Dubar et al. from BHP Petroleum PTY Ltd (U.S. Pat. No. 6,250,244 B1) proposed an offshore liquefaction apparatus using a dual expander cycle for the gas phase refrigerant which is typically nitrogen. The split of nitrogen refrigerant reasonably distributes the cold energy required in the different temperature ranges resulting in better fitting of the cooling curve. The process is suitable for offshore small scale LNG production from stranded gas.

However, all the above offshore LNG production processes focus on relatively large scale (>1 MTPA) processes and the feed gas is mainly stranded gas from the gas field. However, little attention is paid to the rich associated gas which serves as the feed gas of an offshore LNG plant. The increasing use of offshore oil production apparatus (e.g. FPSO) makes the associated gas widely obtainable. Due to the heavy hydrocarbon containing properties of the associated gas, natural gas liquids (NGL) extraction is necessary before the feed gas enters the main liquefaction heat exchanger to avoid the freezing of heavy components at cryogenic temperatures, thus a need for good heat integration exists to keep both the NGL extraction and the LNG process efficient and economical.

Summary of the Invention

In one aspect, there is provided a process for the offshore liquefaction of a natural gas feed, the process comprising:

(a) contacting the natural gas feed with a biphasic refrigerant at a temperature T1;

(b) contacting the natural gas feed with a first gaseous refrigerant operating in an intermediate temperature closed loop at a temperature T2;

(c) contacting the natural gas feed with a second gaseous refrigerant at a temperature T3; and

(d) expanding the refrigerated natural gas feed using an expansion device to form a flash gas stream and a liquefied natural gas stream;

wherein T1, T2 and T3 satisfy the inequality $T1 \geq T2 \geq T3$, and wherein at least a portion of the first gaseous refrigerant following contact with the natural gas feed is expanded in a substantially isentropic process and used to further cool the natural gas feed; and wherein the flash gas stream is recycled for use as the second gaseous refrigerant.

Also disclosed is~~In accordance with the present invention there is provided~~ a process for the offshore liquefaction of a natural gas feed, the process comprising:

(a) contacting the natural gas feed with a biphasic refrigerant at a temperature T1;

(b) contacting the natural gas feed with a first gaseous refrigerant at a temperature T2;

(c) contacting the natural gas feed with a second gaseous refrigerant at a temperature T3; and

(d) expanding the refrigerated natural gas feed using an expansion device to form a flash gas stream and a liquefied natural gas stream;

wherein T1, T2 and T3 satisfy the inequality T1 ≥T2 ≥ T3, and wherein at least a portion of the first gaseous refrigerant following contact with the natural gas feed is expanded in a substantially isentropic process and used to further cool the natural gas feed; and wherein the flash gas stream is recycled for use as the second gaseous refrigerant.

be at a temperature in the range of from about -50 °C to about -20 °C. The biphasic refrigerant in the low pressure kettle may be at an absolute pressure in the range of from about 1 bar to about 2 bar.

The biphasic refrigerant may contact the natural gas feed in a high pressure kettle. The high pressure kettle may be a feed gas chiller. The high pressure kettle may be a condenser. The high pressure kettle may be a scrub column overhead condenser. The biphasic refrigerant in the high pressure kettle may be at a temperature in the range of from about 0 °C to about 20 °C, for example from about 0 °C to about 15 °C. The biphasic refrigerant in the high pressure kettle may be at an absolute pressure in the range of from about 4 bar to about 6 bar.

In accordance with the present ~~invention~~disclosure, the associated gas feed is processed and produces condensate, and rich LNG which contains methane, ethane, propane, and butane, and needs further LPG extraction at the LNG terminal.

The second non-flammable refrigerant closed loop provides the main cooling for liquefaction of natural gas in the main heat exchanger. The open loop plays an important role in the cooling of the liquefied natural gas at the lowest temperature.

The present ~~invention~~disclosure minimises the NGL extraction on the FPSO (floating production and storage offloading vessel) board, which makes the overall process simpler and safer. Only one fractionation column, i.e. scrub column, is needed to extract the condensate and BTX (i.e. benzene, toluene, and xylene). The scrub column can be located before the feed gas treatment (i.e. sweetening, dehydration, and Hg removal) so that dehydration of the raw condensate which is separated from the three phase separator is not necessary before it is fed into the scrub column.

The process according to the present ~~invention~~disclosure is readily operable through the use of fewer columns not adapted for offshore applications and by using operations which are familiar to crude oil operators.

The present ~~invention~~disclosure also offers greater availability of the process by using a pre-cooling refrigeration system, a single N_2 compressor or two compressors operating at 50% and a flash gas refrigeration stream. Should the expander of the nitrogen

refrigerant cycle fail, limited production of LNG is still possible using the flash gas stream as the sole refrigerant.

The process of the present ~~invention~~disclosure is inherently safe through the use of safe, non-flammable refrigerants and through the minimisation of LPG processing and the minimisation of the total amount of equipment required, in particular the amount of cold equipment required.

In an alternative ~~embodiment~~example in this ~~invention~~present disclosure, the associated gas feed is processed and a separate LPG product stream is recovered in addition to an LNG stream. Three fractionation columns are used for the NGL extraction. The first scrub column produces the lean natural gas under specification, the second deethanizer column removes the redundant ethane which is not required in either lean LNG or LPG and condensate, whilst the third debutanizer column delivers the LPG and condensate products, with the first exported to LPG tanks while the latter is spiked to the crude production facilities for management at the oil FPSO from which the associated gas feed originated.

The present ~~invention~~disclosure is ideally suited for associated gas processing, and has the advantage of robustness, simplicity, highly available design with equivalent thermodynamic performance and inherent safety.

Brief Description of the Drawings

Embodiments of the invention will now be described, by way of example only and without limitation, with reference to the accompanying drawings and examples, in which:

Figure 1 is a process schematic of a liquefaction process according to the present invention;

Figure 2 shows typical cooling curves for the process of the present invention indicating the efficient thermodynamic performance;

Figure 3 shows another embodiment of the process suitable for LPG recovery; and