New LNG Process Scheme

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ABSTRACT

A new LNG cycle has been developed for base load liquefaction facilities. This new design offers a different technical and economical solution comparing in efficiency with the classical technologies. The new LNG scheme could offer attractive business opportunities to oil and gas companies that are trying to find paths to monetize gas sources more effectively; particularly for remote or offshore locations where smaller scale LNG facilities might be applicable. This design offers also an alternative route to classic LNG projects, as well as alternative fuel sources.

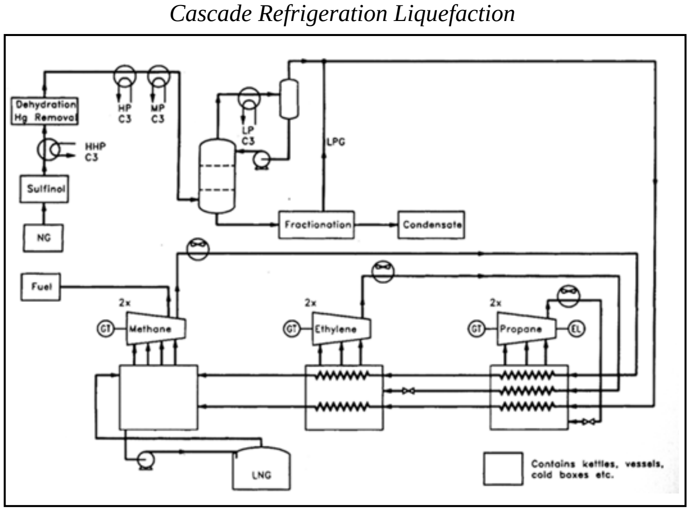
Conceived to offer simplicity and access to industry standard equipment, this design is a hybrid result of combining a standard refrigeration system and turboexpander technology.

BACKGROUND

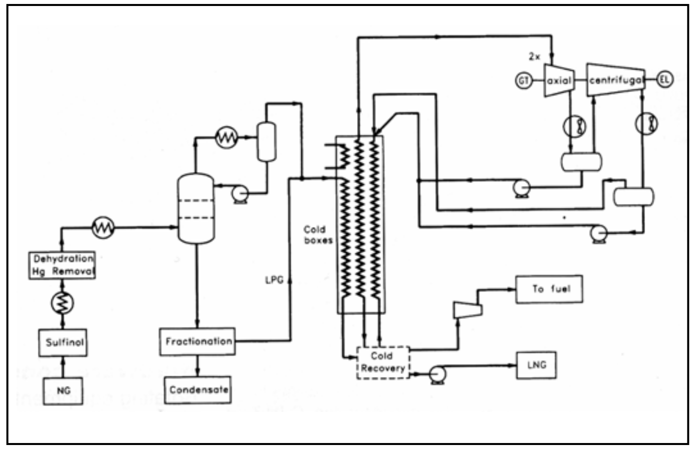
In the early 90's several opportunities to produce isolated, earlier non-commercial reservoirs surfaced among several international producers. Also, an interest to find cleaner and more efficient fuels indicated that LNG could be a potential candidate to fulfill this requirement. On this particular area, several programs sponsored by the U.S. government and major cities' authorities indicated an interest in LNG as a transportation fuel. The career for introducing processes to produce hydrocarbon liquids attractively has propelled several investment initiatives and economic studies to compare economies between methanol, gas-to-liquids processes and LNG production in non-conventional sites.

The world class base-load LNG facilities that have been built since the early 60's have used energy intensive liquefaction cycles that included different types of refrigeration systems (cascade, mixed refrigerants) using propane, ethane and methane as refrigerants, combined with proprietary technology in heat transfer equipment. The following are some of the most known cycles used in base-load facilities:

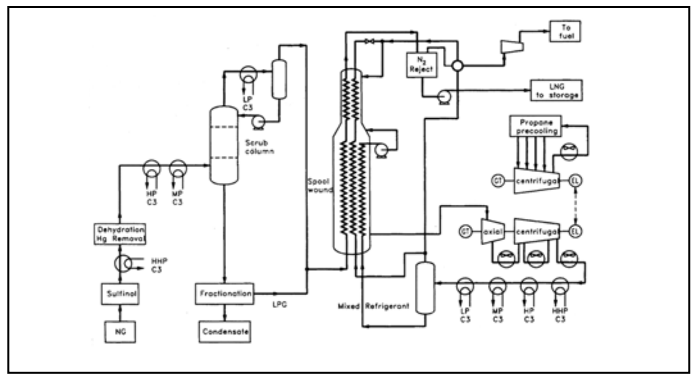
Cascade Refrigeration Liquefaction



Mixed Refrigerants Liquefaction

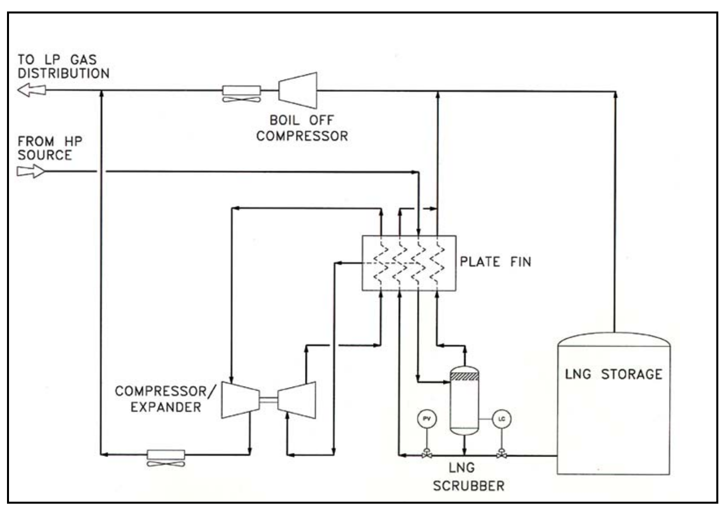


Propane / Mixed Refrigerants Liquefaction



The peak shaving gas facilities have used turboexpander cycles using the refrigeration available by expanding the gas from a high-pressure source, a pipeline, to a low-pressure distribution system. Most plants in the U.S. are used primarily for peak-shaving application. A typical liquefaction cycle is shown.

Typical LNG Peak Shaving Scheme



It is very well known that on a major base load LNG facility the cost of the storage and transportation infrastructure is the major contributor to the cost of the facility. This argument has led to the idea that developing new liquefaction technology does not have merit

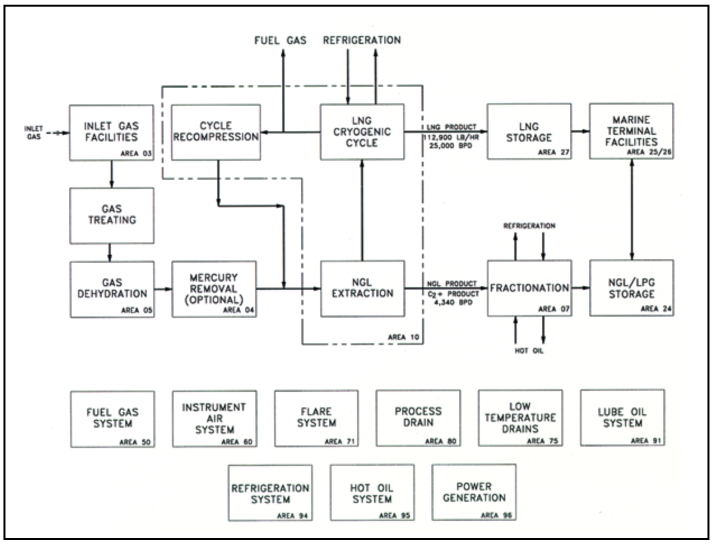
because it would not have a sensible impact in the overall project cost. The technology introduced here offers an opportunity to develop a new capital cost metric.
The LNG process cycle described here uses all proven industry standard equipment and requires minimum space, a detail which makes it appropriate for non conventional sites like offshore platforms or floating production facilities (FPSO's).

PROCESS FUNDAMENTALS

A typical LNG facility comprises the following operations:

- Inlet Gas Facilities
- Gas Treatment
- Gas Dehydration
- Gas Liquefaction and Heavy Liquids Removal
- Product Storage
- Support Systems

Typical LNG Facility



As front end treatments to remove contaminants (*see table 1)* have been widely explained in other publications we will lightly mention them without further details.

Table 1

Contaminants
• Carbon Dioxide
• Hydrogen Sulfide
• Water
• Carbon Disulfide
• Mercaptans
• Mercury
• Heavy Hydrocarbons
• Lube oil

For the purpose of this work, a reservoir with an economic reserve of 400 bcf of gas has been selected as basis (*see table 2*) with a project life of 15 years. Based on these parameters, a plant size of 75 MMscfd is selected to develop the design. This concept will apply for larger or smaller scale production or offshore applications.

Table 2

Basis of Design	
• Economic Gas Reserve	400 bscf
• Project Life	15 years
• Plant Nominal Size	75 MMscfd
Gas Composition	**Mol %**
Carbon Dioxide	0.53
Nitrogen	0.51
Methane	95.15
Ethane	3.05
Propane	0.61
Butanes	0.12
Pentanes	+0.03
• Feed Pressure	985 psig
• Temperature	100 F
• Cooling Media	Air
• Product Specifications	
Nitrogen	0.4 - 1 %
Methane	90 - 97 %
Ethane +	Contract Dependent

The liquefaction of methane requires a cooling stage to remove sensible heat, followed by a condensation step at –260 ^{o}F. Theoretically, this represents 0.151 HP/lb or 267 HP/MMscfd at 550 psia, which is a common pressure used in most of the base-load LNG cycles. At this pressure, most of the gas mixtures to be liquefied are below the critical pressure and they experience multicomponent condensation.. If this process is conducted at 900 psia, the theoretical energy requirement is 0.147 HP/lb or 258.5 HP/MMscfd.

Efficient classical processes require that the sensible heat be extracted at successive steps as the gas is cooled to minimize the energy requirements. To achieve such a low temperature level cascaded or mixed refrigerants refrigeration systems should be used. These are expensive systems.

This new LNG cycle process is a hybrid that combines standard propane mechanical refrigeration with a turboexpander cycle that removes heat from the process while providing additional compression work. The refrigeration system provides refrigeration at a relatively high temperature level, while the turboexpander cycle does it at the low levels. The cold vapors that are used as refrigeration media are recycled to the front end of the unit where they are compressed and returned to the process. This recycle helps to "lean" the inlet gas stream as well as acting as an internal "low level refrigerant stream". The ratio of recycle to the inlet is about 3:1.

PROCESS DESCRIPTION

Inlet Gas Facilities & Inlet Compression

Separation of liquids from the gas stream on the front end of the plant is essential to prevent foaming problems in the sweetening and dehydration sections.

Some applications will require additional inlet compression to boost inlet gas to plant pressure (normally at 900 - 950 psig)

Gas Treating

CO_2 is removed to make the gas suitable for processing and marketing. The main methods of removal are:

- Chemical Absorption Solvents
- Physical Absorption Solvents

Gas Dehydration

H_2O is removed to prevent freezing in the low temperature sections of the LNG plant. (<0.1 ppm). Cyclic operations of molecular sieves are the common practice for this operation.

Mercury Removal

If present, mercury must be removed from the process because it causes corrosion in the aluminum plate-fins. The corrosion mechanism is:

Al + Hg --------> AlHg (amalgam)
2 AlHg + 6 H_2O --------> 2 $Al(OH)_3$ + 3H_2 + 2 Hg (secondary reaction)

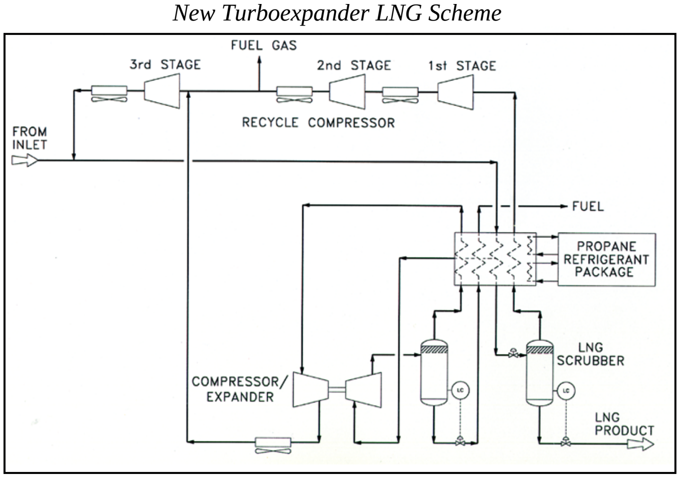
Mercury can be removed by several means:

- Adsorption on sulfur impregnated activated carbon
- Adsorption on activated carbon
- Adsorption on selective molecular sieves

Mercury level should be < 0.1 micrograms/m3.

Gas Liquefaction

New Turboexpander LNG Scheme



After being conditioned, the gas stream enters the gas liquefaction stage. Here, the gas enters the main gas exchanger and is cooled down to –40 deg. F. The gas stream is then split with one stream going to the turboexpander section, and the other continuing through the exchanger.

The side stream enters the turboexpander where it is expanded to 200 psig, decreasing the temperature to –171 deg. F. The discharge of the expander is a two-phase stream that is sent to a separation stage or, depending on the composition and product specifications, to a special demethanizer column where the ethane and heavier components are separated.

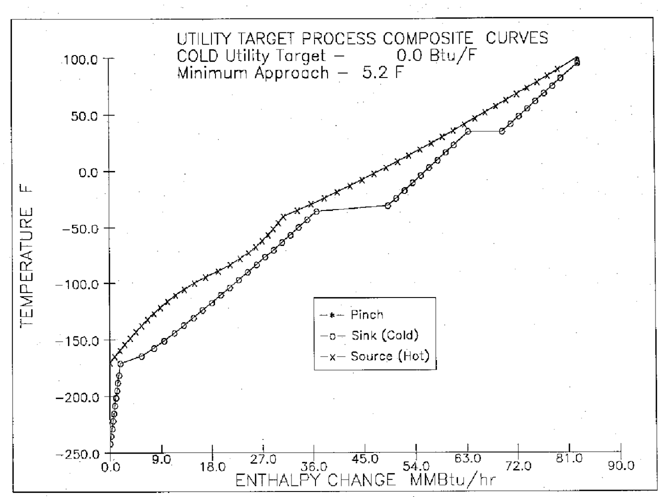
The cold gas and liquid streams from the separation stage are directed to the gas exchanger, where they are warmed up to ambient temperature and become part of the recycle stream. These streams are an important contributor to the energy balance of the unit. Depending on the amount of NGLs in the gas, the liquid stream could leave the gas exchanger as a pressurized liquid or fuel gas.

The warm gas from the gas exchanger enters the booster compressor, where by virtue of the work extracted from the expansion process, the pressure is raised to 280 psig. After being cooled to ambient temperature, this stream is then mixed with the main recycle stream.

The high-pressure gas stream that continued through the cooling process in the gas exchanger reaches a temperature of –170 deg. F before it is expanded to 15 psig. A temperature of –250 deg. F is achieved after this expansion with 67% of the mass flow liquefied. The remaining 33% off-gas vapor is sent back to the gas exchanger, where after providing refrigeration to the process it reaches a temperature of 95 deg. F. The main recycle stream is then compressed until it reaches the booster compressor discharge pressure, at which point is combined with that stream before mixing and continuing to the final compression stage at the front end of the plant. At a medium pressure level, a fuel gas stream is taken for turbines or engine drivers. Depending on the feed pressure conditions, an inlet compression stage will be required, but, as it will be shown later, this is a minor consumer. *(See table 4)*

A further refinement of this scheme includes the use of staged expanders to further reduce the energy consumption. The flash stage would operate at 45 psig, to be then expanded to 15psig. The result of this is a much colder final stage. The vapors from the second flash are sent to the main exchanger.

The liquid produced is sent to a final subcooling stage before is delivered to the storage tank at almost near atmospheric pressure. Vapors from the storage tank are captured and cross-exchanged with the liquid LNG before the expansion and sent to a boil-off compressor that will recover the vapors and send them to the recycle stream.



The refrigeration system consists of a two-stage propane cycle. The design includes the propane vaporization steps included in the main gas plate fin exchanger, using a thermosyphon arrangement. The refrigeration temperature levels are set strategically to minimize the energy requirements. In the case presented here, the refrigeration is set at –35 deg. F for the low temperature level, and 35 deg. F for the high temperature level.

PROCESS EFFICIENCY - COMPARISON WITH OTHER PROCESSES

In order to evaluate the process described, we have utilized a simple energy index to measure the performance—horsepower per unit of mass liquefied. Table 3 shows a comparison of the process described in this work compared with the other industry schemes. It is interesting to mention that this comparison is consistent with other papers presented on the subject. Below is also a table of utilities for the LNG facility with power generation. *(See table 5)*

Table 3

Performance Index Relative HP/lb LNG	
• Traditional Process	.87 – 1.64
• Turnoexpander Cycle	1.0

Table 4

Performance (Compression eff.: 80%)	
• Inlet Compressor 1,130 BHP	• No Inlet Compressor 0 BHP
• Recycle Compressor 22,570 BHP	• Recycle Compressor 22,750 BHP
• Refrigeration 3,745 BHP	• Refrigeration 3,745 BHP
Total 27,445 BHP 0.244 HP / lb 365 HP/MMscfd	Total 26,315 BHP 0.234 HP / lb 350 HP / MMscfd

Table 5

Utilities	
• Electric Power	
Recycle Compr.	77%
Refrig. Compr.	13 %
Others	10 %
• Cooling Duty	
Recycle Compr.	60 %
Booster Aftercooler	11 %
Refrig. Condenser	29 %
• Fuel Gas Usage	
Power Generation	~ 6 %

USE OF PROVEN INDUSTRY STANDARD EQUIPMENT

The turboexpander technology has reached maturity and offers an opportunity to improve an LNG technology technically and economically. When the first LNG plants were designed, the turboexpander manufacturers did not have the reliability and knowledge of the equipment as is known today. Also the thermodynamics of dense phase regions were not known well as to decide to use this process path. Today, we have gone through a multitude of different applications that allows us to say that this technology is a safe and reliable option for LNG plants.

A new contributor that is seen to increase its participation in the future is the liquid expander. With this type of rotating equipment, the expansion temperature can be lowered, improving the energy index.

Plate fin exchangers have extensively been used in cryogenic facilities, i.e.: NGL recovery and nitrogen rejection, and are a perfect fit for LNG production. The scheme described here requires that seven process streams be integrated into a single piece of equipment for maximum heat transfer effectiveness. As the refrigeration system provides only 22% of the duty required for the liquefaction, the exchanger construction is greatly simplified. The whole core is “cold box” packaged to minimize losses. Our industry has achieved extensive experience in designing and packaging these systems.

The refrigeration system and the recycle compression do not need any consideration, as they are part of almost any oil and gas facility.

All of the equipment mentioned above has earned indisputable reputation accumulated in hours of operation.

APPLICATIONS, ONSHORE AND OFFSHORE

Other recent technical presentations have explained how the above-described technology reduces the equipment count requirement for the liquefaction of natural gas. There are numerous LNG business opportunities whose size and production economics could be justified with the use of this technology. The fact that this process scheme uses standard industry equipment makes it more cost effective than the classical licensed unit. With the horizon of depressed oil price, investors will find difficulty in justifying projects using new technologies to synthesize oil and gas derivatives.

The development of deepwater technologies will facilitate the installation of LNG facilities offshore, with floating storage facilities. This will facilitate the movement of the LNG product since the tankers will no longer be limited to deepwater ports. Important projects in this area are foreseen in West Africa and Southeast Asia.

This technology also reduces cost to achieve an LNG facility to produce alternative fuel because all that is required is a connection point to a gas pipeline. Facility costs are further reduced by the fact that gas in the pipeline is already treated for transportation.

Another application with great potential because of the synergism is the generation of energy for either export or internal use to optimize utility consumption.

CONCLUSION

As is shown by the recent publications and presentations, there is an increasing presence of the turboexpander technology as an alternative path for LNG production in base-load facilities. With today’s horizon of oil prices, synthetic fuels technologies are unlikely to compete effectively with LNG.

The technology presented here is simple. It compares in efficiency with the traditional technologies and is suitable for small to medium-scale applications. It uses standard equipment as well as proven operations. A propane cycle and process stream provide refrigeration rather than a mix of refrigerants systems which contributes to lower costs. As a consequence, the installation is simplified and plot plan requirements are reduced.

Table 6

Process Features
• Simple Process Scheme • Standard Equipment (Compressors, Expanders, Plate fins, Vessels) • Modularization from 5 to 100 MMscfd • Reduced Plot Requirements • Simple to Operate • High Reliability • Cost Effective

The turboexpander LNG technology opens an opportunity to optimize the cost of LNG facilities.

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