

(12) STANDARD PATENT
(19) AUSTRALIAN PATENT OFFICE

(11) Application No. **AU 2010308519 B2**

(54) Title
Hydrocarbon gas processing

(51) International Patent Classification(s)
F25J 3/00 (2006.01)

(21) Application No: **2010308519**

(22) Date of Filing: **2010.08.27**

(87) WIPO No: **WO11/049672**

(30) Priority Data

(31) Number	(32) Date	(33) Country
61/351,045	2010.06.03	US
61/244,181	2009.09.21	US
12/869,007	2010.08.26	US
12/869,139	2010.08.26	US
12/868,993	2010.08.26	US
61/346,150	2010.05.19	US

(43) Publication Date: **2011.04.28**

(44) Accepted Journal Date: **2015.05.07**

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(56) Related Art
US 2008/0028790 A1
US 2008/0078205 A1

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
28 April 2011 (28.04.2011)

PCT

(10) International Publication Number
WO 2011/049672 A1

(51) International Patent Classification:
F25J 3/00 (2006.01)

(21) International Application Number:
PCT/US2010/046967

(22) International Filing Date:
27 August 2010 (27.08.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/244,181 21 September 2009 (21.09.2009) US
61/346,150 19 May 2010 (19.05.2010) US
61/351,045 3 June 2010 (03.06.2010) US
12/868,993 26 August 2010 (26.08.2010) US
12/869,139 26 August 2010 (26.08.2010) US
12/869,007 26 August 2010 (26.08.2010) US

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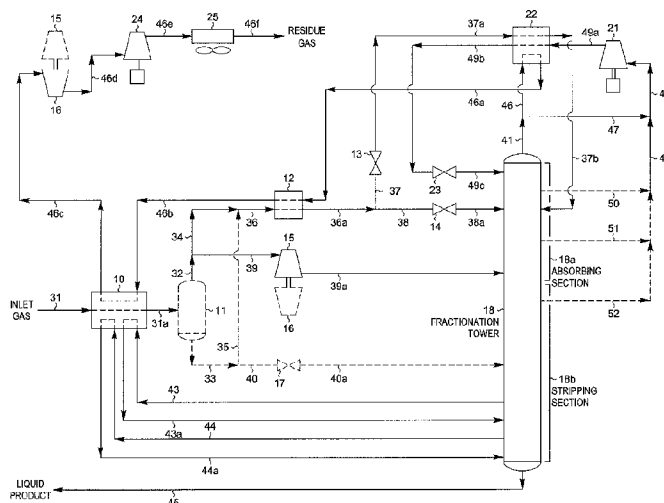
(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU,

[Continued on next page]

(54) Title: HYDROCARBON GAS PROCESSING

FIG. 3



(57) Abstract: A process and an apparatus for recovering heavier hydrocarbons from a hydrocarbon gas stream is disclosed. The stream is cooled and divided into first and second streams. The first stream is further cooled and divided into first and second portions. The first and second portions are expanded to the fractionation tower pressure and supplied to the tower at upper mid-column feed positions after the expanded second portion is heated. The second stream is expanded to tower pressure and supplied at a mid-column feed position. A distillation vapor stream is withdrawn above the feed point of the second stream, combined with a portion of the tower overhead vapor stream, compressed to higher pressure, and cooled to condense at least a part of it, forming a condensed stream. At least a portion of the condensed stream is expanded to tower pressure and directed to the tower as its top feed.

WO 2011/049672 A1

WO 2011/049672 A1



LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, **Published:**
SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, — *with international search report (Art. 21(3))*
GW, ML, MR, NE, SN, TD, TG).

HYDROCARBON GAS PROCESSING

SPECIFICATION

BACKGROUND OF THE INVENTION

[0001] This invention relates to a process and an apparatus for the separation of a gas containing hydrocarbons.

[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, 90.5% methane, 4.1% ethane and other C₂ components, 1.3% propane and other C₃ components, 0.4% iso-butane, 0.3% normal butane, and 0.5% 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. Patent 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. Patent No. 33,408; and co-pending application 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 C₂, C₃, and C₄+ components occur because the top liquid feed contains substantial quantities of these components and

heavier hydrocarbon components, resulting in corresponding equilibrium quantities of C₂ components, C₃ components, C₄ 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 C₂ components, C₃ components, C₄ 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. Patent Nos. 4,889,545; 5,568,737; and 5,881,569, assignee's co-pending application 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, Texas, March 11-13, 2002. These processes use 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 combined with a portion of the column overhead vapor. Because of the relatively high concentration of C₂ components in the vapors lower in the tower, a significant quantity of liquid can be condensed from this combined vapor stream with only a modest elevation in pressure, using the refrigeration available in the remaining portion of the cold overhead vapor leaving the upper rectification section of the column to provide most of the cooling. This condensed liquid, which is predominantly liquid methane, can then be used to absorb C₂ components, C₃ components, C₄ 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, compressing either a portion of the cold overhead vapor stream or compressing a side draw vapor stream to provide reflux for the upper

rectification section of the column has been employed in C₂+ recovery systems, as illustrated in assignee's U.S. Patent No. 4,889,545 and assignee's co-pending application no. 11/839,693, respectively. Surprisingly, applicants have found that combining a portion of the cold overhead vapor with the side draw vapor stream and then compressing the combined stream improves the system efficiency while reducing operating cost.

[0013] In accordance with the present invention, it has been found that C₂ recovery in excess of 84% and C₃ and C₄+ recoveries in excess of 99% can be obtained. In addition, the present invention makes possible essentially 100% separation of methane and lighter components from the C₂ components and heavier components at lower energy requirements compared to the prior art while maintaining 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 assignee's co-pending application no. 11/839,693;

[0016] FIG. 2 is a flow diagram of a natural gas processing plant in accordance with the present invention; and

[0017] FIGS. 3 through 6 are flow diagrams illustrating alternative means of application of the present invention to a natural gas stream.

[0018] 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.

[0019] For convenience, process parameters are reported in both the traditional British units and in the units of the Système 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

[0020] FIG. 1 is a process flow diagram showing the design of a processing plant to recover C₂+ components from natural gas using prior art according to assignee's

co-pending application no. 11/839,693. In this simulation of the process, inlet gas enters the plant at 120°F [49°C] and 1025 psia [7,067 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.

[0021] The feed stream **31** is cooled in heat exchanger **10** by heat exchange with cool residue gas (stream **41b**), demethanizer reboiler liquids at 51°F [11°C] (stream **44**), demethanizer lower side reboiler liquids at 10°F [-12°C] (stream **43**), and demethanizer upper side reboiler liquids at -65°F [-54°C] (stream **42**). 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 **31a** enters separator **11** at -38°F [-39°C] and 1015 psia [6,998 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 465 psia [3,208 kPa(a)]) of fractionation tower **18** by expansion valve **17**, cooling stream **33a** to -67°F [-55°C] before it is supplied to fractionation tower **18** at a lower mid-column feed point.

[0022] The vapor (stream **32**) from separator **11** is divided into two streams, **36** and **39**. Stream **36**, containing about 23% of the total vapor, passes through heat exchanger **12** in heat exchange relation with the cold residue gas (stream **41a**) where it is cooled to substantial condensation. The resulting substantially condensed stream **36a** at -102°F [-74°C] is then flash expanded through expansion valve **14** to slightly above the operating pressure of fractionation tower **18**. 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 **36b** leaving expansion valve **14** reaches a temperature of -127°F [-88°C] before it is supplied at an upper mid-column feed point, in absorbing section **18a** of fractionation tower **18**.

[0023] The remaining 77% of the vapor from separator **11** (stream **39**) enters a work expansion machine **15** in which mechanical energy is extracted from this portion of the high pressure feed. The machine **15** expands the vapor substantially isentropically to the tower operating pressure, with the work expansion cooling the expanded stream **39a** to a temperature of approximately -101°F [-74°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 **16**) that can be used to re-compress the residue gas (stream **41c**), for example. The partially condensed expanded stream **39a** is thereafter supplied as feed to fractionation tower **18** at a mid-column feed point.

[0024] The demethanizer in tower **18** 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 **18a** that contains the trays and/or packing to provide the necessary contact between the vapor portions of the expanded streams **36b** and **39a** rising upward and cold liquid falling downward to condense and absorb the C₂ components, C₃ components, and heavier components; and a lower, stripping section **18b** 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 **18b** also includes one or more reboilers (such as the reboiler and 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 **45**, of methane and lighter components. Stream **39a** enters demethanizer **18** at an intermediate feed position located in the lower region of absorbing section **18a** of demethanizer **18**. The liquid portion of the expanded stream **39a** commingles with liquids falling downward from absorbing section **18a** and the combined liquid continues downward into stripping section **18b** of demethanizer **18**. The vapor portion of the expanded stream **39a** rises upward through absorbing section **18a** and is contacted with cold liquid falling downward to condense and absorb the C₂ components, C₃ components, and heavier components.

[0025] A portion of the distillation vapor (stream **48**) is withdrawn from an intermediate region of absorbing section **18a** in fractionation column **18**, above the feed position of expanded stream **39a** and below the feed position of expanded stream **36b**. The distillation vapor stream **48** at -113°F [-81°C] is compressed to 604 psia

[4,165 kPa(a)] (stream **48a**) by reflux compressor **21**, then cooled from -84°F [-65°C] to -124°F [-87°C] and substantially condensed (stream **48b**) in heat exchanger **22** by heat exchange with cold residue gas stream **41**, the overhead stream exiting the top of demethanizer **18**. The substantially condensed stream **48b** is then expanded through an appropriate expansion device, such as expansion valve **23**, to the demethanizer operating pressure, resulting in cooling of the total stream to -131°F [-91°C]. The expanded stream **48c** is then supplied to fractionation tower **18** as the top column feed. The vapor portion of stream **48c** combines with the vapors rising from the top fractionation stage of the column to form demethanizer overhead stream **41** at -128°F [-89°C].

[0026] The liquid product (stream **45**) exits the bottom of tower **18** at 70°F [21°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 **41** passes countercurrently to the compressed distillation vapor stream in heat exchanger **22** where it is heated to -106°F [-77°C] (stream **41a**), and countercurrently to the incoming feed gas in heat exchanger **12** where it is heated to -66°F [-55°C] (stream **41b**) and in heat exchanger **10** where it is heated to 110°F [43°C] (stream **41c**). The residue gas is then re-compressed in two stages. The first stage is compressor **16** driven by expansion machine **15**. The second stage is compressor **24** driven by a supplemental power source which compresses the residue gas (stream **41e**) to sales line pressure. After cooling to 120°F [49°C] in discharge cooler **25**, the residue gas product (stream **41f**) flows to the sales gas pipeline at 1025 psia [7,067 kPa(a)], sufficient to meet line requirements (usually on the order of the inlet pressure).

[0027] 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]

<u>Stream</u>	<u>Methane</u>	<u>Ethane</u>	<u>Propane</u>	<u>Butanes+</u>	<u>Total</u>
31	25,382	1,161	362	332	28,055
32	25,050	1,096	311	180	27,431
33	332	65	51	152	624
36	5,636	247	70	40	6,172
39	19,414	849	241	140	21,259
48	3,962	100	3	0	4,200
41	25,358	197	2	0	26,056
45	24	964	360	332	1,999

Recoveries*

Ethane	83.06%
Propane	99.50%
Butanes+	99.98%

Power

Residue Gas Compression	10,783 HP	[17,727 kW]
Recycle Compression	260 HP	[427 kW]
Total Compression	11,043 HP	[18,154 kW]

* (Based on un-rounded flow rates)

DESCRIPTION OF THE INVENTION

[0028] FIG. 2 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. 2 are the same as those in FIG. 1. Accordingly, the FIG. 2 process can be compared with that of the FIG. 1 process to illustrate the advantages of the present invention.

[0029] In the simulation of the FIG. 2 process, inlet gas enters the plant at 120°F [49°C] and 1025 psia [7,067 kPa(a)] as stream **31** and is cooled in heat exchanger **10** by heat exchange with cool residue gas (stream **46b**), demethanizer reboiler liquids at 50°F [10°C] (stream **44**), demethanizer lower side reboiler liquids at 8°F [-13°C] (stream **43**), and demethanizer upper side reboiler liquids at -67°F [-55°C] (stream **42**). The cooled

stream **31a** enters separator **11** at -38°F [-39°C] and 1015 psia [6,998 kPa(a)] where the vapor (stream **32**) is separated from the condensed liquid (stream **33**). The separator liquid (stream **33/40**) is expanded to the operating pressure (approximately 469 psia [3,234 kPa(a)]) of fractionation tower **18** by expansion valve **17**, cooling stream **40a** to -67°F [-55°C] before it is supplied to fractionation tower **18** at a lower mid-column feed point (located below the feed point of stream **39a** described later in paragraph [0031]).

[0030] The vapor (stream **32**) from separator **11** is divided into two streams, **34** and **39**. Stream **34**, containing about 26% of the total vapor, passes through heat exchanger **12** in heat exchange relation with the cold residue gas (stream **46a**) where it is cooled to substantial condensation. The resulting substantially condensed stream **36a** at -106°F [-76°C] is then divided into two portions, streams **37** and **38**. Stream **38**, containing about 50.5% of the total substantially condensed stream, is flash expanded through expansion valve **14** to the operating pressure of fractionation tower **18**. During expansion a portion of the stream is vaporized, resulting in cooling of the total stream. In the process illustrated in FIG. 2, the expanded stream **38a** leaving expansion valve **14** reaches a temperature of -127°F [-88°C] before it is supplied at an upper mid-column feed point, in absorbing section **18a** of fractionation tower **18**. The remaining 49.5% of the substantially condensed stream (stream **37**) is flash expanded through expansion valve **13** to slightly above the operating pressure of fractionation tower **18**. The flash expanded stream **37a** is warmed slightly in heat exchanger **22** from -126°F [-88°C] to -125°F [-87°C], and the resulting stream **37b** is then supplied at another upper mid-column feed point in absorbing section **18a** of fractionation tower **18**.

[0031] The remaining 74% of the vapor from separator **11** (stream **39**) enters a work expansion machine **15** in which mechanical energy is extracted from this portion of the high pressure feed. The machine **15** expands the vapor substantially isentropically to the tower operating pressure, with the work expansion cooling the expanded stream **39a** to a temperature of approximately -100°F [-73°C]. The partially condensed expanded stream **39a** is thereafter supplied as feed to fractionation tower **18** at a mid-column feed point (located below the feed points of streams **38a** and **37b**).

[0032] The demethanizer in tower **18** 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 **18a** that contains the trays and/or packing to provide the necessary contact between the vapor portion of the expanded streams **38a** and **39a** and heated expanded stream **37b** rising upward and cold liquid falling downward to condense and absorb the C₂ components, C₃ components, and heavier components from the vapors rising upward; and a lower, stripping section **18b** 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 **18b** also includes one or more reboilers (such as the reboiler and 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 **45**, of methane and lighter components. Stream **39a** enters demethanizer **18** at an intermediate feed position located in the lower region of absorbing section **18a** of demethanizer **18**. The liquid portion of

the expanded stream commingles with liquids falling downward from absorbing section **18a** and the combined liquid continues downward into stripping section **18b** of demethanizer **18**. The vapor portion of the expanded stream commingles with vapors arising from stripping section **18b** and the combined vapor rises upward through absorbing section **18a** and is contacted with cold liquid falling downward to condense and absorb the C₂ components, C₃ components, and heavier components.

[0033] A portion of the distillation vapor (stream **48**) is withdrawn from an intermediate region of absorbing section **18a** in fractionation column **18**, above the feed position of expanded stream **39a** in the lower region of absorbing section **18a** and below the feed positions of expanded stream **38a** and heated expanded stream **37b**. The distillation vapor stream **48** at -116°F [-82°C] is combined with a portion (stream **47**) of overhead vapor stream **41** at -128°F [-89°C] to form combined vapor stream **49** at -118°F [-83°C]. The combined vapor stream **49** is compressed to 592 psia [4,080 kPa(a)] (stream **49a**) by reflux compressor **21**, then cooled from -92°F [-69°C] to -124°F [-87°C] and substantially condensed (stream **49b**) in heat exchanger **22** by heat exchange with residue gas stream **46** (the remaining portion of cold demethanizer overhead stream **41** exiting the top of demethanizer **18**) and with the flash expanded stream **37a** as described previously. The cold residue gas stream is warmed to -110°F [-79°C] (stream **46a**) as it provides cooling to the compressed combined vapor stream **49a**.

[0034] The substantially condensed stream **49b** is flash expanded to the operating pressure of demethanizer **18** by expansion valve **23**. A portion of the stream is vaporized, further cooling stream **49c** to -132°F [-91°C] before it is supplied as cold top column feed

(reflux) to demethanizer **18**. This cold liquid reflux absorbs and condenses the C₂ components, C₃ components, and heavier components rising in the upper rectification region of absorbing section **18a** of demethanizer **18**.

[0035] In stripping section **18b** of demethanizer **18**, the feed streams are stripped of their methane and lighter components. The resulting liquid product (stream **45**) exits the bottom of tower **18** at 68°F [20°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 partially warmed residue gas stream **46a** passes countercurrently to the incoming feed gas in heat exchanger **12** where it is heated to -61°F [-52°C] (stream **46b**) and in heat exchanger **10** where it is heated to 112°F [44°C] (stream **46c**) as it provides cooling as previously described. The residue gas is then re-compressed in two stages, compressor **16** driven by expansion machine **15** and compressor **24** driven by a supplemental power source. After stream **46e** is cooled to 120°F [49°C] in discharge cooler **25**, the residue gas product (stream **46f**) flows to the sales gas pipeline at 1025 psia [7,067 kPa(a)], sufficient to meet line requirements (usually on the order of the inlet pressure).

[0036] 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]

<u>Stream</u>	<u>Methane</u>	<u>Ethane</u>	<u>Propane</u>	<u>Butanes+</u>	<u>Total</u>
31	25,382	1,161	362	332	28,055
32	25,050	1,096	310	180	27,431
33	332	65	52	152	624
34	6,563	287	81	47	7,187
35	0	0	0	0	0
36	6,563	287	81	47	7,187
37	3,249	142	40	23	3,558
38	3,314	145	41	24	3,629
39	18,487	809	229	133	20,244
40	332	65	52	152	624
41	25,874	178	1	0	26,534
47	517	4	0	0	531
48	3,801	79	2	0	4,000
49	4,318	83	2	0	4,531
46	25,357	174	1	0	26,003
45	25	987	361	332	2,052

Recoveries*

Ethane	84.98%
Propane	99.67%
Butanes+	99.99%

Power

Residue Gas Compression	10,801 HP	[17,757 kW]
Reflux Compression	241 HP	[396 kW]
Total Compression	11,042 HP	[18,153 kW]

* (Based on un-rounded flow rates)

[0037] A comparison of Tables I and II shows that, compared to the prior art, the present invention improves ethane recovery from 83.06% to 84.98%, propane recovery from 99.50% to 99.67%, and butanes+ recovery from 99.98% to 99.99%. Comparison of Tables I and II further shows that the improvement in yields was achieved using essentially the same power as the prior art. In terms of the recovery efficiency (defined by the quantity of ethane recovered per unit of power), the present invention represents a 2% improvement over the prior art of the FIG. 1 process.

[0038] The improvement in the recovery efficiency of the present invention over that of the prior art processes can be understood by examining the improvement in the rectification that the present invention provides for the upper region of absorbing section **18a**. Compared to the prior art of the FIG. 1 process, the present invention produces a

better top reflux stream containing more methane and less C₂+ components. Comparing reflux stream **48** in Table I for the FIG. 1 prior art process with reflux stream **49** in Table II for the present invention, it can be seen that the present invention provides a reflux stream that is greater in quantity (nearly 8%) with a significantly lower concentration of C₂+ components (1.9% for the present invention versus 2.5% for the FIG. 1 prior art process). Further, because the present invention uses a portion of substantially condensed feed stream **36a** (expanded stream **37a**) to supplement the cooling provided by the residue gas (stream **46**), the compressed reflux stream **49a** can be substantially condensed at lower pressure, reducing the power required by reflux compressor **21** compared to the FIG. 1 prior art process even though the reflux flow rate is higher for the present invention.

[0039] Unlike the prior art process of assignee's U.S. Patent No. 4,889,545, the present invention uses only a portion of substantially condensed feed stream **36a** (expanded stream **37a**) to provide cooling to compressed reflux stream **49a**. This allows the rest of substantially condensed feed stream **36a** (expanded stream **38a**) to provide bulk recovery of the C₂ components, C₃ components, and heavier hydrocarbon components contained in expanded feed **39a** and the vapors rising from stripping section **18b**. In the present invention, the cold residue gas (stream **46**) is used to provide most of the cooling of compressed reflux stream **49a**, reducing the heating of stream **37a** compared to the prior art so that the resulting stream **37b** can supplement the bulk recovery provided by expanded stream **38a**. The supplemental rectification provided by

reflux stream **49c** can then reduce the amount of C₂ components, C₃ components, and C₄+ components contained in the inlet feed gas that is lost to the residue gas.

[0040] The present invention also reduces the rectification required from reflux stream **49c** in absorbing section **18a** compared to the prior art U.S. Patent No. 4,889,545 process by condensing reflux stream **49c** with less warming of the column feeds (streams **37b**, **38a**, and **39a**) to absorbing section **18a**. If all of the substantially condensed stream **36a** is expanded and warmed to provide condensing as is taught in U.S. Patent No. 4,889,545, not only is there less cold liquid in the resulting stream available for rectification of the vapors rising in absorbing section **18a**, there is much more vapor in the upper region of absorbing section **18a** that must be rectified by the reflux stream. The net result is that the reflux stream of the prior art U.S. Patent No. 4,889,545 process allows more of the C₂ components to escape to the residue gas stream than the present invention does, reducing its recovery efficiency compared to the present invention. The key improvements of the present invention over the prior art U.S. Patent No. 4,889,545 process are that the cold residue gas stream **46** is used to provide most of the cooling of compressed reflux stream **49a** in heat exchanger **22**, and that the distillation vapor stream **48** contains a significant fraction of C₂ components not found in the column overhead stream **41**, allowing sufficient methane to be condensed for use as reflux without adding significant rectification load in absorbing section **18a** due to the excessive vaporization of stream **36a** that is inherent when it is expanded and heated as taught in the U.S. Patent No. 4,889,545 prior art process.

Other Embodiments

[0041] 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 expanded reflux stream (stream **49c**) leaving expansion valve **23**, all or a part of the expanded substantially condensed stream **38a** from expansion valve **14**, and all or a part of the heated expanded stream **37b** leaving heat exchanger **22** can be combined (such as in the piping joining the expansion valves 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 commingling of the three streams, combined with contacting at least a portion of expanded stream **39a**, shall be considered for the purposes of this invention as constituting an absorbing section.

[0042] FIGS. 3 through 6 display other embodiments of the present invention. FIGS. 2 through 4 depict fractionation towers constructed in a single vessel. FIGS. 5 and 6 depict fractionation towers constructed in two vessels, absorber (rectifier) column **18** (a contacting and separating device) and stripper (distillation) column **20**. In such cases, the overhead vapor stream **54** from stripper column **20** flows to the lower section of absorber column **18** (via stream **55**) to be contacted by reflux stream **49c**, expanded substantially condensed stream **38a**, and heated expanded stream **37b**. Pump **19** is used to route the liquids (stream **53**) from the bottom of absorber column **18** 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 **18** in FIGS. 2 through 4) or multiple vessels will depend on a number of factors such as plant size, the distance to fabrication facilities, etc.

[0043] Some circumstances may favor withdrawing the distillation vapor stream **48** in FIGS. 3 and 4 from the upper region of absorbing section **18a** (stream **50**) above the feed point of expanded substantially condensed stream **38a**, rather than from the intermediate region of absorbing section **18a** (stream **51**) below the feed point of expanded substantially condensed stream **38a**. Likewise in FIGS. 5 and 6, the vapor distillation stream **48** may be withdrawn from absorber column **18** above the feed point of expanded substantially condensed stream **38a** (stream **50**) or below the feed point of expanded substantially condensed stream **38a** (stream **51**). In other cases, it may be advantageous to withdraw the distillation vapor stream **48** from the upper region of stripping section **18b** in demethanizer **18** (stream **52**) in FIGS. 3 and 4. Similarly in FIGS. 5 and 6, a portion (stream **52**) of overhead vapor stream **54** from stripper column **20** may be combined with stream **47** to form stream **49**, with any remaining portion (stream **55**) flowing to the lower section of absorber column **18**.

[0044] As described earlier, the compressed combined vapor stream **49a** is substantially 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 **18a** of demethanizer **18** or through absorber column **18**. 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 **18a** of demethanizer **18** or absorber column **18**. Some circumstances may favor partial condensation, rather than substantial condensation, of compressed combined vapor stream **49a** in heat exchanger **22**. Other circumstances may favor that distillation vapor stream **48** be a total vapor side draw from fractionation column **18** or absorber column **18** 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 compressed combined vapor stream **49a** in heat exchanger **22**.

[0045] Feed gas conditions, plant size, available equipment, or other factors may indicate that elimination of work expansion machine **15**, 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 portions of the feed stream (streams **37** and **38**) or the substantially condensed reflux stream leaving heat exchanger **22** (stream **49b**).

[0046] Depending on the quantity of heavier hydrocarbons in the feed gas and the feed gas pressure, the cooled feed stream **31a** leaving heat exchanger **10** in FIGS. 2 through 6 may not contain any liquid (because it is above its dewpoint, or because it is

above its cricondenbar). In such cases, separator **11** shown in FIGS. 2 through 6 is not required.

[0047] In accordance with the present invention, the splitting of the vapor feed may be accomplished in several ways. In the processes of FIGS. 2, 3, and 5, 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 as shown in FIGS. 4 and 6. In some embodiments, vapor splitting may be effected in a separator.

[0048] The high pressure liquid (stream **33** in FIGS. 2 through 6) need not be expanded and fed to a 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 **34** in FIGS. 2, 3, and 5) or the portion of the cooled feed gas (stream **34a** in FIGS. 4 and 6) flowing to heat exchanger **12**. (This is shown by the dashed stream **35** in FIGS. 2 through 6.) 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 mid-column feed point on the distillation column (stream **40a** in FIGS. 2 through 6). Stream **40** 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.

[0049] 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.

[0050] 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. For instance, circumstances may favor combining expanded substantially condensed stream **38a** with heated expanded stream **37b** and supplying the combined stream to a single upper mid-column feed point on fractionation tower **18** (FIGS. 2 through 4) or absorber column **18** (FIGS. 5 and 6).

[0051] The present invention provides improved recovery of C₂ components, C₃ components, and heavier hydrocarbon components or of C₃ 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.

[0052] 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, C₂ components, C₃ components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C₂ components, C₃ components, and heavier hydrocarbon components or said C₃ 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;

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

(3) said first condensed portion is expanded to said lower pressure whereby it is further cooled, and is thereafter supplied to said distillation column at an upper mid-column feed position;

(4) said second condensed portion is expanded to said lower pressure whereby it is further cooled, is heated, and is thereafter supplied to said distillation column at said 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) an overhead vapor stream is withdrawn from an upper region of said distillation column and divided into at least a first vapor portion and a second vapor portion;

(7) said second vapor portion is heated, thereafter discharging at least a portion of said heated second vapor portion 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 combined with said first vapor portion to form a combined vapor stream;

(9) said combined vapor stream is compressed to higher pressure;

(10) said compressed combined vapor stream is cooled sufficiently to condense at least a part of it, thereby forming a condensed stream while supplying at least a portion of the heating of steps (4) and (7);

(11) at least a portion of said condensed stream is expanded to said lower pressure and is thereafter supplied to said distillation column at a top feed position; and

(12) 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, C₂ components, C₃ components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C₂ components, C₃ components, and heavier hydrocarbon components or said C₃ 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 prior to cooling, said gas stream is divided into first and second streams; and

(1) said first stream is cooled to condense substantially all of it;

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

(3) said first condensed portion is expanded to said lower pressure whereby it is further cooled, and is thereafter supplied to said distillation column at an upper mid-column feed position;

(4) said second condensed portion is expanded to said lower pressure whereby it is further cooled, is heated, and is thereafter supplied to said distillation column at said upper mid-column feed position;

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

(6) an overhead vapor stream is withdrawn from an upper region of said distillation column and divided into at least a first vapor portion and a second vapor portion;

(7) said second vapor portion is heated, thereafter discharging at least a portion of said heated second vapor portion 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 combined with said first vapor portion to form a combined vapor stream;

(9) said combined vapor stream is compressed to higher pressure;

(10) said compressed combined vapor stream is cooled sufficiently to condense at least a part of it, thereby forming a condensed stream while supplying at least a portion of the heating of steps (4) and (7);

(11) at least a portion of said condensed stream is expanded to said lower pressure and is thereafter supplied to said distillation column at a top feed position; and

(12) 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, C₂ components, C₃ components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C₂ components, C₃ components, and heavier hydrocarbon components or said C₃ 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;
- (4) said substantially condensed first stream is divided into at least a first condensed portion and a second condensed portion;
- (5) said first condensed portion is expanded to said lower pressure whereby it is further cooled, and is thereafter supplied to said distillation column at an upper mid-column feed position;
- (6) said second condensed portion is expanded to said lower pressure whereby it is further cooled, is heated, and is thereafter supplied to said distillation column at said upper mid-column feed position;
- (7) 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;
- (8) 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;

- (9) an overhead vapor stream is withdrawn from an upper region of said distillation column and divided into at least a first vapor portion and a second vapor portion;
- (10) said second vapor portion is heated, thereafter discharging at least a portion of said heated second vapor portion as said volatile residue gas fraction;
- (11) 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 combined with said first vapor portion to form a combined vapor stream;
- (12) said combined vapor stream is compressed to higher pressure;
- (13) said compressed combined vapor stream is cooled sufficiently to condense at least a part of it, thereby forming a condensed stream while supplying at least a portion of the heating of steps (6) and (10);
- (14) at least a portion of said condensed stream is expanded to said lower pressure and is thereafter supplied to said distillation column at a top feed position; and
- (15) 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, C₂ components, C₃ components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C₂ components, C₃ components, and heavier hydrocarbon components or said C₃ 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 prior to cooling, said gas stream is divided into first and second streams; and

(1) said first stream is cooled to condense substantially all of it;

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

(3) said first condensed portion is expanded to said lower pressure whereby it is further cooled, and is thereafter supplied to said distillation column at an upper mid-column feed position;

- (4) said second condensed portion is expanded to said lower pressure whereby it is further cooled, is heated, and is thereafter supplied to said distillation column at said upper mid-column feed position;
- (5) said second stream is cooled under pressure sufficiently to partially condense it;
- (6) said partially condensed second stream is separated thereby to provide a vapor stream and at least one liquid stream;
- (7) said vapor 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;
- (8) 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;
- (9) an overhead vapor stream is withdrawn from an upper region of said distillation column and divided into at least a first vapor portion and a second vapor portion;
- (10) said second vapor portion is heated, thereafter discharging at least a portion of said heated second vapor portion as said volatile residue gas fraction;
- (11) 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 combined with said first vapor portion to form a combined vapor stream;

(12) said combined vapor stream is compressed to higher pressure;

(13) said compressed combined vapor stream is cooled sufficiently to condense at least a part of it, thereby forming a condensed stream while supplying at least a portion of the heating of steps (4) and (10);

(14) at least a portion of said condensed stream is expanded to said lower pressure and is thereafter supplied to said distillation column at a top feed position; and

(15) 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.

5. In a process for the separation of a gas stream containing methane, C₂ components, C₃ components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C₂ components, C₃ components, and heavier hydrocarbon components or said C₃ 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;

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

(5) said first condensed portion is expanded to said lower pressure whereby it is further cooled, and is thereafter supplied to said distillation column at an upper mid-column feed position;

(6) said second condensed portion is expanded to said lower pressure whereby it is further cooled, is heated, and is thereafter supplied to said distillation column at said upper mid-column feed position;

(7) 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;

(8) 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;

(9) an overhead vapor stream is withdrawn from an upper region of said distillation column and divided into at least a first vapor portion and a second vapor portion;

(10) said second vapor portion is heated, thereafter discharging at least a portion of said heated second vapor portion as said volatile residue gas fraction;

(11) 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 combined with said first vapor portion to form a combined vapor stream;

(12) said combined vapor stream is compressed to higher pressure;

(13) said compressed combined vapor stream is cooled sufficiently to condense at least a part of it, thereby forming a condensed stream while supplying at least a portion of the heating of steps (6) and (10);

(14) at least a portion of said condensed stream is expanded to said lower pressure and is thereafter supplied to said distillation column at a top feed position; and

(15) 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.

6. In a process for the separation of a gas stream containing methane, C₂ components, C₃ components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C₂ components, C₃ components, and heavier hydrocarbon components or said C₃ 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;

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

(3) said first condensed portion is expanded to said lower pressure whereby it is further cooled, 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;

(4) said second condensed portion is expanded to said lower pressure whereby it is further cooled, is heated, and is thereafter supplied to said contacting and separating device at said mid-column feed position;

(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) 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;

(7) said first overhead vapor stream is divided into at least a first vapor portion and a second vapor portion;

(8) said second vapor portion is heated, thereafter discharging at least a portion of said heated second vapor portion 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 combined with said first vapor portion to form a combined vapor stream;

(10) said combined vapor stream is compressed to higher pressure;

(11) said compressed combined vapor stream is cooled sufficiently to condense at least a part of it, thereby forming a condensed stream while supplying at least a portion of the heating of steps (4) and (8);

(12) at least a portion of said condensed stream is expanded to said lower pressure and is thereafter supplied to said contacting and separating device at a top feed position; and

(13) 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. In a process for the separation of a gas stream containing methane, C₂ components, C₃ components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C₂ components, C₃ components, and heavier hydrocarbon components or said C₃ 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 prior to cooling, said gas stream is divided into first and second streams; and

(1) said first stream is cooled to condense substantially all of it;

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

(3) said first condensed portion is expanded to said lower pressure whereby it is further cooled, 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;

(4) said second condensed portion is expanded to said lower pressure whereby it is further cooled, is heated, and is thereafter supplied to said contacting and separating device at said mid-column feed position;

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

(6) 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;

(7) said first overhead vapor stream is divided into at least a first vapor portion and a second vapor portion;

(8) said second vapor portion is heated, thereafter discharging at least a portion of said heated second vapor portion 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 combined with said first vapor portion to form a combined vapor stream;

(10) said combined vapor stream is compressed to higher pressure;

(11) said compressed combined vapor stream is cooled sufficiently to condense at least a part of it, thereby forming a condensed stream while supplying at least a portion of the heating of steps (4) and (8);

(12) at least a portion of said condensed stream is expanded to said lower pressure and is thereafter supplied to said contacting and separating device at a top feed position; and

(13) 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.

8. In a process for the separation of a gas stream containing methane, C₂ components, C₃ components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C₂ components, C₃ components, and heavier hydrocarbon components or said C₃ 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;

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

(5) said first condensed portion is expanded to said lower pressure whereby it is further cooled, 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;

(6) said second condensed portion is expanded to said lower pressure whereby it is further cooled, is heated, and is thereafter supplied to said contacting and separating device at said mid-column feed position;

(7) 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;

(8) 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;

(9) 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;

(10) said first overhead vapor stream is divided into at least a first vapor portion and a second vapor portion;

(11) said second vapor portion is heated, thereafter discharging at least a portion of said heated second vapor portion as said volatile residue gas fraction;

(12) 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 combined with said first vapor portion to form a combined vapor stream;

(13) said combined vapor stream is compressed to higher pressure;

(14) said compressed combined vapor stream is cooled sufficiently to condense at least a part of it, thereby forming a condensed stream while supplying at least a portion of the heating of steps (6) and (11);

(15) at least a portion of said condensed stream is expanded to said lower pressure and is thereafter supplied to said contacting and separating device at a top feed position; and

(16) 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.

9. In a process for the separation of a gas stream containing methane, C₂ components, C₃ components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of

said C₂ components, C₃ components, and heavier hydrocarbon components or said C₃ 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 prior to cooling, said gas stream is divided into first and second streams; and

(1) said first stream is cooled to condense substantially all of it;

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

(3) said first condensed portion is expanded to said lower pressure whereby it is further cooled, 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;

(4) said second condensed portion is expanded to said lower pressure whereby it is further cooled, is heated, and is thereafter supplied to said contacting and separating device at said mid-column feed position;

- (5) said second stream is cooled under pressure sufficiently to partially condense it;
- (6) said partially condensed second stream is separated thereby to provide a vapor stream and at least one liquid stream;
- (7) said vapor 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;
- (8) 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;
- (9) 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;
- (10) said first overhead vapor stream is divided into at least a first vapor portion and a second vapor portion;
- (11) said second vapor portion is heated, thereafter discharging at least a portion of said heated second vapor portion as said volatile residue gas fraction;
- (12) 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 combined with said first vapor portion to form a combined vapor stream;

(13) said combined vapor stream is compressed to higher pressure;

(14) said compressed combined vapor stream is cooled sufficiently to condense at least a part of it, thereby forming a condensed stream while supplying at least a portion of the heating of steps (4) and (11);

(15) at least a portion of said condensed stream is expanded to said lower pressure and is thereafter supplied to said contacting and separating device at a top feed position; and

(16) 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.

10. In a process for the separation of a gas stream containing methane, C₂ components, C₃ components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C₂ components, C₃ components, and heavier hydrocarbon components or said C₃ 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;

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

(5) said first condensed portion is expanded to said lower pressure whereby it is further cooled, 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;

(6) said second condensed portion is expanded to said lower pressure whereby it is further cooled, is heated, and is thereafter supplied to said contacting and separating device at said mid-column feed position;

(7) 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;

(8) 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;

(9) 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;

(10) said first overhead vapor stream is divided into at least a first vapor portion and a second vapor portion;

(11) said second vapor portion is heated, thereafter discharging at least a portion of said heated second vapor portion as said volatile residue gas fraction;

(12) 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 combined with said first vapor portion to form a combined vapor stream;

(13) said combined vapor stream is compressed to higher pressure;

(14) said compressed combined vapor stream is cooled sufficiently to condense at least a part of it, thereby forming a condensed stream while supplying at least a portion of the heating of steps (6) and (11);

(15) at least a portion of said condensed stream is expanded to said lower pressure and is thereafter supplied to said contacting and separating device at a top feed position; and

(16) 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.

11. The improvement according to claim 1, 2, 3, 4, or 5 wherein said distillation vapor stream is withdrawn from a region of said distillation column below said top feed position and above said upper mid-column feed position.

12. The improvement according to claim 1, 2, 3, 4, or 5 wherein said distillation vapor stream is withdrawn from a region of said distillation column below said mid-column feed position.

13. The improvement according to claim 6, 7, 8, 9, or 10 wherein said distillation vapor stream is withdrawn from a region of said contacting and separating device below said top feed position and above said mid-column feed position.

14. The improvement according to claim 6, 7, 8, 9, or 10 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.

15. The improvement according to claim 1, 2, 3, 4, or 5 wherein said heated expanded second condensed portion is supplied to said distillation column at a second upper mid-column feed position.

16. The improvement according to claim 11 wherein said heated expanded second condensed portion is supplied to said distillation column at a second upper mid-column feed position.

17. The improvement according to claim 12 wherein said heated expanded second condensed portion is supplied to said distillation column at a second upper mid-column feed position.

18. The improvement according to claim 6, 7, 8, 9, or 10 wherein said heated expanded second condensed portion is supplied to said contacting and separating device at a second mid-column feed position.

19. The improvement according to claim 13 wherein said heated expanded second condensed portion is supplied to said contacting and separating device at a second mid-column feed position.

20. The improvement according to claim 14 wherein said heated expanded second condensed portion is supplied to said contacting and separating device at a second mid-column feed position.

21. In an apparatus for the separation of a gas stream containing methane, C₂ components, C₃ components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major

portion of said C₂ components, C₃ components, and heavier hydrocarbon components or said C₃ 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) first 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 first dividing means to receive said first stream and cool it sufficiently to substantially condense it;

(3) second dividing means connected to said second cooling means to receive said substantially condensed first stream and divide it into at least a first condensed portion and a second condensed portion;

(4) second expansion means connected to said second dividing means to receive said first condensed portion and expand it to said lower pressure, said second expansion means being further connected to said distillation column to supply

said expanded first condensed portion to said distillation column at an upper mid-column feed position;

(5) third expansion means connected to said second dividing means to receive said second condensed portion and expand it to said lower pressure;

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

(7) said first expansion means being connected to said first 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 dividing means connected to said distillation column to receive said overhead vapor stream separated therein and divide it into at least a first vapor portion and a second vapor portion;

(9) said heat exchange means being further connected to said third dividing means to receive at least a portion of said second vapor portion and heat it, thereafter discharging at least a portion of said heated second vapor portion 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) combining means connected to said third dividing means and said vapor withdrawing means to receive said first vapor portion and said distillation vapor stream and form a combined vapor stream;
- (12) compressing means connected to said combining means to receive said combined vapor stream and compress it to higher pressure;
- (13) said heat exchange means being further connected to said compressing means to receive said compressed combined vapor stream and cool it sufficiently to condense at least a part of it, thereby forming a condensed stream while supplying at least a portion of the heating of steps (6) and (9);
- (14) fourth expansion means connected to said heat exchange means to receive said condensed stream and expand it to said lower pressure, said fourth expansion means being further connected to said distillation column to supply at least a portion of said expanded condensed stream to said distillation column at a top feed position; and
- (15) 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.

22. In an apparatus for the separation of a gas stream containing methane, C₂ components, C₃ components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C₂ components, C₃ components, and heavier hydrocarbon components or said C₃ 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) first dividing means prior to said first cooling means to divide said gas stream into first and second streams;

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

(3) second dividing means connected to said second cooling means to receive said substantially condensed first stream and divide it into at least a first condensed portion and a second condensed portion;

(4) second expansion means connected to said second dividing means to receive said first condensed portion and expand it to said lower pressure, said second expansion means being further connected to said distillation column to supply said expanded first condensed portion to said distillation column at an upper mid-column feed position;

(5) third expansion means connected to said second dividing means to receive said second condensed portion and expand it to said lower pressure;

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

(7) said first cooling means being connected to said first dividing means to receive said second stream and cool it;

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

(9) third dividing means connected to said distillation column to receive said overhead vapor stream separated therein and divide it into at least a first vapor portion and a second vapor portion;

(10) said heat exchange means being further connected to said third dividing means to receive at least a portion of said second vapor portion and heat it, thereafter discharging at least a portion of said heated second vapor portion 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) combining means connected to said third dividing means and said vapor withdrawing means to receive said first vapor portion and said distillation vapor stream and form a combined vapor stream;

(13) compressing means connected to said combining means to receive said combined vapor stream and compress it to higher pressure;

(14) said heat exchange means being further connected to said compressing means to receive said compressed combined vapor stream and cool it sufficiently to condense at least a part of it, thereby forming a condensed stream while supplying at least a portion of the heating of steps (6) and (10);

(15) fourth expansion means connected to said heat exchange means to receive said condensed stream and expand it to said lower pressure, said fourth expansion means being further connected to said distillation column to supply at least a portion of said expanded condensed stream to said distillation column at a top feed position; and

(16) 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.

23. In an apparatus for the separation of a gas stream containing methane, C₂ components, C₃ components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C₂ components, C₃ components, and heavier hydrocarbon components or said C₃ 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) 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) first dividing means connected to said separating means to receive said vapor stream and divide it into first and second streams;

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

(5) second dividing means connected to said second cooling means to receive said substantially condensed first stream and divide it into at least a first condensed portion and a second condensed portion;

(6) second expansion means connected to said second dividing means to receive said first condensed portion and expand it to said lower pressure, said second expansion means being further connected to said distillation column to supply said expanded first condensed portion to said distillation column at an upper mid-column feed position;

(7) third expansion means connected to said second dividing means to receive said second condensed portion and expand it to said lower pressure;

(8) heat exchange means connected to said third expansion means to receive said expanded second condensed portion and heat it, said heat exchange means being further connected to said distillation column to supply said heated expanded second condensed portion to said distillation column at said upper mid-column feed position;

(9) said first expansion means being connected to said first 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;

(10) fourth expansion means connected to said separating means to receive at least a portion of said at least one liquid stream and expand it to said lower pressure, said fourth 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;

(11) third dividing means connected to said distillation column to receive said overhead vapor stream separated therein and divide it into at least a first vapor portion and a second vapor portion;

(12) said heat exchange means being further connected to said third dividing means to receive at least a portion of said second vapor portion and heat it, thereafter discharging at least a portion of said heated second vapor portion as said volatile residue gas fraction;

(13) 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;

(14) combining means connected to said third dividing means and said vapor withdrawing means to receive said first vapor portion and said distillation vapor stream and form a combined vapor stream;

(15) compressing means connected to said combining means to receive said combined vapor stream and compress it to higher pressure;

(16) said heat exchange means being further connected to said compressing means to receive said compressed combined vapor stream and cool it sufficiently to condense at least a part of it, thereby forming a condensed stream while supplying at least a portion of the heating of steps (8) and (12);

(17) fifth expansion means connected to said heat exchange means to receive said condensed stream and expand it to said lower pressure, said fifth expansion means being further connected to said distillation column to supply at least a portion of said expanded condensed stream to said distillation column at a top feed position; and

(18) 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, C₂ components, C₃ components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major

portion of said C₂ components, C₃ components, and heavier hydrocarbon components or said C₃ 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) first dividing means prior to said first cooling means to divide said gas stream into first and second streams;

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

(3) second dividing means connected to said second cooling means to receive said substantially condensed first stream and divide it into at least a first condensed portion and a second condensed portion;

(4) second expansion means connected to said second dividing means to receive said first condensed portion and expand it to said lower pressure, said second expansion means being further connected to said distillation column to supply

said expanded first condensed portion to said distillation column at an upper mid-column feed position;

(5) third expansion means connected to said second dividing means to receive said second condensed portion and expand it to said lower pressure;

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

(7) said first cooling means being connected to said first dividing means to receive said second stream, said first cooling means being adapted to cool said second stream under pressure sufficiently to partially condense it;

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

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

(10) fourth expansion means connected to said separating means to receive at least a portion of said at least one liquid stream and expand it to said lower

pressure, said fourth 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;

(11) third dividing means connected to said distillation column to receive said overhead vapor stream separated therein and divide it into at least a first vapor portion and a second vapor portion;

(12) said heat exchange means being further connected to said third dividing means to receive at least a portion of said second vapor portion and heat it, thereafter discharging at least a portion of said heated second vapor portion as said volatile residue gas fraction;

(13) 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;

(14) combining means connected to said third dividing means and said vapor withdrawing means to receive said first vapor portion and said distillation vapor stream and form a combined vapor stream;

(15) compressing means connected to said combining means to receive said combined vapor stream and compress it to higher pressure;

(16) said heat exchange means being further connected to said compressing means to receive said compressed combined vapor stream and cool it sufficiently to condense at least a part of it, thereby forming a condensed stream while supplying at least a portion of the heating of steps (6) and (12);

(17) fifth expansion means connected to said heat exchange means to receive said condensed stream and expand it to said lower pressure, said fifth expansion means being further connected to said distillation column to supply at least a portion of said expanded condensed stream to said distillation column at a top feed position; and

(18) 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, C₂ components, C₃ components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C₂ components, C₃ components, and heavier hydrocarbon components or said C₃ 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) 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) first dividing means connected to said separating means to receive said vapor stream and divide it into first and second streams;
- (4) first combining means connected to said first dividing means and said 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 first combining means to receive said combined stream and cool it sufficiently to substantially condense it;
- (6) second dividing means connected to said second cooling means to receive said substantially condensed combined stream and divide it into at least a first condensed portion and a second condensed portion;
- (7) second expansion means connected to said second dividing means to receive said first condensed portion and expand it to said lower pressure, said second expansion means being further connected to said distillation column to supply said expanded first condensed portion to said distillation column at an upper mid-column feed position;

(8) third expansion means connected to said second dividing means to receive said second condensed portion and expand it to said lower pressure;

(9) heat exchange means connected to said third expansion means to receive said expanded second condensed portion and heat it, said heat exchange means being further connected to said distillation column to supply said heated expanded second condensed portion to said distillation column at said upper mid-column feed position;

(10) said first expansion means being connected to said first 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;

(11) fourth expansion means being connected to said separating means to receive any remaining portion of said at least one liquid stream and expand it to said lower pressure, said fourth 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;

(12) third dividing means connected to said distillation column to receive said overhead vapor stream separated therein and divide it into at least a first vapor portion and a second vapor portion;

(13) said heat exchange means being further connected to said third dividing means to receive at least a portion of said second vapor portion and heat it,

thereafter discharging at least a portion of said heated second vapor portion as said volatile residue gas fraction;

(14) 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;

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

(16) compressing means connected to said second combining means to receive said combined vapor stream and compress it to higher pressure;

(17) said heat exchange means being further connected to said compressing means to receive said compressed combined vapor stream and cool it sufficiently to condense at least a part of it, thereby forming a condensed stream while supplying at least a portion of the heating of steps (9) and (13);

(18) fifth expansion means connected to said heat exchange means to receive said condensed stream and expand it to said lower pressure, said fifth expansion means being further connected to said distillation column to supply at least a portion of said expanded condensed stream to said distillation column at a top feed position; and

(19) 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, C₂ components, C₃ components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C₂ components, C₃ components, and heavier hydrocarbon components or said C₃ 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) first 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 first dividing means to receive said first stream and cool it sufficiently to substantially condense it;

(3) second dividing means connected to said second cooling means to receive said substantially condensed first stream and divide it into at least a first condensed portion and a second condensed portion;

(4) second expansion means connected to said second dividing means to receive said first condensed portion and expand it to said lower pressure, said second expansion means being further connected to a contacting and separating means to supply said expanded first condensed portion 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) third expansion means connected to said second dividing means to receive said second condensed portion and expand it to said lower pressure;

(6) heat exchange means connected to said third expansion means to receive said expanded second condensed portion and heat it, said heat exchange means being further connected to said contacting and separating means to supply said heated expanded second condensed portion to said contacting and separating means at said mid-column feed position;

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

(9) 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;

(10) third dividing means connected to said contacting and separating means to receive said second overhead vapor stream separated therein and divide it into at least a first vapor portion and a second vapor portion;

(11) said heat exchange means being further connected to said third dividing means to receive at least a portion of said second vapor portion and heat it, thereafter discharging at least a portion of said heated second vapor portion 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) combining means connected to said third dividing means and said vapor withdrawing means to receive said first vapor portion and said distillation vapor stream and form a combined vapor stream;

(14) compressing means connected to said combining means to receive said combined vapor stream and compress it to higher pressure;

(15) said heat exchange means being further connected to said compressing means to receive said compressed combined vapor stream and cool it sufficiently to condense at least a part of it, thereby forming a condensed stream while supplying at least a portion of the heating of steps (6) and (11);

(16) fourth expansion means connected to said heat exchange means to receive said condensed stream and expand it to said lower pressure, said fourth expansion means being further connected to said contacting and separating means to supply at least a portion of said expanded condensed stream to said contacting and separating means at a top feed position; and

(17) 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, C₂ components, C₃ components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C₂ components, C₃ components, and heavier hydrocarbon components or said C₃ 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) first dividing means prior to said first cooling means to divide said gas stream into first and second streams;

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

(3) second dividing means connected to said second cooling means to receive said substantially condensed first stream and divide it into at least a first condensed portion and a second condensed portion;

(4) second expansion means connected to said second dividing means to receive said first condensed portion and expand it to said lower pressure, said second expansion means being further connected to a contacting and separating means to supply said expanded first condensed portion 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) third expansion means connected to said second dividing means to receive said second condensed portion and expand it to said lower pressure;

(6) heat exchange means connected to said third expansion means to receive said expanded second condensed portion and heat it, said heat exchange means being further connected to said contacting and separating means to supply said heated expanded second condensed portion to said contacting and separating means at said mid-column feed position;

(7) said first cooling means being connected to said first dividing means to receive said second stream and cool it;

(8) said first expansion means being connected to said first cooling means to receive said cooled 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 cooled second stream to said contacting and separating means at a first lower column feed position below said 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) third dividing means connected to said contacting and separating means to receive said second overhead vapor stream separated therein and divide it into at least a first vapor portion and a second vapor portion;

(12) said heat exchange means being further connected to said third dividing means to receive at least a portion of said second vapor portion and heat it, thereafter discharging at least a portion of said heated second vapor portion 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) combining means connected to said third dividing means and said vapor withdrawing means to receive said first vapor portion and said distillation vapor stream and form a combined vapor stream;

(15) compressing means connected to said combining means to receive said combined vapor stream and compress it to higher pressure;

(16) said heat exchange means being further connected to said compressing means to receive said compressed combined vapor stream and cool it sufficiently to condense at least a part of it, thereby forming a condensed stream while supplying at least a portion of the heating of steps (6) and (12);

(17) fourth expansion means connected to said heat exchange means to receive said condensed stream and expand it to said lower pressure, said fourth expansion means being further connected to said contacting and separating means to supply at least a portion of said expanded condensed stream to said contacting and separating means at a top feed position; and

(18) 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, C₂ components, C₃ components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C₂ components, C₃ components, and heavier hydrocarbon components or said C₃ 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) 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) first dividing means connected to said separating means to receive said vapor stream and divide it into first and second streams;

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

(5) second dividing means connected to said second cooling means to receive said substantially condensed first stream and divide it into at least a first condensed portion and a second condensed portion;

(6) second expansion means connected to said second dividing means to receive said first condensed portion and to expand it to said lower pressure, said second expansion means being further connected to a contacting and separating means to supply said expanded first condensed portion 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) third expansion means connected to said second dividing means to receive said second condensed portion and expand it to said lower pressure;

(8) heat exchange means connected to said third expansion means to receive said expanded second condensed portion and heat it, said heat exchange means being further connected to said contacting and separating means to supply said

heated expanded second condensed portion to said contacting and separating means at said mid-column feed position;

(9) said first expansion means being connected to said first 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;

(10) fourth expansion means connected to said separating means to receive at least a portion of said at least one liquid stream and expand it to said lower pressure, said fourth 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;

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

(12) 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;

(13) third dividing means connected to said contacting and separating means to receive said second overhead vapor stream separated therein and divide it into at least a first vapor portion and a second vapor portion;

(14) said heat exchange means being further connected to said third dividing means to receive at least a portion of said second vapor portion and heat it, thereafter discharging at least a portion of said heated second vapor portion as said volatile residue gas fraction;

(15) 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;

(16) combining means connected to said third dividing means and said vapor withdrawing means to receive said first vapor portion and said distillation vapor stream and form a combined vapor stream;

(17) compressing means connected to said combining means to receive said combined vapor stream and compress it to higher pressure;

(18) said heat exchange means being further connected to said compressing means to receive said compressed combined vapor stream and cool it sufficiently to condense at least a part of it, thereby forming a condensed stream while supplying at least a portion of the heating of steps (8) and (14);

(19) fifth expansion means connected to said heat exchange means to receive said condensed stream and expand it to said lower pressure, said fifth expansion means being further connected to said contacting and separating means to supply at least a portion of said expanded condensed stream to said contacting and separating means at a top feed position; and

(20) 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. In an apparatus for the separation of a gas stream containing methane, C₂ components, C₃ components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C₂ components, C₃ components, and heavier hydrocarbon components or said C₃ 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) first dividing means prior to said first cooling means to divide said gas stream into first and second streams;

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

(3) second dividing means connected to said second cooling means to receive said substantially condensed first stream and divide it into at least a first condensed portion and a second condensed portion;

(4) second expansion means connected to said second dividing means to receive said first condensed portion and to expand it to said lower pressure, said second expansion means being further connected to a contacting and separating means to supply said expanded first condensed portion 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) third expansion means connected to said second dividing means to receive said second condensed portion and expand it to said lower pressure;

(6) heat exchange means connected to said third expansion means to receive said expanded second condensed portion and heat it, said heat exchange means being further connected to said contacting and separating means to supply said heated expanded second condensed portion to said contacting and separating means at said mid-column feed position;

(7) said first cooling means being connected to said first dividing means to receive said second stream, said first cooling means being adapted to cool said second stream under pressure sufficiently to partially condense it;

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

(9) said first expansion means being connected to said separating means to receive said vapor 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 vapor stream to said contacting and separating means at a first lower column feed position below said mid-column feed position;

(10) fourth expansion means connected to said separating means to receive at least a portion of said at least one liquid stream and expand it to said lower pressure, said fourth 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;

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

(12) 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;

(13) third dividing means connected to said contacting and separating means to receive said second overhead vapor stream separated therein and divide it into at least a first vapor portion and a second vapor portion;

(14) said heat exchange means being further connected to said third dividing means to receive at least a portion of said second vapor portion and heat it, thereafter discharging at least a portion of said heated second vapor portion as said volatile residue gas fraction;

(15) 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;

(16) combining means connected to said third dividing means and said vapor withdrawing means to receive said first vapor portion and said distillation vapor stream and form a combined vapor stream;

(17) compressing means connected to said combining means to receive said combined vapor stream and compress it to higher pressure;

(18) said heat exchange means being further connected to said compressing means to receive said compressed combined vapor stream and cool it sufficiently to condense at least a part of it, thereby forming a condensed stream while supplying at least a portion of the heating of steps (6) and (14);

(19) fifth expansion means connected to said heat exchange means to receive said condensed stream and expand it to said lower pressure, said fifth expansion means being further connected to said contacting and separating means to supply at least a portion of said expanded condensed stream to said contacting and separating means at a top feed position; and

(20) 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.

30. In an apparatus for the separation of a gas stream containing methane, C₂ components, C₃ components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C₂ components, C₃ components, and heavier hydrocarbon components or said C₃ 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) 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) first dividing means connected to said separating means to receive said vapor stream and divide it into first and second streams;

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

(6) second dividing means connected to said second cooling means to receive said substantially condensed combined stream and divide it into at least a first condensed portion and a second condensed portion;

(7) second expansion means connected to said second dividing means to receive said first condensed portion and to expand it to said lower pressure, said second expansion means being further connected to a contacting and separating means to supply said expanded first condensed portion 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) third expansion means connected to said second dividing means to receive said second condensed portion and expand it to said lower pressure;

(9) heat exchange means connected to said third expansion means to receive said expanded second condensed portion and heat it, said heat exchange means being further connected to said contacting and separating means to supply said heated expanded second condensed portion to said contacting and separating means at said mid-column feed position;

(10) said first expansion means being connected to said first 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;

(11) fourth expansion means connected to said separating means to receive any remaining portion of said at least one liquid stream and expand it to said lower pressure, said fourth 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;

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

(13) 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;

(14) third dividing means connected to said contacting and separating means to receive said second overhead vapor stream separated therein and divide it into at least a first vapor portion and a second vapor portion;

(15) said heat exchange means being further connected to said third dividing means to receive at least a portion of said second vapor portion and heat it, thereafter discharging at least a portion of said heated second vapor portion as said volatile residue gas fraction;

(16) 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;

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

(18) compressing means connected to said second combining means to receive said combined vapor stream and compress it to higher pressure;

(19) said heat exchange means being further connected to said compressing means to receive said compressed combined vapor stream and cool it sufficiently to condense at least a part of it, thereby forming a condensed stream while supplying at least a portion of the heating of steps (9) and (15);

(20) fifth expansion means connected to said heat exchange means to receive said condensed stream and expand it to said lower pressure, said fifth

expansion means being further connected to said contacting and separating means to supply at least a portion of said expanded condensed stream to said contacting and separating means at a top feed position; and

(21) 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.

31. The improvement according to claim 21, 22, 23, 24, or 25 wherein said vapor withdrawing means is connected to said distillation column to receive said distillation vapor stream from a region of said distillation column below said top feed position and above said upper mid-column feed position.

32. The improvement according to claim 21, 22, 23, 24, or 25 wherein said vapor withdrawing means is connected to said distillation column to receive said distillation vapor stream from a region of said distillation column below said mid-column feed position.

33. The improvement according to claim 26, 27, 28, 29, or 30 wherein said vapor withdrawing means is connected to said contacting and separating means to receive said distillation vapor stream from a region of said contacting and separating means below said top feed position and above said mid-column feed position.

34. The improvement according to claim 26, 27, 28, or 29 wherein

(1) a fourth 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 device is adapted to be connected to said fourth dividing means to receive said second distillation vapor stream at said second lower column feed position; and

(3) said combining means is adapted to be connected to said fourth dividing means to receive said distillation vapor stream.

35. The improvement according to claim 30 wherein

(1) a fourth 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 device is adapted to be connected to said fourth dividing means to receive said second distillation vapor stream at said second lower column feed position; and

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

36. The improvement according to claim 21, 22, 23, 24, or 25 wherein said heated expanded second condensed portion is supplied to said distillation column at a second upper mid-column feed position.

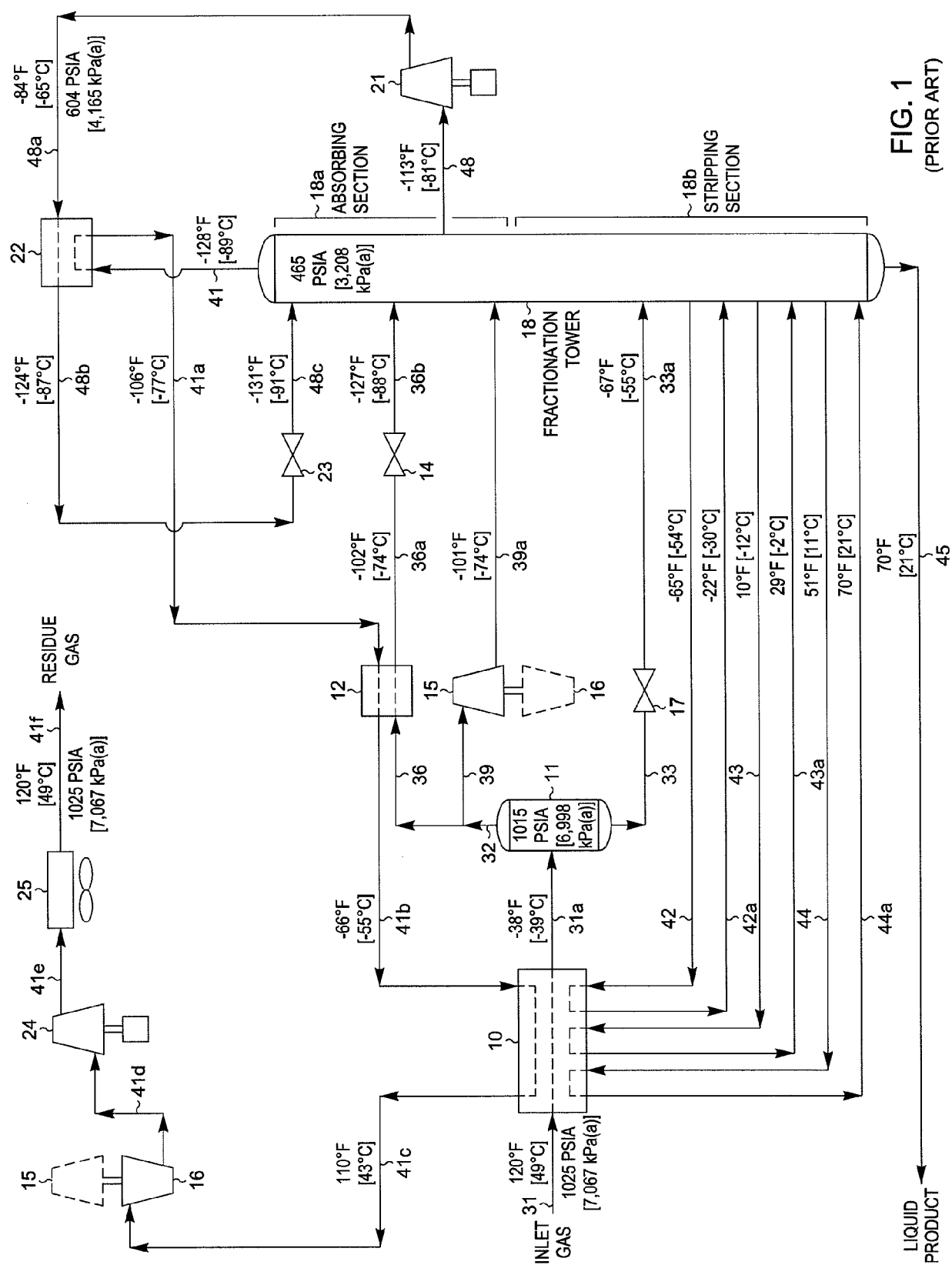
37. The improvement according to claim 31 wherein said heated expanded second condensed portion is supplied to said distillation column at a second upper mid-column feed position.

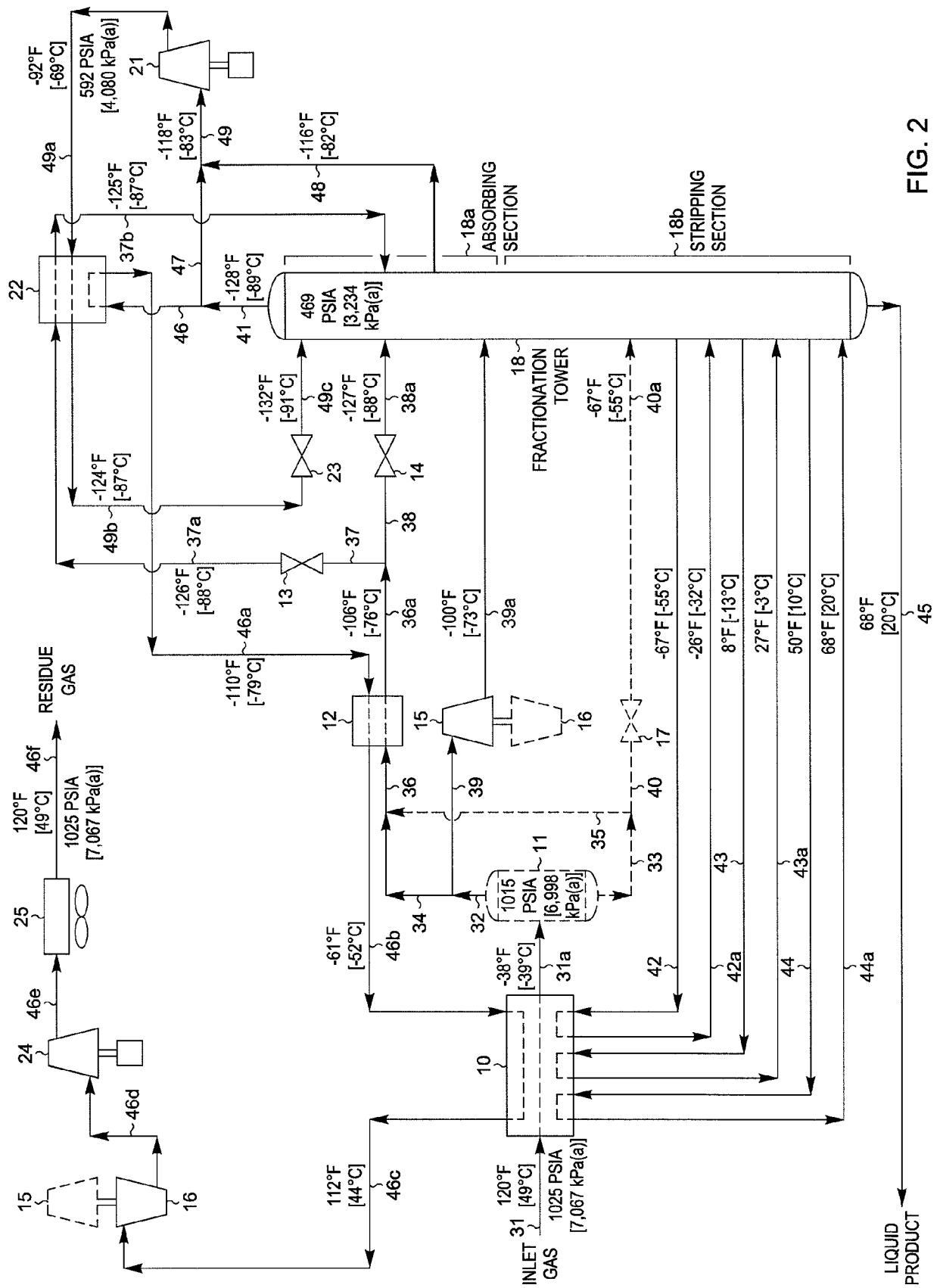
38. The improvement according to claim 32 wherein said heated expanded second condensed portion is supplied to said distillation column at a second upper mid-column feed position.

39. The improvement according to claim 26, 27, 28, 29, 30, or 35 wherein said heated expanded second condensed portion is supplied to said contacting and separating device at a second mid-column feed position.

40. The improvement according to claim 33 wherein said heated expanded second condensed portion is supplied to said contacting and separating device at a second mid-column feed position.

41. The improvement according to claim 34 wherein said heated expanded second condensed portion is supplied to said contacting and separating device at a second mid-column feed position.





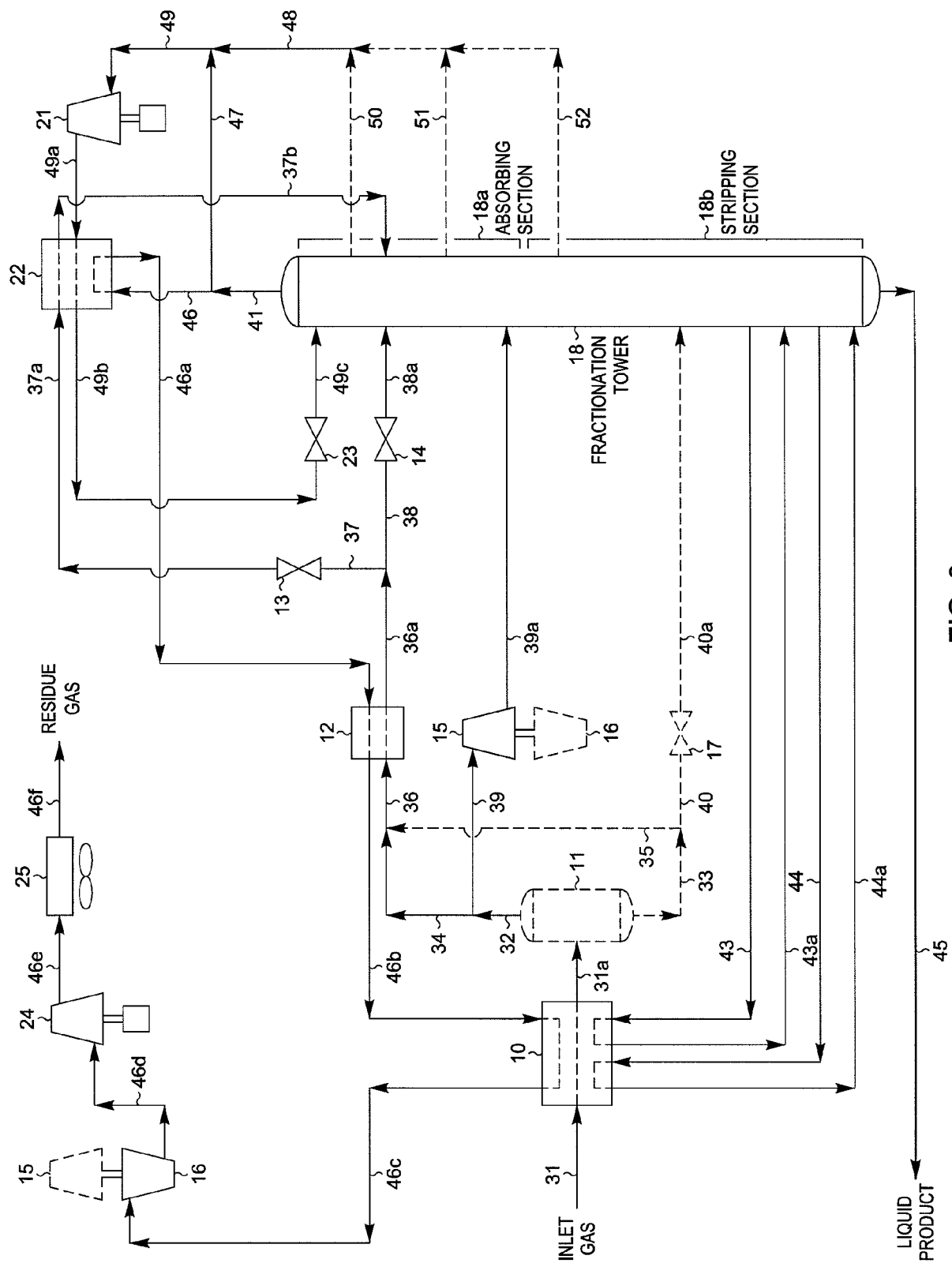


FIG. 3

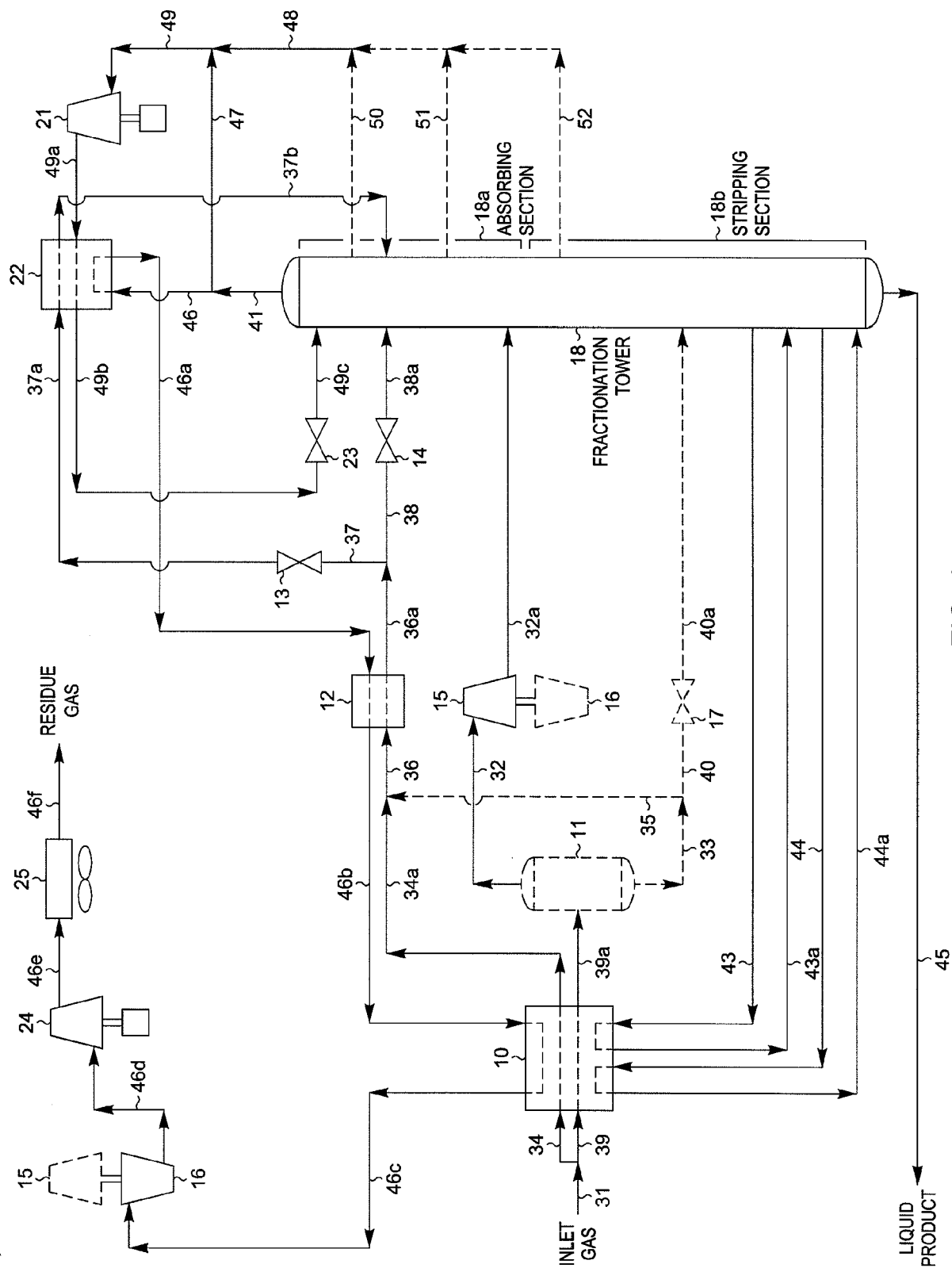


FIG. 4

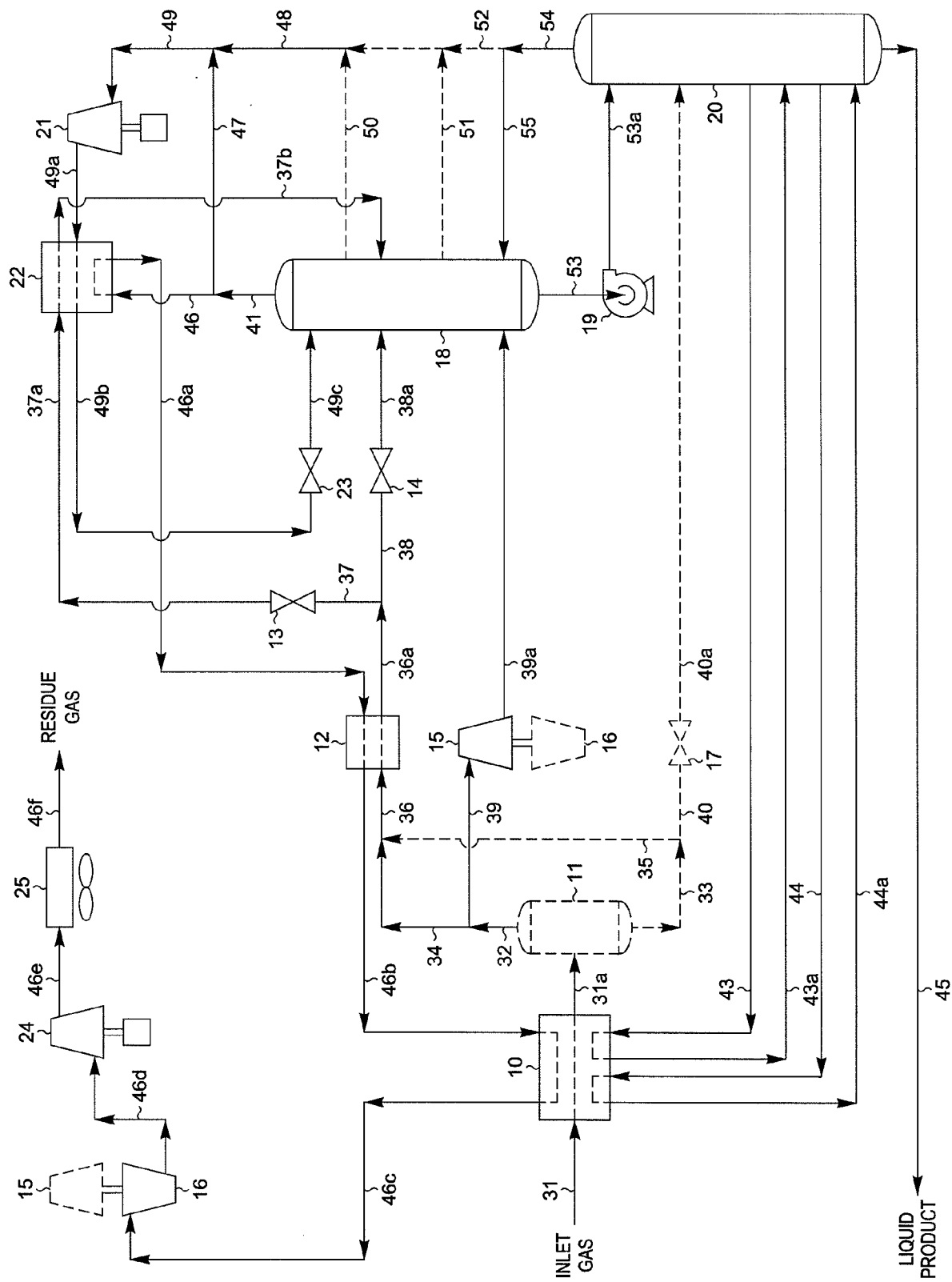


FIG. 5

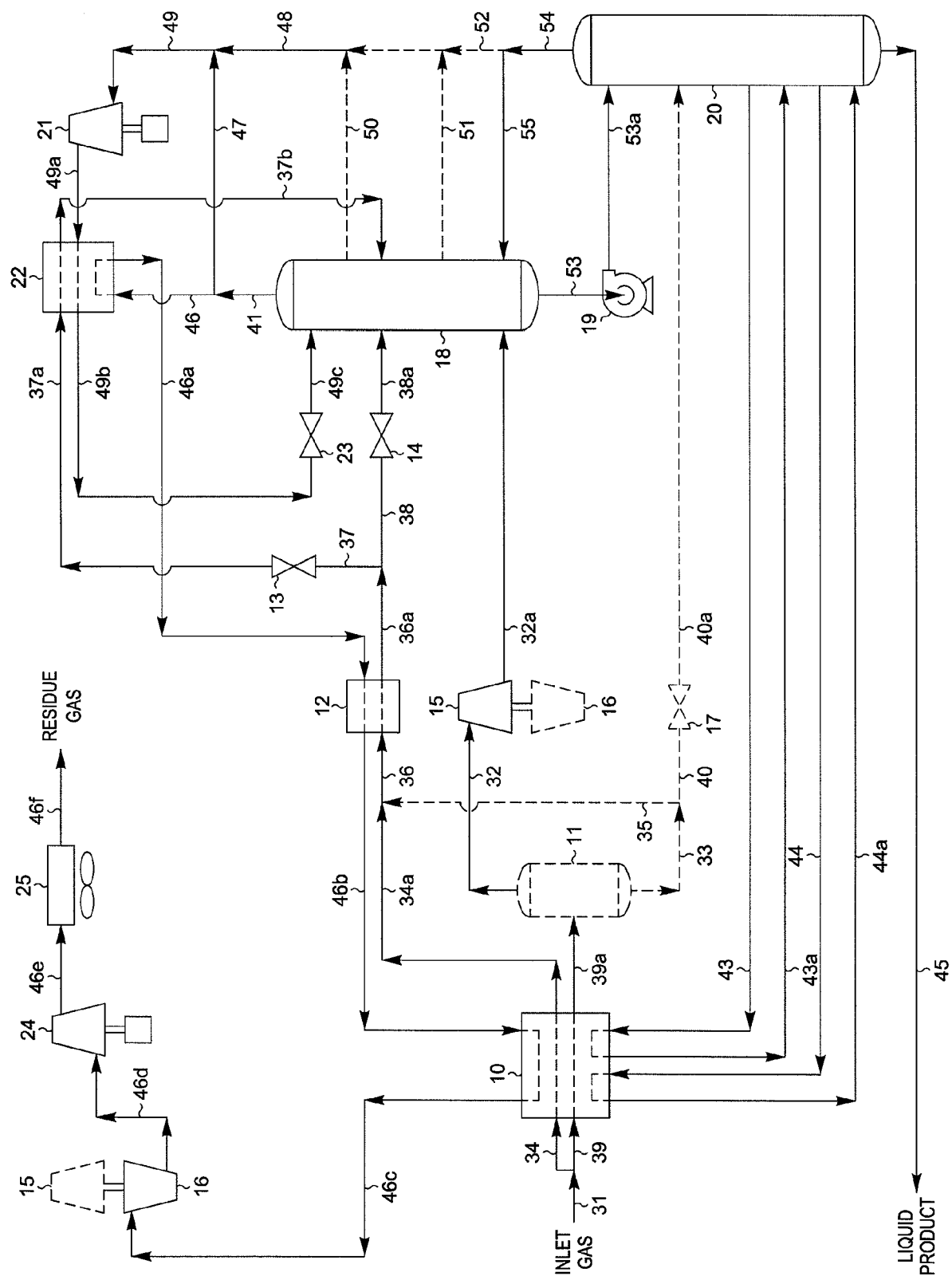


FIG. 6