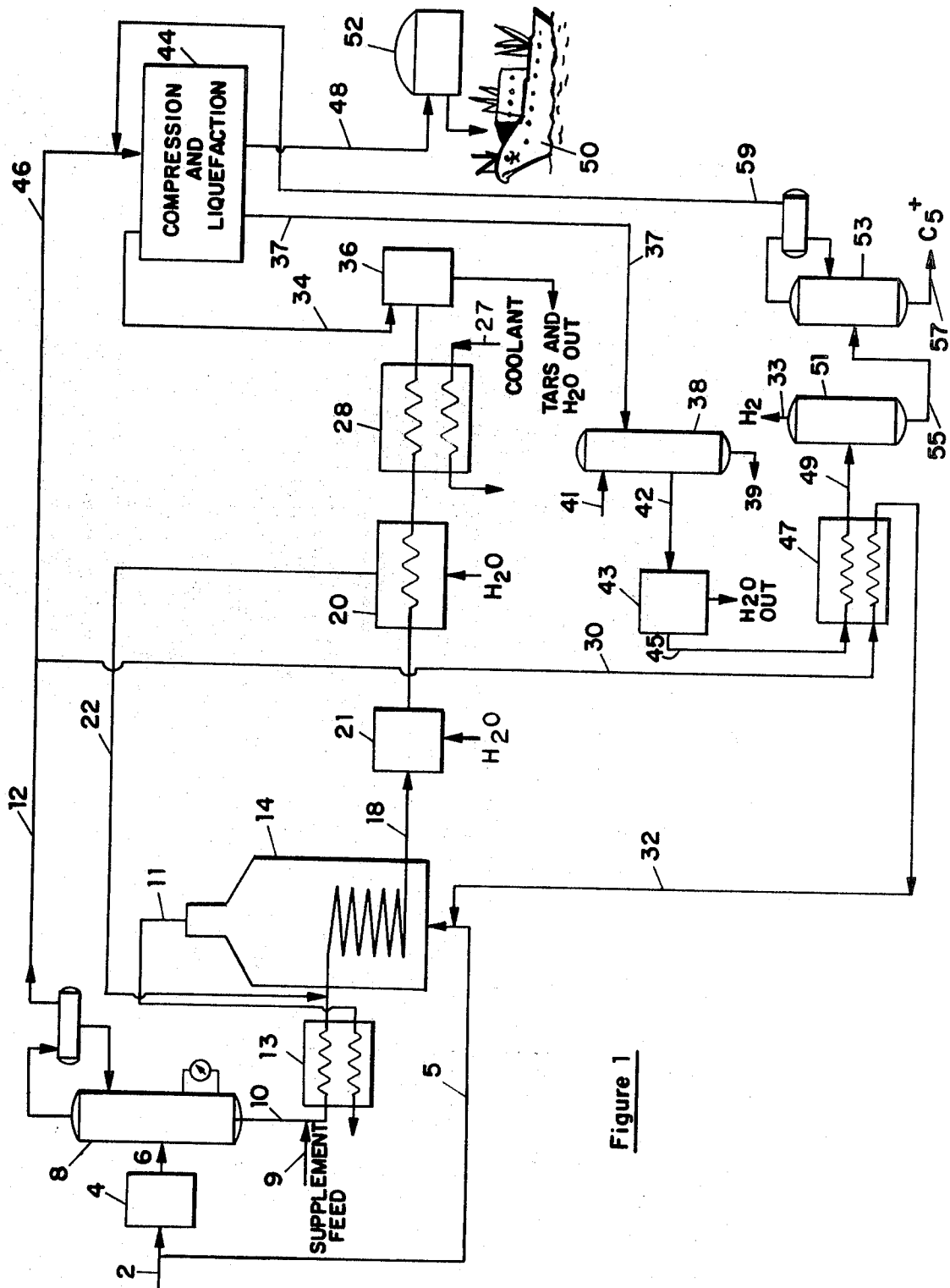


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R. H. HARVEY

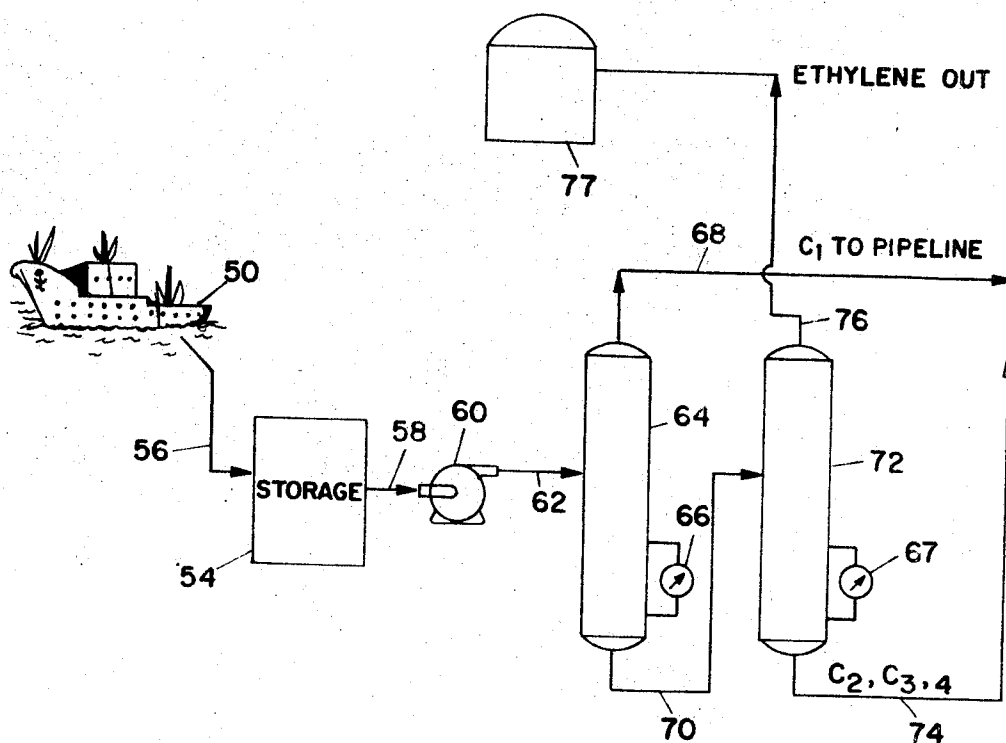
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INTEGRATED ETHYLENE PRODUCTION AND LNG TRANSPORTATION

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Figure 2



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**INTEGRATED ETHYLENE PRODUCTION AND
LNG TRANSPORTATION**

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11 Claims

ABSTRACT OF THE DISCLOSURE

The instant disclosure is directed to a process wherein ethylene production, liquefied natural gas transportation, and ethylene purification are advantageously integrated to mutual benefit. A large economical cracking facility is provided at the source of the natural gas and by performing the cracking operation at this location, improvements in the overall manufacturing economics are achieved.

BACKGROUND OF THE INVENTION

The instant invention relates generally to the production and transportation of liquefied natural gas, hereinafter referred to as LNG. More particularly, the process of the instant invention is directed to an LNG production and transportation scheme involving an integrated ethylene production operation.

Natural gas is often available in areas remote to where it will be ultimately used. Quite often the source of this fuel is separated from the point of utilization by a large body of water and it may then prove necessary to affect bulk transfer of the natural gas by large tankers designed for such transport. Under these circumstances, economics dictate that the natural gas be liquefied so as to greatly reduce its volume and that it be transported at substantially atmospheric pressures. Under these conditions, the LNG is at a temperature of about -258° F., which represents the boiling point of methane at about atmospheric pressure. It is to be noted, however, that the LNG often contains amounts of heavier hydrocarbons such as ethane, propane, butane and the like.

It is often highly desirable to utilize some of the higher molecular weight constituents mentioned above as raw materials or feedstocks for the production of various petrochemicals or for the manufacture of liquefied petroleum gases. Thus, in the past the production of ethylene from the ethane in the LNG has developed and is continuing to develop into a major business. This is normally done in conjunction with the regasification of the LNG (to render it more useful as a fuel) at the point of delivery. While certain modifications in the prior art processes for producing ethylene from natural gas exist, these processes are all characterized by the fact that the production of ethylene is done at or near the LNG receiving point. These processes separate the methane, ethane, and other LNG constituents via a distillation or fractionation operation and then subject the ethane and perhaps some of the other separated constituents to a cracking process to produce ethylene.

In contrast to the prior art, the process to be described hereinafter achieves substantial advantages by having the separation and ethylene production carried out at, or close to, the source of the natural gas.

SUMMARY OF THE INVENTION

According to the teachings of the instant invention, the separation of the natural gas into methane and a C_2 and higher fraction is carried out at the source of the natural gas. The C_2 and higher fraction is then cracked at this location in large cracking furnaces, taking advantage of

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the low fuel cost at the LNG production site. The compression and liquefaction of the cracked products utilize the same large compression facilities used for the liquefaction of the methane at the natural gas liquefaction site.

Thus the methane and the cracked products, i.e. ethylene (including any mixed methane, ethane, and heavier hydrocarbon), are combined just prior to liquefaction and are then shipped to the receiving port. The ethylene and heavier materials mixed into the methane insures that all the benefits normally associated with shipping the heavier hydrocarbons in connection with liquefied methane are retained. It is also contemplated that C_2 and heavier materials from supplemental sources may also serve as feed stocks to the cracking furnace. The use of supplemental feeds leads to less costly liquefaction by providing a greater percentage of C_2 and heavier constituents in the material to be liquefied.

At the receiving end the liquefied methane/ethylene and heavier mixture is fractionated using the available refrigeration present in the liquefied cargo. This, of course, obviates the need for any compression and refrigeration facilities at the receiving end. The liquefied methane is regasified and sent to a gas distribution system for ultimate consumer usage. The high purity ethylene obtained from the fractionation just mentioned is sold as a chemical product and the relatively small amount of ethane and heavier constituents may be blended off into the methane to be supplied to the gas customers thereby controlling its heating value or may be burned for other utility requirements in the receiving plant.

Thus, the advantages offered by the instant invention include the following:

C_2 and heavier streams are cracked at a location where fuel cost is cheap; lower liquefaction costs may be achieved by the bringing in of supplemental C_2 and heavier feed stocks; the cracked gas compression and the hydrogen/methane and heavier separation is carried out where incremental refrigeration and compression is available from large facilities required for the normal liquefaction of natural gas to produce LNG; and the LNG/ethylene fractionation is carried out at the receiving facilities, which can be in many different locations without the need for compression and refrigeration facilities at the points of receipt.

Thus, it is a major object of the instant invention to provide an integrated ethylene production and a natural gas transportation scheme which results in substantial economic savings over ethylene production schemes heretofore employed.

Another object of the instant invention is to utilize the cold made available by the subsequent regasification of the LNG at the point of receipt in the separation and purification of the ethylene from the liquefied cargo as received.

Other objects of the present invention will become more apparent from the following description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic flow plan diagrammatically illustrating a preferred embodiment to be used at the source of the natural gas.

FIG. 2 is a schematic diagram illustrating one embodiment of the process to be used at the point of receipt.

Referring to FIG. 1 in detail, natural gas from the well or other source enters the system via the line 2 from which it is conducted to a preseparation cooling complex 4. In complex 4 facilities are present (not shown) for removing CO_2 , H_2S and H_2O prior to the main cooling operation. As will be understood by those skilled in the art, these constituents must be removed at this point to

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prevent their freezing out as the temperature of the natural gas is lowered. The cooled natural gas leaves complex 4 via the line 6 at a temperature in the range of from about -30 to about -100° F. and is then conducted to a separation tower 8. This tower effects the separation of methane from the C_2 and heavier hydrocarbons present in the natural gas. The methane leaves tower 8 via the line 12 and is conducted via the line 46 to a liquefaction complex 44. The bottoms from separation tower 8 are conducted via the line 10 into a cracking furnace 14.

It should also be appreciated that the feed stock to furnace 14 is not limited to materials recovered from the natural gas. Thus line 9 is provided to allow C_2 and heavier feeds from other outside sources to be fed to furnace 14 if desired. Where outside feed sources are in fact utilized, these will serve to raise the LNG liquefaction temperature to a higher level by providing a greater percentage of C_2 and heavier constituents in the material to be liquefied. This, in turn, serves to lower overall liquefaction costs.

Cracking furnace 14 is preferably of the tubular type with which it is possible to obtain maximum ethylene yields with the short residence time and high temperatures required to minimize the amounts of hydrogen and methane formed. The furnace may be either of the horizontal tube design or the vertical tube design and may be of the type that is oil and gas firing or gas firing alone. In the instant invention, however, a gas firing furnace is preferably in that a portion of the natural gas feed in line 2 may be bypassed in the line 5 and used as the source of fuel for the furnace 14, as illustrated in FIG. 1.

The flue gas exiting the furnace 14 via the line 11 may be passed in heat exchange relationship with the bottoms from the separation tower 8 in the heat exchanger 13, thus serving to raise the temperature of the materials to be cracked in the furnace prior to their entry therein. The cracked materials leave furnace 14 via the line 18, a typical composition for the effluent being indicated in Table I.

TABLE I

Component:	Mole percent
Ethane -----	18
Ethylene -----	33
C_3 and higher -----	6
H_2 -----	30
Methane -----	12
Others -----	1

In line with the concept of short residence time, the cracked products leaving the cracking furnace 14 via the line 18 must be cooled as rapidly as possible. In the absence of quick cooling, an adiabatic reaction normally continues which results in undesired polymerization of olefins and similar undesired reactions. Where low severity cracking furnaces are employed, e.g. where the cracking furnace effluent temperature is relatively low (1300 to 1450° F.), indirect quenching by rapid heat removal is a most common method used in the prior art. Thus, the furnace effluent is made to flow directly to a transfer line exchanger through a minimum distance transfer line. However, in high severity cracking furnaces the furnace effluent is at a higher temperature, which temperature requires minimum residence time in transfer lines. To quickly drop the temperature and freeze the reaction, a water quench is located right at the furnace outlet. Thus, in the process illustrated in FIG. 1, a direct water quench 21 is provided on the line 18. The partially cooled furnace effluent is then conducted to a transfer line exchanger 20. In further cooling the furnace effluent, high pressure steam may conveniently be formed in transfer line exchanger 20. This steam is conducted via the line 22 into the furnace inlet line 10. After being cooled in transfer line exchanger 20, the furnace effluent is

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conducted via a line to another heat exchanger 28. The function of this exchanger is to further cool the furnace effluent to a temperature suitable for economic compression.

It will be appreciated by those skilled in the art that in a plant where mostly ethane or propane is the material to be cracked, as in the instant illustration, the pyrolysis effluent contains very little hydrocarbon material which will condense at atmospheric conditions. Thus, where the gas is cooled to economic compression conditions, only water and trace quantities of hydrocarbons will normally condense. However, since these hydrocarbons may be tarry in nature, they should be removed along with any water in suitable equipment indicated schematically at 36 since they might foul the downstream processing equipment.

The effluent exiting equipment 36 is conducted via the line 34 through compression equipment in complex 44 whereby its pressure is increased so that it is in the range of from about 300 to about 700 p.s.i. The effluent then leaves complex 44 via the line 37 and is introduced into a caustic scrubber 38. The function of the scrubber is to remove acid gases, e.g. sulfur compounds and carbon dioxide. Since the volatilities of these gases are close to the ethylene, they would remain in the ethylene product if not removed. Also, these materials might cause subsequent freezout in liquefaction complex 44. Since CO_2 and H_2S can be removed in the same manner, they are scrubbed out concurrently. The acid gases are removed by absorption, for example, in an aqueous solution of sodium hydroxide introduced into scrubber 38 via the line 41. The hydroxide reacts with CO_2 and H_2S to form mixtures of sodium carboxylate/biscarbonate and sodium sulfide-bisulfide, the spent caustic (normally discarded) being discharged via the line 39. However, if desired, a system (not shown) employing a regenerable material such monoethanolamine may be used to greatly reduce caustic consumption.

Since the acid gas removal step discussed above includes contacting with aqueous solutions, the effluent must be dried after this step. Hence, it is fed via the line 42 to a drier or drying complex 43. At this point, it will be understood by those in the art that the gases exiting the drier 43 must be sufficiently free of water so that in the subsequent compression and liquefaction operations, freezout of water does not occur. The material exiting drier 43 is then conducted (via the line 45) through heat exchanger 47. Cooling is accomplished in exchanger 47 by utilizing cold available from the methane vapors in line 12. Thus a portion of the cold vapors from line 12 are conducted via the line 30 through exchanger 47. The warmed methane vapors in line 32 are fed to the furnace 14, where they may be used as supplemental fuel. The cooled materials exiting exchanger 47 are conducted to a flash drum 51 via the line 49. Any hydrogen present is removed at this time via the line 33. The hydrogen free materials leaving drum 51 are conducted via the line 55 to separation tower 53. In tower 53 any C_5 and heavier materials are removed via the line 57, and the remaining materials are then conducted via the line 59 to line 46. These materials are then recompressed and liquefied with the incoming methane, and the final liquefied product leaves the complex 44 via the line 48, which is in communication with an insulated storage tank 52 maintained at or about atmospheric pressure. The material is then transferred to a tanker indicated schematically at 50, which is used to transport it to a point of utilization.

A process typifying that which may be utilized at the destination point is diagrammatically illustrated in FIG. 2. The liquefied cargo is transferred from the tanker 50 via the line 56 to a suitable insulated storage tank 54. The material is transferred from tank 54 via the line 58 and is pumped up by pump 60 to the operating pressure of the demethanizer. This pressure may be in the range of from about 300 to about 500 p.s.i.g. The overhead from

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demethanizer 64, which is provided with a reboiler 66, leaves via the line 68. This material is, of course, substantially all methane and is fed via the line 68 to a pipeline distribution system (not shown). Liquid exiting from the base of demethanizer 64 via the line 70 contains the C₂ and other higher molecular weight hydrocarbons. This material is led to an ethane/ethylene splitter 72 provided with a reboiler 67. Ethylene exits from the top of this column via the line 76 and is conducted to a suitable storage tank 77. The bottoms from splitter 72 comprising ethane and/or heavier hydrocarbons are conducted via the line 74 out of the system. They may then be introduced into the lean gas (i.e. methane) in line 68 and thence introduced into the fuel gas distribution network. If desired, these materials may be further fractionated to obtain propane, propylene and the like.

It will be appreciated by those skilled in the art that there is no need at the point of utilization for the compression and refrigeration facilities normally associated with ethylene fractionation equipment. Thus, it may be seen that the separation of the ethylene from the other constituents in the product received is carried out in a greatly simplified manner.

It is to be understood that while the foregoing arrangement has been described in considerable detail, it has been so described for purposes of illustration and obviously many variations may be made thereto. Furthermore, the percentages, operating temperatures and pressures specified hereinabove can be varied considerably for any given mixture. It is also to be understood that other ethylene separation and purification schemes may be employed. Accordingly, reference should be had to the following appended claims in determining the full scope of the invention.

What is claimed is:

1. A process for producing a liquefied product having, as major constituents ethylene and methane, which comprises the following steps in combination:

- (a) chilling natural gas;
- (b) passing the chilled natural gas into a demethanizer to obtain a methane fraction and an ethane and heavier hydrocarbon fraction;
- (c) passing said ethane and heavier fraction to a cracking furnace whereby a portion of said ethane and heavier fraction is converted into ethylene;
- (d) combining said cracked ethane and heavier fraction with said methane fraction; and thereafter
- (e) liquefying said combined fractions to produce said liquefied product.

2. The process of claim 1 wherein prior to the chilling of said natural gas a portion of said natural gas is fed to said furnace to be used as a fuel therefor.

3. The process of claim 2 further characterized in that the flue gas exiting said furnace is passed in heat exchange relationship with said ethane and heavier fraction prior to the latter's entry into said furnace.

4. An integrated process for producing a liquefied product having as major constituents ethylene and methane which comprises the following steps in combination:

- (a) splitting natural gas into a first stream and a second stream;
- (b) passing said first stream to a purification complex so as to remove naturally occurring impurities such as CO₂, H₂O, and H₂S;
- (c) chilling the purified first stream resulting from step (b);
- (d) fractionating the chilled purified first stream resulting from step (c) to obtain a first fraction rich in methane and a second fraction rich in ethane and heavier molecular weight constituents;
- (e) passing said second fraction to a cracking furnace whereby a portion of said second fraction is converted into ethylene, said furnace having at least part of its fuel requirements supplied by the said second stream;

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(f) combining said first fraction with the cracked fraction resulting from step (e) thereby forming a combined stream; and

(g) liquefying said combined stream to form said liquefied product.

5. The process of claim 4 wherein prior to liquefaction a portion of said first fraction is passed in heat exchange relationship with the cracked second fraction whereby said cracked second fraction is cooled prior to its liquefaction.

6. The process of claim 5 further characterized in that the flue gas exiting said furnace is passed in heat exchange relationship with said second fraction prior to the second fraction's entry into said furnace.

7. An integrated process for producing a liquefied product having as major constituents ethylene and methane which comprises the following steps in combination:

- (a) splitting natural gas into a first stream and a second stream;
- (b) passing said first stream to a purification complex so as to remove CO₂, H₂O, and H₂S;
- (c) chilling the purified first stream resulting from step (b);
- (d) fractionating the chilled purified first stream resulting from step (c) to obtain a first fraction rich in methane and a second fraction rich in ethane and heavier molecular weight constituents;
- (e) passing said second fraction to a cracking furnace wherein a portion of said second fraction is converted into ethylene, said furnace having at least part of its fuel requirements supplied by the said second stream;
- (f) passing a portion of said first fraction in heat exchange relationship with the cracked second fraction resulting from step (e) whereby said cracked second fraction is cooled;
- (g) passing the flue gas exiting said furnace in heat exchange relationship with said second fraction prior to said second fraction's entry into said furnace;
- (h) passing said portion of said first fraction which was passed in heat exchange relationship with said cracked second fraction to said furnace to supply at least part of the fuel requirements of said furnace;
- (i) combining the remainder of said first fraction and said cracked second fraction whereby a combined stream is formed; and thereafter
- (j) liquefying said combined stream to form said liquefied product.

8. A process for producing ethylene and methane rich gas which comprises the following steps in combination:

- (a) chilling a stream of natural gas;
- (b) passing said chilled natural gas into a demethanizer to obtain a first fraction rich in methane and a second fraction rich in ethane and heavier hydrocarbons;
- (c) passing said second fraction to a cracking furnace whereby a portion of said second fraction is converted into ethylene;
- (d) combining said first fraction and said cracked second fraction;
- (e) liquefying said combined fractions;
- (f) passing said combined fractions to a second demethanizer to obtain a methane rich gas and a C₂ and heavier hydrocarbon fraction; and thereafter
- (g) passing said C₂ and heavier hydrocarbon fraction to a fractionation column to obtain a first product rich in ethylene and a second product rich in ethane and heavier hydrocarbon constituents.

9. The process of claim 8 further characterized in that prior to the chilling of said natural gas a portion of said natural gas is fed to said furnace to be used as a fuel therefor; and the effluent gas exiting said furnace is passed in heat exchange relationship with said second fraction prior to the entry of said second fraction into said furnace.

10. The process of claim 9 further characterized in that a portion of said first fraction rich in methane is passed

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in heat exchange relationship with the cracked second fraction leaving said furnace, whereby said cracked second fraction is cooled prior to its liquefaction.

11. The process of claim 10 wherein that portion of said first fraction rich in methane, which is passed in heat exchange relationship with said cracked second fraction, is then passed to said furnace as additional fuel.

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