ETHANE RECOVERY PROCESSES EVOLVE TO MEET MARKET NEEDS

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1 Introduction/Background

World ethylene consumption is growing quickly and in gas producing regions such as the Middle East, North Africa and Venezuela, there has been a threefold increase in ethane based production capacity in the last 10 years.

To be competitive with liquid based crackers, ethane must be extracted at the lowest marginal cost that means

- Large capacities to offset the infrastructure costs and benefit from economies of scale
- Lowest possible energy consumption
- Minimise losses of valuable propane during shutdown of the steam cracker when ethane must be rejected to the demethaniser overhead.
- Build synergies with LNG plants that provide a source of large quantities of ethane through large throughputs of natural gas and increasingly lean LNG specifications

This paper will describe new processes that are being applied in different gas and LNG projects to meet the above challenges

- Extraction of C_2+ NGL from the pre-treated natural gas feed to meet reduced LNG Wobbe index specifications in two contexts:
  - Existing plant: how to incorporate a C_2 recovery unit in an existing LNG scheme equipped with a scrub column, and enlarge the LNG market for the operator.
  - A new plant designed for the new LNG specifications
- Production of a C_3+ NGL and a separate ethane stream to provide LNG/gas plant flexibility with respect to ethane demand. The cooled and expanded natural gas is introduced into a de-methanizer. The C_2^+ bottom stream is sent to a de-ethanizer. Flexibility is achieved through the fact that the ethane product is recovered at any required rate at an intermediate level while the top product is used as a secondary reflux to the top of the demethaniser.

2 Importance of modern ethane recovery processes

World LNG market is divided in three main importing areas:

- Asia , which is the major LNG importer
- Europe
- US

However, natural gas specification such as High Heating Value (HHV) and gas interchangeability index (Wobbe index), can be widely different depending on the region.

	HHV MJ/Sm^3	Wobbe Index kWh/m^3
Japan	39.8 – 43.2	
Korea	40.0 – 43.4	
USA	35.8 – 40.8	
Europe	-	13.6 -15.81

Wobbe index, which is more stringent than HHV, is defined as followed:

$$Wobbe\,Index = \frac{HHV}{\sqrt{Gas\,Specific\,Gravity}}$$

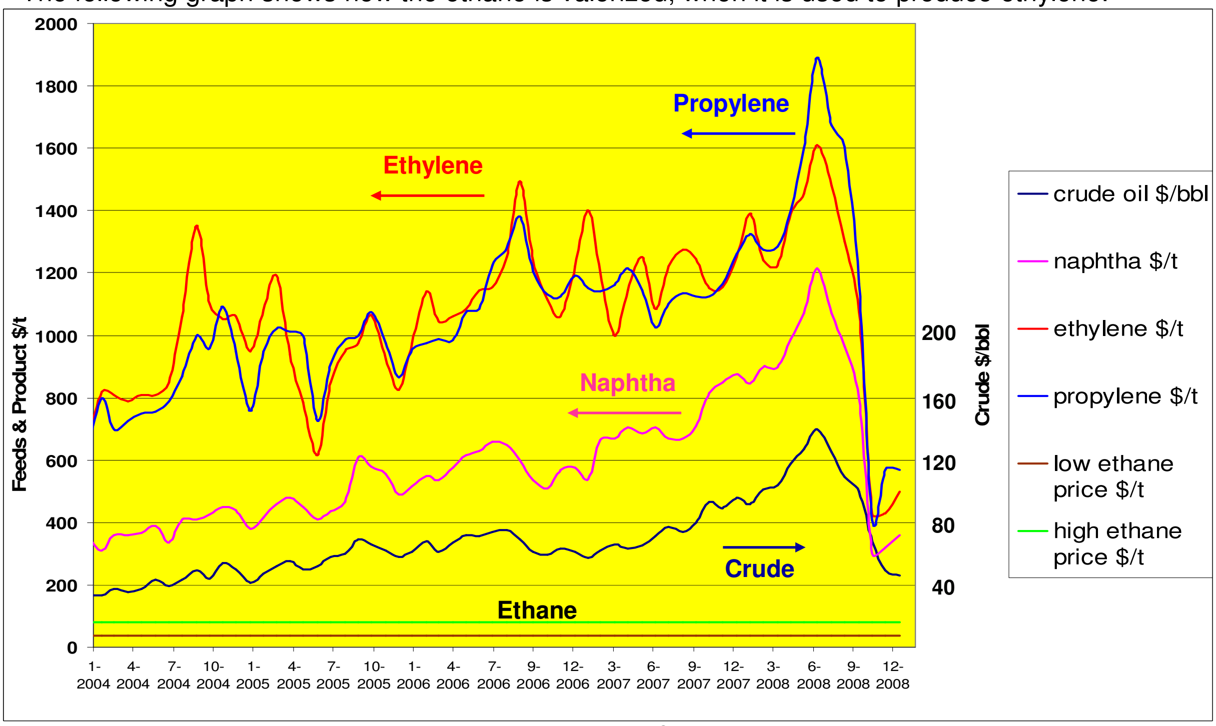
Hence, when an LNG plant has been designed for the Asian market, as it was the case for most of the plants for the last twenty years, and produces a rich liquefied natural gas, it is essential to reduce HHV to export this LNG to US market.

Methods to produce leaner LNG could consist in:

- Increasing the scrub column condenser duty: The consequence is to increase the propane and Mixed Refrigerant (MR) cycle, or to decrease the LNG production, if the limit of the refrigerant cycle and Main Cryogenic Heat Exchanger (MCHE) is reached.
- Adding a NGL recovery unit before liquefaction. Moreover, NGL recovery unit allows extracting, at a marginal cost, ethane, propane and butane from natural gas.

If the LNG plant is located close to a steam cracker, the ethane can be then produced at petrochemical grade which can be used as feedstock for the steam cracking unit.

The following graph shows how the ethane is valorized, when it is used to produce ethylene:



Similarly, if we compare LPG price, with natural gas/LNG price, there is an opportunity to increase the producer revenue, by extracting it from the natural gas/LNG.
Indeed, the following order of price can be given:

- Natural gas price is around 200 $/t
- LPG price is around 400 $/t
- Condensate price is around 600 $/t

This paper will present how processes have evolved, to face the following challenges:

- How to valorize ethane and LPG contained in the gas. With regards to ethylene price, deep C_2 recovery processes combined with steam cracker is a way to valorize the ethane contained in gas or LNG.
- How to vary the quantity of ethane recovered in a gas plant without affecting propane recovery.
- How to incorporate a C_2 recovery unit in a LNG plant and enlarge the LNG market for the operator. The ethane recovery is only adjusted to reach the HHV imposed by the LNG market. The ethane is mixed with fuel gas if possible

3 C2 extraction unit combined with a steam cracker (LNG and Gas plant)

When Company decides to valorise the ethane by extracting ethane from natural gas/LNG and send it to a steam cracker, the NGL recovery unit design has to incorporate the following constrains:

- Maximum ethane extraction, when the steam cracker is producing at full capacity.
- Minimum ethane extraction (around 2%) when the steam cracker is shut down, which consists in maintaining maximum LNG production.
- 99% LPG recovery, whatever the mode.

Compare to a scrub column, modern NGL recovery unit with expander, allows reaching 99% recovery in LPG, and an increase non-negligible of the Company revenue. This arrangement becomes very attractive when the gas is rich in LPG.
One of the most efficient deep C_2 recovery units (minimised power consumption) is the Multiple Reflux Ethane Recovery (CRYOMAX® MRE Process):

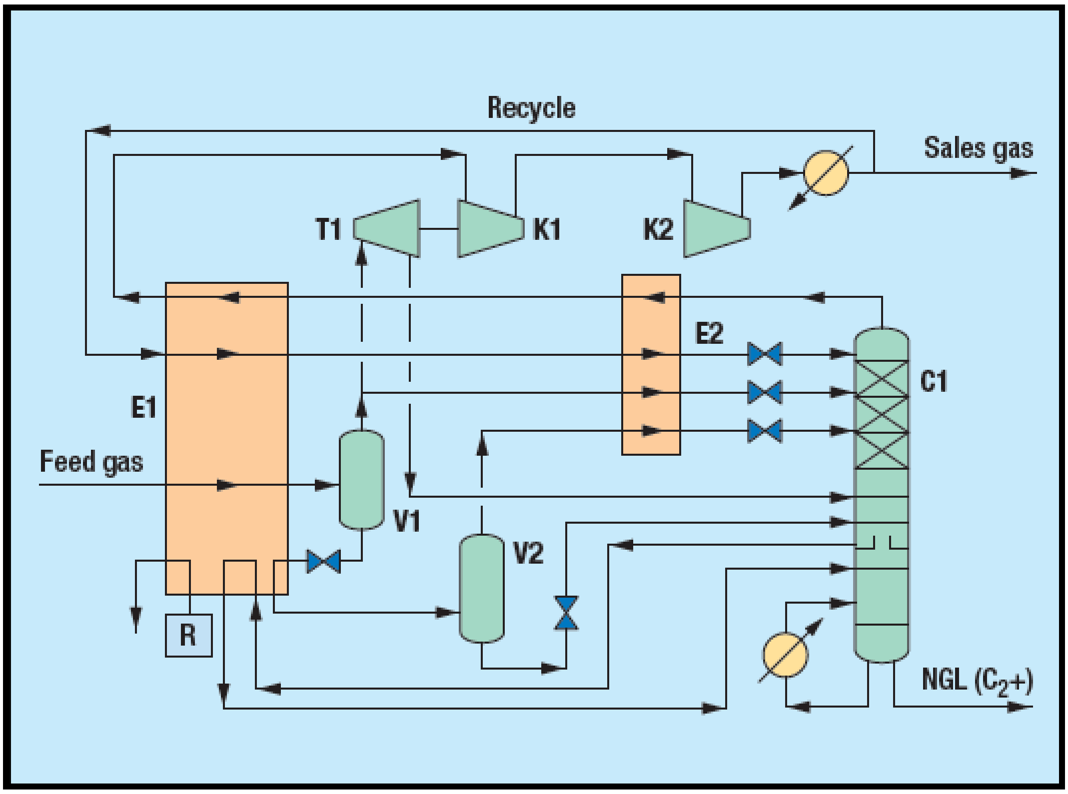


Figure 1 : Multiple Reflux Ethane recovery scheme

However, this scheme, as most of C_2 recovery scheme, doesn't allow flexibility in ethane recovery.
In order to improve the flexibility and operability of the LNG plant combined with a steam cracker, the operators must be able to select any C_2 recovery, and to match with the steam cracker production, without reducing the natural gas/LNG production.

The following chapter shows, how these schemes shall be adapted to improve the flexibility, depending on the localisation in the overall scheme (new plant or debottlenecking).

a. New plant

The following chapters show how to reach all this constrains with a continuous scheme (the operator is not obliged to switch the mode between C_2 recovery, and C_2 rejection), by describing:

- A deep C_3 recovery scheme, and the requirement to reach 99%
- A deep C_2 recovery scheme and the requirement to reach 98%
- How to combine both scheme and meet all the above requirement

C_3 recovery scheme (99% recovery)

The following figure shows typical C_3 recovery scheme for very high propane recovery rate (99% recovery):

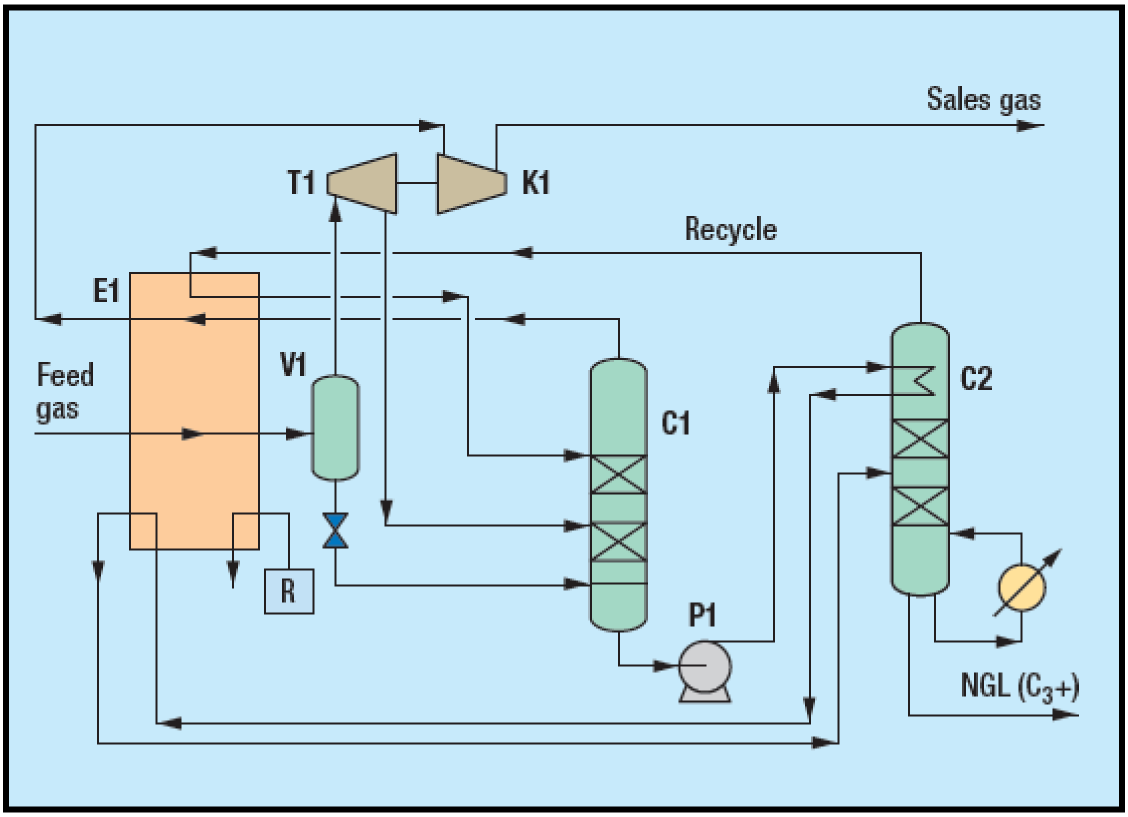


Figure 2 : Propane recovery scheme

The process comprises the following steps:

- The feed gas generally available at high pressure is cooled down in the main cold box, against the Sales gas from the recovery Tower.
- The feed gas is then expanded through the turbo-expander, is cooled down to -80°C and is sent to the recovery tower. The gas stream from the expander still contains some C_3, and 99% recovery cannot be reached, without an additional reflux.
- The liquid (NGL) is sent to the deethaniser. This liquid contains around 15% of methane. Indeed, the methane cannot be stripped in the bottom of the Recovery tower (via a reboiler), without degrading considerably the C_3 recovery due to propane which will be vaporized in the reboiler.
- The ethane is removed from the C_3+ product, via the deethaniser reboiler. The deethaniser condenser is adjusted to minimize propane entrainment with the outlet gas from the deethaniser. This gas contains mainly methane, ethane and some propane.
- This gas is cooled down in the main cold box with the sales gas. The liquid is used as reflux in the recovery tower, and absorbs all the C_3 in the vapour from the expander. 99% propane recovery is then achieved.

In this example, 99% C_3 recovery is obtained with a lean truly sub cooled reflux.

C_2 recovery scheme (up to 98% recovery)

The following figure shows typical C_2 recovery scheme:

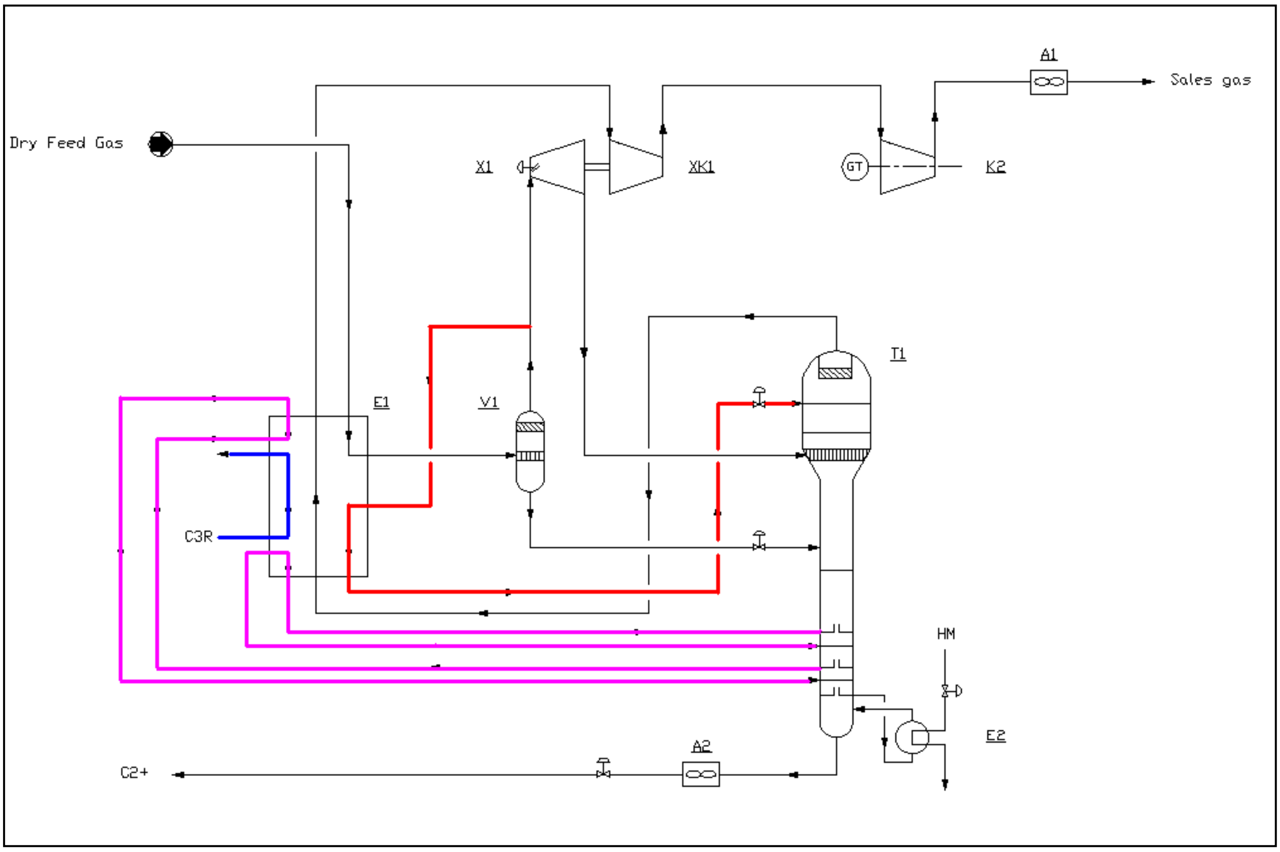


Figure 3: Single Reflux Ethane recovery scheme

Main differences between C_2 recovery scheme and C_3 recovery scheme are:

- Most of the time both column are stacked (Recovery tower and demethaniser).
- The deethaniser is replaced by a demethaniser: the C1 specification in ethane product is adjusted via the demethaniser reboiler.
- Deethaniser is then part of the fractionation unit.
- Additional reflux is done by a by-pass of the turbo-expander (around 20%). The feed gas by-passed is cooled down with the sale gas in the main cold box (under pressure), and flash through the control valve (same differential pressure than the expander). The reflux allows absorbing the ethane contained in the vapour from the expander and the reboiler.
- Side boilers are added for thermal integration.

Presented scheme allows 80 to 90% C2 recovery. An additional reflux from the sales gas export compressor considered as a lean reflux, allows reaching higher recovery rate generally at around 98 % ethane recovery. This represents an enhancement of the original C_2 recovery scheme presented in Figure 3:

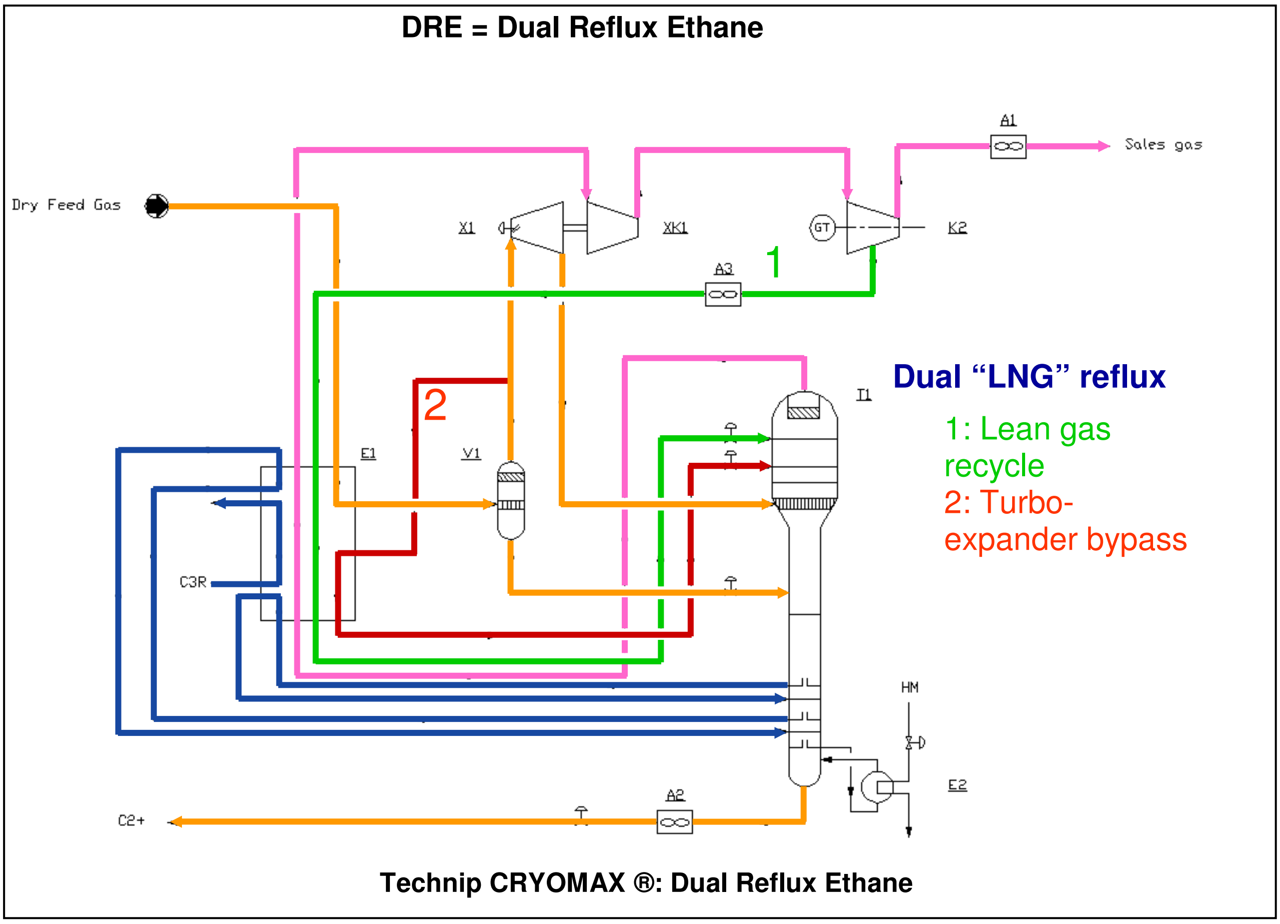


Figure 4: Dual Reflux ethane recovery scheme

The main characteristics of these schemes are:

- Methane is stripped via the demethaniser reboiler.
- C_2 Recovery is reached with an lean additional reflux which allows absorbing remaining ethane vapour in the higher part of the Recovery Tower
- According to the C_2 recovery level required, one or two reflux is necessary (turbo by-pass and Sales gas recycle)

Flexible NGL Recovery scheme

The following scheme is a flexible NGL recovery scheme which combines ethane and propane recovery schemes. This kind of scheme allows reaching an ethane recovery rate from 2% to 98% depending on the design in a smooth and bumpless manner:

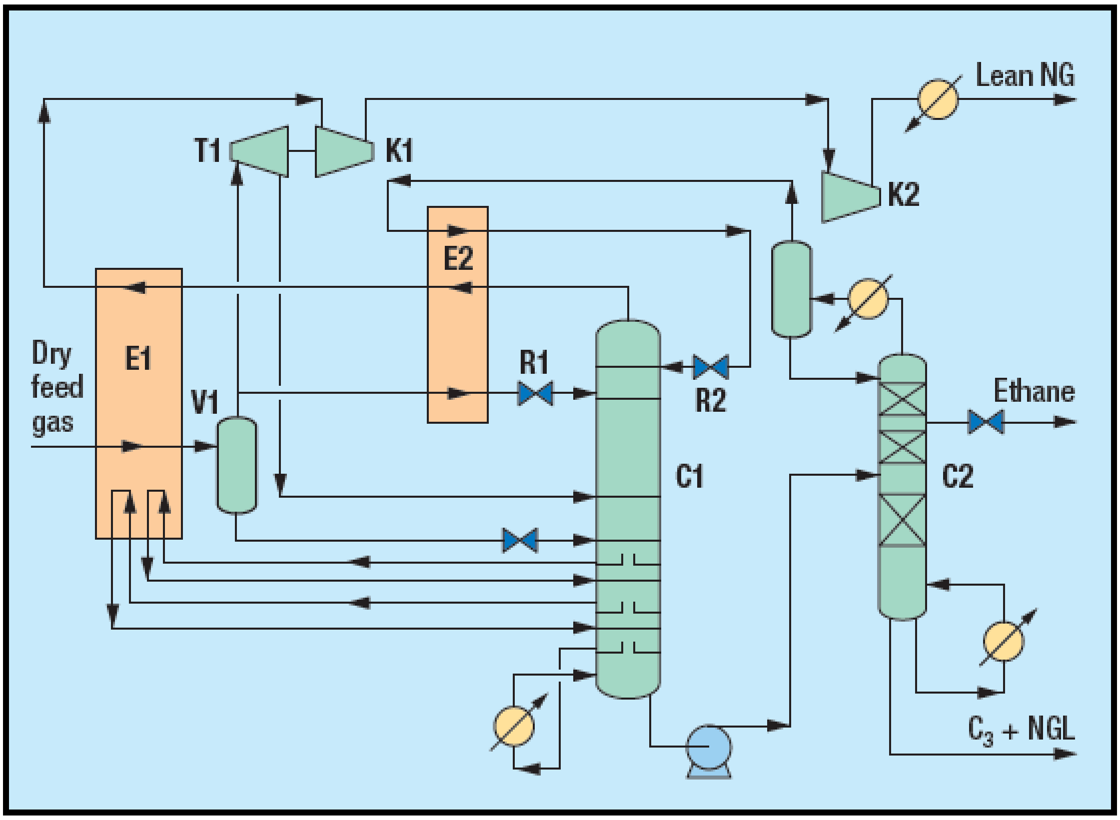


Figure 5: Flexible dual reflux ethane recovery scheme

The main differences with a C_2 recovery scheme are described as follows:

- As for C_3 recovery, the vapour of the top of the deethaniser is cooled down with a part of the sale gas and used as an additional reflux.
- This additional reflux allows full C_3 recovery, whatever the C_2 recovery. In C_2 rejection (or C_3 recovery), the C_2 production is stopped, all the ethane is contained in the vapour outlet of the deethaniser. The ethane, which is not necessary for the reflux, is mixed directly in the sale gas.
- We can extract any C_2 flow from 2% C_2 recovery (contains in the C_3+ flow) to maximum C_2 recovery (depends on the design), by adjusting the ethane product flow.

Maximum flexibility is obtained.

Moreover, this kind of process is very environmental friendly. Indeed, in case of a scheme described in previous figures , with ethane feeding a steam cracker, when the steam cracker is stopped, a part of ethane shall be sent to fuel respecting Gas Turbine vendor limitations, the remaining part shall be sent to flare for a limited time. A flexible NGL recovery scheme adaptable to steam cracker operation is thus environmental friendly and allows operator maximum profit whatever the configuration case.

b. Debottlenecking of LNG plant for C_2 extraction

In this type of process, rich LNG is produced, since, most of the LPG's are re-injected in the LNG.

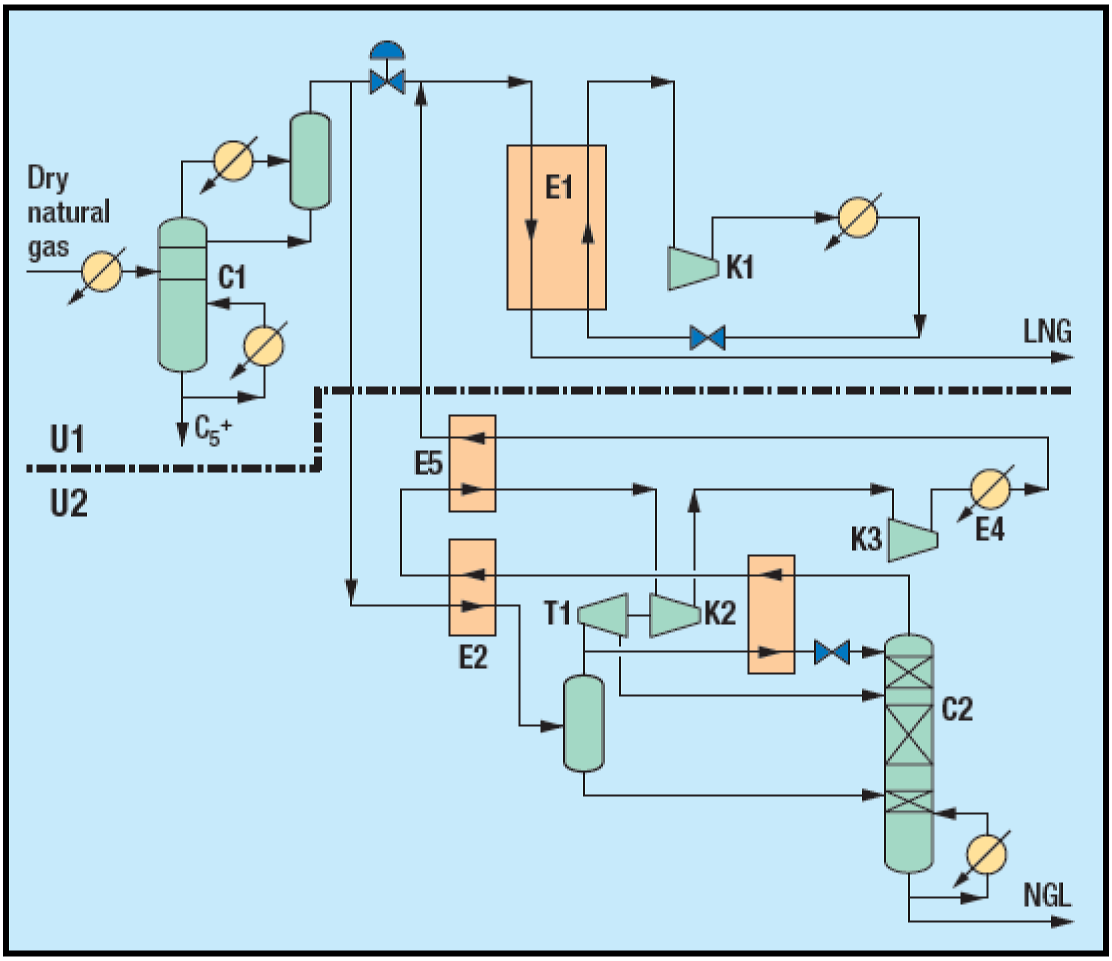


Figure 6 : LNG Process with flexible NGL recovery unit integration

In order to reduce HHV of LNG and to extract ethane at the lowest marginal cost, a NGL recovery Unit can be added in the existing plant at the overhead of the scrub column. Lean gas is then produced before being routed to the mixed refrigerant main exchanger. LPG produced can be separated in a new fractionation facility. Ethane produced is routed to Steam cracking facilities.
This kind of arrangement is very interesting since it allows in the same time to enlarge LNG market and to produce ethane product at a least cost with a minimal investment.

As the NGL recovery unit is dedicated to the Steam cracker, flexibility is done by the turndown of the NGL recovery unit. When the steam cracker is out of service, the LNG plant is operating as per its original design.

4 C_2 extraction for LNG HHV adjustment

Most LNG plants extract some ethane for refrigerant make-up. The quantity can be increased slightly to allow minor adjustment of LNG HHV using simple scrub column schemes.
To reach higher rates of propane recovery (99%), cryogenic expansion process shall be used.

The NGL recovery is implemented upstream of the liquefaction unit, the HHV of the LNG is adjusted by the ethane extraction in the NGL recovery. In this case, scrub column is not required anymore and there is no LPG's re-injection in the liquefied natural gas. The surplus of ethane due to HHV specification is burnt as fuel gas.
NGL recovery unit has for aim to recover most of the propane of feed; in general propane recovery is over 99%, and all butanes and heavier hydrocarbons are also recovered:

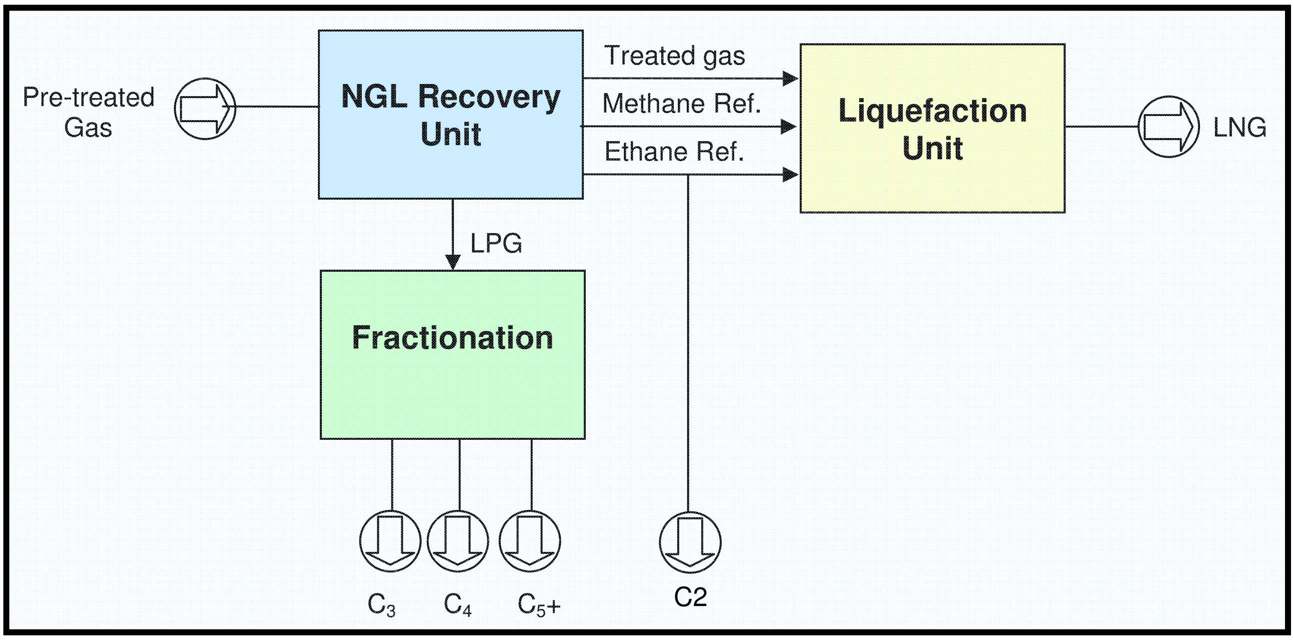
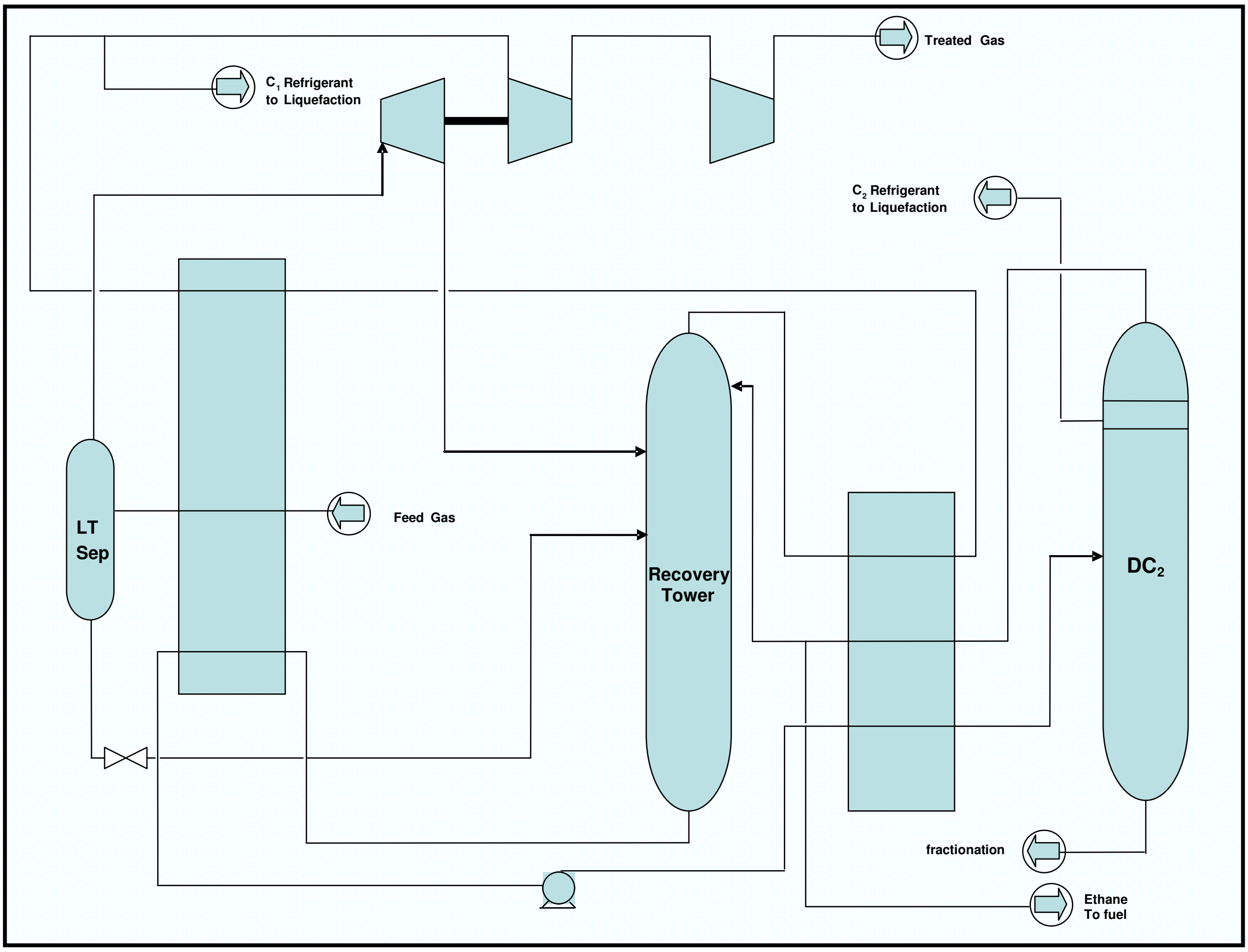


Figure 7: Liquefaction steps

For this purpose, a deep C_2 recovery is not required. Typical NGL recovery unit can be schematized as follows (only one reflux from deethaniser overhead):



CRYOMAX Process

Figure 8: Front end NGL recovery process in an LNG plant

Deethanizer is operating at a pressure higher of around 2-3 bar more than the recovery tower, which allows a major part of the overhead of the deethanizer being used as reflux to the Recovery Tower in order to reach a 99% propane recovery.
At this point, treated natural gas can be pre-cooled and liquefied in the Main Cryogenic Heat Exchanger of the liquefaction unit.

One can notice that the NGL recovery unit and the Liquefaction Unit are much linked since NGL recovery provides ethane refrigerant make-up to Mixed Refrigerant.

This type of arrangement doesn't require a high flexibility in C2 recovery, as the adjustment is done only for HHV LNG specification. Conventional C2 recovery system can be used, as CRYOMAX SRE, DRE or MRE.

5 Conclusions

The market for LNG, natural gas and ethane for ethylene are evolving and are interlinked. This paper has shown how modern processes have evolved to meet changing market requirements while retaining goods efficiency and operability.

References

[1] David Coyle, Felix F. de la Vega, Charles Durr, “Natural Gas Specification Challenges”

[2] Tariq Shurkri, “LNG Technology selection”, Hydrocarbon Engineering February 2004

[3] D. Chrétien, “Process for the adjustments of the HHV in the LNG plants”, 23rd World Gas Conference, 2006

[4] Robert Van Rede, “Markets in harmony”

[5] Paradowski et al., Pat. US 4,689,063, “Process of fractionating gas feeds and apparatus for carrying out the said process”, 1987

[6] Paradowski et al., Pat. US 4,690,702, “Method and apparatus for cryogenic fractionation of a gaseous feed”, 1987

[7] Paradowski et al., Pat. US 5,114,450, “Method of recovering liquid hydrocarbons in a gaseous charge and plant for carrying out the method”, 1992

[8] Paradowski, Pat. US 7,237,407, “Process and plant for the simultaneous production of an liquefiable natural gas and a cut of natural gas liquids”, 2007

[9] Paradowski, Pat. US 7,458,232, “Method and installation for producing treated natural gas, a C3+ hydrocarbon cut and an ethane rich stream”, 2008

[10] Paradowski, Pat. US 6,578,379, “Process and installation for separation of a gas mixture containing methane by distillation”, 2003