supplied to said distillation column at a top feed position.

21. The improvement according to claim **15** wherein
(1) said condensed stream is divided into at least a first portion and a second portion;
(2) said first portion is supplied to said contacting and separating device at said top feed position; and
(3) said second portion is supplied to said distillation column at a top feed position.

22. The improvement according to claim **16** wherein
(1) said condensed stream is divided into at least a first portion and a second portion;
(2) said first portion is supplied to said contacting and separating device at said top feed position; and
(3) said second portion is supplied to said distillation column at a top feed position.

23. In an apparatus for the separation of a gas stream containing methane, C_2 components, C_3 components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C_2 components, C_3 components, and heavier hydrocarbon components or said C_3 components and heavier hydrocarbon components, in said apparatus there being
(a) a first cooling means to cool said gas stream under pressure connected to provide a cooled stream under pressure;
(b) a first expansion means connected to receive at least a portion of said cooled stream under pressure and expand it to a lower pressure, whereby said stream is further cooled; and
(c) a distillation column connected to receive said further cooled stream, said distillation column being adapted to separate said further cooled stream into an overhead vapor stream and said relatively less volatile fraction;

the improvement wherein said apparatus includes
(1) dividing means connected to said first cooling means to receive said cooled stream and divide it into first and second streams;
(2) second cooling means connected to said dividing means to receive said first stream and cool it sufficiently to substantially condense it;
(3) second expansion means connected to said second cooling means to receive said substantially condensed first stream and expand it to said lower pressure;
(4) heat exchange means connected to said second expansion means to receive said expanded cooled first stream and heat it, said heat exchange means being further connected to said distillation column to supply said heated expanded first stream to said distillation column at an upper mid-column feed position;
(5) said first expansion means being connected to said dividing means to receive said second stream and expand it to said lower pressure, said first expansion means being further connected to said distillation column to supply said expanded second stream to said distillation column at a mid-column feed position below said upper mid-column feed position;
(6) said heat exchange means being further connected to said distillation column to receive at least a portion of said overhead vapor stream separated therein and heat it, thereafter discharging at least a portion of said heated overhead vapor stream as said volatile residue gas fraction;
(7) vapor withdrawing means connected to said distillation column to receive a distillation vapor stream from a region of said distillation column below said upper mid-column feed position and above said mid-column feed position;
(8) said heat exchange means being further connected to said vapor withdrawing means to receive said distillation vapor stream and cool it sufficiently to condense at least a part of it, thereby supplying at least a portion of the heating of steps (4) and (6);
(9) separating means connected to said heat exchange means to receive said partially condensed distillation vapor stream and separate it, thereby forming a residual vapor stream and a condensed stream, said separating means being further connected to said distillation column to supply at least a portion of said condensed stream to said distillation column at a top feed position; and
(10) control means adapted to regulate the quantities and temperatures of said feed streams to said distillation column to maintain the overhead temperature of said distillation column at a temperature whereby the major portions of the components in said relatively less volatile fraction are recovered.

24. In an apparatus for the separation of a gas stream containing methane, C_2 components, C_3 components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C_2 components, C_3 components, and heavier hydrocarbon components or said C_3 components and heavier hydrocarbon components, in said apparatus there being
(a) a first cooling means to cool said gas stream under pressure connected to provide a cooled stream under pressure;
(b) a first expansion means connected to receive at least a portion of said cooled stream under pressure and expand it to a lower pressure, whereby said stream is further cooled; and
(c) a distillation column connected to receive said further cooled stream, said distillation column being adapted to separate said further cooled stream into an overhead vapor stream and said relatively less volatile fraction;

the improvement wherein said apparatus includes
(1) said first cooling means being adapted to cool said gas stream under pressure sufficiently to partially condense it;
(2) first separating means connected to said first cooling means to receive said partially condensed gas stream and separate it into a vapor stream and at least one liquid stream;
(3) dividing means connected to said first separating means to receive said vapor stream and divide it into first and second streams;
(4) second cooling means connected to said dividing means to receive said first stream and cool it sufficiently to substantially condense it;

(5) second expansion means connected to said second cooling means to receive said substantially condensed first stream and expand it to said lower pressure;

(6) heat exchange means connected to said second expansion means to receive said expanded cooled first stream and heat it, said heat exchange means being further connected to said distillation column to supply said heated expanded first stream to said distillation column at an upper mid-column feed position;

(7) said first expansion means being connected to said dividing means to receive said second stream and expand it to said lower pressure, said first expansion means being further connected to said distillation column to supply said expanded second stream to said distillation column at a mid-column feed position below said upper mid-column feed position;

(8) third expansion means connected to said first separating means to receive at least a portion of said at least one liquid stream and expand it to said lower pressure, said third expansion means being further connected to said distillation column to supply said expanded liquid stream to said distillation column at a lower mid-column feed position below said mid-column feed position;

(9) said heat exchange means being further connected to said distillation column to receive at least a portion of said overhead vapor stream separated therein and heat it, thereafter discharging at least a portion of said heated overhead vapor stream as said volatile residue gas fraction;

(10) vapor withdrawing means connected to said distillation column to receive a distillation vapor stream from a region of said distillation column below said upper mid-column feed position and above said mid-column feed position;

(11) said heat exchange means being further connected to said vapor withdrawing means to receive said distillation vapor stream and cool it sufficiently to condense at least a part of it, thereby supplying at least a portion of the heating of steps (6) and (9);

(12) second separating means connected to said heat exchange means to receive said partially condensed distillation vapor stream and separate it, thereby forming a residual vapor stream and a condensed stream, said second separating means being further connected to said distillation column to supply at least a portion of said condensed stream to said distillation column at a top feed position; and

(13) control means adapted to regulate the quantities and temperatures of said feed streams to said distillation column to maintain the overhead temperature of said distillation column at a temperature whereby the major portions of the components in said relatively less volatile fraction are recovered.

25. In an apparatus for the separation of a gas stream containing methane, C_2 components, C_3 components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C_2 components, C_3 components, and heavier hydrocarbon components or said C_3 components and heavier hydrocarbon components, in said apparatus there being

(a) a first cooling means to cool said gas stream under pressure connected to provide a cooled stream under pressure;

(b) a first expansion means connected to receive at least a portion of said cooled stream under pressure and expand it to a lower pressure, whereby said stream is further cooled; and

(c) a distillation column connected to receive said further cooled stream, said distillation column being adapted to separate said further cooled stream into an overhead vapor stream and said relatively less volatile fraction;

the improvement wherein said apparatus includes

(1) said first cooling means being adapted to cool said gas stream under pressure sufficiently to partially condense it;

(2) first separating means connected to said first cooling means to receive said partially condensed gas stream and separate it into a vapor stream and at least one liquid stream;

(3) dividing means connected to said first separating means to receive said vapor stream and divide it into first and second streams;

(4) combining means connected to said dividing means and said first separating means to receive said first stream and at least a portion of said at least one liquid stream and form a combined stream;

(5) second cooling means connected to said combining means to receive said combined stream and cool it sufficiently to substantially condense it;

(6) second expansion means connected to said second cooling means to receive said substantially condensed combined stream and expand it to said lower pressure;

(7) heat exchange means connected to said second expansion means to receive said expanded cooled combined stream and heat it, said heat exchange means being further connected to said distillation column to supply said heated expanded combined stream to said distillation column at an upper mid-column feed position;

(8) said first expansion means being connected to said dividing means to receive said second stream and expand it to said lower pressure, said first expansion means being further connected to said distillation column to supply said expanded second stream to said distillation column at a mid-column feed position below said upper mid-column feed position;

(9) third expansion means being connected to said first separating means to receive any remaining portion of said at least one liquid stream and expand it to said lower pressure, said third expansion means being further connected to said distillation column to supply said expanded liquid stream to said distillation column at a lower mid-column feed position below said mid-column feed position;

(10) said heat exchange means being further connected to said distillation column to receive at least a portion of said overhead vapor stream separated therein and heat it, thereafter discharging at least a portion of said heated overhead vapor stream as said volatile residue gas fraction;

(11) vapor withdrawing means connected to said distillation column to receive a distillation vapor stream from a region of said distillation column below said upper mid-column feed position and above said mid-column feed position;

(12) said heat exchange means being further connected to said vapor withdrawing means to receive said distillation vapor stream and cool it sufficiently to condense at

least a part of it, thereby supplying at least a portion of the heating of steps (7) and (10);

(13) second separating means connected to said heat exchange means to receive said partially condensed distillation vapor stream and separate it, thereby forming a residual vapor stream and a condensed stream, said second separating means being further connected to said distillation column to supply at least a portion of said condensed stream to said distillation column at a top feed position; and

(14) control means adapted to regulate the quantities and temperatures of said feed streams to said distillation column to maintain the overhead temperature of said distillation column at a temperature whereby the major portions of the components in said relatively less volatile fraction are recovered.

26. In an apparatus for the separation of a gas stream containing methane, C_2 components, C_3 components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C_2 components, C_3 components, and heavier hydrocarbon components or said C_3 components and heavier hydrocarbon components, in said apparatus there being

(a) a first cooling means to cool said gas stream under pressure connected to provide a cooled stream under pressure;

(b) a first expansion means connected to receive at least a portion of said cooled stream under pressure and expand it to a lower pressure, whereby said stream is further cooled; and

(c) a distillation column connected to receive said further cooled stream, said distillation column being adapted to separate said further cooled stream into a first overhead vapor stream and said relatively less volatile fraction;

the improvement wherein said apparatus includes

(1) dividing means connected to said first cooling means to receive said cooled stream and divide it into first and second streams;

(2) second cooling means connected to said dividing means to receive said first stream and cool it sufficiently to substantially condense it;

(3) second expansion means connected to said second cooling means to receive said substantially condensed first stream and expand it to said lower pressure;

(4) heat exchange means connected to said second expansion means to receive said expanded cooled first stream and heat it, said heat exchange means being further connected to a contacting and separating means to supply said heated expanded first stream to said contacting and separating means at a mid-column feed position, said contacting and separating means being adapted to produce a second overhead vapor stream and a bottom liquid stream;

(5) said first expansion means being connected to said dividing means to receive said second stream and expand it to said lower pressure, said first expansion means being further connected to said contacting and separating means to supply said expanded second stream to said contacting and separating means at a first lower column feed position below said mid-column feed position;

(6) said distillation column being connected to said contacting and separating means to receive at least a portion of said bottom liquid stream;

(7) said contacting and separating means being further connected to said distillation column to receive at least a portion of said first overhead vapor stream at a second lower column feed position below said mid-column feed position;

(8) said heat exchange means being further connected to said contacting and separating means to receive at least a portion of said second overhead vapor stream separated therein and heat it, thereafter discharging at least a portion of said heated second overhead vapor stream as said volatile residue gas fraction;

(9) vapor withdrawing means connected to said contacting and separating means to receive a distillation vapor stream from a region of said contacting and separating device below said mid-column feed position and above said first and second lower column feed positions;

(10) said heat exchange means being further connected to said vapor withdrawing means to receive said distillation vapor stream and cool it sufficiently to condense at least a part of it, thereby supplying at least a portion of the heating of steps (4) and (8);

(11) separating means connected to said heat exchange means to receive said partially condensed distillation vapor stream and separate it, thereby forming a residual vapor stream and a condensed stream, said separating means being further connected to said contacting and separating means to supply at least a portion of said condensed stream to said contacting and separating means at a top feed position; and

(12) control means adapted to regulate the quantities and temperatures of said feed streams to said contacting and separating means to maintain the overhead temperature of said contacting and separating means at a temperature whereby the major portions of the components in said relatively less volatile fraction are recovered.

27. In an apparatus for the separation of a gas stream containing methane, C_2 components, C_3 components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C_2 components, C_3 components, and heavier hydrocarbon components or said C_3 components and heavier hydrocarbon components, in said apparatus there being

(a) a first cooling means to cool said gas stream under pressure connected to provide a cooled stream under pressure;

(b) a first expansion means connected to receive at least a portion of said cooled stream under pressure and expand it to a lower pressure, whereby said stream is further cooled; and

(c) a distillation column connected to receive said further cooled stream, said distillation column being adapted to separate said further cooled stream into a first overhead vapor stream and said relatively less volatile fraction;

the improvement wherein said apparatus includes

(1) said first cooling means being adapted to cool said gas stream under pressure sufficiently to partially condense it;

(2) first separating means connected to said first cooling means to receive said partially condensed gas stream and separate it into a vapor stream and at least one liquid stream;

(3) dividing means connected to said first separating means to receive said vapor stream and divide it into first and second streams;

(4) second cooling means connected to said dividing means to receive said first stream and cool it sufficiently to substantially condense it;

(5) second expansion means connected to said second cooling means to receive said substantially condensed first stream and expand it to said lower pressure;

(6) heat exchange means connected to said second expansion means to receive said expanded cooled first stream and heat it, said heat exchange means being further connected to a contacting and separating means to supply said heated expanded first stream to said contacting and separating means at a mid-column feed position, said contacting and separating means being adapted to produce a second overhead vapor stream and a bottom liquid stream;

(7) said first expansion means being connected to said dividing means to receive said second stream and expand it to said lower pressure, said first expansion means being further connected to said contacting and separating means to supply said expanded second stream to said contacting and separating means at a first lower column feed position below said mid-column feed position;

(8) third expansion means connected to said first separating means to receive at least a portion of said at least one liquid stream and expand it to said lower pressure, said third expansion means being further connected to said distillation column to supply said expanded liquid stream to said distillation column at a mid-column feed position;

(9) said distillation column being connected to said contacting and separating means to receive at least a portion of said bottom liquid stream;

(10) said contacting and separating means being further connected to said distillation column to receive at least a portion of said first overhead vapor stream at a second lower column feed position below said mid-column feed position;

(11) said heat exchange means being further connected to said contacting and separating means to receive at least a portion of said second overhead vapor stream separated therein and heat it, thereafter discharging at least a portion of said heated second overhead vapor stream as said volatile residue gas fraction;

(12) vapor withdrawing means connected to said contacting and separating means to receive a distillation vapor stream from a region of said contacting and separating device below said mid-column feed position and above said first and second lower column feed positions;

(13) said heat exchange means being further connected to said vapor withdrawing means to receive said distillation vapor stream and cool it sufficiently to condense at least a part of it, thereby supplying at least a portion of the heating of steps (6) and (11);

(14) second separating means connected to said heat exchange means to receive said partially condensed distillation vapor stream and separate it, thereby forming a residual vapor stream and a condensed stream, said second separating means being further connected to said contacting and separating means to supply at least a portion of said condensed stream to said contacting and separating means at a top feed position; and

(15) control means adapted to regulate the quantities and temperatures of said feed streams to said contacting and separating means to maintain the overhead temperature of said contacting and separating means at a temperature whereby the major portions of the components in said relatively less volatile fraction are recovered.

28. In an apparatus for the separation of a gas stream containing methane, C_2 components, C_3 components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C_2 components, C_3 components, and heavier hydrocarbon components or said C_3 components and heavier hydrocarbon components, in said apparatus there being

(a) a first cooling means to cool said gas stream under pressure connected to provide a cooled stream under pressure;

(b) a first expansion means connected to receive at least a portion of said cooled stream under pressure and expand it to a lower pressure, whereby said stream is further cooled; and

(c) a distillation column connected to receive said further cooled stream, said distillation column being adapted to separate said further cooled stream into a first overhead vapor stream and said relatively less volatile fraction;

the improvement wherein said apparatus includes

(1) said first cooling means being adapted to cool said gas stream under pressure sufficiently to partially condense it;

(2) first separating means connected to said first cooling means to receive said partially condensed gas stream and separate it into a vapor stream and at least one liquid stream;

(3) dividing means connected to said first separating means to receive said vapor stream and divide it into first and second streams;

(4) combining means connected to said dividing means and said first separating means to receive said first stream and at least a portion of said at least one liquid stream and form a combined stream;

(5) second cooling means connected to said combining means to receive said combined stream and cool it sufficiently to substantially condense it;

(6) second expansion means connected to said second cooling means to receive said substantially condensed combined stream and expand it to said lower pressure;

(7) heat exchange means connected to said second expansion means to receive said expanded cooled combined stream and heat it, said heat exchange means being further connected to a contacting and separating means to supply said heated expanded combined stream to said contacting and separating means at a mid-column feed position, said contacting and separating means being adapted to produce a second overhead vapor stream and a bottom liquid stream;

(8) said first expansion means being connected to said dividing means to receive said second stream and expand it to said lower pressure, said first expansion means being further connected to said contacting and

separating means to supply said expanded second stream to said contacting and separating means at a first lower column feed position below said mid-column feed position;

(9) third expansion means connected to said first separating means to receive any remaining portion of said at least one liquid stream and expand it to said lower pressure, said third expansion means being further connected to said distillation column to supply said expanded liquid stream to said distillation column at a mid-column feed position;

(10) said distillation column being connected to said contacting and separating means to receive at least a portion of said bottom liquid stream;

(11) said contacting and separating means being further connected to said distillation column to receive at least a portion of said first overhead vapor stream at a second lower column feed position below said mid-column feed position;

(12) said heat exchange means being further connected to said contacting and separating means to receive at least a portion of said second overhead vapor stream separated therein and heat it, thereafter discharging at least a portion of said heated second overhead vapor stream as said volatile residue gas fraction;

(13) vapor withdrawing means connected to said contacting and separating means to receive a distillation vapor stream from a region of said contacting and separating device below said mid-column feed position and above said first and second lower column feed positions;

(14) said heat exchange means being further connected to said vapor withdrawing means to receive said distillation vapor stream and cool it sufficiently to condense at least a part of it, thereby supplying at least a portion of the heating of steps (7) and (12);

(15) second separating means connected to said heat exchange means to receive said partially condensed distillation vapor stream and separate it, thereby forming a residual vapor stream and a condensed stream, said second separating means being further connected to said contacting and separating means to supply at least a portion of said condensed stream to said contacting and separating means at a top feed position; and

(16) control means adapted to regulate the quantities and temperatures of said feed streams to said contacting and separating means to maintain the overhead temperature of said contacting and separating means at a temperature whereby the major portions of the components in said relatively less volatile fraction are recovered.

29. The improvement according to claim **23** wherein

(1) a combining means is connected to said distillation column and said separating means to receive said overhead vapor stream and said residual vapor stream and form a combined vapor stream; and

(2) said heat exchange means is adapted to receive said combined vapor stream from said combining means and direct it into heat exchange relation with said distillation vapor stream, thereby heating said combined vapor stream and supplying at least a portion of said cooling of said distillation vapor stream, and thereafter discharging at least a portion of said heated combined vapor stream as said volatile residue gas fraction.

30. The improvement according to claim **24** wherein

(1) a combining means is connected to said distillation column and said second separating means to receive said overhead vapor stream and said residual vapor stream and form a combined vapor stream; and

(2) said heat exchange means is adapted to receive said combined vapor stream from said combining means and direct it into heat exchange relation with said distillation vapor stream, thereby heating said combined vapor stream and supplying at least a portion of said cooling of said distillation vapor stream, and thereafter discharging at least a portion of said heated combined vapor stream as said volatile residue gas fraction.

31. The improvement according to claim **25** wherein

(1) a second combining means is connected to said distillation column and said second separating means to receive said overhead vapor stream and said residual vapor stream and form a combined vapor stream; and

(2) said heat exchange means is adapted to receive said combined vapor stream from said second combining means and direct it into heat exchange relation with said distillation vapor stream, thereby heating said combined vapor stream and supplying at least a portion of said cooling of said distillation vapor stream, and thereafter discharging at least a portion of said heated combined vapor stream as said volatile residue gas fraction.

32. The improvement according to claim **26** wherein

(1) a combining means is connected to said contacting and separating means and said separating means to receive said second overhead vapor stream and said residual vapor stream and form a combined vapor stream; and

(2) said heat exchange means is adapted to receive said combined vapor stream from said combining means and direct it into heat exchange relation with said distillation vapor stream, thereby heating said combined vapor stream and supplying at least a portion of said cooling of said distillation vapor stream, and thereafter discharging at least a portion of said heated combined vapor stream as said volatile residue gas fraction.

33. The improvement according to claim **27** wherein

(1) a combining means is connected to said contacting and separating means and said second separating means to receive said second overhead vapor stream and said residual vapor stream and form a combined vapor stream; and

(2) said heat exchange means is adapted to receive said combined vapor stream from said combining means and direct it into heat exchange relation with said distillation vapor stream, thereby heating said combined vapor stream and supplying at least a portion of said cooling of said distillation vapor stream, and thereafter discharging at least a portion of said heated combined vapor stream as said volatile residue gas fraction.

34. The improvement according to claim **28** wherein

(1) a second combining means is connected to said contacting and separating means and said second separating means to receive said second overhead vapor stream and said residual vapor stream and form a combined vapor stream; and

(2) said heat exchange means is adapted to receive said combined vapor stream from said second combining means and direct it into heat exchange relation with said distillation vapor stream, thereby heating said combined vapor stream and supplying at least a portion of said

cooling of said distillation vapor stream, and thereafter discharging at least a portion of said heated combined vapor stream as said volatile residue gas fraction.

35. The improvement according to claim **23** or **29** wherein said vapor withdrawing means is adapted to be connected to said distillation column to receive said distillation vapor stream from a region of said distillation column below said mid-column feed position.

36. The improvement according to claim **24**, **25**, **30**, or **31** wherein said vapor withdrawing means is adapted to be connected to said distillation column to receive said distillation vapor stream from a region of said distillation column below said mid-column feed position.

37. The improvement according to claim **23** wherein

(1) said vapor withdrawing means is adapted to be connected to said distillation column to receive a first distillation vapor stream from said region of said distillation column below said upper mid-column feed position and above said mid-column feed position;

(2) a second vapor withdrawing means is connected to said distillation column to receive a second distillation vapor stream from a region of said distillation column below said mid-column feed position;

(3) a combining means is connected to said vapor withdrawing means and said second vapor withdrawing means to receive said first distillation vapor stream and said second distillation vapor stream and form said distillation vapor stream; and

(4) said heat exchange means is adapted to be connected to said combining means to receive said distillation vapor stream.

38. The improvement according to claim **24** wherein

(1) said vapor withdrawing means is adapted to be connected to said distillation column to receive a first distillation vapor stream from said region of said distillation column below said upper mid-column feed position and above said mid-column feed position;

(2) a second vapor withdrawing means is connected to said distillation column to receive a second distillation vapor stream from a region of said distillation column below said mid-column feed position;

(3) a combining means is connected to said vapor withdrawing means and said second vapor withdrawing means to receive said first distillation vapor stream and said second distillation vapor stream and form said distillation vapor stream; and

(4) said heat exchange means is adapted to be connected to said combining means to receive said distillation vapor stream.

39. The improvement according to claim **25** or **30** wherein

(1) said vapor withdrawing means is adapted to be connected to said distillation column to receive a first distillation vapor stream from said region of said distillation column below said upper mid-column feed position and above said mid-column feed position;

(2) a second vapor withdrawing means is connected to said distillation column to receive a second distillation vapor stream from a region of said distillation column below said mid-column feed position;

(3) a second combining means is connected to said vapor withdrawing means and said second vapor withdrawing means to receive said first distillation vapor stream and said second distillation vapor stream and form said distillation vapor stream; and

(4) said heat exchange means is adapted to be connected to said second combining means to receive said distillation vapor stream.

40. The improvement according to claim **29** wherein

(1) said vapor withdrawing means is adapted to be connected to said distillation column to receive a first distillation vapor stream from said region of said distillation column below said upper mid-column feed position and above said mid-column feed position;

(2) a second vapor withdrawing means is connected to said distillation column to receive a second distillation vapor stream from a region of said distillation column below said mid-column feed position;

(3) a second combining means is connected to said vapor withdrawing means and said second vapor withdrawing means to receive said first distillation vapor stream and said second distillation vapor stream and form said distillation vapor stream; and

(4) said heat exchange means is adapted to be connected to said second combining means to receive said distillation vapor stream.

41. The improvement according to claim **31** wherein

(1) said vapor withdrawing means is adapted to be connected to said distillation column to receive a first distillation vapor stream from said region of said distillation column below said upper mid-column feed position and above said mid-column feed position;

(2) a second vapor withdrawing means is connected to said distillation column to receive a second distillation vapor stream from a region of said distillation column below said mid-column feed position;

(3) a third combining means is connected to said vapor withdrawing means and said second vapor withdrawing means to receive said first distillation vapor stream and said second distillation vapor stream and form said distillation vapor stream; and

(4) said heat exchange means is adapted to be connected to said third combining means to receive said distillation vapor stream.

42. The improvement according to claim **26** or **32** wherein

(1) a second dividing means is connected to said distillation column to receive said first overhead vapor stream and divide it into said distillation vapor stream and a second distillation vapor stream;

(2) said contacting and separating means is adapted to be connected to said second dividing means to receive said second distillation vapor stream at said second lower column feed position; and

(3) said heat exchange means is adapted to be connected to said second dividing means to receive said distillation vapor stream.

43. The improvement according to claim **27**, **28**, **33**, or **34** wherein

(1) a second dividing means is connected to said distillation column to receive said first overhead vapor stream and divide it into said distillation vapor stream and a second distillation vapor stream;

(2) said contacting and separating means is adapted to be connected to said second dividing means to receive said second distillation vapor stream at said second lower column feed position; and

(3) said heat exchange means is adapted to be connected to said second dividing means to receive said distillation vapor stream.

44. The improvement according to claim **26** wherein

(1) said vapor withdrawing means is adapted to be connected to said contacting and separating means to receive a first distillation vapor stream from said region of said contacting and separating means below said mid-column feed position and above said first and second lower column feed positions;

(2) a second dividing means is connected to said distillation column to receive said first overhead vapor stream and divide it into a second distillation vapor stream and a third distillation vapor stream;

(3) said contacting and separating means is adapted to be connected to said second dividing means to receive said second distillation vapor stream at said second lower column feed position;

(4) a combining means is connected to said vapor withdrawing means and said second dividing means to receive said first distillation vapor stream and said third distillation vapor stream and form said distillation vapor stream; and

(5) said heat exchange means is adapted to be connected to said combining means to receive said distillation vapor stream.

45. The improvement according to claim **27** wherein

(1) said vapor withdrawing means is adapted to be connected to said contacting and separating means to receive a first distillation vapor stream from said region of said contacting and separating means below said mid-column feed position and above said first and second lower column feed positions;

(2) a second dividing means is connected to said distillation column to receive said first overhead vapor stream and divide it into a second distillation vapor stream and a third distillation vapor stream;

(3) said contacting and separating means is adapted to be connected to said second dividing means to receive said second distillation vapor stream at said second lower column feed position;

(4) a combining means is connected to said vapor withdrawing means and said second dividing means to receive said first distillation vapor stream and said third distillation vapor stream and form said distillation vapor stream; and

(5) said heat exchange means is adapted to be connected to said combining means to receive said distillation vapor stream.

46. The improvement according to claim **28** or **33** wherein

(1) said vapor withdrawing means is adapted to be connected to said contacting and separating means to receive a first distillation vapor stream from said region of said contacting and separating means below said mid-column feed position and above said first and second lower column feed positions;

(2) a second dividing means is connected to said distillation column to receive said first overhead vapor stream and divide it into a second distillation vapor stream and a third distillation vapor stream;

(3) said contacting and separating means is adapted to be connected to said second dividing means to receive said second distillation vapor stream at said second lower column feed position;

(4) a second combining means is connected to said vapor withdrawing means and said second dividing means to receive said first distillation vapor stream and said third distillation vapor stream and form said distillation vapor stream; and

(5) said heat exchange means is adapted to be connected to said second combining means to receive said distillation vapor stream.

47. The improvement according to claim **32** wherein

(1) said vapor withdrawing means is adapted to be connected to said contacting and separating means to receive a first distillation vapor stream from said region of said contacting and separating means below said mid-column feed position and above said first and second lower column feed positions;

(2) a second dividing means is connected to said distillation column to receive said first overhead vapor stream and divide it into a second distillation vapor stream and a third distillation vapor stream;

(3) said contacting and separating means is adapted to be connected to said second dividing means to receive said second distillation vapor stream at said second lower column feed position;

(4) a second combining means is connected to said vapor withdrawing means and said second dividing means to receive said first distillation vapor stream and said third distillation vapor stream and form said distillation vapor stream; and

(5) said heat exchange means is adapted to be connected to said second combining means to receive said distillation vapor stream.

48. The improvement according to claim **34** wherein

(1) said vapor withdrawing means is adapted to be connected to said contacting and separating means to receive a first distillation vapor stream from said region of said contacting and separating means below said mid-column feed position and above said first and second lower column feed positions;

(2) a second dividing means is connected to said distillation column to receive said first overhead vapor stream and divide it into a second distillation vapor stream and a third distillation vapor stream;

(3) said contacting and separating means is adapted to be connected to said second dividing means to receive said second distillation vapor stream at said second lower column feed position;

(4) a third combining means is connected to said vapor withdrawing means and said second dividing means to receive said first distillation vapor stream and said third distillation vapor stream and form said distillation vapor stream; and

(5) said heat exchange means is adapted to be connected to said third combining means to receive said distillation vapor stream.

49. The improvement according to claim **23**, **29**, **37**, or **40** wherein

(1) a second dividing means is connected to said separating means to receive said condensed stream and divide it into at least a first portion and a second portion;

(2) said distillation column is adapted to be connected to said second dividing means to receive said first portion at said top feed position; and

(3) said distillation column is further adapted to be connected to said second dividing means to receive said second portion at a second mid-column feed position below said mid-column feed position.

50. The improvement according to claim **24**, **25**, **30**, **31**, **38**, or **41** wherein

(1) a second dividing means is connected to said second separating means to receive said condensed stream and divide it into at least a first portion and a second portion;

(2) said distillation column is adapted to be connected to said second dividing means to receive said first portion at said top feed position; and

(3) said distillation column is further adapted to be connected to said second dividing means to receive said second portion at a second mid-column feed position below said mid-column feed position.

51. The improvement according to claim **35** wherein

(1) a second dividing means is connected to said separating means to receive said condensed stream and divide it into at least a first portion and a second portion;

(2) said distillation column is adapted to be connected to said second dividing means to receive said first portion at said top feed position; and

(3) said distillation column is further adapted to be connected to said second dividing means to receive said second portion at a second mid-column feed position below said mid-column feed position.

52. The improvement according to claim **36** wherein

(1) a second dividing means is connected to said second separating means to receive said condensed stream and divide it into at least a first portion and a second portion;

(2) said distillation column is adapted to be connected to said second dividing means to receive said first portion at said top feed position; and

(3) said distillation column is further adapted to be connected to said second dividing means to receive said second portion at a second mid-column feed position below said mid-column feed position.

53. The improvement according to claim **39** wherein

(1) a second dividing means is connected to said second separating means to receive said condensed stream and divide it into at least a first portion and a second portion;

(2) said distillation column is adapted to be connected to said second dividing means to receive said first portion at said top feed position; and

(3) said distillation column is further adapted to be connected to said second dividing means to receive said second portion at a second mid-column feed position below said mid-column feed position.

54. The improvement according to claim **26** or **32** wherein

(1) a second dividing means is connected to said separating means to receive said condensed stream and divide it into at least a first portion and a second portion;

(2) said contacting and separating means is adapted to be connected to said second dividing means to receive said first portion at said top feed position; and

(3) said distillation column is adapted to be connected to said second dividing means to receive said second portion at a top feed position.

55. The improvement according to claim **27**, **28**, **33**, or **34** wherein

(1) a second dividing means is connected to said second separating means to receive said condensed stream and divide it into at least a first portion and a second portion;

(2) said contacting and separating means is adapted to be connected to said second dividing means to receive said first portion at said top feed position; and

(3) said distillation column is adapted to be connected to said second dividing means to receive said second portion at a top feed position.

56. The improvement according to claim **42** wherein

(1) a third dividing means is connected to said separating means to receive said condensed stream and divide it into at least a first portion and a second portion;

(2) said contacting and separating means is adapted to be connected to said third dividing means to receive said first portion at said top feed position; and

(3) said distillation column is adapted to be connected to said third dividing means to receive said second portion at a top feed position.

57. The improvement according to claim **43** wherein

(1) a third dividing means is connected to said second separating means to receive said condensed stream and divide it into at least a first portion and a second portion;

(2) said contacting and separating means is adapted to be connected to said third dividing means to receive said first portion at said top feed position; and

(3) said distillation column is adapted to be connected to said third dividing means to receive said second portion at a top feed position.

58. The improvement according to claim **44** or **47** wherein

(1) a third dividing means is connected to said separating means to receive said condensed stream and divide it into at least a first portion and a second portion;

(2) said contacting and separating means is adapted to be connected to said third dividing means to receive said first portion at said top feed position; and

(3) said distillation column is adapted to be connected to said third dividing means to receive said second portion at a top feed position.

59. The improvement according to claim **45** or **48** wherein

(1) a third dividing means is connected to said second separating means to receive said condensed stream and divide it into at least a first portion and a second portion;

(2) said contacting and separating means is adapted to be connected to said third dividing means to receive said first portion at said top feed position; and

(3) said distillation column is adapted to be connected to said third dividing means to receive said second portion at a top feed position.

60. The improvement according to claim **46** wherein

(1) a third dividing means is connected to said second separating means to receive said condensed stream and divide it into at least a first portion and a second portion;

(2) said contacting and separating means is adapted to be connected to said third dividing means to receive said first portion at said top feed position; and

(3) said distillation column is adapted to be connected to said third dividing means to receive said second portion at a top feed position.

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