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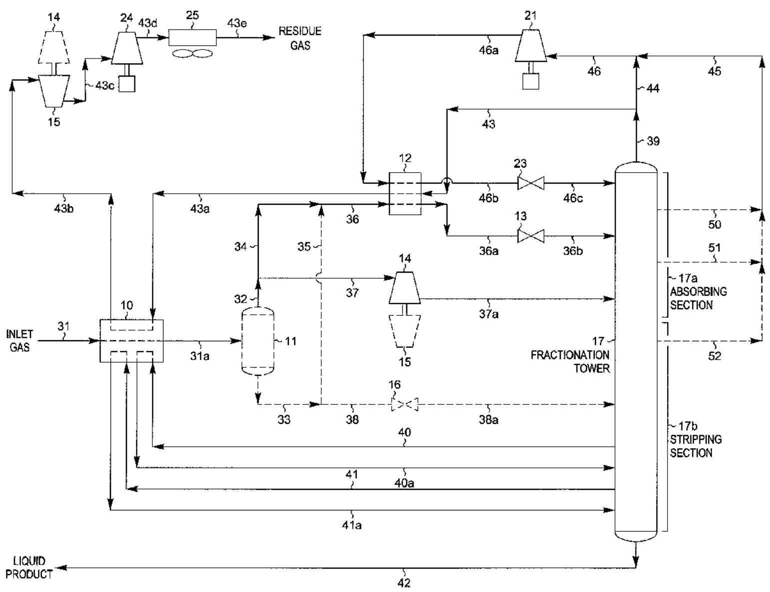
(54) **Title**: HYDROCARBON GAS PROCESSING

FIG. 3



(57) **Abstract**: A process and an apparatus are disclosed for the recovery of ethane, ethylene, propane, propylene, and heavier hydrocarbon components from a hydrocarbon gas stream The stream is cooled and divided into first and second streams The first stream is further cooled to condense substantially all of it and is thereafter expanded to the fractionation tower pressure and supplied to the fractionation tower at an upper mid-column feed position The second stream is expanded to the tower pressure and supplied to the column at a mid-column feed position A distillation vapor stream is withdrawn from the column above the feed point of the first stream, combined with a portion of the tower overhead vapor stream, compressed to higher pressure, and directed into heat exchange relation with the remaining tower overhead vapor stream to cool the compressed combined vapor stream and condense at least a part of it, forming a condensed stream

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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, 88.1% methane, 6.0% ethane and other C_2 components, 2.5% propane and other C_3 components, 0.2% iso-butane, 0.2% 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 C_2, C_3, and C_4+ components occur because the top liquid feed contains substantial quantities of these components and heavier hydrocarbon components, resulting in corresponding equilibrium quantities of C_2 components, C_3 components, C_4 components, and heavier hydrocarbon components in the vapors leaving the top fractionation stage of the demethanizer. The loss of these desirable components could be significantly reduced if the rising vapors could be brought into contact with a significant quantity of liquid (reflux) capable of absorbing the C_2 components, C_3 components, C_4 components, and heavier hydrocarbon components from the vapors.

[0010] In recent years, the preferred processes for hydrocarbon separation use an upper absorber section to provide additional rectification of the rising vapors. The source of the reflux stream for the upper rectification section is typically a recycled stream of residue gas supplied under pressure. The recycled residue gas stream is usually cooled to substantial condensation by heat exchange with other process streams, e.g., the cold fractionation tower overhead. The resulting substantially condensed stream is then expanded through an appropriate expansion device, such as an expansion valve, to the pressure at which the demethanizer is operated. During expansion, a portion of the liquid will usually vaporize, resulting in cooling of the total stream. The flash expanded stream is then supplied as top feed to the demethanizer. Typically, the vapor portion of the expanded stream and the demethanizer overhead vapor combine in an upper separator section in the fractionation tower as residual methane product gas. Alternatively, the cooled and expanded stream may be supplied to a separator to provide vapor and liquid streams, so that thereafter the vapor is combined with the tower overhead and the liquid is supplied to the column as a top column feed. Typical process schemes of this type are disclosed in U.S. 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 C_2 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, often using only the refrigeration available in the remaining portion of the cold overhead vapor leaving the upper rectification section of the column. This condensed liquid, which is predominantly liquid methane, can then be used to absorb C_2 components, C_3 components, C_4 components, and heavier hydrocarbon components from the vapors rising through the upper rectification section and thereby capture these valuable components in the bottom liquid product from the demethanizer.

[0012] Heretofore, 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 C_2+ 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 C_2 recovery in excess of 95% and C_3 and C_4+ 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 C_2 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 United States Patent No. 4,889,545;

[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 C_2+ components from natural gas using prior art according to U.S. Pat. No. 4,889,545. In this simulation of the process, inlet gas enters the plant at 120°F [49°C] and 1040 psia [7,171 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 **43a**), liquid product at 72°F [22°C] (stream **42a**), demethanizer reboiler liquids at 52°F [11°C] (stream **41**), and demethanizer side reboiler liquids at -20°F [-29°C] (stream **40**). 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 -18°F [-28°C] and 1025 psia [7,067 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 392 psia [2,701 kPa(a)]) of fractionation tower **17** by expansion valve **16**, cooling stream **33a** to -53°F [-47°C] before it is supplied to fractionation tower **17** at a lower mid-column feed point.

[0022] The vapor (stream **32**) from separator **11** is divided into two streams, **36** and **37**. Stream **36**, containing about 38% of the total vapor, passes through heat exchanger **12** in heat exchange relation with the cold residue gas (stream **43**) where it is cooled to substantial condensation. The resulting substantially condensed stream **36a** at -142°F [-96°C] is then flash expanded through expansion valve **13** to slightly above the operating pressure of fractionation tower **17**. 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 **13** reaches a temperature of -144°F [-98°C]. The expanded stream **36b** is warmed to -139°F [-95°C] and further vaporized in heat exchanger **22** as it provides cooling and condensation of compressed recycle stream **44a** (described later in paragraph [0026]). The warmed stream **36c** is then supplied at an upper mid-column feed point, in absorbing section **17a** of fractionation tower **17**.

[0023] The remaining 62% of the vapor from separator **11** (stream **37**) enters a work expansion machine **14** in which mechanical energy is extracted from this portion of the high pressure feed. The machine **14** expands the vapor substantially isentropically to the tower operating pressure, with the work expansion cooling the expanded stream **37a** to a temperature of approximately -94°F [-70°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 **15**) that can be used to re-compress the residue gas (stream **43b**), for example. The partially condensed expanded stream **37a** is thereafter supplied as feed to fractionation tower **17** at a mid-column feed point.

[0024] The demethanizer in tower **17** 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 **17a** that contains the trays and/or packing to provide the necessary contact between the vapor portions of the expanded streams **36c** and **37a** rising upward and cold liquid falling downward to condense and absorb the C_2 components, C_3 components, and heavier components; and a lower, stripping section **17b** 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 **17b** also includes one or more reboilers (such as the reboiler and side reboiler 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 **42**, of methane and lighter components. Stream **37a** enters demethanizer **17** at an intermediate feed position located in the lower region of absorbing section **17a** of demethanizer **17**. The liquid portion of the expanded stream **37a** commingles with liquids falling downward from absorbing section **17a** and the combined liquid continues downward into stripping section **17b** of demethanizer **17**. The vapor portion of the expanded stream **37a** rises upward through absorbing section **17a** and is contacted with cold liquid falling downward to condense and absorb the C_2 components, C_3 components, and heavier components.

[0025] In stripping section **17b** of demethanizer **17**, the feed streams are stripped of their methane and lighter components. The resulting liquid product (stream **42**) exits the bottom of tower **17** at 67°F [19°C] (based on a typical specification of a methane to ethane ratio of 0.015:1 on a volume basis in the bottom product) and is pumped to heat exchanger **10** by pump **20** to be heated to 116°F [47°C] as it provides cooling to the feed gas as described earlier.

[0026] Cold demethanizer overhead stream **39** exits the top of demethanizer **17** at -146°F [-99°C] and is divided into cold residue gas stream **43** and recycle stream **44**. Recycle stream **44** is compressed to 492 psia [3,390 kPa(a)] by compressor **21** before entering heat exchanger **22**. The compressed recycle stream **44a** is cooled from -121°F [-85°C] to -140°F [-96°C] and substantially condensed by heat exchange with expanded substantially condensed stream **36b** as described previously. The substantially condensed stream **44b** 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 -150°F [-101°C]. The expanded stream **44c** is then supplied to fractionation tower **17** as the top column feed. The vapor portion of stream **44c** combines with the vapors rising from the top fractionation stage of the column to form demethanizer overhead stream **39**.

[0027] The cold residue gas stream **43** passes countercurrently to the incoming feed gas in heat exchanger **12** where it is heated to -26°F [-32°C] (stream **43a**) and in heat exchanger **10** where it is heated to 98°F [37°C] (stream **43b**). The residue gas is then re-compressed in two stages. The first stage is compressor **15** driven by expansion machine **14**. The second stage is compressor **24** driven by a supplemental power source which compresses the residue gas (stream **43d**) to sales line pressure. After cooling to 120°F [49°C] in discharge cooler **25**, the residue gas product (stream **43e**) flows to the sales gas pipeline at 1040 psia [7,171 kPa(a)], sufficient to meet line requirements (usually on the order of the inlet pressure).

[0028] A summary of stream flow rates and energy consumption for the process illustrated in FIG. 1 is set forth in the following table:

Table I

(FIG. 1)

Stream Flow Summary - Lb. Moles/Hr [kg moles/Hr]

Stream	Methane	Ethane	Propane	Butanes+	Total
31	24,193	1,650	687	234	27,451
32	24,042	1,608	641	168	27,142
33	151	42	46	66	309
36	9,184	614	245	64	10,368
37	14,858	994	396	104	16,774
39	28,419	82	0	0	29,216
44	4,263	12	0	0	4,382
43	24,156	70	0	0	24,834
42	37	1,580	687	234	2,617

Recoveries*

Ethane	95.79%				
Propane	100.00%				
Butanes+	100.00%				

Power

Residue Gas Compression	13,294	HP	[	21,855	kW]
Recycle Compression	224	HP	[	368	kW]
Total Compression	13,518	HP	[	22,223	kW]

* (Based on un-rounded flow rates)

DESCRIPTION OF THE INVENTION

[0029] 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.

[0030] In the simulation of the FIG. 2 process, inlet gas enters the plant at 120°F [49°C] and 1040 psia [7,171 kPa(a)] as stream **31** and is cooled in heat exchanger **10** by heat exchange with cool residue gas (stream **43a**), liquid product at 74°F [24°C] (stream **42a**), demethanizer reboiler liquids at 54°F [12°C] (stream **41**), and demethanizer side reboiler liquids at -19°F [-28°C] (stream **40**). The cooled stream **31a** enters separator **11** at -24°F [-31°C] and 1025 psia [7,067 kPa(a)] where the vapor (stream **32**) is separated from the condensed liquid (stream **33**). The separator liquid (stream **33/38**) is expanded to the operating pressure (approximately 401 psia [2,766 kPa(a)]) of fractionation tower **17** by expansion valve **16**, cooling stream **38a** to -59°F [-51°C] before it is supplied to fractionation tower **17** at a lower mid-column feed point (located below the feed point of stream **37a** described later in paragraph [0032]).

[0031] The vapor (stream **32**) from separator **11** is divided into two streams, **34** and **37**. Stream **34**, containing about 28% of the total vapor, passes through heat exchanger **12** in heat exchange relation with the cold residue gas (stream **43**) where it is cooled to substantial condensation. The resulting substantially condensed stream **36a** at -140°F [-96°C] is then flash expanded through expansion valve **13** to the operating pressure of fractionation tower **17**. 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 **36b** leaving expansion valve **13** reaches a temperature of -144°F [-98°C] before it is supplied at an upper mid-column feed point, in absorbing section **17a** of fractionation tower **17**.

[0032] The remaining 72% of the vapor from separator **11** (stream **37**) enters a work expansion machine **14** in which mechanical energy is extracted from this portion of the high pressure feed. The machine **14** expands the vapor substantially isentropically to the tower operating pressure, with the work expansion cooling the expanded stream **37a** to a temperature of approximately -97°F [-72°C]. The partially condensed expanded stream **37a** is thereafter supplied as feed to fractionation tower **17** at a mid-column feed point (located below the feed point of stream **36b**).

[0033] The demethanizer in tower **17** 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 **17a** that contains the trays and/or packing to provide the necessary contact between the vapor portion of the expanded streams **36b** and **37a** rising upward and cold liquid falling downward to condense and absorb the C_2 components, C_3 components, and heavier components from the vapors rising upward; and a lower, stripping section **17b** 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 **17b** also includes one or more reboilers (such as the reboiler and side reboiler 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 **42**, of methane and lighter components. Stream **37a** enters demethanizer **17** at an intermediate feed position located in the lower region of absorbing section **17a** of demethanizer **17**. The liquid portion of the expanded stream **37a** commingles with liquids falling downward from absorbing section **17a** and the combined liquid continues downward into stripping section **17b** of demethanizer **17**. The vapor portion of the expanded stream **37a** rises upward through absorbing section **17a** and is contacted with cold liquid falling downward to condense and absorb the C_2 components, C_3 components, and heavier components.

[0034] A portion of the distillation vapor (stream **45**) is withdrawn from the upper region of absorbing section **17a** in fractionation column **17**, above the feed position of expanded stream **36b** in the middle region of absorbing section **17a**. The distillation vapor stream **45** at -142°F [-96°C] is combined with a first portion (stream **44**) of overhead vapor stream **39** at -144°F [-98°C] to form combined vapor stream **46** at -144°F [-98°C]. The combined vapor stream **46** is compressed to 686 psia [4,728 kPa(a)] by reflux compressor **21**, then cooled from -84°F [-65°C] to -140°F

[-96°C] and substantially condensed (stream **46b**) in heat exchanger **12** by heat exchange with cold residue gas stream **43**, the remaining second portion of demethanizer overhead stream **39** exiting the top of demethanizer **17**.

[0035] The substantially condensed stream **46b** is flash expanded to the operating pressure of demethanizer **17** by expansion valve **23**. A portion of the stream is vaporized, further cooling stream **46c** to -149°F [-101°C] before it is supplied as cold top column feed (reflux) to demethanizer **17**. This cold liquid reflux absorbs and condenses the C_2 components, C_3 components, and heavier components rising in the upper rectification region of absorbing section **17a** of demethanizer **17**.

[0036] In stripping section **17b** of demethanizer **17**, the feed streams are stripped of their methane and lighter components. The resulting liquid product (stream **42**) exits the bottom of tower **17** at 69°F [21°C] (based on a typical specification of a methane to ethane ratio of 0.015:1 on a volume basis in the bottom product) and is pumped to heat exchanger **10** by pump **20** to be heated to 116°F [47°C] as it provides cooling to the feed gas as described earlier. The cold residue gas stream **43** passes countercurrently to the incoming feed gas and compressed combined vapor stream in heat exchanger **12** where it is heated to -37°F [-39°C] (stream **43a**), and countercurrently to the incoming feed gas in heat exchanger **10** where it is heated to 97°F [36°C] (stream **43b**) as it provides cooling as previously described. The residue gas is then re-compressed in two stages, compressor **15** driven by expansion machine **14** and compressor **24** driven by a supplemental power source. After stream **43d** is cooled to 120°F [49°C] in discharge cooler **25**, the residue gas product (stream **43e**) flows to the sales gas pipeline at 1040 psia [7,171 kPa(a)] , sufficient to meet line requirements (usually on the order of the inlet pressure).

[0037] A summary of stream flow rates and energy consumption for the process illustrated in FIG. 2 is set forth in the following table:

Table II

(FIG. 2)

Stream Flow Summary - Lb. Moles/Hr [kg moles/Hr]

Stream	Methane	Ethane	Propane	Butanes+	Total
31	24,193	1,650	687	234	27,451
32	23,983	1,593	626	157	27,042
33	210	57	61	77	409
34	6,607	439	172	43	7,450
35	0	0	0	0	0
36	6,607	439	172	43	7,450
37	17,376	1,154	454	114	19,592
38	210	57	61	77	409
39	27,081	78	0	0	27,845
44	2,925	8	0	0	3,007
45	194	1	0	0	200
46	3,119	9	0	0	3,207
43	24,156	70	0	0	24,838
42	37	1,580	687	234	2,613

Recoveries*

Ethane	95.77%				
Propane	99.99%				
Butanes+	100.00%				

Power

Residue Gas Compression	12,573	HP	[	20,670	kW]
Reflux Compression	401	HP	[	659	kW]
Total Compression	12,974	HP	[	21,329	kW]

* (Based on un-rounded flow rates)

[0038] A comparison of Tables I and II shows that the present invention maintains essentially the same recoveries as the prior art. However, further comparison of Tables I and II shows that the product yields were achieved using significantly less power than the prior art. In terms of the recovery efficiency (defined by the quantity of ethane recovered per unit of power), the present invention represents more than a 4% improvement over the prior art of the FIG. 1 process.

[0039] Like the prior art of the FIG. 1 process, the present invention uses the expanded substantially condensed feed stream **36b** supplied to absorbing section **17a** of demethanizer **17** to provide bulk recovery of the C_2 components, C_3 components, and heavier hydrocarbon components contained in expanded feed **37a** and the vapors rising from stripping section **17b**, and the supplemental rectification provided by reflux stream **46c** to reduce the amount of C_2 components, C_3 components, and C_4+ components contained in the inlet feed gas that is lost to the residue gas. However, the present invention reduces the rectification required in absorbing section **17a** over that of the prior art FIG. 1 process by condensing reflux stream **46c** without warming any of the feeds (stream **36b** and **37a**) to absorbing section **17a**. If the substantially condensed stream **36b** is warmed to provide condensing as is taught in the prior art FIG. 1 process, not only is there less cold liquid from stream **36b** available for rectification of the vapors rising in absorbing section **17a**, there is much more vapor in the upper region of absorbing section **17a** that must be rectified by the reflux stream. As can be seen by comparing reflux stream **44** in Table I with reflux stream **46** in Table II, the net result is that more reflux is required by the prior art FIG. 1 process to prevent the C_2 components from escaping to the residue gas stream than the present invention requires, reducing its recovery efficiency compared to the present invention. The key improvement of the present invention over the prior art process is that only the cold residue gas stream **43** is needed to provide the cooling in heat exchanger **12**, thereby condensing sufficient methane from compressed combined vapor stream **46a** for use as reflux while avoiding adding significant rectification load in absorbing section **17a** due to the excessive vaporization of stream **36b** that is inherent in the prior art FIG. 1 process.

<u>Other Embodiments</u>

[0040] 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 **46c**) leaving expansion valve **23** and all or a part of the expanded substantially condensed stream **36b** from expansion valve **13** can be combined (such as in the piping joining the expansion valves 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 two streams, combined with contacting at least a portion of expanded stream **37a**, shall be considered for the purposes of this invention as constituting an absorbing section.

[0041] 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 **17** (a contacting and separating device) and stripper (distillation) column **19**. In such cases, the overhead vapor stream **48** from stripper column **19** flows to the lower section of absorber column **17** (via stream **49**) to be contacted by reflux stream **46c** and expanded substantially condensed stream **36b**. Pump **18** is used to route the liquids (stream **47**) from the bottom of absorber column **17** to the top of stripper column **19** 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 **17** 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.

[0042] Some circumstances may favor withdrawing the distillation vapor stream **45** in FIGS. 3 and 4 from the lower region of absorbing section **17a** above the feed point of expanded stream **37a** (stream **51**), rather than from the upper region of absorbing section **17a** above the feed point of expanded substantially condensed stream **36b** (stream **50**). Likewise in FIGS. 5 and 6, the vapor distillation stream **45** may be withdrawn from absorber column **17** above the feed point of expanded substantially condensed stream **36b** (stream **50**) or above the feed point of expanded stream **37a** (stream **51**). In other cases, it may be advantageous to withdraw the distillation vapor stream **45** from the upper region of stripping section **17b** in demethanizer **17** (stream **52**) in FIGS. 3 and 4. Similarly in FIGS. 5 and 6, a portion (stream **52**) of overhead vapor stream **48** from stripper column **19** may be combined with stream **44**, with any remaining portion (stream **49**) flowing to the lower section of absorber column **17**.

[0043] As described earlier, the compressed combined vapor stream **46a** 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 **17a** of demethanizer **17** or through absorber column **17**. 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 **17a** of demethanizer **17** or absorber column **17**. Some circumstances may favor partial condensation, rather than substantial condensation, of compressed combined vapor stream **46a** in heat exchanger **12**. Other circumstances may favor that distillation vapor stream **45** be a total vapor side draw from fractionation column **17** or absorber column **17** 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 **46a** in heat exchanger **12**.

[0044] Feed gas conditions, plant size, available equipment, or other factors may indicate that elimination of work expansion machine **14**, or replacement with an alternate expansion device (such as an expansion valve), is feasible. Although individual stream expansion is depicted in particular expansion devices, alternative expansion means may be employed where appropriate. For example, conditions may warrant work expansion of the substantially condensed portion of the feed stream (stream **36a**) or the substantially condensed reflux stream (stream **46b**) leaving heat exchanger **12**.

[0045] 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.

[0046] 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**) 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 **38a** in FIGS. 2 through 6). Stream **38** 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.

[0047] 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.

[0048] 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.

[0049] 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.

[0050] The present invention provides improved recovery of C_2 components, C_3 components, and heavier hydrocarbon components or of C_3 components and heavier hydrocarbon components per amount of utility consumption required to operate the process. An improvement in utility consumption required for operating the demethanizer or deethanizer process may appear in the form of reduced power requirements for compression or re-compression, reduced power requirements for external refrigeration, reduced energy requirements for tower reboilers, or a combination thereof.

[0051] While there have been described what are believed to be preferred embodiments of the invention, those skilled in the art will recognize that other and further modifications may be made thereto, e.g. to adapt the invention to various conditions, types of feed, or other requirements without departing from the spirit of the present invention as defined by the following claims.

WE CLAIM:

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

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

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

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

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

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

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

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

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

(5) a distillation vapor stream is withdrawn from a region of said distillation column above said upper mid-column feed position and is combined with said first portion to form a combined vapor stream;

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

(7) said compressed combined vapor stream is directed into heat exchange relation with said second portion, whereby said second portion is heated and said compressed combined vapor stream is cooled sufficiently to condense at least a part of it and thereby form a condensed stream, and thereafter discharging at least a portion of said heated second portion as said volatile residue gas fraction;

(8) 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

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

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

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

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

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

the improvement wherein 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 and is thereafter expanded to said lower pressure whereby it is further cooled;

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

(3) 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;

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

(5) a distillation vapor stream is withdrawn from a region of said distillation column above said upper mid-column feed position and is combined with said first portion to form a combined vapor stream;

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

(7) said compressed combined vapor stream is directed into heat exchange relation with said second portion, whereby said second portion is heated and said compressed combined vapor stream is cooled sufficiently to condense at least a part of it and thereby form a condensed stream, and thereafter discharging at least a portion of said heated second portion as said volatile residue gas fraction;

(8) 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

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

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

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

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

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

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

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

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

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

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

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

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

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

(8) a distillation vapor stream is withdrawn from a region of said distillation column above said upper mid-column feed position and is combined with said first portion to form a combined vapor stream;

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

(10) said compressed combined vapor stream is directed into heat exchange relation with said second portion, whereby said second portion is

heated and said compressed combined vapor stream is cooled sufficiently to condense at least a part of it and thereby form a condensed stream, and thereafter discharging at least a portion of said heated second portion as said volatile residue gas fraction;

(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.

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

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

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

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

the improvement wherein 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 and is thereafter expanded to said lower pressure whereby it is further cooled;

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

(3) said second stream is cooled under pressure sufficiently to partially condense it;

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

(5) 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;

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

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

(8) a distillation vapor stream is withdrawn from a region of said distillation column above said upper mid-column feed position and is combined with said first portion to form a combined vapor stream;

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

(10) said compressed combined vapor stream is directed into heat exchange relation with said second portion, whereby said second portion is heated and said compressed combined vapor stream is cooled sufficiently to condense

at least a part of it and thereby form a condensed stream, and thereafter discharging at least a portion of said heated second portion as said volatile residue gas fraction;

(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.

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

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

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

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

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

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

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

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

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

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

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

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

(8) a distillation vapor stream is withdrawn from a region of said distillation column above said upper mid-column feed position and is combined with said first portion to form a combined vapor stream;

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

(10) said compressed combined vapor stream is directed into heat exchange relation with said second portion, whereby said second portion is heated and said compressed combined vapor stream is cooled sufficiently to condense

at least a part of it and thereby form a condensed stream, and thereafter discharging at least a portion of said heated second portion as said volatile residue gas fraction;

(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.

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

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

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

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

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

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

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

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

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

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

(6) a distillation vapor stream is withdrawn from a region of said contacting and separating device above said mid-column feed position and is combined with said first portion to form a combined vapor stream;

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

(8) said compressed combined vapor stream is directed into heat exchange relation with said second portion, whereby said second portion is heated and said compressed combined vapor stream is cooled sufficiently to condense at least a part of it and thereby form a condensed stream, and thereafter discharging at least a portion of said heated second portion as said volatile residue gas fraction;

(9) 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

(10) 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, C_2 components, C_3 components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C_2 components, C_3 components, and heavier hydrocarbon components or said C_3 components and heavier hydrocarbon components, in which process

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

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

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

the improvement wherein 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 and is thereafter expanded to said lower pressure whereby it is further cooled;

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

(3) said second stream is 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;

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

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

(6) a distillation vapor stream is withdrawn from a region of said contacting and separating device above said mid-column feed position and is combined with said first portion to form a combined vapor stream;

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

(8) said compressed combined vapor stream is directed into heat exchange relation with said second portion, whereby said second portion is heated and said compressed combined vapor stream is cooled sufficiently to condense at least a part of it and thereby form a condensed stream, and thereafter discharging at least a portion of said heated second portion as said volatile residue gas fraction;

(9) 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

(10) 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, C_2 components, C_3 components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C_2 components, C_3 components, and heavier hydrocarbon components or said C_3 components and heavier hydrocarbon components, in which process

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

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

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

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

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

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

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

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

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

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

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

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

(9) a distillation vapor stream is withdrawn from a region of said contacting and separating device above said mid-column feed position and is combined with said first portion to form a combined vapor stream;

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

(11) said compressed combined vapor stream is directed into heat exchange relation with said second portion, whereby said second portion is heated and said compressed combined vapor stream is cooled sufficiently to condense at least a part of it and thereby form a condensed stream, and thereafter discharging at least a portion of said heated second portion as said volatile residue gas fraction;

(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.

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

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

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

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

the improvement wherein 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 and is thereafter expanded to said lower pressure whereby it is further cooled;

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

(3) said second stream is cooled under pressure sufficiently to partially condense it;

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

(5) 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;

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

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

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

(9) a distillation vapor stream is withdrawn from a region of said contacting and separating device above said mid-column feed position and is combined with said first portion to form a combined vapor stream;

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

(11) said compressed combined vapor stream is directed into heat exchange relation with said second portion, whereby said second portion is heated and said compressed combined vapor stream is cooled sufficiently to condense at least a part of it and thereby form a condensed stream, and thereafter discharging at least a portion of said heated second portion as said volatile residue gas fraction;

(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.

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

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

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

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

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

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

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

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

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

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

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

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

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

(9) a distillation vapor stream is withdrawn from a region of said contacting and separating device above said mid-column feed position and is combined with said first portion to form a combined vapor stream;

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

(11) said compressed combined vapor stream is directed into heat exchange relation with said second portion, whereby said second portion is heated and said compressed combined vapor stream is cooled sufficiently to condense at least a part of it and thereby form a condensed stream, and thereafter discharging at least a portion of said heated second portion as said volatile residue gas fraction;

(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.

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 upper mid-column feed position and above said 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 mid-column feed position and above said first and second lower column feed positions.

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

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

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

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

the improvement wherein said apparatus includes

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

(4) 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;

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

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

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

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

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

(10) 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 step (6);

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

(12) 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.

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

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

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

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

the improvement wherein said apparatus includes

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

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

(5) 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;

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

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

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

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

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

(11) 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 step (7);

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

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

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

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

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

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

the improvement wherein said apparatus includes

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

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

(6) 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;

(7) third 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 third expansion means being further connected to said distillation column to supply said expanded liquid stream to said distillation column at a lower mid-column feed position below said mid-column feed position;

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

(9) heat exchange means connected to said second dividing means to receive at least a portion of said second portion and heat it, thereafter discharging at least a portion of said heated second 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 above said upper mid-column feed position;

(11) combining means connected to said second dividing means and said vapor withdrawing means to receive said first 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 step (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.

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

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

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

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

the improvement wherein said apparatus includes

(1) 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 expansion means connected to said second cooling means to receive said substantially condensed first stream and expand it to

said lower pressure, said second expansion means being further connected to said distillation column to supply said expanded cooled first stream to said distillation column at an upper mid-column feed position;

(4) 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;

(5) 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;

(6) 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;

(7) third 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 third expansion means being further connected to said distillation column to supply said expanded liquid stream to said distillation column at a lower mid-column feed position below said mid-column feed position;

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

(9) heat exchange means connected to said second dividing means to receive at least a portion of said second portion and heat it, thereafter

discharging at least a portion of said heated second 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 above said upper mid-column feed position;

(11) combining means connected to said second dividing means and said vapor withdrawing means to receive said first 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 step (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.

19. In an apparatus for the separation of a gas stream containing methane, C_2 components, C_3 components, and heavier hydrocarbon components into a

volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C_2 components, C_3 components, and heavier hydrocarbon components or said C_3 components and heavier hydrocarbon components, in said apparatus there being

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

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

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

the improvement wherein said apparatus includes

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

(2) 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 expansion means connected to said second cooling means to receive said substantially condensed combined stream and expand it to said lower pressure, said second expansion means being further connected to said distillation column to supply said expanded cooled combined stream to said distillation column at an 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 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 third expansion means being further connected to said distillation column to supply said expanded liquid stream to said distillation column at a lower mid-column feed position below said mid-column feed position;

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

(10) heat exchange means connected to said second dividing means to receive at least a portion of said second portion and heat it, thereafter

discharging at least a portion of said heated second 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 above said upper mid-column feed position;

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

(13) compressing means connected to said second 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 step (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.

20. In an apparatus for the separation of a gas stream containing methane, C_2 components, C_3 components, and heavier hydrocarbon components into a

volatile residue gas fraction and a relatively less volatile fraction containing a major portion of said C_2 components, C_3 components, and heavier hydrocarbon components or said C_3 components and heavier hydrocarbon components, in said apparatus there being

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

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

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

the improvement wherein said apparatus includes

(1) 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 expansion means connected to said second cooling means to receive said substantially condensed first stream and expand it to said lower pressure, said second expansion means being further connected to a contacting and separating means to supply said expanded cooled first stream to said contacting and separating means at a mid-column feed position, said contacting and separating means being adapted to produce a second overhead vapor stream and a bottom liquid stream;

(4) 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;

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

(6) 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;

(7) second 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 portion and a second portion;

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

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

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

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

(12) 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 step (8);

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

(14) 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.

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

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

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

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

the improvement wherein said apparatus includes

(1) 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 expansion means connected to said second cooling means to receive said substantially condensed first stream and expand it to said lower pressure, said second expansion means being further connected to a contacting and separating means to supply said expanded cooled first stream to said contacting and separating means at a mid-column feed position, said contacting and separating means being adapted to produce a second overhead vapor stream and a bottom liquid stream;

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

(5) 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;

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

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

(8) second 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 portion and a second portion;

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

(10) 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 above said mid-column feed position;

(11) combining means connected to said second dividing means and said vapor withdrawing means to receive said first 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 step (9);

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

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

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

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

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

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

the improvement wherein said apparatus includes

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

(2) 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 expansion means connected to said second cooling means to receive said substantially condensed first stream and expand it to said lower pressure, said second expansion means being further connected to a contacting and separating means to supply said expanded cooled first stream to said contacting and separating means at a mid-column feed position, said contacting and separating means being adapted to produce a second overhead vapor stream and a bottom liquid stream;

(6) 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;

(7) third 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 third expansion means being further connected to said distillation column to supply said expanded liquid stream to said distillation column at a mid-column feed position;

(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) second 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 portion and a second portion;

(11) heat exchange means connected to said second dividing means to receive at least a portion of said second portion and heat it, thereafter discharging at least a portion of said heated second 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 above said mid-column feed position;

(13) combining means connected to said second dividing means and said vapor withdrawing means to receive said first 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 step (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.

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

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

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

(c) a distillation column connected to receive said further cooled stream, said distillation column being adapted to separate said further cooled stream into 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 expansion means connected to said second cooling means to receive said substantially condensed first stream and expand it to said lower pressure, said second expansion means being further connected to a contacting and separating means to supply said expanded cooled first stream to said contacting and separating means at a mid-column feed position, said contacting and separating means being adapted to produce a second overhead vapor stream and a bottom liquid stream;

(4) 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;

(5) 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;

(6) 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;

(7) third 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 third expansion means being further connected to said distillation column to supply said expanded liquid stream to said distillation column at a mid-column feed position;

(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) second 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 portion and a second portion;

(11) heat exchange means connected to said second dividing means to receive at least a portion of said second portion and heat it, thereafter discharging at least a portion of said heated second 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 above said mid-column feed position;

(13) combining means connected to said second dividing means and said vapor withdrawing means to receive said first 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 step (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.

24. In an apparatus for the separation of a gas stream containing methane, C_2 components, C_3 components, and heavier hydrocarbon components into a volatile residue gas fraction and a relatively less volatile fraction containing a major

portion of said C_2 components, C_3 components, and heavier hydrocarbon components or said C_3 components and heavier hydrocarbon components, in said apparatus there being

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

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

(c) a distillation column connected to receive said further cooled stream, said distillation column being adapted to separate said further cooled stream into 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 expansion means connected to said second cooling means to receive said substantially condensed combined stream and expand it to said lower pressure, said second expansion means being further connected to a contacting and separating means to supply said expanded cooled combined stream to said contacting and separating means at a mid-column feed position, said contacting and separating means being adapted to produce a second overhead vapor stream and a bottom liquid stream;

(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) third 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 third expansion means being further connected to said distillation column to supply said expanded liquid stream to said distillation column at a mid-column feed position;

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

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

(11) second 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 portion and a second portion;

(12) heat exchange means connected to said second dividing means to receive at least a portion of said second portion and heat it, thereafter discharging at least a portion of said heated second 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 above said mid-column feed position;

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

(15) compressing means connected to said second 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 step (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.

25. The improvement according to claim 15, 16, 17, 18, or 19 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 upper mid-column feed position and above said mid-column feed position.

26. The improvement according to claim 15, 16, 17, 18, or 19 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.

27. The improvement according to claim 20, 21, 22, 23, or 24 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 mid-column feed position and above said first and second lower column feed positions.

28. The improvement according to claim 20, 21, 22, or 23 wherein

(1) a third 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 third 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 third dividing means to receive said distillation vapor stream.

29. The improvement according to claim 24 wherein

(1) a third 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 third 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 third dividing means to receive said distillation vapor stream.

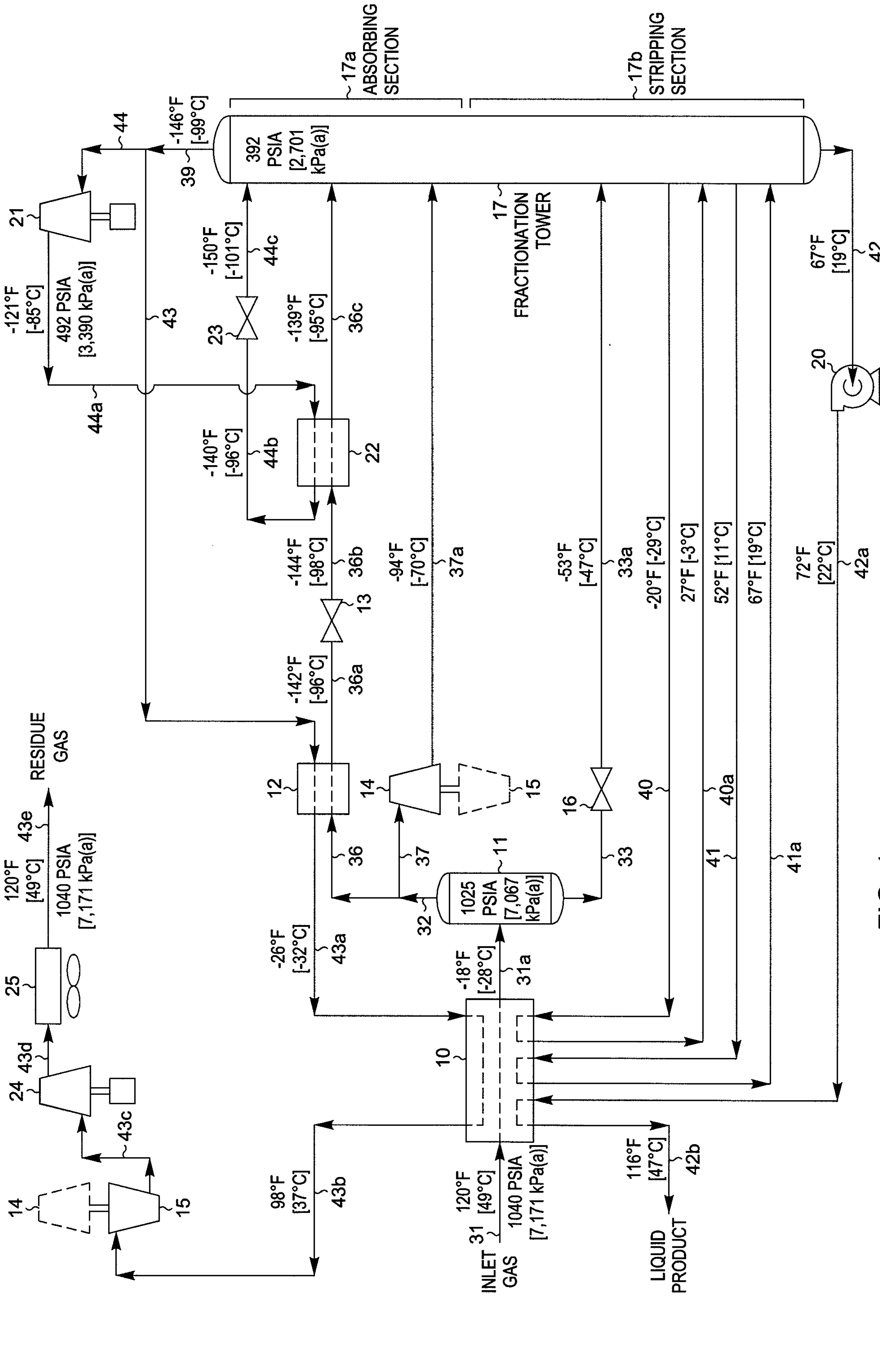


FIG. 1
(PRIOR ART)

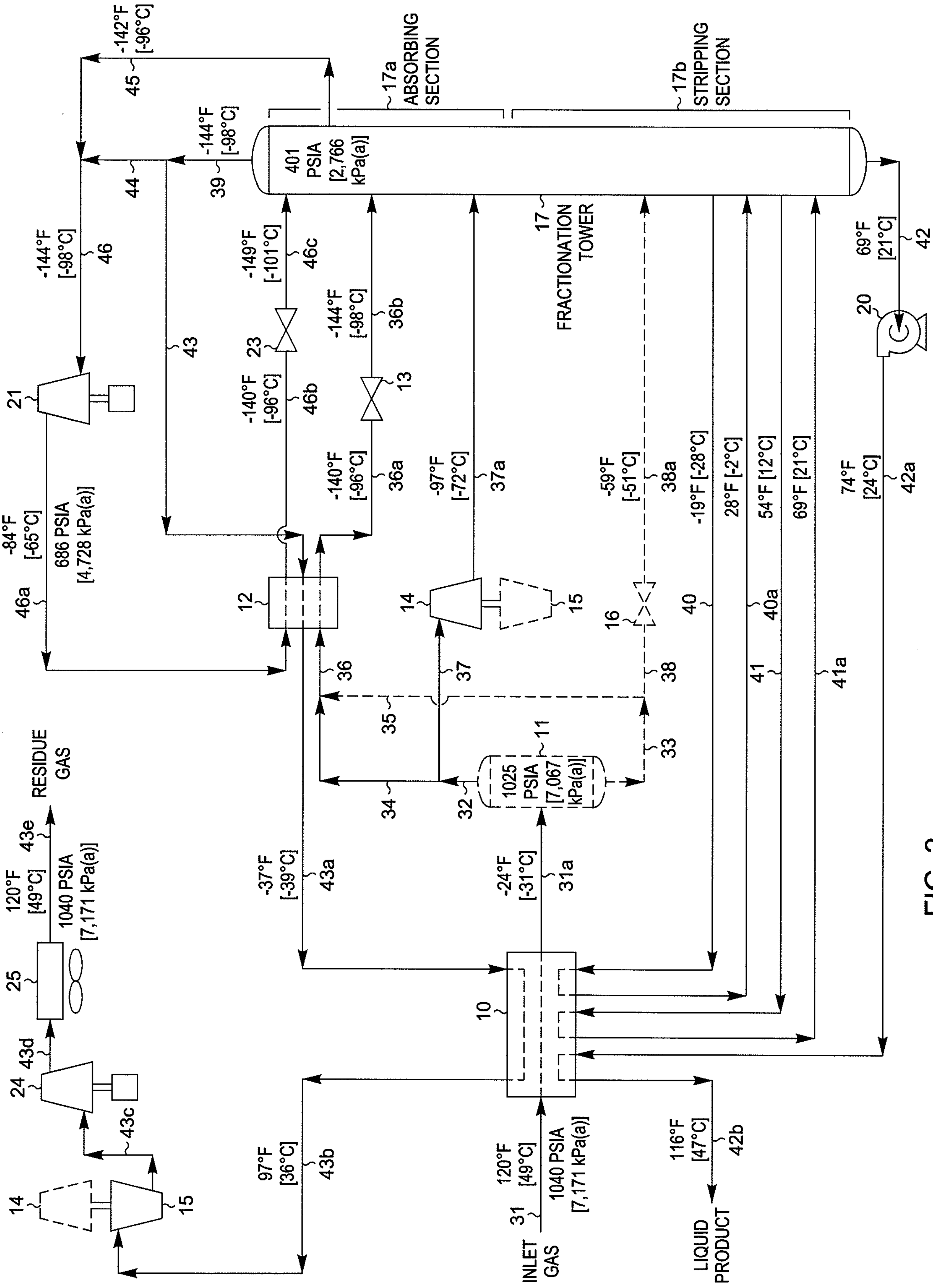

17a ABSORBING SECTION
17b STRIPPING SECTION
17 FRACTIONATION TOWER
401 PSIA [2,766 kPa(a)]
-142°F [-96°C]
45
-144°F [-98°C]
39
44
-144°F [-98°C]
46
21
43
-149°F [-101°C]
46c
23
-140°F [-96°C]
46b
-144°F [-98°C]
36b
13
-140°F [-96°C]
36a
-97°F [-72°C]
37a
-59°F [-51°C]
38a
-19°F [-28°C]
28°F [-2°C]
54°F [12°C]
69°F [21°C]
74°F [24°C]
42a
69°F [21°C]
42
20
-84°F [-65°C]
686 PSIA [4,728 kPa(a)]
46a
12
14
15
16
40
40a
36
37
38
41
41a
35
33
11
1025 PSIA [7,067 kPa(a)]
32
34
RESIDUE GAS
43e
120°F [49°C]
1040 PSIA [7,171 kPa(a)]
25
-37°F [-39°C]
43a
-24°F [-31°C]
31a
10
43d
24
43c
14
15
97°F [36°C]
43b
120°F [49°C]
1040 PSIA [7,171 kPa(a)]
31
INLET GAS
116°F [47°C]
42b
LIQUID PRODUCT

FIG. 2

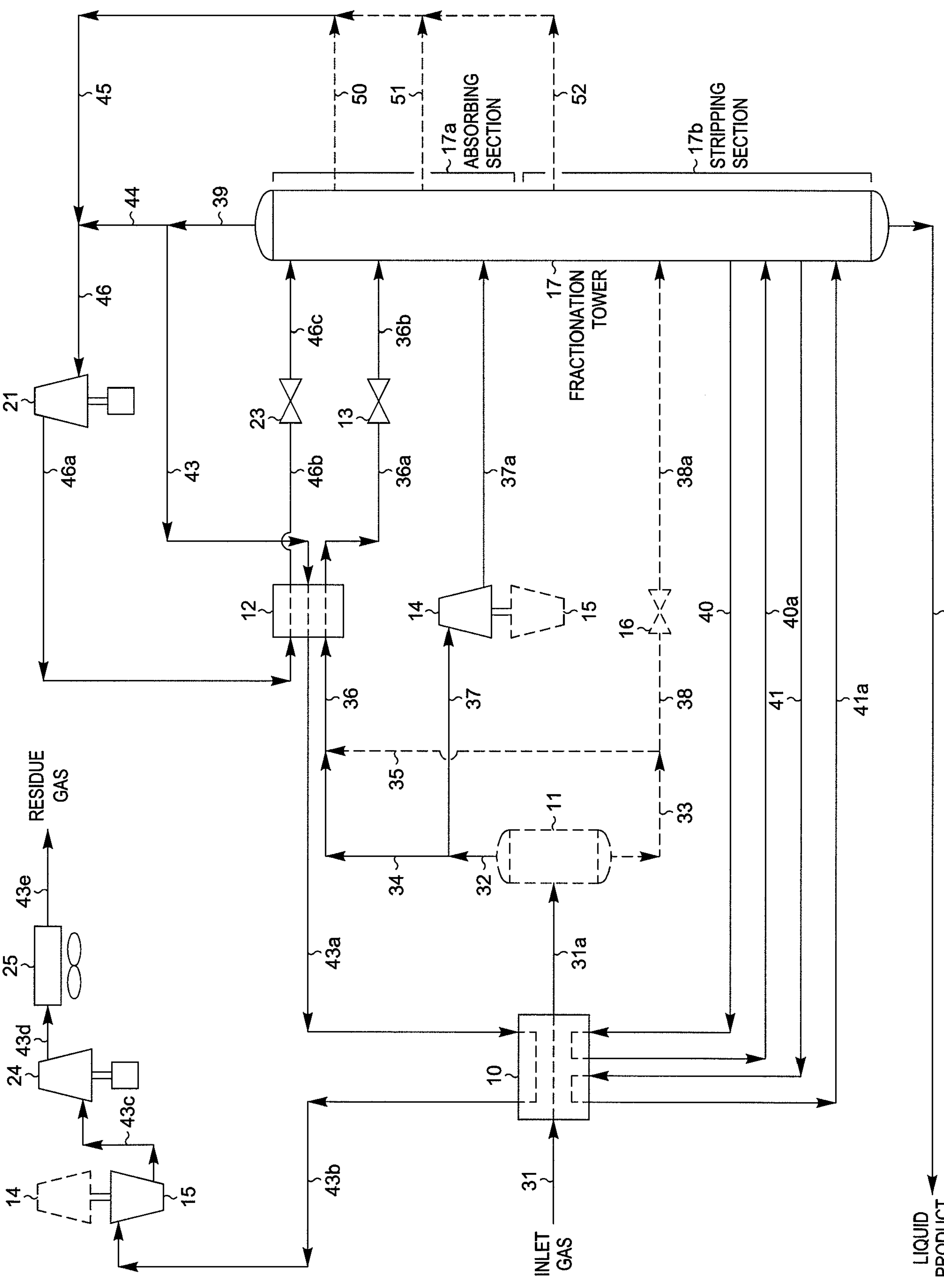

INLET GAS
31
10
31a
11
32
33
34
35
36
37
38
12
13
14
15
16
17
FRACTIONATION TOWER
17a ABSORBING SECTION
17b STRIPPING SECTION
21
23
24
25
36a
36b
37a
38a
39
40
40a
41
41a
42
43
43a
43b
43c
43d
43e
44
45
46
46a
46b
46c
50
51
52
RESIDUE GAS
LIQUID PRODUCT

FIG. 3

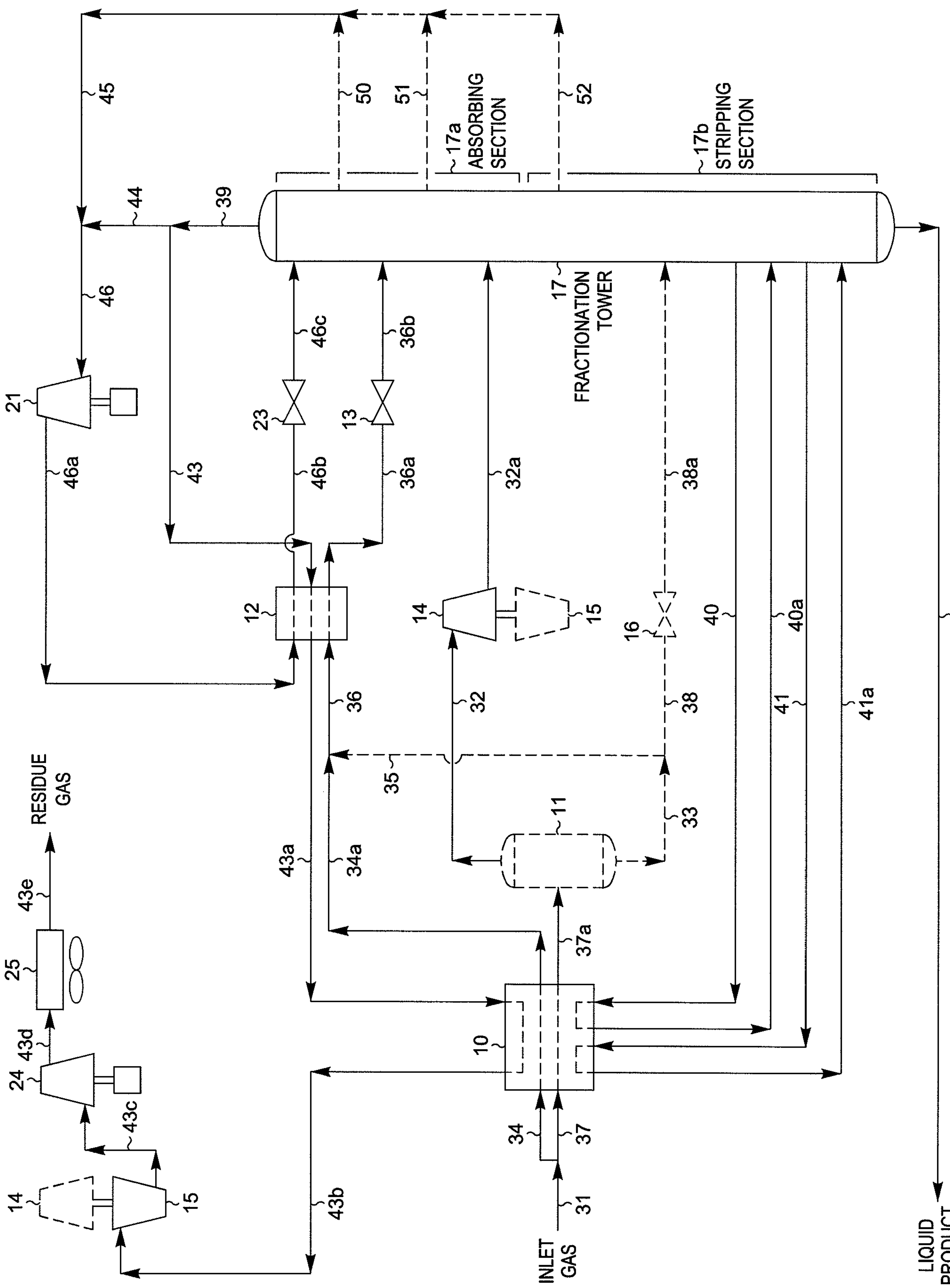
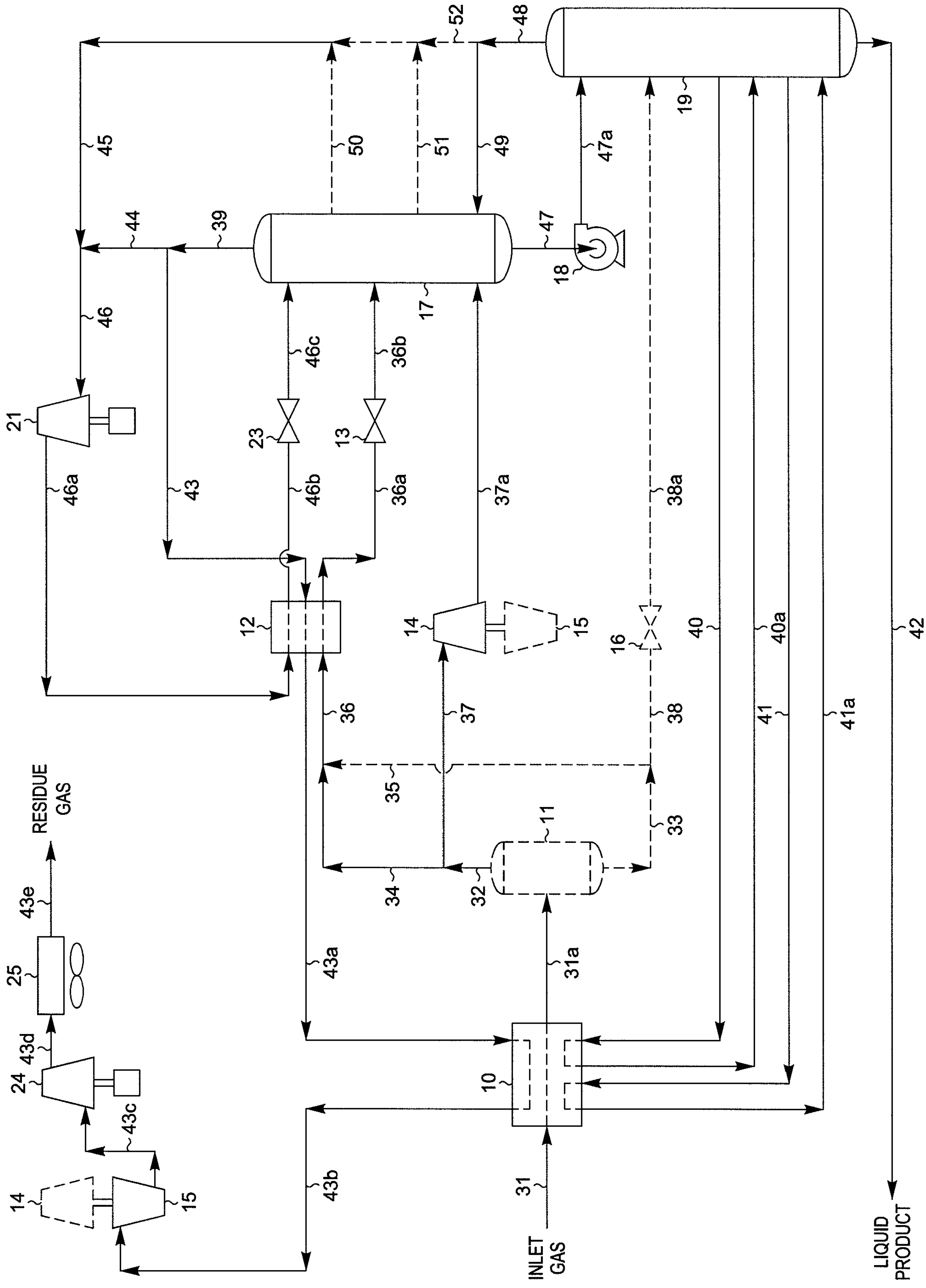

RESIDUE GAS
43e
25
43d
24
43c
14
15
43b
INLET GAS
31
34
37
10
37a
34a
43a
11
33
35
32
36
38
12
14
15
16
40
40a
41
41a
42
LIQUID PRODUCT
46a
43
46b
36a
32a
38a
21
23
13
46
46c
36b
17 FRACTIONATION TOWER
44
39
45
50
51
17a ABSORBING SECTION
52
17b STRIPPING SECTION

FIG. 4


RESIDUE GAS
INLET GAS
LIQUID PRODUCT
10
11
12
13
14
15
16
17
18
19
21
23
24
25
31
31a
32
33
34
35
36
36a
36b
37
37a
38
38a
39
40
40a
41
41a
42
43
43a
43b
43c
43d
43e
44
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46a
46b
46c
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47a
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51
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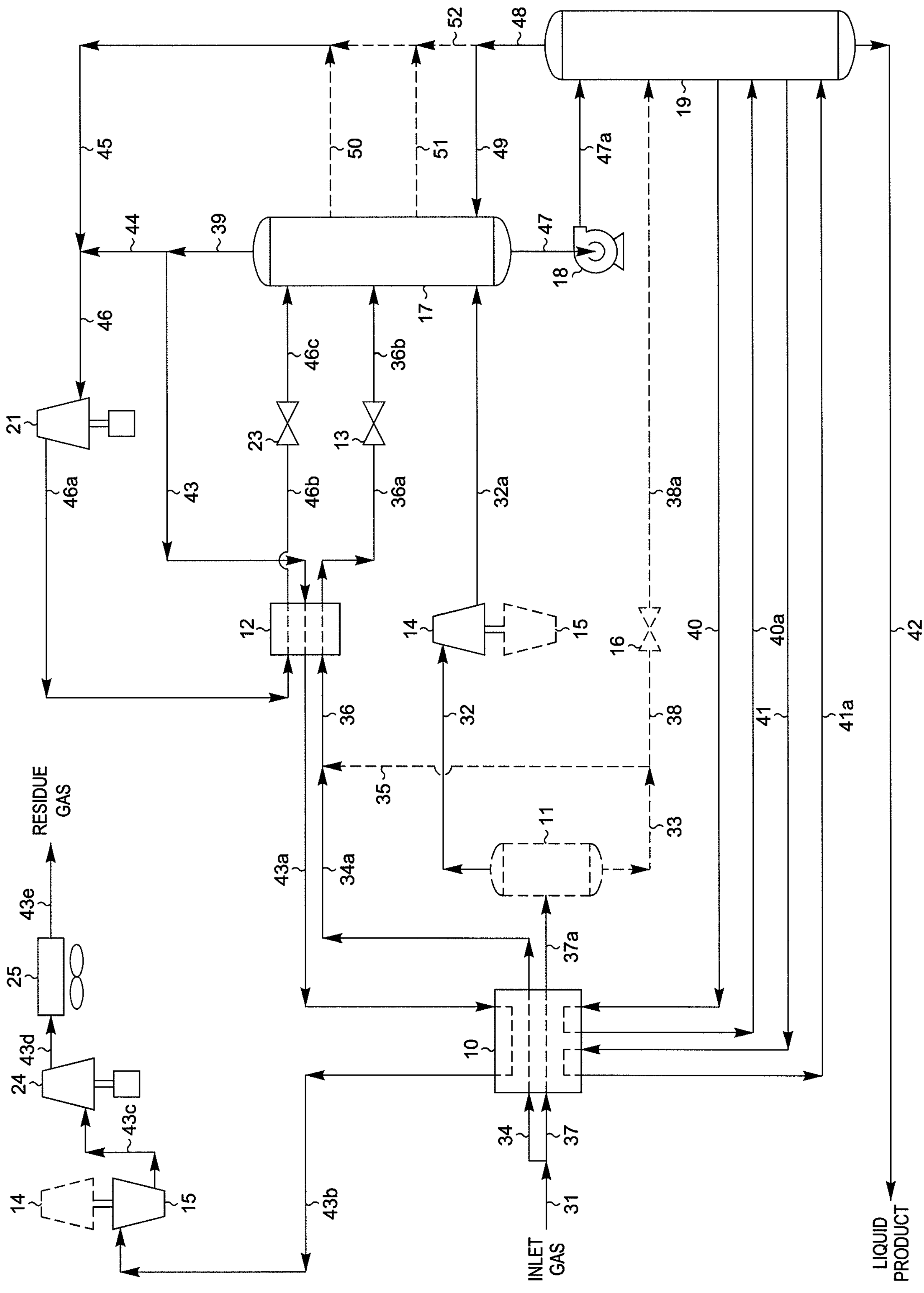
FIG. 5


RESIDUE GAS
INLET GAS
LIQUID PRODUCT
10
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14
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23
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25
31
32
32a
33
34
34a
35
36
36a
36b
37
37a
38
38a
39
40
40a
41
41a
42
43
43a
43b
43c
43d
43e
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45
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46a
46b
46c
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47a
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FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2010/046966

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F25J 3/00 (2010.01)
USPC - 62/620

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - F25J 3/00, 3/02 (2010.01)
USPC - 62/619, 620, 621, 623, 625

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
USPTO EAST System (US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT), PatBase

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,889,545 A (CAMPBELL et al) 26 December 1989 (26.12.1989) entire document	1-29
A	US 2009/0100862 A1 (WILKINSON et al) 23 April 2009 (23.04.2009) entire document	1-29
A	US 2008/0078205 A1 (CUELLAR et al) 03 April 2008 (03.04.2008) entire document	1-29
A	US 7,191,617 B2 (CUELLAR et al) 20 March 2007 (20.03.2007) entire document	1-29
A	US 2006/0032269 A1 (CUELLAR et al) 16 February 2006 (16.02.2006) entire document	1-29

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
08 October 2010	15 OCT 2010

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774