Investigation on NG to LNG Conversion Processes- A Review

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Abstract

The Natural gas (NG) is preferably better fuel than conventional fossil fuel in terms of cost and eco-friendliness. The current scenario of India is it has huge demand of energy but problem is, India has very limited non-renewable sources available. To overcome this problem, we are progressing towards the use of renewable energy sources that is conventional energy sources. In this domain use of natural gas as a fuel is a best solution now-a -days. If this Natural Gas is converted to Liquefied Natural Gas (LNG), it is more convenient to transport as the specific weight of LNG is more than that of NG. The Natural Gas is converted into liquid form by cooling it under high pressure. From the point of view of so many environmentalists, natural gas is a natural bridge fuel between the dominant fossil fuels of today and the renewable fuels of tomorrow. This paper presents necessity for conversion of Natural Gas to Liquefied Natural Gas. The paper focuses on various methods for conversion of NG to LNG. The investigation is done on various processes of conversion of natural gas to liquefied natural gas.

Keywords: LNG, NG, Cryogenic, Expander, Mixed Refrigerant

1. Introduction

Now a day, the natural gas is known as cleanest energy resource with a low capital expenses. From the forecasting of International Energy Agency, it is seen that the demand for natural gas will continue to increase for the next decades and replace coal as the second main fuel, hence making natural gas play an important role in today's energy markets.

Table 1 Natural Gas Composition

Component	Composition
Methane	70-90%
Ethane	0-20%
Propane	0-20%
Butane	0-20%
Carbon Dioxide	0-8%
Oxygen	0-0.2%
Nitrogen	0-5%
Hydrogen Sulphide	0-5%

Table 1 gives standard components of natural gas. LNG is nothing but Liquefied Natural Gas obtained at the temperature of approximately -160°C (113K). Its volume is reduced to 1/600th of its gaseous form, which allows larger storing capacity and transportation to longer and far distances. Generally, LNG facilities are built offshore to combine the function of production, storage, and offloading. In short, this is terminal where liquefaction process, temporary storage, and off-loading is provided. LNG terminal is installed in deep water and are slaved in outside areas where production and transportation are not good enough.

Today LNG facilities are grown in numbers and first and largest LNG facility of the world is developed by Shell and it's in operation since 2016. Now a days research is going on to produce LNG layout, processes, and LNG tankers less hazardous. LNG risk is typically ship collision and LNG spills, occurrence of this has caused significant loss of life and injuries to human beings. Therefore, risk assessment is considered while designing LNG terminal to find out risk potential and limit them. By using either qualitative and quantitative observations the risk assessment is carried out.

2. Recent Trends

In 2009, the report of world's LNG production is designed by International Gas Union. According to IGU, LNG imports to the United States originated in Trinidad which constitutes 54%, Egypt constitutes 34%, Norway constitutes 8%, and Nigeria as 4%. Now a days, some of the LNG shipments are also come from Algeria, Qatar, Equatorial Guinea, Malaysia, Oman, Australia and other nations. Brunei, Indonesia, Libya and the United Arab Emirates that is UAE also export LNG and may be U.S. suppliers in the coming days. In advancement to importing LNG to the lower 48 states, the United States exports Alaskan LNG to Japan.

For conversion of NG into LNG there are many processes are available. These are as follows AP -X® - designed by Air Products & Chemicals, Inc. (APCI), DMR (Dual Mixed Refrigerant), SMR (Single Mixed Refrigerant), MFC® (mixed fluid cascade) - designed by Linde, PRICO® (SMR) - designed by Black & Veatc. All these processes are used for liquefaction in foreign countries. Among these processes we had selected AP-X® - designed by Air Products & Chemicals, Inc. (APCI) for our project to liquefy natural gas.

3. Necessity of conversion of NG to LNG

Primary energy demand is ever increasing day by day. World is struggling to find new energy sources as fossil fuels are going to diminish one day. Natural gas is the fastest growing hydrocarbon within hydrocarbon family. Estimated average growth rate of 1.5 to 2 %.

According to the many of environmentalist's natural gas is a natural bridge fuel between the dominants fossil fuels of today and the renewable fuels of tomorrow. Burning of natural gas forms almost half as much carbon dioxide which is the main reason of global warming, as burning coal for a given amount of heat energy. Though the electricity generation is one of the basic consumption source of natural gas also it is becoming popular because its burning is cleaner than oil and coal and forms less quantity of greenhouse gases. This ability of a natural gas arises the possibility that it could come up as a critical transition fuel which could help to fight with global warming.

Natural gas is available in much more quantity than oil in nature. At the current consumption rates, most of the oil economists suggests that the natural gas reserves minimum 15% higher than oil reserves. Today oil reserves are assessed at 40 odd years whereas natural gas reserves are assessed to last in excess of 60 years. In the US, over the last few years approximately eighteen hundred Tcf of natural gas reserves have been found out that brings the total reserves almost three thousand Tcf. Even for the United States which is known as world's largest gas market, this presents approximately 100 years of supply.

The discovery of non-renewable gas or in particular, 'Shale gas' which is perused to be a game changer in market. Natural gas is known as a regionally based fuel, continuously flared off in oil field because it had less use, at one point in past.

When natural gas is cooled to temperature less than minus 155℃ (118 K), it condenses into liquefied natural gas (LNG). In liquid form, natural gas occupies 600 times less volume than its gaseous form. So, it is stored more effectively and conveniently in a limited space and can be more readily transported from one place to another which is at longer distance.

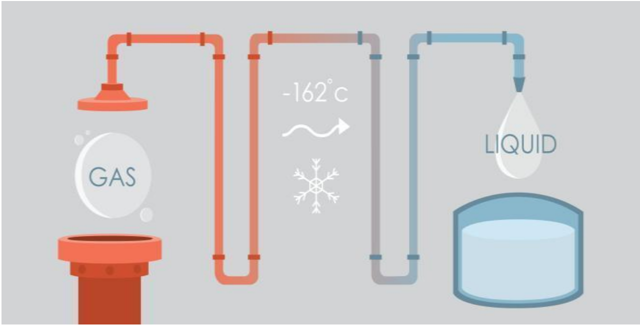

Fig .1 CNG to LNG Conversion [Pettersen(2008)]

4. Conversion Process

4.1 Air Product Corporation Inc C3-MR (APCI C3-MR)

AP C3 -MR stands for Air Products Propane precooled Mixed Refrigerant cycle. It consists of three main circuits. First one is the series of heat exchanger which uses propane as the refrigerant for precooling of natural gas. The three heat exchangers which are connected in series each having propane at a different pressure that is high pressure, medium pressure, low pressure. Propane is cooled at various pressures and at various temperatures to allow the natural gas to be cooled at inlet temperature of spiral wound type of heat exchanger.

As in the spiral wound type of heat exchanger, a propane precooling series is also used on second cooling loop. After it is compressed, the heat exchanger in series runs high pressured, medium pressured and low pressured propane to precool the refrigerant. Then it enters a flash tank. In a flash tank it gets separated into two streams and from here the spiral wound type of heat exchanger is used for further cooling of natural gas. After each stage of cooling in the spiral wound type of heat exchanger, another method which allows the refrigerant to be cooled is expansion through an expansion valve.

The mixed refrigerant which is used is composed of methane, propane, nitrogen, ethane and butane. The composition of mixed refrigerant is shown in Table 2. The work done on the compressor is optimized based on composition of refrigerant. The determined composition is as shown in Table 3.

Table 2 Composition of Mixed Refrigerant

Component	Composition
Methane	27-30%
Propane	18-20%
Butane	1-2%
Nitrogen	1%
Ethane	50%

Table 3 Composition of Mixed Refrigerant

Component	Composition
Methane	0.27

Propane	0.2
Butane	0.01
Nitrogen	0.01
Ethane	0.50

Decreasing the temperature of the streams in both stages, the compressor works were further optimized. The total compressor work is decreased by changing the valve outlet pressure and it is done by using an optimizer and to decrease the temperature approach the outlet temperature of the hot streams are adjusted. The outlet pressure of the valve is increased from 15 psia to 66 psia in the first refrigeration stage. In the second refrigeration stage it is increased from 15 psia to 67 psia and it is the stopping point of the optimization. The compressor work is as shown in the Table 4

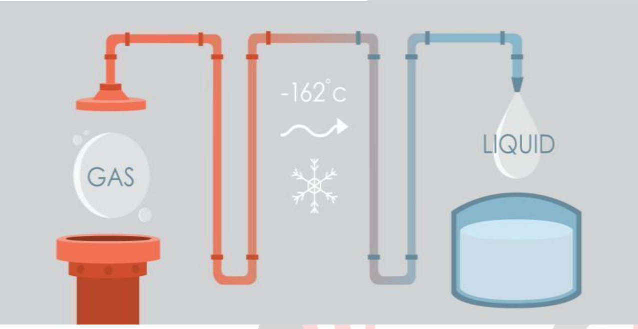

Table 4 Compressor Specification

	Compressor Work (HP)	Outlet Pressure (psia)
C1 (Stage one)	13960	500
C2 (Stage two)	10759	495
C3 (Stage three)	3675	1000

As the APCI C3-MR is one of the widely used process for liquefaction, most of the liquefaction industries uses this process. The maximum working capacity of C3-MR process is approximately 5 Metric tonnes per annum. The main disadvantage of C3-MR process is having high cost of equipment. With the use of propane heat exchangers, there is not only a high utility cost associated with it but also large cost of the spiral wound type of heat exchanger. The amount of the work done required by the compressor is very large which in turn increases the cost of the process. For the compression of refrigerant in the process a large compressor or multiple compressors are used.

4.2 Air Product Corporation Inc AP-X (APCI AP-X)

An AP-X process is a hybrid modification of APCI C3-MR process. The change is the addition of a nitrogen sub-cooling loop after the spiral wound type of heat exchanger. Due to this addition, the capacity and the efficiency of process is increased. It is because the amount of work done in the spiral wound type of heat exchanger is reduced like pre-cooling loop does. As in C3-MR process, propane pre-cooling is followed by the mixed refrigerant loop. With the mixed refrigerant loop, it uses the propane pre-cooling also. The components of APCI AP-X are same as that of C3-MR process that is propane, butane, methane, nitrogen and ethane. But the composition had changed to optimize the flowing rate of compressor. The initial and final composition of the refrigerant in this process were the same as the composition of refrigerant for C3-MR process. For the composition of the refrigerant for this process refer the table no. 2 and 3.

Pure nitrogen loop is the added final loop. It is then compressed by two compressors. It is further cooled by two heat exchanger which are water cooled followed by expansion in expander. The ability of nitrogen is to cool at temperature which is much lower than the cooling temperature of mixed refrigerant. Due to this more cooling is done in final loop as well as the needed quantity of mixed refrigerant in spiral wound type of heat exchanger is lowered.

The hybridization created in this process is due to the addition of nitrogen sub-cooling loop. It pairs with a spiral wound type of heat exchanger that utilize mixed refrigerants with a plate fin type of heat exchanger. The refrigerant used is a pure component refrigerant that is not a hydrocarbon. It increases the capacity of this process from 5 Metric tonnes per annum to almost 9 Metric tonnes per annum which indicates that how much process is supposed to be efficient.

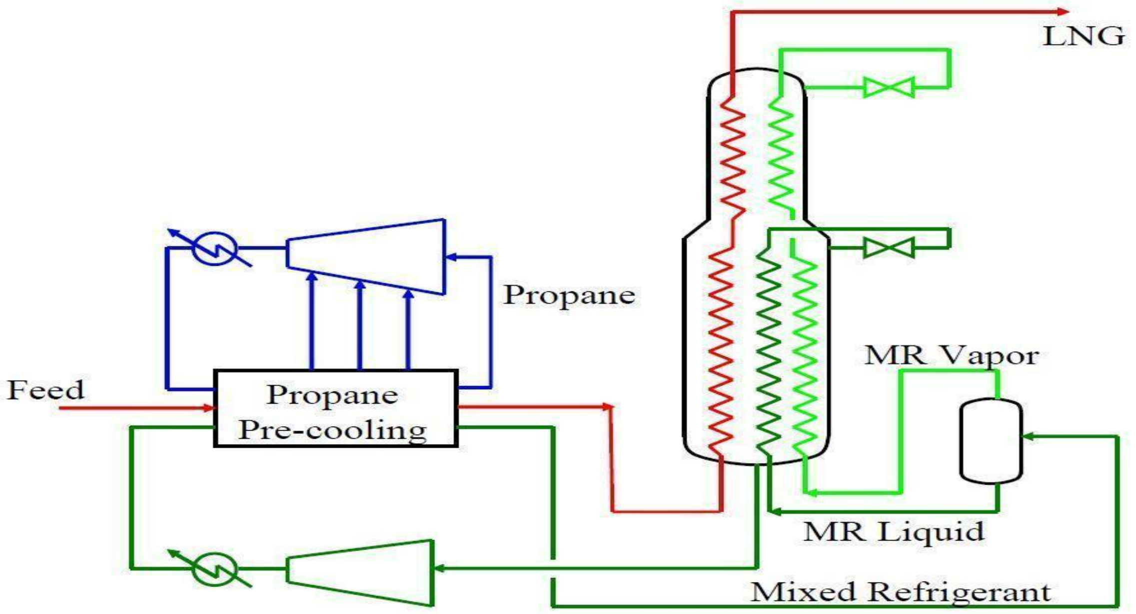

Fig .2 Propane Pre-Cooled Mixed Refrigerant Process [Bower AP&C (2006)]

Because of simple modification in C3-MR process the AP-X process is increasing in popularity. The increased capacity is main advantage of this process. Very few processes have such a high capacity. The drawback of this process is same as that of C3-MR process. It requires more compressor work. Also, it has very costly equipment and these are the main cost aside from spiral wound type of heat exchanger.

5. Comparison of Processes

Table 5 gives the comparison of various processes investigated in this paper.

Table 5 Summary of Processes

Parameter	APCI C3-MR	AP-X
Compressor Work	More	Less
Terminal Capacity	Less	More
Nitrogen Expander	Absent	Present
State of Natural Gas after passing through MCHE	Sub-Cooled	Semi-Cooled
Efficiency	Less	More

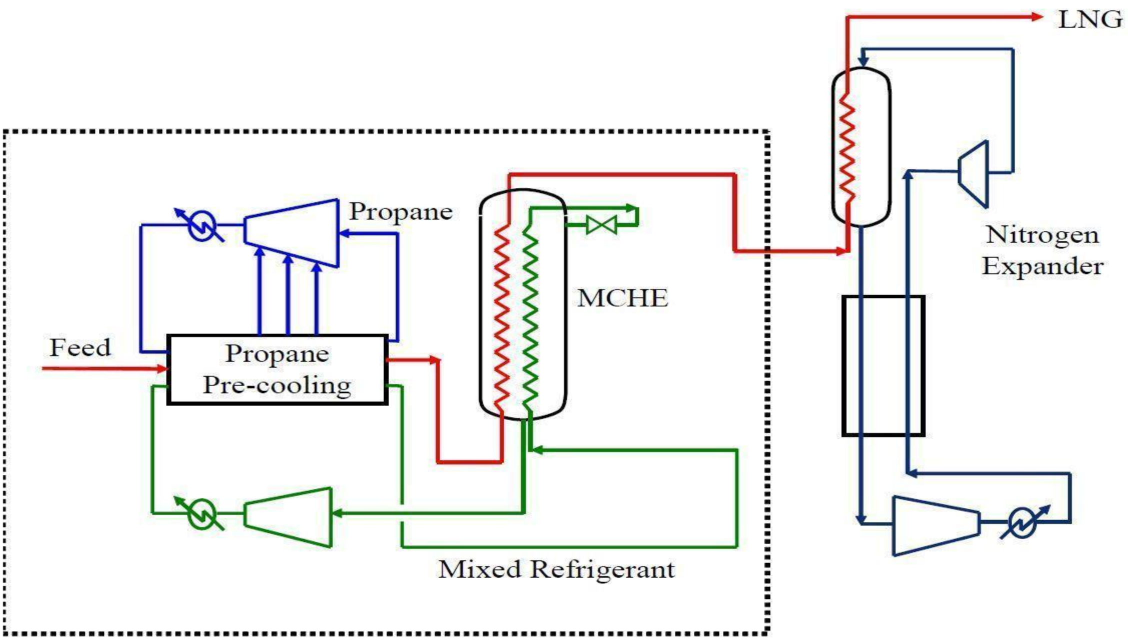

Fig .3 APCI AP-X Cycle [Bower AP&C (2006)]

6. Conclusions

The C3MR liquefaction process has proved that it is a reliable process for liquefaction of natural gas. It is most economic and efficient process for liquefying natural gas. Now a days, new LNG plants face a wider range of process requirements than ever before. Various technological advancements have been made and allowed it to meet demands of larger train capacity. It is also possible to operate it in colder climates.

The demand for increased train capacity is being fulfilled through advancement of the AP- X process as well as enhancements to the Air Products' main cryogenic heat exchanger (MCHE) and better progress of the process with the compressors and drivers.

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