NITROGEN REMOVAL

ADRIAN FINN, COSTAIN ENERGY & PROCESS, UK, EXPLAINS THE BENEFIT OF A RELIABLE, EFFICIENT NITROGEN REMOVAL SYSTEM FOR LNG FUEL GAS.

Refrigeration compressors and their gas turbine drivers are the most critical parts of any LNG plant to ensure high availability and to maintain LNG production levels. Any plant upset or loss of performance can have serious consequences on plant revenues. Stable operation and avoiding machine trips relies on maintaining consistent fuel gas quality, particularly as refrigeration compressor drivers have a limited range of permissible calorific value and Wobbe number. If the LNG plant feed gas contains an appreciable amount of nitrogen, as is increasingly the case with many gas monetisation developments worldwide, then maintaining a suitable fuel gas composition can be a significant challenge.

LNG plant fuel gas is normally obtained from the flash gas evolved by reducing LNG pressure to atmospheric pressure for storage and from the LNG storage boil-off gas. Control of fuel gas composition and its quality (in terms of meeting burner requirements) is well understood on LNG production plants that use mature liquefaction technology and have experienced operators and feed gas devoid of nitrogen. For new liquefaction technology, detailed technical assessment is needed to ensure the design is robust, even if there is little or no nitrogen in the feed gas. Otherwise there may be operational scenarios that lead to fuel gas compositions being outside allowable limits, with consequent loss of performance or even compressor driver trips. For new liquefaction plant designs and more complex driver arrangements, particularly with floating liquefaction facilities where vessel motion effects can influence plant operation, significant engineering studies are needed to ensure the LNG plant will be operable over the feasible range of process and sea conditions that could be encountered. Most LNG plants have very high overall availability to maximise production revenue. Plant upsets and trips can result in the need to restart the LNG plant, which can require 12 hours or more even from cold conditions.

The need for nitrogen removal

If the plant feed gas contains nitrogen, this must be removed to limit the nitrogen content of the produced LNG to no more than 1 – 2%. Traditionally, the maximum nitrogen content of LNG has been dictated by fuel quality limitations. However, with increasing trade in LNG import, storage and export, significant quantities of LNG can be held in storage, particularly in the US. In this event, it is not unusual for a limit of 1% nitrogen in LNG to be imposed to avoid any possibility of 'auto-stratification' in the LNG storage tanks, which can be a precursor to tank 'rollover'.

For relatively low feed gas nitrogen levels of approximately 1 – 2 mol%, nitrogen removal can be achieved by flashing of the LNG, as nitrogen accumulates in flash gas. For nitrogen levels greater than approximately 2 mol%, a fractionation column is normally required to strip nitrogen from the LNG (Figure 1). This column typically incorporates a reboiler to produce stripping vapour, which ensures the nitrogen level in the LNG is less than 1 mol%. A stripping column is effective in removing nitrogen from the LNG but significant quantities of methane are revaporised and pass with the overhead nitrogen. This column overhead stream is normally compressed and used as fuel gas for generation of power, or to drive compression machinery in the liquefaction plant. Revaporising LNG to produce fuel gas at ambient temperature is clearly inefficient.

Whilst ensuring that the LNG nitrogen content meets specifications, it must also be ensured that the fuel gas nitrogen level is not too high for the gas turbine drivers (whether from flash gas or stripping column overhead gas). Nitrogen accumulates in flash gas and particularly so in boil-off gas. At best, this means a control concern, to ensure the two competing demands of sufficiently low nitrogen level in both LNG and fuel gas can be achieved continuously. Clearly the higher the level of nitrogen in the plant feed gas, the more nitrogen needs to be removed to avoid LNG product contamination. However, the quantity of flash gas (or column overhead gas) can then exceed the fuel gas demands of the plant. To ensure both fuel gas balance and fuel gas quality are maintained, total nitrogen removal from the process is needed with higher feed gas nitrogen levels, and may be justified for any feed gas with a nitrogen level siginificantly higher than 2%.

With the increased use of aero-derivative gas turbines as refrigeration compressor drivers, concerns over the nitrogen content of fuel gas are increased as tolerance to fuel gas inerts is lower than with industrial gas turbines.

Aero-derivatives have higher thermal efficiency than industrial units, and are lighter, more compact and easier to maintain. All of these advantages are important to LNG production and particularly for floating liquefaction, hence the increasing interest in their use. However, they are normally limited to using fuel gas with no more than 15% nitrogen content. High nitrogen in fuel gas is also a concern in conventional industrial gas turbines if low nitrogen oxide emissions are required.

Nitrogen removal options

Nitrogen removal from the LNG plant feed gas itself could be proposed rather than nitrogen rejection from flash gas[1]. However, removing nitrogen from natural gas with minimal nitrogen content is likely to be more expensive than removal in the LNG plant. With upstream removal, the whole natural gas stream needs to be processed, leading to large equipment. It is more economical to allow the nitrogen through the pretreatment and liquefaction

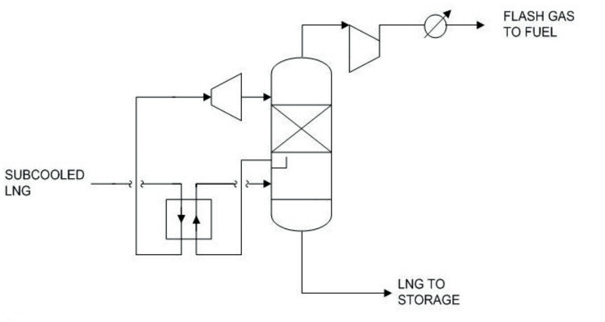

Figure 1. LNG stripping to remove nitrogen.

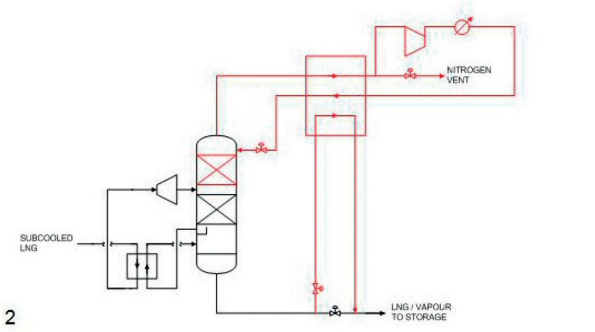

Figure 2. Column reflux by warming LNG product.

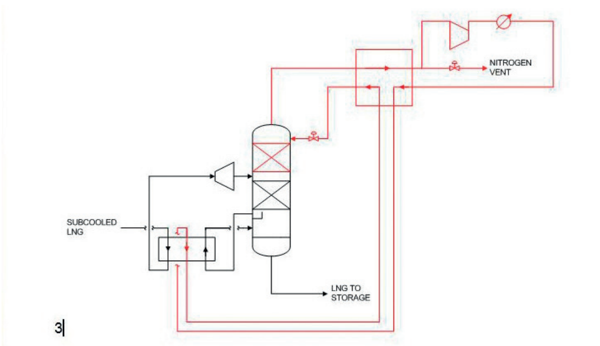

Figure 3. Column reflux by warming LNG before feeding to column.

Table 1. The main process features of the nitrogen removal system
Maintain LNG and fuel gas quality
LNG production maximised
Simple to operate and accomodates varying feed conditions
Reliable
Small footprint
Low capital cost
Conventional gas processing equipment
Easily integrated in new or existing plant

facilities rather than remove it upstream, unless the nitrogen level in the feed gas exceeds several percent, at which stage the plant energy consumption is excessive and LNG production is limited so much that upstream nitrogen removal is preferable[2]. Removing nitrogen as part of the gas liquefaction process has been considered but integration is difficult[3]. It also incurs penalties on both LNG production performance and liquefaction plant simplicity that could compromise plant availability.

Proposed nitrogen removal process

Evaluation of various process schemes for nitrogen removal from LNG, and the concerns from high and/or varying feed gas content led Costain to develop an alternative cryogenic nitrogen removal system that has low capital cost and can be easily integrated into an LNG production plant of any capacity, either at initial plant design or as a retrofit. The process is flexible to changes in feed gas composition and simple in operation. Experience from the process design, engineering and operation of many cryogenic gas processing and liquefaction plants has been brought to bear in ensuring an optimal solution. Engineering and operational experience from large-scale cryogenic nitrogen rejection plants has been important in its development.

Simplicity, efficiency and maximised production

A number of 'end-flash' nitrogen removal systems have been proposed and implemented on operational LNG plants. These produce a nitrogen-rich off gas to be used for fuel or, where the nitrogen level is too high, as feed gas for cryogenic nitrogen rejection downstream. In contrast, the Costain design uses a simple process to efficiently remove nitrogen from the process and to vent it into the air in the same way as most large-scale cryogenic nitrogen rejection facilities do. Rather than sending the stripping column overheads to a separate nitrogen rejection unit, virtually all methane is recovered by adding a rectification section to the stripping column, so the overhead stream is essentially methane free. A nitrogen rich reflux stream is provided by compressing and recycling the nitrogen overhead stream from the stripping column at a pressure of between 20 and 30 bar. This enables condensation against evaporating methane rich streams (normally LNG) that are at close to atmospheric pressure. The heat transfer in the condenser is performed with very small temperature difference between the condensing column overheads and the evaporating LNG for maximum process efficiency and maximum LNG production.

The two product streams consist of a pure nitrogen stream that is suitable for venting and a methane stream stripped of nitrogen to meet LNG quality specifications. Nitrogen is therefore removed and cannot contaminate the fuel gas system or initiate operability problems that could lead to reduced plant availability and difficulties in start-up. Constant quality is achieved, even for varying nitrogen levels in the plant feed gas and flash gas, simply by varying the recycle nitrogen flowrate.

LNG product can be used as the source of methane-rich liquid that is evaporated to condense the nitrogen-rich reflux stream (Figure 2). This option effectively utilises capacity in the LNG flash gas/boil off gas compressor to recompress the evaporated liquid.

Alternatively, evaporation of methane-rich liquid in the reboiler of the fractionation column can be used to condense the nitrogen reflux stream (Figure 3). As the refrigeration provided by reboil would otherwise be used for subcooling the LNG feed, this option effectively utilises capacity in the main LNG refrigeration cycle to condense the nitrogen-rich reflux stream. The process flowscheme in Figure 2 would be expected to be more applicable than that in Figure 3.

Experience with cryogenic nitrogen rejection plants has demonstrated that very low levels of hydrocarbons in vented nitrogen can be achieved economically. The plant performance can be predicted accurately via high quality vapour-liquid equilibrium data, and thermodynamic properties developed specifically for low temperature processing at pressures close to the critical pressure of nitrogen[4].

Further performance advantages

By using a limited number of equipment items, the nitrogen removal system is simple to operate, highly reliable and occupies a small area, all factors that are particularly important for floating LNG production. Although the column could be subject to vessel motion effects, it is not tall and is within normal design limits used for offshore columns, particularly for structured packing. The process can be easily simulated and analysed for off-design cases. Any fluctuation in the level of nitrogen in the LNG stream to be processed is easily catered for automatically. All plant equipment is standard to gas processing and LNG production, with multiple suppliers to ensure competitive pricing. The plant design lends itself to being modularised for supply in one overall module as a fully piped-up, instrumented, wired and insulated unit. The main process features are summarised in Table 1.

This process technology has been patented[5] and is currently in the application phase with the World Intellectual Property Organisation – publication number WO2011/064605. **LNG**

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