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(54) **ETHYLENE PLANT REFRIGERATION SYSTEM**

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(57) **ABSTRACT**

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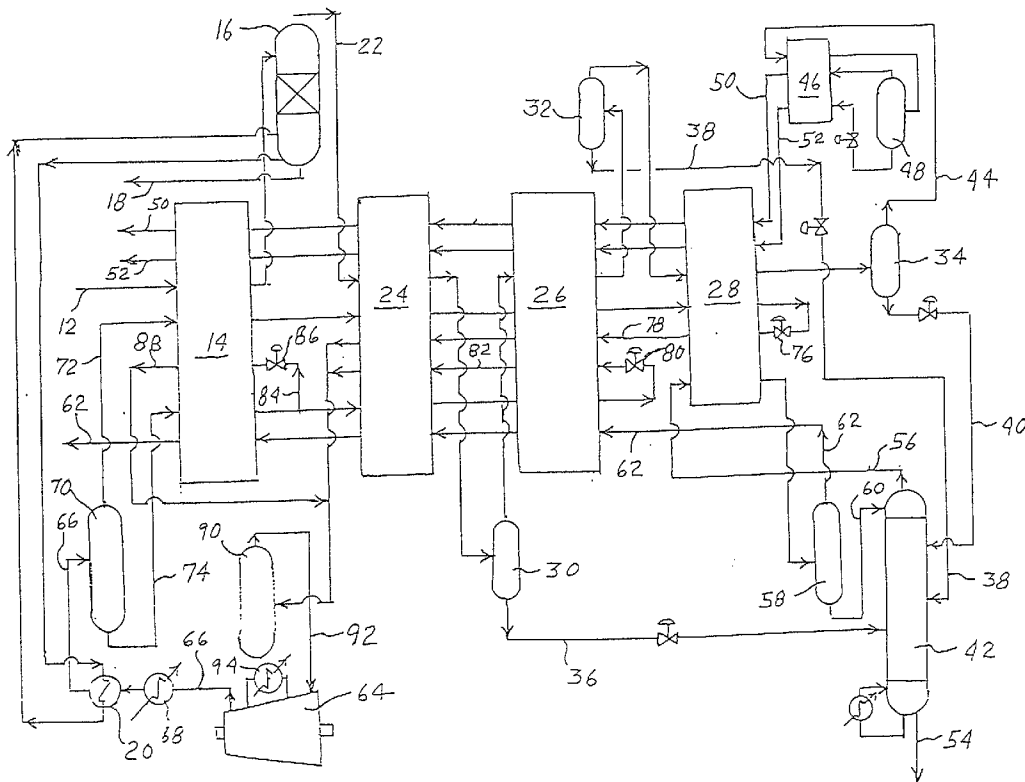
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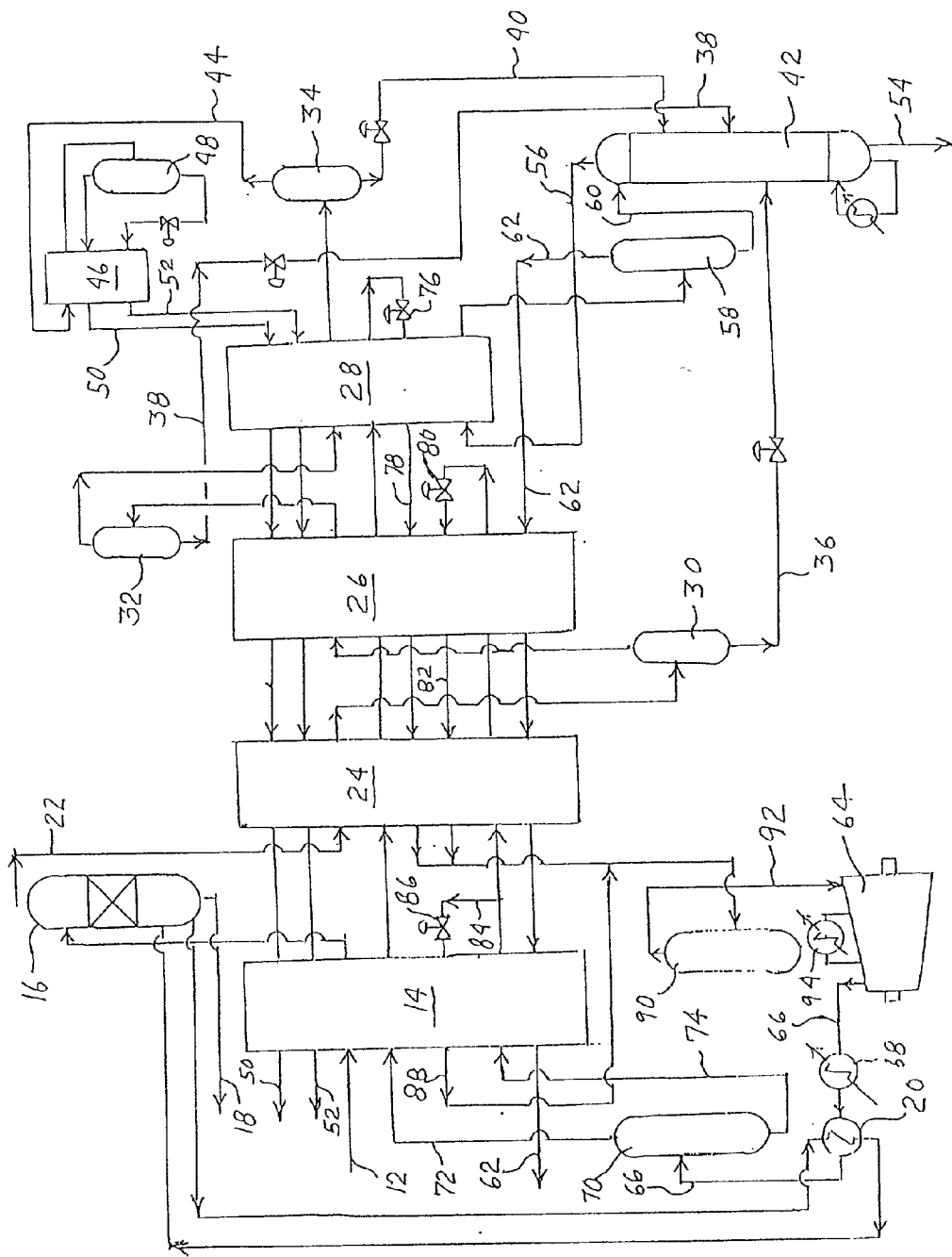
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The refrigeration system for an ethylene plant comprises a tertiary refrigerant containing methane, ethylene and propylene. In the closed loop system, a portion of the constant composition refrigerant from the compressor is separated into a methane-rich vapor portion and a propylene-rich liquid portion. The various refrigerant streams are then used to cool the charge gas to separate the C₂ and heavier hydrocarbons from the hydrogen and methane. The separated refrigerant streams are then recombined to form the constant composition before recycle to the compressor.





ETHYLENE PLANT REFRIGERATION SYSTEM

BACKGROUND OF THE INVENTION

[0001] The present invention pertains to a refrigeration system to provide the cooling requirements of an ethylene plant. More particularly, the invention is directed to the use of a tertiary or trinary refrigerant comprising a mixture of methane, ethylene and propylene for cooling in an ethylene plant.

[0002] Ethylene plants require refrigeration to separate out desired products from the cracking heater effluent. Typically, a C₃ refrigerant, usually propylene, and a C₂ refrigerant, typically ethylene, are used. Often, particularly in systems using low pressure demethanizers where lower temperatures are required, a separate methane refrigeration system is also employed. Thus three separate refrigeration systems are required, cascading from lowest temperature to highest. Three compressor and driver systems complete with suction drums, separate exchangers, piping, etc. are required. Also, a methane refrigeration cycle often requires reciprocating compressors which can partially offset any capital cost savings resulting from the use of low pressure demethanizers.

[0003] Mixed refrigerant systems have been well known in the industry for many decades. In these systems, multiple refrigerants are utilized in a single refrigeration system to provide refrigeration covering a wider range of temperatures, enabling one mixed refrigeration system to replace multiple pure component cascade refrigeration systems. These mixed refrigeration systems have found widespread use in base load liquid natural gas plants. The application of a binary mixed refrigeration system to ethylene plant design is disclosed in U.S. Pat. No. 5,979,177 in which the refrigerant is a mixture of methane and either ethylene or ethane. However, such a binary refrigeration system cascades against a separate propylene refrigeration system to provide the refrigeration in the temperature range of -40° C. and warmer. Therefore, two separate refrigeration systems are required.

SUMMARY OF THE INVENTION

[0004] It is an object of the present invention, therefore, to provide a simplified, single refrigeration system for an ethylene plant having a low pressure demethanizer utilizing a mixture of methane, ethylene and propylene, as a tertiary refrigerant. This system replaces the separate methane, ethylene and propylene refrigeration systems or the binary methane/ethylene systems which are used in conjunction with a propylene refrigeration system in conventional plants and thereby reduces the number of compressor systems. The invention involves the processing of the constant composition tertiary refrigerant from the single compressor including the separation of the refrigerant compressor effluent into a methane-rich fraction and a propylene-rich fraction so as to provide various temperatures and levels of refrigeration in various heat exchange stages while maintaining the constant refrigerant composition flowing back to the compressor. The objects, arrangement and advantages of the refrigeration system of the present invention will be apparent from the description which follows.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The drawing is a schematic flow diagram of a portion of an ethylene plant illustrating the refrigeration system of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0006] The present invention involves an ethylene plant wherein a pyrolysis gas is first processed to remove methane and hydrogen and then processed in a known manner to produce and separate ethylene as well as propylene and some other by-products. The separation of the gases in an ethylene plant through condensation and fractionation at cryogenic temperatures requires refrigeration over a wide temperature range. The capital cost involved in the refrigeration system of an ethylene plant can be a significant part of the overall plant cost. Therefore, capital savings for the refrigeration system will significantly affect the overall plant cost.

[0007] Ethylene plants with high pressure demethanizers operate at pressures higher than 2.758 MPa (400 psi) and can produce overhead reflux by condensation against a pure component ethylene refrigeration. Demethanizer overhead temperatures of these systems are typically in the range of -85° C. to -100° C. Ethylene refrigeration at approximately -101° C. is typically used for chilling the overhead condenser. At pressures below 2.758 MPa, the overhead temperature is typically too low to use ethylene refrigeration unless a vacuum suction is used. But that is not desirable because of the capital cost increase and the safety concern due to potential air leakage into the system.

[0008] The present invention involves the use of a low pressure demethanizer and a tertiary refrigerant system. For purposes of the present invention, a low pressure demethanizer is one which operates below about 2.41 MPa (350 psi) and generally in the range of 0.345 to 1.034 MPa (50 to 150 psi) and with overhead temperatures in the range of -105 to -145° C. The advantage of the low pressure demethanizer is the lower total plant power requirement and lower total plant capital cost while the disadvantage is the lower refrigeration temperature required and, therefore, the need heretofore of two or three separate refrigeration systems and compressors.

[0009] The tertiary refrigerant of the present invention comprises a mixture of methane, ethylene and propylene. The percentage of these components can vary depending on the ethylene plant cracking feedstock, the cracking severity and the chilling train pressure among other considerations, but will generally be in the range of 8 to 20 percent methane, 10 to 30 percent ethylene and 50 to 82 percent propylene. A typical composition would be 10% methane, 15% ethylene and 75% propylene. The use of the tertiary refrigerant provides the refrigeration load and temperatures required for an ethylene plant having a low pressure demethanizer while obviating the need for two or three separate refrigerant systems. The tertiary refrigerant of this invention can also be used with a high pressure demethanizer. In that case, the tertiary system can be designed to provide ethylene and propylene levels of refrigeration. The methane content in the refrigerant would then be 5 to 12%.

[0010] The purpose of the present invention is to provide the necessary refrigeration for the pyrolysis charge gas to separate out the hydrogen and methane and provide the feed for the demethanizer. The tertiary refrigeration system of the invention reduces the capital cost for refrigeration and provides operational stability. Referring to the drawing, the charge gas feed 12, which is the pyrolysis gas conditioned as required and cooled, is typically at a temperature of about

−35 to −37° C. and a pressure of about 3.45 MPa (500 psi), and is typically already partially liquified. The charge gas contains hydrogen, methane, and C₂ and heavier components including ethylene and propylene.

[0011] The charge gas 12 is first cooled in the heat exchanger 14 to about −40° C. and then sent to the stripper 16. A methane free bottom stream 18 is produced which is sent directly to a deethanizer (not shown). This substantially reduces the ethylene to be recovered in the deep chilling sections of the refrigeration system and in the demethanizer. The stripper reboiler is shown at 20 where it provides a portion of the condensing duty for the compressed tertiary refrigerant as will be discussed later.

[0012] The vapor 22 from the stripper 16 is further cooled sequentially in the heat exchanges 24, 26 and 28 with intermediate separations at 30 and 32 and another separation at 34. The separated liquids from the separation drums 30, 32 and 34 respectively form the lower feed 36, the middle feed 38 and the top feed 40 to the demethanizer 42. The vapor 44 from the separation drum 34, which is normally at about −130° C., feeds the Joules-Thomson heat exchanger 46 and separator 48 where a high purity (about 95%) hydrogen stream 50 and a low pressure methane stream 52 are produced. The demethanizer 42 recovers the ethylene and heavier components in the bottom stream 54. The overhead 56, which is at a temperature of about −135° C., is partially condensed in heat exchanger 28 and separated in drum 58 to generate the required reflux 60 for the demethanizer 42. The refrigeration value of the remaining vapor distillate 62 is recovered in the heat exchangers 26, 24 and 14 and is then sent as high pressure methane, normally as regeneration gas in the ethylene plant.

[0013] The supply of the refrigeration in the present invention is from a single tertiary refrigeration system. The system is a closed loop with constant refrigerant composition through each stage of the compressor 64. The compressor effluent 66 is at a pressure in the range of 3.0 Mpa to 5.0 Mpa and has a fixed ratio of methane, ethylene and propylene with this ratio being selected on the basis of the loading profile of the required refrigeration levels. The compressor effluent 66 is partially condensed at 68 by cooling water and further partially condensed in the reboiler 20 of the stripper 16. The partially condensed tertiary refrigerant is sent to the separation drum 70. The temperature in the separation drum 70 is normally in the range of 5 to 20° C. depending on the desired split of the vapor 72 and the liquid 74 to generate the desired lighter and heavier refrigerants respectively. The proportions of vapor and liquid can be varied by changing the level of cooling at 68 and 20.

[0014] The tertiary refrigerant vapor 72 is rich in methane and usually contains a portion of the ethylene. After further condensing and subcooling in the heat exchangers 14, 24, 26 and 28, it is flashed through the letdown valve 76 forming the stream 78 which is at a pressure approaching that of the compressor suction. This stream 78 supplies the levels of refrigeration equivalent to methane and ethylene refrigeration ranging from −150° C. to −45° C. in the heat exchangers 28, 26 and 24. The liquid 74 from the separator 70 is rich in propylene and usually contains the other portion of the ethylene. This supplies the ethylene and propylene refrigerant levels warmer than −102° C. This liquid 74 is subcooled in the heat exchangers 14, 24 and 26 and flashed through the

letdown valve 80 to form the refrigerant stream 82 also at a pressure approaching that of the compressor suction. This refrigerant stream 82 provides refrigeration to the heat exchangers 26, 24 and 14 by the vaporization of the mixed refrigerant at different temperatures. To supplement the condensation and subcooling duty for the lighter refrigerant 72, a slip-stream 84 of the subcooled liquid 74 at the exit from the heat exchanger 14 is flashed through letdown valve 86 and passed as stream 88 back through the heat exchanger 14 where it is superheated.

[0015] The variables which can be used to control the process chilling duties include the adjustment of the temperature in the separation drum 70, the adjustment of the overall refrigerant composition and adjustment of the compressor operating conditions. The system design is responsive to be able to achieve the total recovery of the ethylene which is mainly affected by the drum 34 temperature (normally about −130° C.) and the ability to generate the reflux 60 in the drum 58. Small variations in the temperatures in drum 30 and 32 can also be used as control features.

[0016] The superheated refrigerant vapor 88 is mixed with the refrigerant streams 78 and 82 in the suction drum 90 before entering the compressor 64 through line 92. Since all three refrigerant streams 78, 82 and 88 are re-mixed in the suction drum 90, the composition of the tertiary refrigerant at the compressor suction is identical to the composition at the compressor discharge. Maintaining a constant composition of the refrigerant through the compressor is similar to the operation of a conventional single component refrigeration compressor. Therefore, the stability and operating flexibility of the compressor is enhanced.

[0017] Another important issue addressed by the present invention and relating to the operating stability of the compressor is the degree of superheating of the refrigerant at the compressor suction. Higher superheating results in more compression power while providing the capability of avoiding any phase separation in the suction drum 90. A phase separation would have an immediate impact on the refrigerant composition. Therefore, a reasonable degree of superheating above the refrigerant dew point (normally 5 to 30° C.) will not only provide operating stability during load variations and process upsets, but also simplify the design of the total system and provide investment cost savings. To conserve energy and maintain the operating feasibility of the compressor, it is normally provided with one or more intercoolers 94 to reduce the interstage temperatures.

[0018] The closed loop tertiary refrigeration system of the present invention provides a versatile system in which various refrigerant compositions can be formed while maintaining a single, constant refrigerant composition in each and every stage of the refrigerant compressor. This provides precise temperature control in an efficient and economical manner. There is a reduction in the number of compressor systems needed and there is the ability to use all centrifugal or axial compressors instead of a methane reciprocating compressor.

1. In a process for the production of ethylene from a charge gas containing hydrogen, methane, ethylene and other C₂ and heavier hydrocarbons wherein said process includes a low pressure demethanizer operating at a pressure below 2.41 MPa (350 psi) and wherein said charge gas is cooled by a refrigeration system, a method for cooling said

charge gas by the use of a tertiary refrigerant in said refrigeration system comprising the steps of:

- (a) compressing a tertiary refrigerant comprising a mixture of methane, ethylene and propylene having a selected composition;
 - (b) cooling and partially condensing said tertiary refrigerant and forming a vapor refrigerant stream having an increased percentage of methane and a liquid refrigerant stream having an increased percentage of propylene;
 - (c) progressively cooling said vapor refrigerant stream and said liquid refrigerant stream in a series of heat exchangers;
 - (d) bringing said charge gas into heat exchange contact in said series of heat exchangers with said progressively cooled vapor refrigerant stream and said progressively cooled liquid refrigerant stream thereby cooling said charge gas and producing a remaining gas stream containing said hydrogen and a portion of said methane and producing liquid demethanizer feed streams containing another portion of said methane and concentrated in said ethylene and other C₂ and heavier hydrocarbons;
 - (e) feeding said liquid demethanizer feed streams to said low pressure demethanizer and producing a demethanizer overhead stream consisting essentially of methane and producing a demethanizer bottoms product stream;
 - (f) contacting said demethanizer overhead stream with said progressively cooled refrigerant streams; and
 - (g) combining said vapor refrigerant stream and said liquid refrigerant stream to form a combined refrigerant stream having said selected composition and returning said combined refrigerant stream to said step of compressing.
2. In a process as recited in claim 1 and further including the steps of separating a portion of said liquid refrigerant stream, superheating said separated portion of said liquid refrigerant stream and combining said superheated portion of said liquid refrigerant stream with said combined refrigerant stream for return to said step of compressing.

3. In a process as recited in claim 1 wherein said demethanizer overhead stream is partially condensed in said heat exchanger and said condensed part is returned as reflux to said demethanizer.

4. In a process for the production of ethylene from a charge gas containing hydrogen, methane, ethylene and other C₂ and heavier hydrocarbons wherein said process includes a low pressure demethanizer and wherein said charge gas is cooled by a refrigeration system, a method for cooling said charge gas by the use of a tertiary refrigerant in said refrigeration system comprising the steps of:

- (a) compressing a tertiary refrigerant comprising a mixture of methane, ethylene and propylene having a selected composition;
- (b) cooling and partially condensing at least a portion of said tertiary refrigerant;
- (c) separating said partially condensed tertiary refrigerant into a vapor refrigerant stream having an increased percentage of methane and a liquid refrigerant stream having an increased percentage of propylene;
- (d) cooling said charge gas by heat contact with said vapor refrigerant stream and said liquid refrigerant stream thereby cooling said charge gas and producing a remaining gas stream containing hydrogen and a portion of said methane and producing a liquid demethanizer feed stream containing another portion of said methane and concentrated in said ethylene and other C₂ and heavier hydrocarbons;
- (e) combining said vapor refrigerant stream and said liquid refrigerant stream to form a combined refrigerant stream having said selected composition and returning said combined refrigerant stream to said step of compressing.

5. In a process as recited in claim 4 and further including the steps of separating a portion of said liquid refrigerant stream, superheating said separated portion of said liquid refrigerant stream and combining said superheated portion of said liquid refrigerant stream with said combined refrigerant stream for return to said step of compressing.

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