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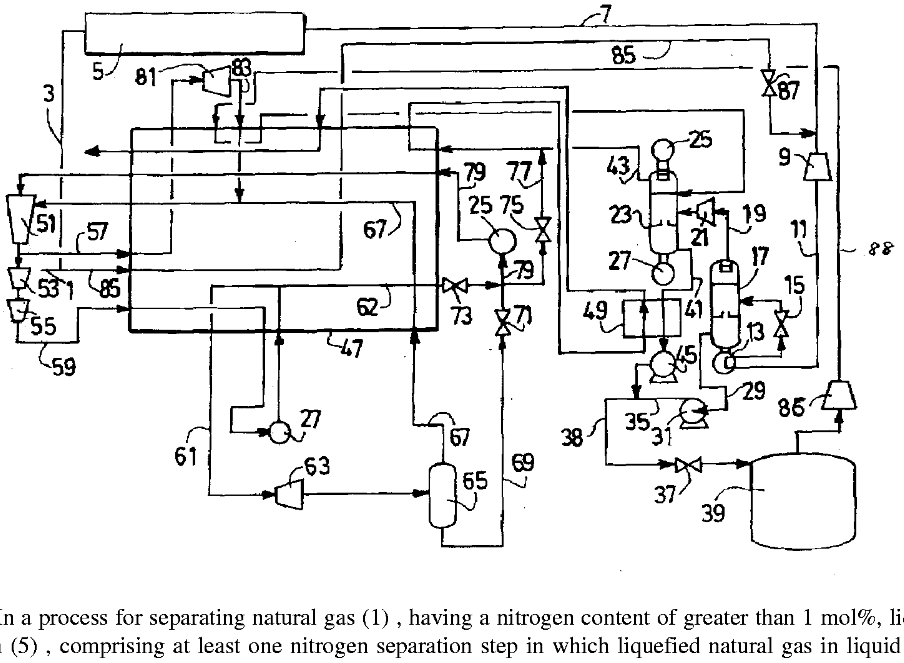
(54) **Title:** LIQUEFIED NATURAL GAS SEPARATION PROCESS AND INSTALLATION



(57) **Abstract:** In a process for separating natural gas (1) , having a nitrogen content of greater than 1 mol%, liquefied in a main liquefaction train (5) , comprising at least one nitrogen separation step in which liquefied natural gas in liquid form is sent to a separation unit (17, 23), a stream (38) of liquefied natural gas purified of nitrogen and a stream (43) of nitrogen-enriched vapour are produced in the separation unit, and the nitrogen- enriched vapour is recondensed by means of a refrigerant fluid (61), the nitrogen content of which is greater than 80 mol%, the refrigerant fluid having a normal boiling point below that of methane, and being generated by a refrigeration cycle different from that of the main natural-gas liquefaction train.

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Liquefied natural gas separation process and installation

The present invention relates to a process for separating liquefied natural gas and to a liquefied natural gas separation system.

The known processes for liquefying natural gas generally comprise, and particularly when the feed gas contains nitrogen with a content of greater than 1 mol% (the usual content of the product before it is loaded into LNG tankers), a nitrogen separation unit so as to reduce the proportion of this constituent in the liquefied natural gas.

A known process comprises a succession of free expansions of the liquefied gas, thus producing a vapour enriched in light constituents (for example nitrogen and helium). The fraction that remains liquid therefore sees its content of light constituents decrease.

Instead of this process or in addition to this process, the liquefied natural gas may be separated in a distillation column that operates at a pressure close to atmospheric pressure and is fitted with a sump warmer. The charge is generally introduced in liquid form at the top of the column, and a portion of this charge is vaporized by the sump warmer. The vapour thus generated allows mass exchange by contact with distillation trays, with structured or unstructured packings, or any other known distillation means compatible with the cryogenic temperatures at which this mass transfer takes place. The ascending vapour is therefore enriched with nitrogen and with any constituent lighter than methane. The liquid produced in the column sump is therefore depleted in nitrogen, thereby making it possible to achieve the required nitrogen content (typically < 1 mol%).

In these two known processes, the vapour generated by successive expansions or obtained at the top of columns, although enriched with nitrogen, nevertheless have a high residual methane content - this is because, since no fluid "colder" than this vapour is available, it is therefore not possible to introduce a recondensation system which would make it possible to improve the nitrogen purity of the ascending vapour and therefore increase the production of liquefied natural gas to the required specification. This therefore means a loss of liquefied product and the impossibility of utilizing, as pure product, the vapour generated as it is too rich in methane. Such vapour is therefore commonly used as combustible gas.

Moreover, the liquefied natural gas is then sent to storage tanks, which themselves generate vapour, in particular owing to:

- heat influx due to imperfect insulation of the storage tanks and due to the pumping of the liquefied gas from the production installation to the storage tanks; and
- possibly the production of gas resulting from the pressure difference between the production installation and the storage tanks (called "flash").

This vapour, referred to as boil-off, also occasions an additional loss of LNG.

The proposed solution consists in improving the nitrogen separation by the use of at least one column containing an overhead vapour recondensation device by heat exchange with a fluid lighter than methane, and therefore preferably a nitrogen-enriched fluid. The boil-off from the storage tanks may also be treated and recondensed so as to minimize, or even eliminate, the loss of LNG.

For this purpose, and to prevent methane and other hydrocarbons from solidifying, it may be pertinent to operate the separation column at high pressure.

The sump warmer may be the same fluid, used at a higher pressure than in the vapour recondensation device.

The use of this fluid, possibly in liquid form in the vapour recondensation device, means that a refrigeration cycle has to be used, preferably employing a nitrogen-enriched cycle gas, near the LNG train. This liquefier, as cold fluid source, advantageously makes it possible:

- to purify the overhead produced at the top of the denitrogenation column of the LNG train. Thus it becomes conceivable to produce a large part of the nitrogen within the natural gas in a purified (liquid or gaseous) form. Likewise, it becomes conceivable to produce helium possibly contained in the natural gas with a purity sufficient for it to be able to be directly treated by a PSA unit;
- to recondense the boil-off from the liquefied natural gas storage tanks, or any other methane-enriched vapour, for example that generated when filling LNG tankers;
- to increase the production of liquefied natural gas, since methane molecules, previously lost with the nitrogen-enriched vapour, may be recovered as LNG; and
- even more advantageously, it is also possible for pretreated natural gas to be liquefied directly, in order to avoid any problem of blocking due to the solidification of heavy components, since it generates the refrigeration power at temperatures equal to or below the normal liquefaction temperature of natural gas. This additional production is therefore not generated by the "main" natural-gas liquefaction train.

One subject of the invention is a process for separating liquefied natural gas, having a nitrogen content of greater than 1 mol%, in a main liquefaction train comprising at least one nitrogen separation step in which liquefied natural gas in liquid or "pseudo-liquid" form is sent into a separation unit, a stream of liquefied natural gas purified of nitrogen and a stream of nitrogen-enriched vapour are produced in the separation unit and the nitrogen-enriched vapour is partially recondensed by means of a refrigerant fluid, the nitrogen content of which is greater than 80 mol%, the refrigerant fluid having a normal boiling point below that of methane, and being generated by a refrigeration cycle differing from that of the main natural-gas liquefaction train, characterized in that the stream of liquefied natural gas purified of nitrogen is sent to a storage tank, where it partially vaporizes to form a boil-off, and the boil-off is recondensed by means of the refrigerant fluid.

Liquefied natural gas under supercritical pressure is in "pseudoliquid" form.

According to other optional aspects of the invention:

- the separation unit comprises at least one distillation column;
- the sump of at least one of the columns is warmed by means of the refrigerant fluid;
- a stream of natural gas is liquefied by heat exchange with the refrigerant fluid;
- the liquefied natural gas contains helium and the separation unit produces a helium-enriched stream from the liquefied natural gas; and
- the feed fluid for the separation unit is a vapour containing mainly methane, this vapour coming from an existing natural-gas liquefaction train, for the purpose of increasing the production thereof.

Another subject of the invention is a liquefied natural gas separation system integrated into a main liquefaction train, the natural gas having a nitrogen content of greater than 1 mol%, which system comprises at least one nitrogen separation unit, means for sending liquefied natural gas in liquid form into the separation unit, means for withdrawing a stream of liquefied natural gas purified of nitrogen and a stream of nitrogen-enriched vapour from the separation unit, means for recondensing the nitrogen-enriched vapour, the means for recondensing the nitrogen-enriched vapour being a heat exchanger, a cycle of refrigerant fluid, the nitrogen content of which is greater than 80 mol%, the refrigerant fluid having a normal boiling point below that of methane, the refrigeration cycle being different from that of the main natural-gas liquefaction train, and means for sending the refrigerant fluid to the exchanger, characterized in that it includes means for sending the liquefied natural gas purified of nitrogen to a storage tank, where it partially vaporizes to form a boil-off, and means for recondensing the boil-off by means of the refrigerant fluid.

According to other optional aspects of the invention:

- the separation unit comprises at least two distillation columns;
- the sump of at least one of the columns is warmed by means of the refrigerant fluid;
- the system includes means for sending at least one portion of the boil-off to one of the distillation columns;
- the system includes means for liquefying an additional stream of natural gas by heat exchange with the refrigerant fluid;
- the liquefied natural gas contains helium and the separation unit produces a helium-enriched stream from the liquefied natural gas; and
- the boil-off is cooled and/or the additional stream is liquefied in the exchanger.

The invention will be described in greater detail with reference to the figure, which shows schematically an installation according to the invention. To simplify the figure, the overhead condenser 25 of the column 23 is illustrated both as being in the top of the column 23 and forming part of a cooling circuit. It will be understood that these two elements 25 correspond to a single condenser. The same applies to the sump reboiler 27 of the column 23.

In Figure 1, a stream 3 of natural gas is sent to a liquefier 5 in order to form a stream of nitrogen-containing liquefied natural gas 7. This stream 7 is expanded in a turbine 9, so as to form an expanded stream 11, and sent to the reboiler 13 of a distillation column 17. The stream 11 is cooled, warming the sump of the column 17 through the reboiler 13. The stream 11 is then expanded in a valve 15 and sent to the column 17. A nitrogen-depleted liquid 29 collects in the sump of the column 17 and is withdrawn, pressurized in the pump 31 in order to form the stream 35, expanded in a valve, and sent to the storage tank 39 to be stored at about 1.05 - 1.1 bar absolute. The gas stream 19 produced as overhead of the column 17 is compressed in a compressor 21 and sent to the column 23.

A stream 41 is withdrawn as bottoms from the column 23, pumped by the pump 45 after being subcooled in the exchanger 49, mixed with the stream 35 to form the stream 38 which, after expansion in the valve 37, is sent to the storage tank. The gaseous nitrogen 43 produced as overhead of the column 23 is warmed in the exchanger 47, sent to the subcooler 49 and then to an intermediate point on the exchanger 47, in which it is warmed.

The column 17 operates at about 1.25 bar and the column 23 operates at about 4 bar.

The refrigeration for the condenser 25 and the heat for the reboiler 27 are provided by a nitrogen cycle independent of the liquefier 5.

The nitrogen compressed in a compressor 51 is divided into two portions. A portion 57 of the nitrogen is cooled in the exchanger 47 down to an intermediate level, then sent to an expansion turbine 81 so as to produce an expanded stream 83. The rest of the nitrogen is supercharged in at least one supercharger 53, 55, to form a high-pressure stream 59. This stream is partially cooled in the exchanger 47 before being used for reboiling the column 23 by means of the reboiler 27. The gas thus cooled is divided into two, forming two fractions. One fraction 61 is expanded in a turbine 63 and sent to a separator pot. The liquid 69 produced in the separator pot 65 is expanded in a valve 71 and the gas 67 is warmed in the exchanger 47 and sent to the compressor 51, after being mixed with the stream 83 coming from the turbine 81. The other fraction 62 continues to be cooled in the exchanger 47, is expanded in a valve 73 and mixed with the stream 69. The stream formed by the streams 62, 69 is divided into two, in order to form the streams 77, 79. The stream 77 is remixed with the stream 43. The stream 79 is used to cool the overhead condenser 25 of the column 23 and the thus warmed stream 79 is warmed further in the exchanger 47 before being returned to the compressor 51.

Optionally, the boil-off 88 from the storage tank 39 may be compressed in a compressor 86 and sent to an intermediate level of the exchanger 47, where it is cooled down to an intermediate level. The cooled gas is then sent to the column 23, in order to be reliquefied and sent to the storage tank. In the same way, any other methane-enriched vapour capable of being recondensed by the condenser 25 may also be treated.

The exchanger 47 may also serve for liquefying a fraction 85 of the total stream 1 of natural gas, the liquefied gas 85 being expanded in a valve 87 and then sent to the columns, possibly upstream of the turbine 9, for nitrogen separation. Thus, it becomes possible to debottleneck a liquefier 5 that has reached its production limit.

Since the final nitrogen/natural gas separation has been improved, or even taken to completion, the production of any one natural gas liquefaction unit will be substantially increased, especially when the feed gas is rich in nitrogen.

It becomes possible to utilize the nitrogen contained in the natural gas, either in liquid form or in gaseous form, at commercial purity.

It also becomes possible to produce a mixture sufficiently rich in helium to be directly purified in a PSA unit.

CLAIMS

1. Process for separating liquefied natural gas, having a nitrogen content of greater than 1 mol%, in a main liquefaction train comprising at least one nitrogen separation step in which a stream of natural gas (85, 88) is liquefied by heat exchange with a refrigerant fluid, the nitrogen content of which is greater than 80 mol%, the refrigerant fluid having a normal boiling point below that of methane, and being generated by a refrigeration cycle differing from that of the main natural-gas liquefaction train, in which process liquefied natural gas in liquid or "pseudo-liquid" form is sent into a separation unit, a stream (41) of liquefied natural gas purified of nitrogen and a stream of nitrogen-enriched vapour (43) are produced in the separation unit and the nitrogen-enriched vapour is partially recondensed by means of the refrigerant fluid (79), characterized in that the stream (41) of liquefied natural gas purified of nitrogen is sent to a storage tank (39), where it partially vaporizes to form a boil-off (88), and the boil-off is recondensed by means of the refrigerant fluid.

2. Process according to Claim 1, in which the separation unit comprises at least one distillation column (17, 23).

3. Process according to Claim 2, in which the sump of at least one of the columns is warmed by means of the refrigerant fluid.

4. Process according to one of the preceding claims, in which the liquefied natural gas contains helium and the separation unit produces a helium-enriched stream from the liquefied natural gas.

5. Process according to one of the preceding claims, in which the feed fluid for the separation unit is a

vapour containing mainly methane, this vapour coming from an existing natural-gas liquefaction train (5), for the purpose of increasing the production thereof.

6. Liquefied natural gas separation system integrated into a main liquefaction train in which the natural gas is liquefied by heat exchange with a refrigerant fluid, the natural gas having a nitrogen content of greater than 1 mol%, which system comprises at least one nitrogen separation unit, means for sending liquefied natural gas in liquid form into the separation unit, means for withdrawing a stream of liquefied natural gas purified of nitrogen and a stream of nitrogen-enriched vapour from the separation unit, means for recondensing the nitrogen-enriched vapour, the means for recondensing the nitrogen-enriched vapour being a heat exchanger (47), a cycle of the refrigerant fluid, the nitrogen content of which is greater than 80 mol%, the refrigerant fluid having a normal boiling point below that of methane, the refrigeration cycle being different from that of the main natural-gas liquefaction train, and means for sending the refrigerant fluid to the exchanger, characterized in that it includes means for sending the liquefied natural gas purified of nitrogen to a storage tank (39), where it partially vaporizes to form a boil-off (88), and means for recondensing the boil-off by means of the refrigerant fluid.

7. System according to Claim 6, in which the separation unit comprises at least two distillation columns (17, 23).

8. System according to Claim 7, in which the sump of at least one of the columns (23) is warmed by means of the refrigerant fluid.

9. System according to one of Claims 6 to 8, which includes means for sending at least one portion of the boil-off (88) to one of the distillation columns (23).

10. System according to one of Claims 6 to 9, which includes means for liquefying an additional stream (85) of natural gas by heat exchange with the refrigerant fluid.

11. System according to one of Claims 6 to 10, in which the liquefied natural gas contains helium and the separation unit produces a helium-enriched stream from the liquefied natural gas.

12. System according to one of Claims 6 to 11, in which the boil-off is cooled and/or the additional stream is liquefied in the exchanger (47).

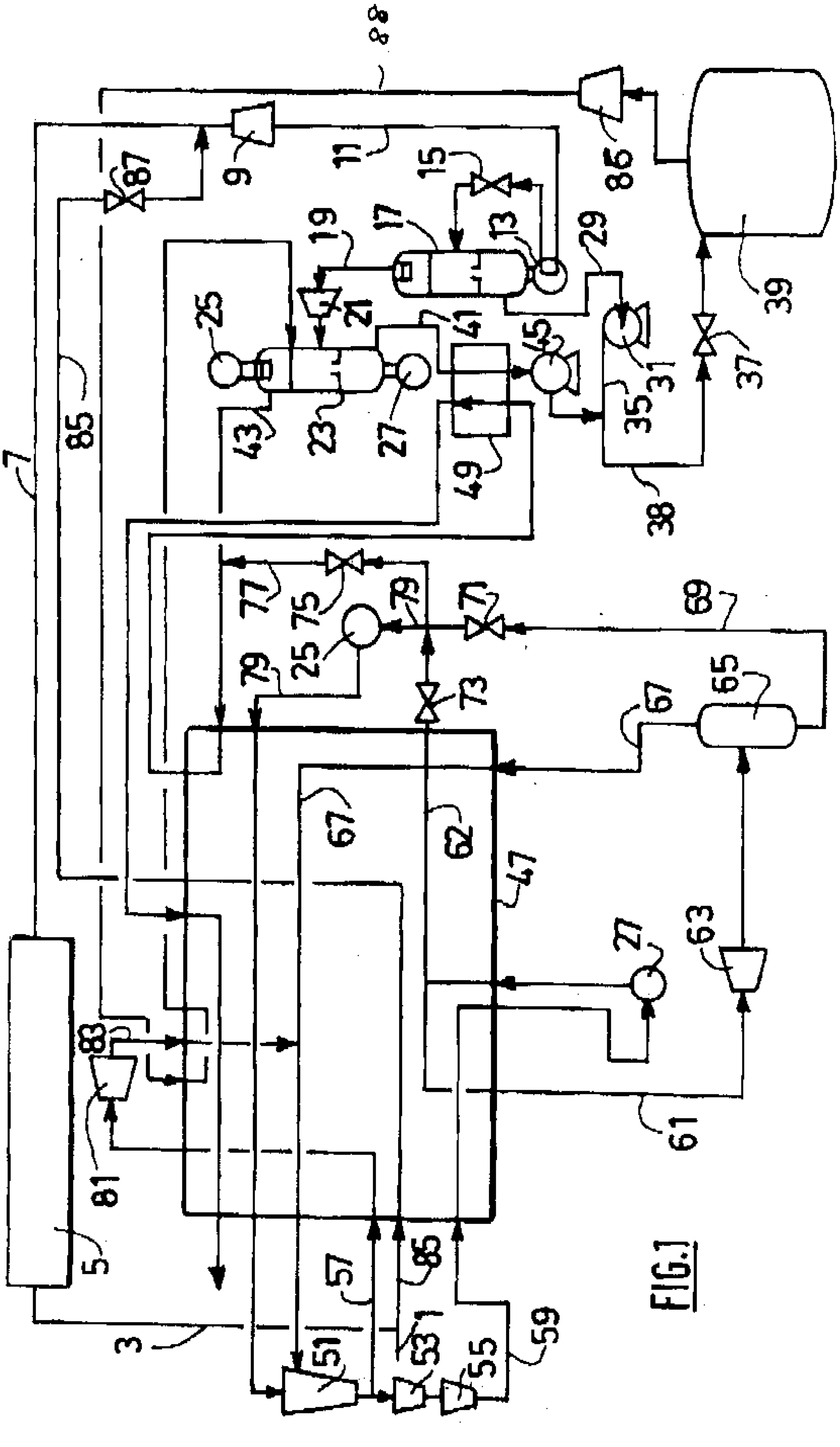

FIG.1