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[54] **PROCESS OF AND APPARATUS FOR THE RECOVERY OF HELIUM FROM A NATURAL GAS STREAM**

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[58] **Field of Search** 62/22, 23, 24, 27, 62/28, 29

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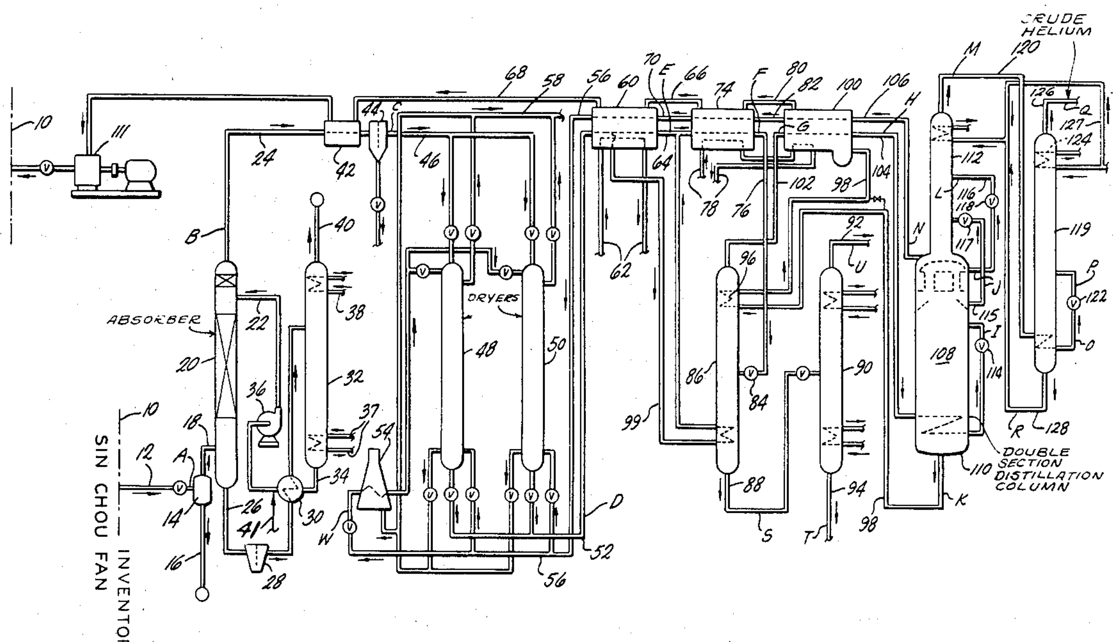
[57] **ABSTRACT**

A process for recovery of helium from a natural gas stream containing components such as acid gases, moisture, hydrocarbons, nitrogen and helium. The process includes steps of feed gas preparation, refrigeration cooling and liquefaction, and separation of helium from the hydrocarbons and then nitrogen. Apparatus for carrying out the process is disclosed.

3 Claims, 1 Drawing Figure



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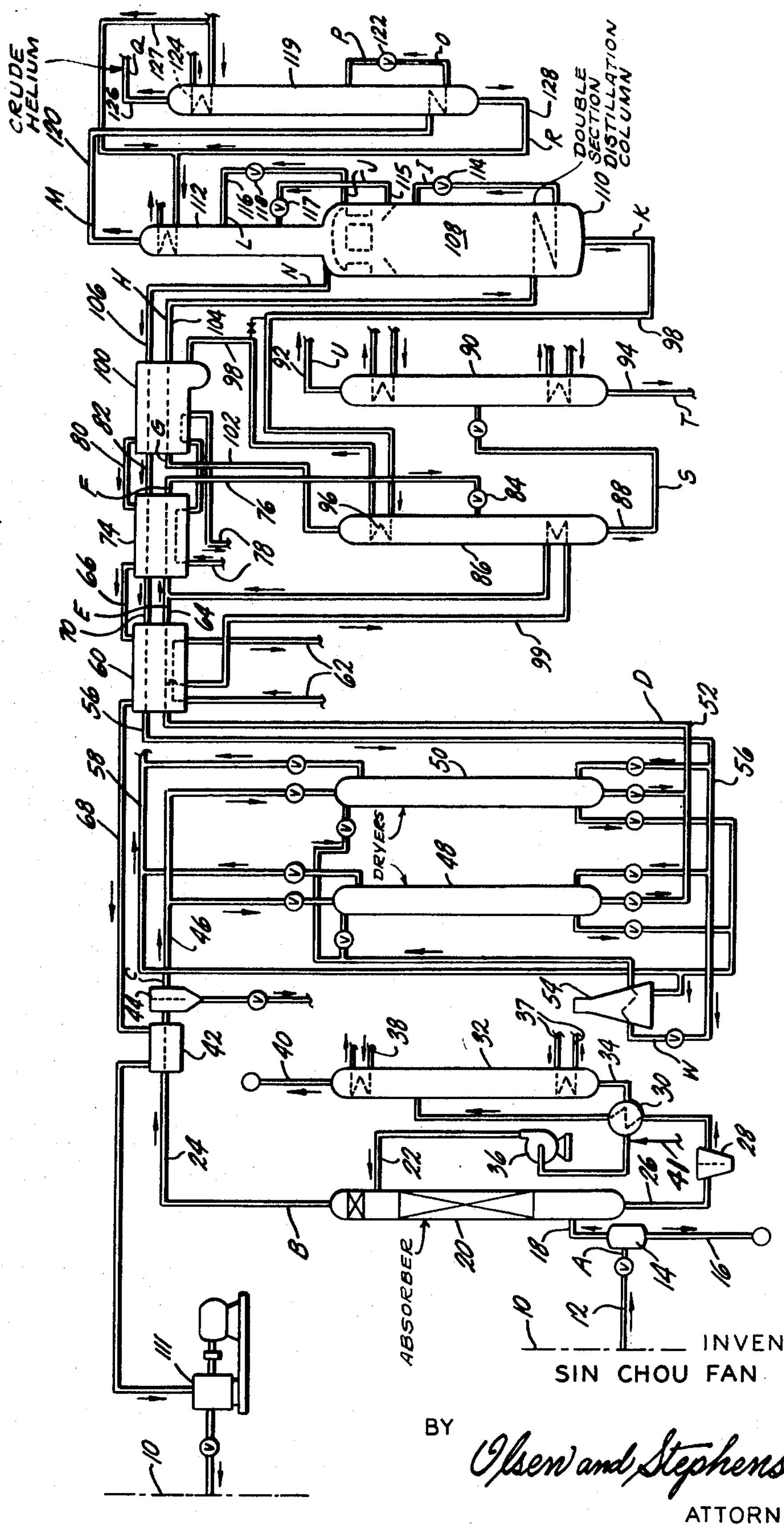

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PROCESS OF AND APPARATUS FOR THE RECOVERY OF HELIUM FROM A NATURAL GAS STREAM

BACKGROUND OF THE INVENTION

The present invention relates to the recovery of helium from natural gas streams.

Natural gas is the commercial source of helium. The helium contents vary from a few parts per million to several percent. Presently natural gas streams having a helium content of approximately 0.4 percent and up are being processed for helium. In the future, the helium processors, however, may have to extract helium from gas streams with very low helium contents so that more effective procedures for helium recovery will be required than are now employed. For example, gas with a helium content of 0.05–0.07 percent is being processed in Russia now.

Natural gas is a complex gas mixture and contains variable quantity of methane and heavier hydrocarbons. There are also present some inert gases such as nitrogen and acid gases such as CO_2 and H_2S. In addition, there are added during production and transmission impurities which can be anything from dusty solids to lube oil. All the heavy hydrocarbons, inert and acid gases will affect the process of liquefaction to some extent and must be reduced to a tolerable level. Also, all the added impurities should be removed completely from the gas streams.

SUMMARY OF THE INVENTION

The present invention is directed to a helium recovery plant wherein the feed or natural gas is taken from a high pressure pipe line and the tail gas is recompressed back to the same pipe line. The extraction process for the helium recovery can be divided into the steps of feed gas preparation, cooling and partial liquefaction, and the separation of the helium from hydrocarbons and nitrogen.

One of the improvements of this process is the operation at a higher pressure level, as compared to the existing processes, which will result in refrigeration savings. Another is taking the advantage of a double distillation column for the separation of nitrogen and helium from other hydrocarbons. With the use of such a double column, the upper section is operated at a lower pressure and the lower section at a higher pressure, which carries the major separation. By so doing, the refrigeration requirement for reflux condensation in the lower section can be properly met by utilizing part of the bottoms in the upper section. This will result in additional savings in refrigeration. The bottom stream from the upper section will be used as purge gas for effective regeneration of the desiccant dryers.

The bottom stream from the lower section will be first utilized as a refrigerant to cool the incoming gas and then compressed back to the pipe line. The higher the pressure level of this stream, the less the power requirement will be. This will result in savings in fixed and operation costs.

According to one form of the present invention, a process is provided for the separation of helium from a natural gas stream containing acid gases, moisture, hydrocarbons, nitrogen and helium comprising the steps of purifying the atream by removing acid gases and moisture at a relatively high pressure of about 700 psia, gradually cooling the gas stream to a temperature

sufficient to partially liquefy the purified stream to provide a liquid portion of relatively heavier hydrocarbons and a gaseous portion at about 600 psia and −126° F enriched in helium, nitrogen and relatively lighter hydrocarbons, further cooling the enriched gaseous portion to about −130° F and expanding the same into the lower section of a double distillation column at a pressure of about 500 psia to produce a lower liquid stream and a top stream, expanding the top stream to a pressure of 300 psia into the upper section of the same column in heat transfer relation above said first lower section to produce a top stream containing mainly, nitrogen and helium and a lower liquid stream in the bottom of the upper section in cooling relation to the top stream of the lower section, cooling the top stream in said upper section to about −255° F and then expanding the top stream of nitrogen and helium into a succeeding distillation column at a pressure of about 75 psia to produce a lower liquid stream of mainly nitrogen at about −290° F and an upper stream of crude helium, and passing said lower liquid stream of nitrogen in heat transfer relationship to the top stream in said upper section of the double distillation column for cooling the top stream to −255° F. The lower liquid stream from the lower section of the double column represents high pressure tail gas at about 500 psia which can be passed in heat transfer relation to said feed gas stream for cooling the same and which is then vaporized and recompressed to about 700 psia for discharge into the source of the natural gas stream. The lower liquid stream from the upper section of the double column is passed in heat transfer relation to the gas stream for cooling the same and is then utilized as purge gas for the regeneration of the desiccant dryers.

Thus, operating pressures of about 600 psia are utilized initially in separating the gaseous portion enriched in helium, nitrogen and relatively lighter hydrocarbons, and thereafter, pressures of about 500 psia are utilized in the lower section of the double column. By virtue of these operating procedures, a less amount of power is required in order to recompress the tail gas and return it to the original source or stream of natural gas. Also, the effective use that is made of the tail gases for cooling purposes reduces the extent of refrigeration required during cooling and liquefaction.

The process is carried out by apparatus which is constructed and arranged to permit recovery of the helium through a series of steps at the pressures and temperatures set forth. In part, this apparatus includes unique double column separation unit for separating the nitrogen and helium from the gas stream.

Accordingly, it is among the objects of the present invention to provide improved method and apparatus for extracting helium from a natural gas stream characterized by the effective and economical results realized.

More specifically, the primary objects of this invention is to provide an improved process for effectively recovering helium from natural gases and to accomplish this recovery with a minimum requirement of external power for compression and refrigeration. An additional object is to recover helium with a method which minimizes the pressure differences between the feed gas and the tail gas.

Other objects of this invention will appear in the following description and appended claims, reference being had to the accompanying drawing forming a part of this specification.

BRIEF DESCRIPTION OF THE DRAWING

The drawing illustrates schematically one embodiment of apparatus for carrying out the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Before explaining the present invention in detail, it is to be understood that the invention is not limited in its application to the details of construction and arrangement of parts illustrated in the accompanying drawing, since the invention is capable of other embodiments and of being practiced or carried out in various ways. Also, it is to be understood that the phraseology or terminology employed herein is for the purpose of description and not of limitation.

Referring now to the drawing and to the follwing Table I, the invention will be described in greater detail. It should be pointed out that the information listed in Table I is only one example. In case the composition of the feed gas shown on Column A of Table I varies, the results in other columns will vary also. In Table I, the data set forth in the columns under the letters A–U, inclusive, correspond respectively to locations in the drawing identified with these letters.

The feed gas is taken from the pipe line **10** through the conduit **12** to a gas filter **14** where impurities such as dust solids, lube oil, and the like will be filtered out and can be removed at **16** and the purified gas flows through the conduit **18** to the absorber **20**.

Carbon dioxide and water vapor are the most troublesome impurities due to freezing characteristics at low temperature. The ice formation on the surfaces of heat exchanger fins and tubes will not only add resistance to heat transfer, but also in the extreme case, block the gas flow. Systems for carbon dioxide removal are known. These include amine treating, hot potasium carbonate scrubbing, water washing, etc. The absorber **20** is part of an amine treating system for removal of carbon dioxide. As shown in column A of Table I, the natural gas stream flowing through the conduit **12** contains carbon dioxide, which can readily be removed in the absorber **20** together with any other acid gases which may be present. As shown in the drawing, the gas enters into the absorber **20** adjacent to the bottom, and a monoethanolamine (MEA) solution adjacent to the top at **22.** The absorber can be a packing column, filled with, for example, Raschig rings, or it may be a tray column. The gas from which the acid gases have been removed leaves the absorber **20** at the top via the conduit **24** with the gas composition being that shown in column B of Table I.

the MEA solution. The regenerated MEA solution flows out of the stripper **32** through conduit **34** and via the heat exchanger **30** to the amine pump **36** for circulation back to the absorber **20** by way of the conduit **22.** For regeneration purposes, the stripper is provided with steam coils **37** at the bottom and cooling coils **38** at the top. The stripped gases are discharged from the top of the stripper through conduit **40.** Any make-up MEA solution will be added into the system through the conduit **41.**

The natural gas stream next flows through the heat exchanger **42** where the temperature of the stream is reduced to about 80° F. Due to the lowering in temperature, there will be water condensation. The moisture content in the gas stream is thus reduced, about 30 percent lower than the original, and the condensed water being collected and removed in the separator **44.** The natural gas stream then flows through the conduit **46** to the two desiccant dryers **48** and **50** which are piped in parallel as shown, one being in service while the other is in regeneration. Such dryers are filled with desiccant materials such as molecular sieves. The gas to be dried has the composition shown in column C of Table I and enters into the appropriate dryer at the top and flows out the bottom through the conduit **52.**

In special circumstances the procedure of operation of the apparatus described above may vary. For instance, the removal of acid gases and drying may be carried out simultaneously in columns **48** and **50** if the content of such acid gases in the feed gas is very low. That is, the feed gas will be lead directly to columns **48** and **50** and the columns **20** and **32** and their auxiliaries will be eliminated from use.

The desiccant dryers, when saturated with moisture, are subjected to regeneration. The valves are so arranged and the regeneration may be carried out in the following three steps: (a) heating of the dryer to approximately 600° F. by means of the gas heater **54** which is arranged to heat return low pressure tail gas flowing in conduit **56** to this temperature; (b) stripping with the return low pressure tail gas from the conduit **56** for discharge through the conduit **58**; and (c) by means of the return tail gas, cooling to the operating temperature of approximately 80° F. The low pressure tail gas flowing from the conduit **56** and either through the gas heater **54** and one of the dryers **48, 50** for heating the same or directly through such dryer for cooling the same then is discharged via conduit **58** to the power plant of the system. The fuel gas for the heater **54** may be obtained from the conduit **58,** as shown.

The purified natural gas stream having the composition shown in Column D now flows via the conduit **52**

TABLE I. MATERIAL BALANCE

	A*	B*	C*	D	E	F [a]	G	H [a]	I	J	K	L	M	N	O	P	Q	R	S	T	U
He	0.4	0.4	0.4	0.4		0.4	0.4		0.4	0.4	Trace		0.39	0.01			0.38	0.01			
N_2	3.4	3.4	3.4	3.4		3.4	3.4		3.4	3.0	0.4		2.8	0.2			0.2	2.6			
CO_2	2.5	Nil																			
H_2S																					
CH_4	86.8	86.8	86.8	86.8		86.8	85.85		85.85	20.6	65.25		0.3	20.3				0.3	0.95		
C_2H_6	6.5	6.5	6.5	6.5		6.5	0.91		0.91		0.91								5.59		
C_3H_8	2.5	2.5	2.5	2.5		2.5													2.5		
CnHm	0.4	0.4	0.4	0.4		0.4													0.4		
Moles/hr	102.5	100	100	100		100	90.56			21	66.56		3.49	20.51			0.58	2.91	9.44		
PSIA [b]	700						600		500	500		300	300	300		75	75	75	600	200	200
F [b]	100	100	80		−35	−100	−126	−130		−150	−135		−255	−160			−314	−290	45		

*Dry basis.
[a] Partially liquified state.
[b] Operating conditions given are approximate.

The absorber **20** has an outlet **26** at the bottom through which a rich solution of the acid gases flows first through a liquid filter **28** and then via the amine heat exchanger **30** to the stripper **32** for regenerating

to heat exchanger **60** equipped with a propane refrigeration system **62.** As shown in Column E, the exit temperature is −35° F at conduit **64.** The heat exchanger **60** is a four stream design, one for the gas stream to be cooled, one for the propane refrigeration, one for high pressure tail gas which will flow through the heat exchanger for cooling purposes from the conduit 66 to the conduit **68,** and one for low pressure tail gas, also for cooling purposes, which will enter from the conduit **70** and will be discharged through the conduit **56.**

The main gas stream is further cooled to −100° F by passing through heat exchanger **74** and being discharged to the conduit **76.** The heat exchanger **74** is also a four stream design; one for the main gas stream, the second for the stream from the ethylene refrigeration system **78,** the third for the high pressure tail gas entering from the conduit **80** and discharging via the conduit **66,** and the fourth for the low pressure tail gas entering from the conduit **82** and discharging via the conduit **70.** The propane and ethylene refrigeration systems are not described in detail, because they may be conventional construction.

The natural gas stream at −100° F and 700 psia is next expanded through a throttle valve **84** and the pressure is reduced to 600 pounds psia. The gas stream at the reduced pressure is discharged into the hydrocarbon separation column **86** where the heavier hydrocarbons will be condensed and separated from the gas stream. The gas and liquid stream compositions from the separation column **86** are shown in Columns G and S, respectively, of Table I.

Approximately 90 percent of the heavier hydrocarbons are removed from the feed gas in separation column **86.** The heavier hydrocarbons from the bottom will be removed at **88** where they can be further processed into ethane and propane-plus, if this should be necessary. This can be accomplished in the separation column **90** wherein ethane can be removed at the top via the conduit **92** and propane-plus can be removed at the bottom via the conduit **94.**

In the separation column **86** cooling is provided at the top of the separation column with the coils **96** by vaporizing part of the return liquid via conduit **98.** Heat is provided by the higher temperature gas via conduit **99** at the bottom of the separation column.

The gas stream from the top of the separation column **86** contains mainly methane, nitrogen and helium, and this gas mixture is further cooled to a temperature of approximately −130° F in the heat exchanger and vaporizer **100.** The latter is a four stream design; one is for the gas stream flowing through the conduit **102** to the outlet conduit **104,** one is for the high pressure liquid flowing through the conduit **98** vaporized in the vaporizer **100** and discharging through the conduit **80,** and the third is for the low pressure tail gas flowing from the conduit **106** and discharging through the conduit **82,** and the fourth is for the ethylene refrigeration system **78.** The partially liquefied gas stream in conduit **104** next flows to the separation or fractional distillation column **108** which is divided into two sections, the lower section **110** being operated at a pressure of 500 psia, and the upper section **112** being operated at a pressure of 300 psia. The conduit **104** passes through the lower portion of the lower section **110** to provide the necessary heat requirement in the reboiler and then through the expansion valve **114** whereby the gas is expanded to a pressure of 500 psia and discharged into an intermediate portion of the lower section as shown. The top streams from the lower section **110** will be fed to the upper section via the conduits **115** and **116** through the expansion valves **117** and **118** so that the pressure is reduced to 300 psia in the upper section **112.** The feed to the top section is designed to be approximately **25** percent of the feed gas to the plant in the disclosed form of the invention. The gas stream or low pressure tail gas discharged from the lower portion of the upper section **112** will be used later for purging of columns **48** or **50** and then as plant fuel. The liquid stream from the bottom of the lower section **110** will have the composition shown in Column K of Table I, and the average composition of the top streams will have the composition shown in Column J of the table. Likewise, the vapor taken from the bottom of the upper section will have the composition shown in Column N of the Table I. As previously explained, the liquid from the bottom of the lower section **110** passes back through the heat exchangers via the conduit **98** for cooling purposes, and vaporized, and there it is recompressed to 700 psia by the compressor **111** and is discharged into the supply pipe line **10.**

The gas stream from the top of the upper section **112** contains mainly nitrogen and helium as is shown in Column M of Table I. This gas which is at a pressure of 300 psia and a temperature of about −250° F next flows to the helium separation or fractional distillation column **119** via the conduit **120** and after passing through the expansion valve **122** is discharged into the column at a pressure of 75 psia. The temperature at the top of this column is −314° F and at the bottom is −290° F. In order to achieve the temperature at the top, it is necessary that liquid nitrogen refrigeration be used at **124.** The liquid nitrogen refrigeration system is conventional. The helium product which is extracted via the conduit **126** has the composition shown in Column Q. This crude product can be compressed and stored in gas form in conventional storage bottles. The liquid nitrogen is extracted at the bottom of the separation column **119** and has the composition shown in Column R. This liquid nitrogen can be passed via the conduit **128** through the cooling coils at the top of the section **112** of column **108** to provide the cooling requirement for reflux condensation. Additional liquid nitrogen will be added via conduit **127,** if necessary.

From the foregoing description it will be recognized that the disclosed helium recovery plant is designed to operate so that the pressure drop through the system is kept small. By so doing, there are savings in refrigeration as well as in power which is required to recompress the tail gas to the inlet pressure. Thus, the process is more economical by virtue of the operating pressures for the separation of the light hydrocarbons, nitrogen and helium from the gas stream being maintained at a high level. Also, maximum refrigeration economy is realized by the flow circuits disclosed. Of special significance in this respect is the construction and arrangement of the separation column **108.**

I claim:

1. A process for the separation of helium from a natural gas stream containing carbon dioxide, moisture, relatively heavier and lighter hydrocarbons, nitrogen and helium comprising the steps of purifying said stream by removing carbon dioxide and moisture from said gas stream at a relatively high pressure of about 700 psia, gradually cooling the purified gas stream to a temperature sufficient to partially liquefy the purified stream to produce a liquid portion of relatively heavier hydrocarbons and a gaseous portion at about 600 psia and −126° F enriched in helium, nitrogen and relatively lighter hydrocarbons, further cooling the enriched gaseous portion to about −130° F and expanding the same into a lower section of a double section, fractional distillation column at a pressure of about 500 psia to produce a lower liquid stream and a top stream, expanding the top stream to a pressure of about 300 psia in the upper section of the fractional distillation column in heat transfer relation above said lower section to produce a top stream of nitrogen and helium and a lower liquid stream in the bottom of the upper section in cooling relation to the top stream of the lower section, the top stream of said lower section being condensed and used as reflux in said lower section, cooling the top stream in said upper section to about −255° F and then expanding the top stream of nitrogen and helium into a succeeding fractional distillation column at a pressure of about 75 psia to produce a lower liquid stream of nitrogen at about −290° F and an upper stream of crude helium, and passing said lower liquid stream of nitrogen in heat transfer relation to the top stream in said upper section for cooling the top stream to −255° F.

2. The process that is defined in claim **1**, wherein the lower liquid stream from said lower section is passed in heat transfer relation to said gas stream for cooling the same and is then recompressed as a gas to 700 psia for discharge into the source of the natural gas stream.

3. The process that is defined in claim **1**, wherein the lower liquid stream from said upper section is passed in heat transfer relation to said incoming gas stream for cooling the same and is then utilized as purge gas in conjunction with the removal of moisture from the natural gas stream and thereafter as plant fuel gas.

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