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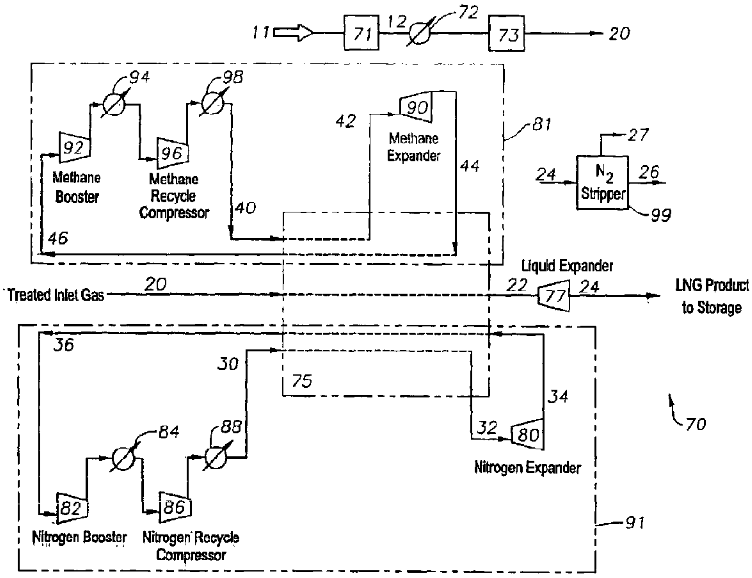
(54) Title: LNG PRODUCTION USING DUAL INDEPENDENT EXPANDER REFRIGERATION CYCLES

Production of LNG Using Dual Independent Expander Refrigeration Cycles



(57) **Abstract:** A process for producing a liquified natural gas stream that includes cooling at least a portion of a pressurized natural gas feed stream by heat exchange contact with first and second expanded refrigerants that are used in independent refrigeration cycles. The first expanded refrigerant is selected from methane, ethane and treated and pressurized natural gas. The second expanded refrigerant is nitrogen.

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LNG PRODUCTION USING DUAL INDEPENDENT EXPANDER REFRIGERATION CYCLES

BACKGROUND OF THE INVENTION

Technical Field

This invention relates to a liquefaction process for a pressurized hydrocarbon stream using refrigeration cycles. More particularly, this invention relates to a process for producing a liquefied natural gas stream from an inlet gas feed stream.

Background of the Invention

Hydrocarbon gases, such as natural gas, are liquefied to reduce their volume for easier transportation and storage. There are numerous prior art processes for gas liquefaction, most involving mechanical refrigeration or cooling cycles using one or more refrigerant gases.

U.S. Patent Nos. 5,768,912 and 5,916,260 to Dubar disclose a process for producing a liquefied natural gas product where refrigeration duty is provided by a single nitrogen refrigerant stream. The refrigerant stream is divided into at least two separate streams which are cooled when expanded through separate turbo-expanders. The cooled, expanded nitrogen refrigerant cross-exchanged with a gas stream to produce liquified natural gas.

U.S. Patent No. 5,755,114 to Foglietta discloses a dual refrigeration cycle useful in the liquefaction of natural gas. These dual refrigeration cycles shown cycles are interconnected such that they function in a dependent fashion using traditional refrigerants in mechanical refrigeration cycles utilizing the latent heat of valorization as a driving force.

U.S. Patent No. 6,105,389 to Paradowski et al also teaches a double refrigeration cycle with the cycles being connected and therefore dependent. As in Foglietta, Paradowski teaches the use of traditional mechanical refrigeration cycles that make use of the latent heat associated with phase change.

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U.S. Patent No. 4,911,741 to Davis and U. S. Patent No. 6,041,619 to Fischer et al also disclose the use of two or more connected refrigerant cycles utilizing traditional refrigerants to make use of the latent heat of vaporization.

There is a need for simplified refrigeration cycles for the liquefaction of natural gas. Conventional liquefaction refrigeration cycles use refrigerants which undergo a change of phase during the refrigeration cycle which require specialized equipment for both liquid and gas refrigerant phases.

The invention disclosed herein meets these and other needs.

SUMMARY OF THE INVENTION

This invention is a cryogenic process for producing a liquified natural gas stream including the step of cooling at least a portion of the inlet gas feed stream by heat exchange contact with first and second expanded refrigerants. At least one of the first and second expanded refrigerants is circulated in a gas phase refrigeration cycle where the refrigerant remains in gas phase throughout the cycle. In this manner, a liquefied natural gas stream is produced.

According to a first aspect of the invention, there is provided a process for producing a liquefied natural gas stream from an inlet gas feed stream, the process comprising the steps of:

cooling at least a portion of the inlet gas feed stream by heat exchange contact with first and second expanded refrigerants in a first and second turboexpander refrigeration cycle, wherein at least one of the first and second expanded refrigerants is circulated in a gas phase such that at least one of the first and second turboexpander refrigeration cycle is a gas phase refrigeration cycle, and whereby a liquefied natural gas stream is produced.

This process includes the steps of cooling at least a portion of an inlet hydrocarbon gas feed stream by heat exchange contact with a first refrigeration cycle having a first expanded refrigerant and a second refrigeration cycle having a second expanded refrigerant that are operated in dual, independent refrigeration cycles. The first expanded refrigerant may be selected from methane, ethane and other hydrocarbon gas, preferably treated inlet gas. The second expanded refrigerant may be nitrogen. These dual, independent refrigerant cycles may be operated at the same time or operated independently.

According to a second aspect of the invention, there is provided a process for producing a liquefied natural gas stream from an inlet gas feed stream, the process comprising the steps of:

cooling at least a portion of the inlet gas feed stream by heat exchange contact with a first gas-phase refrigerant in a methane refrigeration cycle operated independently of a second gas-phase refrigerant in a nitrogen refrigeration cycle;

the methane refrigeration cycle comprising the steps of:

expanding the first gas-phase refrigerant comprising methane to form a cold methane vapor stream;

cooling at least a portion of the inlet feed gas stream by heat exchange contact with the cold methane vapor stream;

compressing the cold methane vapor stream to form a compressed methane vapor stream; and

cooling at least a portion of the compressed methane vapor stream by heat exchange contact with the cold methane vapor stream; and

the nitrogen refrigeration cycle comprising the steps of:

expanding a second gas-phase refrigerant comprising nitrogen to a cold nitrogen vapor stream;

cooling at least a portion of the inlet feed gas stream by heat exchange contact with the cold nitrogen vapor stream simultaneously as cooling at least a portion of the inlet feed gas stream by heat exchange contact with the cold methane vapor stream;

compressing the cold nitrogen vapor stream to form a compressed nitrogen vapor stream; and

cooling at least a portion of the compressed nitrogen vapor stream by heat exchange contact with the cold nitrogen vapor stream;

whereby a liquefied natural gas stream is produced.

According to a third aspect of the invention, there is provided a process for producing a liquefied natural gas stream from an inlet gas feed stream, the process comprising the steps of:

cooling at least a portion of the inlet gas feed stream by heat exchange contact with first and second expanded refrigerants, wherein the first and second expanded refrigerants remain in a gas-phase and are used in a plurality of independent turboexpander refrigeration cycles, and whereby a liquefied natural gas stream is produced.

In one embodiment of the third aspect of the first expanded refrigerant is selected from the group consisting essentially of methane and ethane, and the second expanded refrigerant is nitrogen.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the manner in which the features, advantages and objects of the invention, as well as others which will become apparent, may be understood in more detail, more particular description of the invention briefly summarized above may be had by reference to the embodiment thereof which is illustrated in the appended drawings, which form a part of this specification. It is to be noted, however, that the drawings illustrate only a preferred embodiment of the invention and is therefore not to be considered limiting of the invention's scope as it may admit to other equally effective embodiments.

Fig. 1 is a simplified flow diagram of dual, independent expander refrigeration cycles. This figure demonstrates the independent refrigeration cycles of the invention utilising a nitrogen stream and/or a methane stream as refrigerants.

Fig. 2 is a simplified flow diagram of another embodiment of the invention of Fig. 1 wherein a nitrogen stream and/or an inlet gas stream are used as gas phase refrigerants throughout the refrigerant cycle.

Fig. 3 is a plot of a comparison of a nitrogen warming curve and a LNG/Nitrogen cooling curves for a prior art process.

Fig. 4 is a plot of a comparison of a refrigerant warming curve and a LNG/nitrogen/methane cooling curve for the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

The present invention is directed to an improved process for the liquefaction of hydrocarbon gases, preferably a pressurized natural gas, which employs dual independent cycles. In a preferred embodiment, the process has a first refrigeration cycle using an expanded hydrocarbon refrigerant and a second refrigeration cycle using a expanded nitrogen. The expanded hydrocarbon refrigerant may be, for example, pressurized methane, ethane or treated inlet gas.

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As used herein, the term "inlet gas" will be taken to mean a hydrocarbon gas that is substantially comprised of methane, for example, 85% by volume methane, with the balance being ethane, higher hydrocarbons, nitrogen and other trace gases.

The detailed description of preferred embodiments of this invention is made with reference to the liquefaction of a pressurised inlet gas which has an initial pressure of about 800 psia at ambient temperature. Preferably, the inlet gas will have an initial pressure between about 500 to about 1200 psia at ambient temperature. As discussed herein, the expanding steps, preferably by isentropic expansion, may be effectuated with a turboexpander, Joule-Thompson expansion valves, a liquid expander or the like. Also, the expanders may be linked to corresponding staged compression units to produce compression work by gas expansion. In the first and third aspects of the invention, the expanders are turboexpanders.

Referring now to Figure 1 of the drawings, a pressurised inlet gas stream, preferably a pressurised natural gas stream, is introduced. In the embodiment illustrated, the inlet gas stream is at a pressure of about 900 psia and ambient temperature. Inlet gas stream 11 is treated in a treatment unit 71 to removed acid gases, such as carbon dioxide, hydrogen sulphide, and the like, by known methods such as desiccation, amine extraction or the like. Also, the pre-treatment unit 71 may serve as a dehydration unit of conventional design to remove water from the natural gas stream. In accordance with conventional practice in cryogenic processes, water may be removed from inlet gas streams to prevent freezing and plugging of the lines and heat exchangers at the low temperatures subsequently encountered in the process. Conventional dehydration units which include gas desiccants and molecular sieves may be used.

Treated inlet gas stream 12 may be pre-cooled via one or more unit operations. Stream 12 may be pre-cooled via cooling water in cooler 72. Stream 12 may be further pre-cooled by a conventional mechanical refrigeration device 73 to form pre-cooled and treated stream 19 ready for liquefaction as treated inlet gas stream 20. Such a mechanical refrigeration device may include a refrigerant selected from propane and propylene.

Treated inlet gas stream 20 is supplied to a refrigeration section 70 of a liquid natural gas manufacturing facility. Stream 20 is cooled and liquefied in exchanger 75 by countercurrent heat exchange contact with a first refrigeration cycle 81 and a second refrigeration cycle 91. These refrigeration cycles are designed to be operated independently and/or concurrently depending upon the refrigeration duty required to liquefy an inlet gas stream. The first and second expanded refrigerants may be used in a plurality of independent refrigeration cycles.

In a preferred embodiment, a first refrigeration cycle 81 uses an expanded methane refrigerant and a second refrigeration cycle 91 uses an expanded nitrogen refrigerant. In the first refrigeration cycle 81, expanded methane is used as a refrigerant. A cold, expanded methane stream 44 enters exchanger 75, preferably at about -119°F and about 200 psia and is cross-exchanged with treated inlet gas 20 and compressed methane stream 40. Methane stream 44 is warmed in exchanger 75 and then enters one or more compression stages as stream 46. Warm methane stream 46 is partially compressed in a first compression stage in methane booster compressor 92. Next, stream 46 is then compressed again in a second compression stage in methane recycle compressor 96 to a pressure from about 500 to 1400 psia. Stream 46 is water cooled in exchangers 94 and 98 and enters exchanger 75 as compressed methane stream 40. Stream 40 enters exchanger 75 at about 90°F and preferably about 1185 psia. Stream 40 is cooled to about 20°F and about 995 psia by cross-exchange with cold, expanded methane stream 44 and exits exchanger 75 as cooled methane stream 42. Stream 42 is preferably isentropically expanded in expander 90, to about -110 to -130° F, preferably to about -119° F and about 200 psia. Stream 42 enters exchanger 75 as cold, expanded methane stream 44.

In the second refrigeration cycle 91, a cold, expanded nitrogen stream 34 enters exchanger 75 at preferably about -260°F and about 200 psia and is cross-exchanged with treated inlet gas stream 20 and compressed nitrogen stream 30. Nitrogen stream 34 is warmed in exchanger 75 and then enters one or more compression steps as stream 36. Warm nitrogen stream 36 is partially compressed in nitrogen booster compressor 82 and then compressed again in nitrogen recycle compressor 86 to a pressure from about 500 to 1200 psia. Stream 36 is water cooled in exchangers 84 and 88 and enters exchanger 75 as compressed nitrogen stream 30. Stream 30 enters exchanger 75 at about 90°F and preferably about 1185 psia. Stream 30 is cooled to preferably about -130°F and about 1180 psia by cross-exchange with cold, expanded nitrogen stream 34 and exits exchanger 75 as cooled nitrogen stream 32. Stream 32 is preferably isentropically expanded in expander 80 to about -250 to -280°F, preferably to about -260°F and about 200 psia. Stream 32 enters exchanger 75 as cold, expanded nitrogen stream 34.

The first and second dual, independent refrigeration cycles work independently to cool and liquefy inlet gas stream 20 from about -240 to -260° F, preferably to about -255° F. Liquified gas stream 22 is preferably isentropically expanded in expander 77 to a pressure from about 15 to 50 psia, preferably to about 20 psia to produce a liquified gas product stream 24.

Product stream 24 may contain nitrogen and other trace gases. To remove these unwanted gases, stream 24 is introduced to a nitrogen removal unit 99, such as a nitrogen stripper, to produce a treated product stream 26 and a nitrogen rich gas 27. Rich gas 27 may be used for low pressure fuel gas or recompressed and recycled with the inlet gas stream 11.

In another preferred embodiment, treated inlet gas may be used to supply at least a portion of refrigeration duty required by the process. As shown in Fig. 2, the first refrigeration cycle 191 uses an expanded hydrocarbon gas mixture as a refrigerant. The hydrocarbon gas mixture refrigerant is selected from methane, ethane and inlet gas. The second refrigeration cycle operates as discussed above. Thus, a nitrogen stream and/or an inlet gas stream are used as gas phase refrigerants throughout the refrigerant cycle. This utilizes the sensible heat of the refrigerant as the driving force for refrigeration cycle. While Fig. 2 demonstrates the use of at least one gas phase refrigeration cycle, the refrigeration cycles are not independent from each other in that the inlet gas stream is used as a refrigerant in one cycle creating a dependence between the two refrigerant cycles.

In the first refrigeration cycle 191, cold expanded hydrocarbon gas mixture 144 enters exchanger 75 at preferably about -119°F and 200 psia and is cross-exchanged with an inlet gas mixture 174 to be liquified. Gas mixture stream 144 is warmed in exchanger 75 and then enters one or more compression stages as stream 146. Warm gas mixture stream 146 is partially compressed in a first compression stage in methane booster compressor 92. Stream 146 is then compressed again in a second compression stage in methane recycle compressor 96 to a pressure from about 500 to 1400 psia. Stream 146 is water cooled in exchangers 94 and 98 as compressed gas mixture stream 140. Preferably, treated inlet gas 120 is mixed with compressed gas mixture 140 to form stream 174 to be liquified. Also, treated inlet gas 120 may be mixed with stream 146 prior to entering one or more compression stages. Stream 174 enters exchanger 75 at preferably about 90° F and about 1000 psia. Stream 174 is cooled to preferably about 20° F and about 995 psia by cross-exchange with cold, expanded gas mixture stream 144 and exits exchanger 75 as cooled gas mixture stream 142. Stream 142 is preferably isentropically expanded in expander 90 to about -110 to -130° F, preferably to about -119° F and about 200 psia. Stram 142 enters exchanger 75 as cold, expanded gas mixture stream 144.

The first and/or second dual refrigeration cycles work to cool and liquify inlet gas mixture 174 from about -240 to -260° F, preferably to about -255° F. Liquified gas mixture stream 176 is preferably isentropically expanded in expander 77 to a pressure from about 15 to 50 psia, preferably to about 20 psia to produce a liquified gas mixture product stream 180.

As noted above, the refrigerant gases in each dual refrigerant cycle may be sent to their respective booster compressors and/or recycle compressors to recompress the refrigerant. The booster compressors and/or recycle compressors may be driven by a corresponding or operably linked turbo-expander in the process. In addition, the booster compressor may be operated in post-boost mode and located downstream from the recycle compressor to supply additional compression of about 50 to 100 psia to the refrigerant gases. The booster compressor may also be operated as pre-boosted mode and located upstream from the recycle compressor to partially compress the refrigerant gases about 50 to 100 psia before being sent to the final recycle compressors.

Fig. 3 illustrates warming and cooling curves for a prior art liquefaction process. The warming curve of the nitrogen refrigerant is essentially a straight line having a slope which is adjusted by varying the circulation rate of nitrogen refrigerant until a close approximation is achieved between the warming curve of the nitrogen refrigerant and the cooling curve of the feed gas at the warm end of the exchanger. This sets the upper limit of operation of the liquefaction process. Thus, by using this prior art method it is possible to obtain relatively close approximations at both the warm and cold ends of the heat exchanger between the different curves. However, because of the different shapes of the respective curves in the intermediate portion of each it is not possible to maintain a close approximation between the two curves over the entire temperature range of the process, i.e. the two curves diverge from each other in their intermediate portions. Although the nitrogen refrigerant warming curve approximates a straight line, the cooling curve of the feed gas and nitrogen is of a complex shape and diverges markedly from the linear warming curve of the nitrogen refrigerant. The divergence between the linear warming curve and the complex cooling curve is a measure of and represents thermodynamic inefficiencies or lost work in operating the overall process. Such inefficiencies or lost work are partly responsible for the higher power consumption of using the nitrogen refrigerant cycle compared to other processes such as the mixed refrigerant cycle.

Fig. 4 illustrates a warming and cooling curves for a preferred embodiment of this invention. This invention demonstrates improved thermodynamic efficiency or reduced lost work as compared to prior art gas liquefaction processes by utilising the cooling capacity upon expansion of a hydrocarbon gas mixture, such as high pressure methane, ethane and/or inlet gas. In addition, thermodynamic efficiency is also improved over prior art processes because the dual refrigeration cycles and/or the dual, independent refrigeration cycles of the invention maybe adjust and/or adapt to the particular refrigeration duty needed to liquefy a given inlet gas stream of known pressure, temperature and composition. That is, there is no need to supply more refrigeration duty that is required. As a result, the warming and cooling curves are more closely matched so that the temperature gradients and hence thermodynamic losses between the refrigerant and inlet gas stream are reduced.

In the process illustrated in Fig. 1, a simplified flow diagram of dual, independent expander refrigeration cycles is shown. This figure demonstrates the use of independent refrigeration cycles utilizing a nitrogen stream and a methane stream as refrigerants. Alternate embodiments (not shown) include the use of traditional refrigerants in one or both of the independent cycles. In the example shown in Fig. 1, the warming curve is divided into two discrete sections by splitting the refrigeration duty required to liquefy the inlet gas into two refrigeration cycles. In the first cycle, a hydrocarbon gas mixture, such as methane refrigerant is expanded, preferably in a turboexpander, to a lower pressure at a lower temperature and provides cooling of the inlet gas stream. The second cycle is used where a nitrogen refrigerant is expanded, preferably in a turboexpander, to a lower pressure and temperature and provides further cooling of the gas stream. The flow rate of the refrigeration in the second cycle is chosen so that the slope of the warming curve is approximately the same as that of the cooling curve. Because of the shape and slope of the cooling curves in the last portion of the cooling process, it is the nitrogen cycle that provides the major portion of the refrigeration duty in this invention. As a result, a minimum temperature approach of approximately 5°F is achieved through the exchanger. Thus, a cooling curve for the first and second refrigerants approaches a cooling curve for the inlet gas feed stream by at least about 5°F.

Embodiments of the invention have significant advantages. First, the process is adaptable to different quality of the feed inlet gas by adjusting the relationship between the nitrogen and/or gas refrigerants and thereby more thermodynamically efficient. Second, the circulating refrigerants are in the gaseous phase. This eliminates the need for liquid separators or liquid storage and the concomitant environmental safety impacts. Gas phase refrigerants simplify the heat exchanger construction and design.

While the present invention has been described and/or illustrated with particular reference to the process for the liquefaction of hydrocarbons, such as natural gas, in which nitrogen and a second refrigerant, such as methane or other hydrocarbon gas, is used as refrigerants in dual, independent cycles, it is noted that the scope of the present invention is not restricted to the embodiment(s) described. It should be apparent to those skilled in the art that the scope of the invention includes other methods and applications of the process using nitrogen and/or to the use of other gases in the improved application or in other applications than those specifically described. Moreover, those skilled in the art will appreciate that the invention described above is susceptible to variations and modifications other than those specifically described. It is understood that the present invention includes all such variations and modifications which are within the spirit and scope of the invention. It is intended that the scope of the invention not be limited by the specification, but be defined by the claims set forth below.

Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that that prior publication (or information derived from it) or known matter forms part of the common general knowledge in the field of endeavour to which this specification relates.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A process for producing a liquefied natural gas stream from an inlet gas feed stream, the process comprising the steps of:

cooling at least a portion of the inlet gas feed stream by heat exchange contact with first and second expanded refrigerants in a first and second turboexpander refrigeration cycle, wherein at least one of the first and second expanded refrigerants is circulated in a gas phase such that at least one of the first and second turboexpander refrigeration cycle is a gas phase refrigeration cycle, and whereby a liquefied natural gas stream is produced.

2. The process of claim 1 wherein the first expanded refrigerant is selected from methane, ethane and inlet gas.

3. The process of claim 1 or claim 2 wherein the second expanded refrigerant is nitrogen.

4. The process of claim 3 wherein the nitrogen is expanded to a temperature of about -250°F to about -280°F (about -157°C to about -173°C).

5. The process of any one of the preceding claims wherein the first and second expanded refrigerants are used in a plurality of independent refrigeration cycles.

6. The process of any one of the preceding claims wherein the liquefied natural gas stream is cooled to a temperature of about -240°F to about -260°F (about -151°C to about -162°C).

7. The process of any one of the preceding claims wherein the inlet gas stream is at an inlet pressure of about 500 psia to about 1200 psia.

8. The process of any one of the preceding claims wherein a cooling curve for the first and second refrigerants approaches a cooling curve for the inlet gas feed stream by at least

about 5°F.

9. The process of any one of the preceding claims wherein the cooling step includes cooling at least a portion of the inlet gas feed stream with a mechanical refrigeration cycle.

10. The process of claim 9 wherein the mechanical refrigeration cycle includes a refrigerant selected from propane and propylene.

11. The process of any one of the preceding claims wherein the cooling step includes cooling at least a portion of the inlet gas feed stream with cooling water.

12. The process of any one of the preceding claims further comprising the step of removing nitrogen and other trace gases from the liquified natural gas stream.

13. The process of any one of the preceding claims further comprising the step of expanding the liquefied natural gas stream to a pressure from about 15 psia to about 50 psia.

14. A process for producing a liquefied natural gas stream from an inlet gas feed stream, the process comprising the steps of:

cooling at least a portion of the inlet gas feed stream by heat exchange contact with a first gas-phase refrigerant in a methane refrigeration cycle operated independently of a second gas-phase refrigerant in a nitrogen refrigeration cycle;

the methane refrigeration cycle comprising the steps of:

expanding the first gas-phase refrigerant comprising methane to form a cold methane vapor stream;

cooling at least a portion of the inlet feed gas stream by heat exchange contact with the cold methane vapor stream;

compressing the cold methane vapor stream to form a compressed methane vapor stream; and

cooling at least a portion of the compressed methane vapor stream by heat exchange contact with the cold methane vapor stream; and

the nitrogen refrigeration cycle comprising the steps of:

expanding a second gas-phase refrigerant comprising nitrogen to a cold nitrogen vapor stream;

cooling at least a portion of the inlet feed gas stream by heat exchange contact with the cold nitrogen vapor stream simultaneously as cooling at least a portion of the inlet feed gas stream by heat exchange contact with the cold methane vapor stream;

compressing the cold nitrogen vapor stream to form a compressed nitrogen vapor stream; and

cooling at least a portion of the compressed nitrogen vapor stream by heat exchange contact with the cold nitrogen vapor stream;

whereby a liquefied natural gas stream is produced.

15. The process of claim 14 wherein the compressing step of the methane refrigeration cycle includes mixing at least a portion of the inlet gas feed stream with the compressed methane vapor stream to form the refrigerant stream.

16. The process of claim 14 or 15 wherein the methane refrigeration cycle includes expanding the first gas-phase refrigerant to a temperature of about -110°F to about -130°F (about -79°C to about -90°C).

17. The process of any one of claims 14 to 16 wherein the nitrogen is expanded to a temperature of about -250°F to about -280°F (about -157°C to about -173°C).

18. The process of any one of claims 14 to 17 wherein the compressed nitrogen vapor stream of the nitrogen refrigeration cycle is compressed to a pressure of about 500 psia to about 1200 psia.

19. The process of any one of claims 14 to 18 wherein the compressed methane vapor stream of the methane refrigeration cycle is compressed to a pressure of about 500 psia to about 1400 psia.

20. The process of any one of claims 14 to 19 further comprising the step of removing nitrogen and other trace gases from the liquified natural gas stream.

21. The process of any one of claims 14 to 20 further comprising the step of expanding the liquified natural gas stream to a pressure from about 15 psia to about 50 psia.

22. A process for producing a liquefied natural gas stream from an inlet gas feed stream, the process comprising the steps of:

cooling at least a portion of the inlet gas feed stream by heat exchange contact with first and second expanded refrigerants, wherein the first and second expanded refrigerants remain in a gas-phase and are used in a plurality of independent turboexpander refrigeration cycles, and whereby a liquefied natural gas stream is produced.

23. The process of claim 22 wherein the first expanded refrigerant is selected from the group consisting essentially of methane and ethane, and the second expanded refrigerant is nitrogen.

24. A process for producing a liquefied natural gas stream from an inlet gas feed stream, substantially as hereinbefore described with reference to Figure 1 or 2 of the accompanying drawings.

Production of LNG Using Dual Independent Expander Refrigeration Cycles

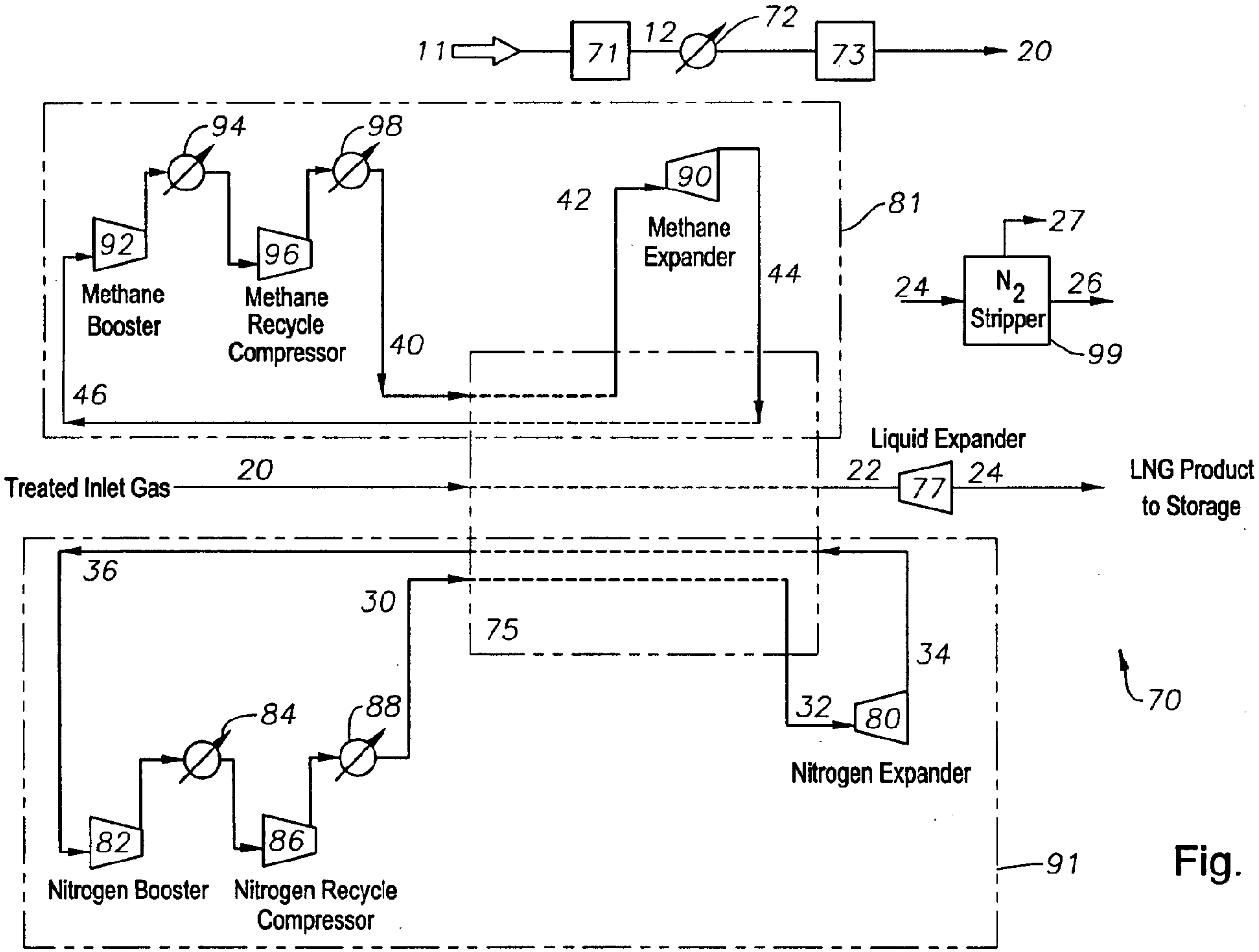

Fig. 1

Production of LNG Using Dual Independent Expander Refrigeration Cycles

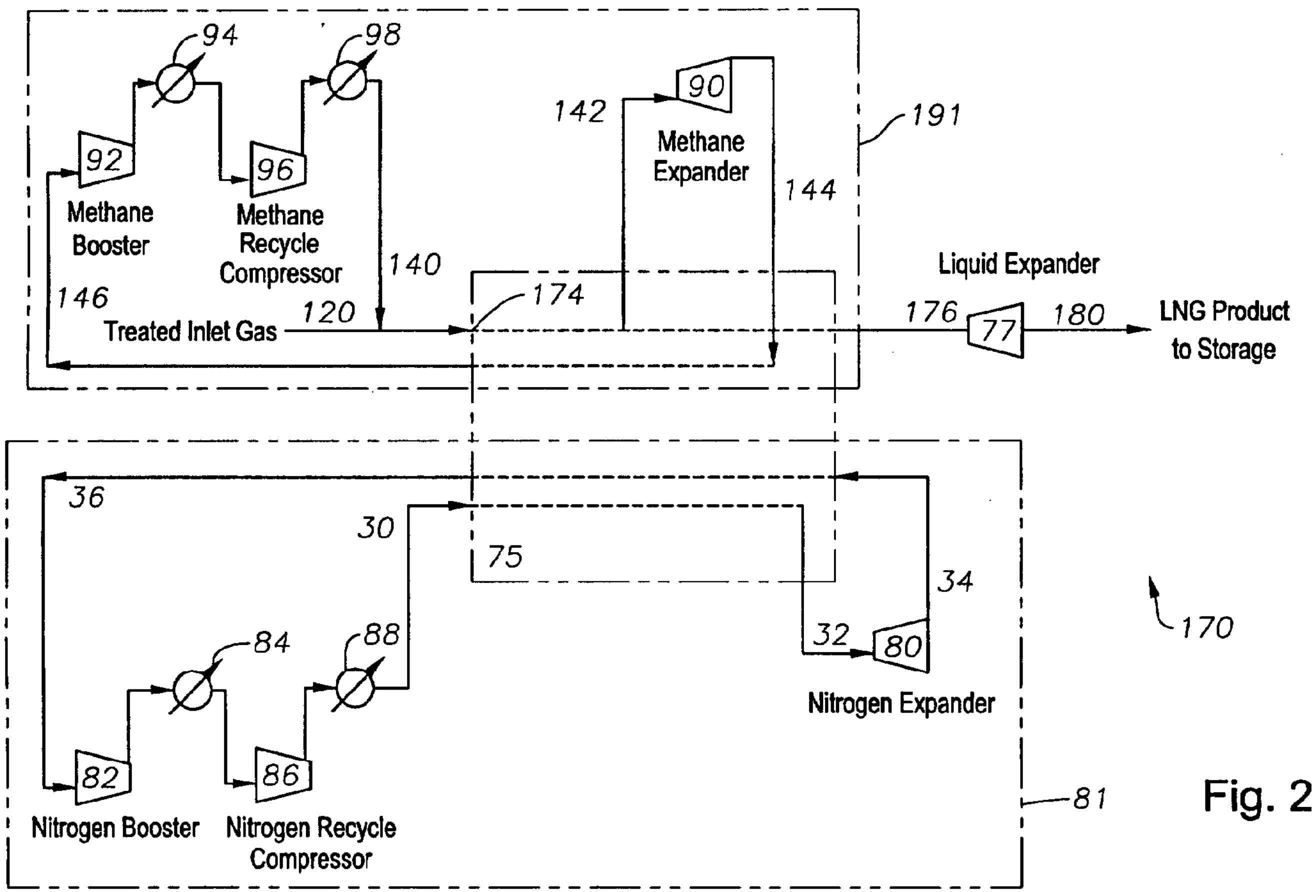

Fig. 2

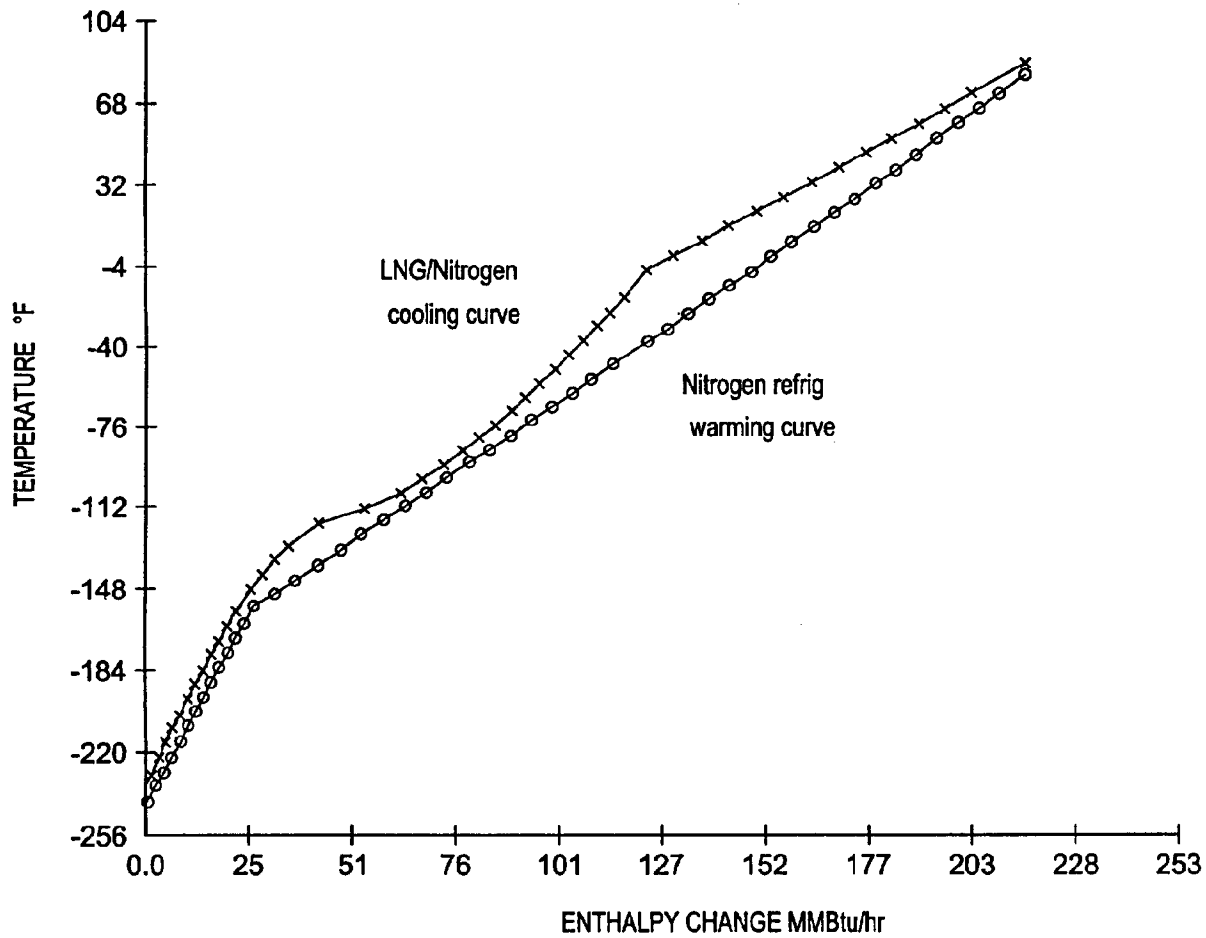

Fig. 3
(Prior Art)

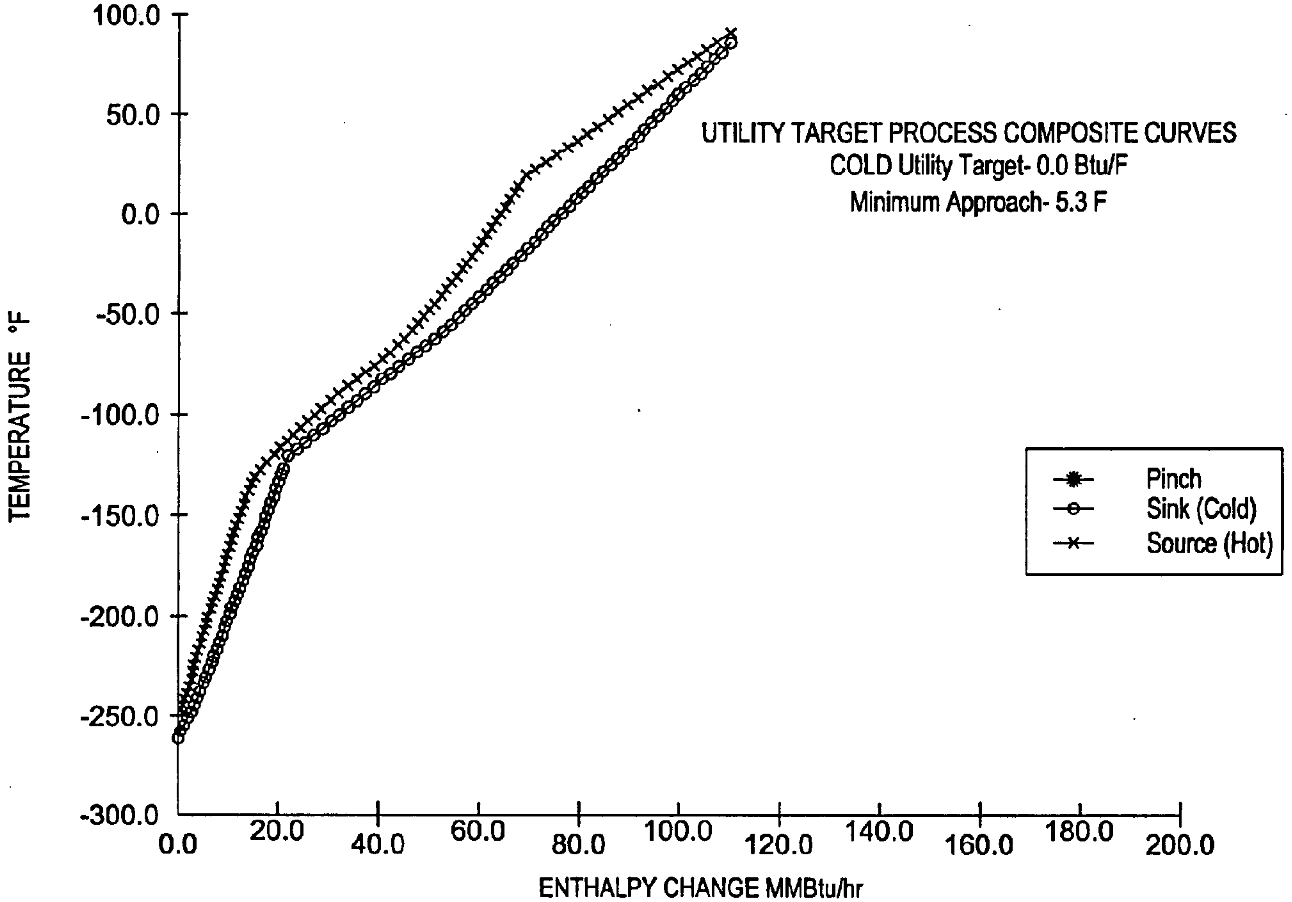
UTILITY TARGET PROCESS COMPOSITE CURVES
COLD Utility Target- 0.0 Btu/F
Minimum Approach- 5.3 F
Pinch
Sink (Cold)
Source (Hot)
TEMPERATURE °F
100.0
50.0
0.0
-50.0
-100.0
-150.0
-200.0
-250.0
-300.0
0.0
20.0
40.0
60.0
80.0
100.0
120.0
140.0
160.0
180.0
200.0
ENTHALPY CHANGE MMBtu/hr

Fig. 4