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Review Article

The process of liquefied natural gas

Zhaoyin Jiang*, Lixi Peng, Shiyao Chang, Ping Ouyang

Petrochemical Institute, Daqing University of Technology, Heilongjiang, China
**Correspondence:gas-Zhaoyinzyh@gmail.com*

ABSTRACT

In this paper, the analysis of liquefied natural gas process plant technology, into the device before the natural gas compression, and then through the MEA aqueous solution to remove CO_2. Finally, the compressed water removed; clean natural gas before entering the liquefaction unit. In the liquefaction unit, the high-pressure natural gas is cooled and liquefied deep. The required cooling capacity is obtained by circulating the gas turbine to drive the closed mixed refrigerant nitrogen, methane, ethylene, propane and other components, and liquefied natural gas (LNG), which is finally stored in an atmospheric tank through a liquefied natural gas container or liquefied natural gas tanker for distribution. The recycle of the recycle refrigerant is carried out by means of environmental conditions. The heating medium required during the installation process is the hot oil heated by the exhaust gas of the gas turbine. The liquefied gas in the liquefied natural gas tank is compressed to regenerate the desiccant and then sent to the gas turbine as the fuel gas.

KEYWORDS: Natural Gas Liquefaction; Design Data; Technical Analysis; Process System

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In 2004, China completed and put into operation the largest domestic load-bearing liquefied natural gas (LNG) plant, which deals with natural gas 1.5 million m^3 and LNG annual output of about 430,000 tons. The plant is supplied by Linde, Germany, for natural gas treatment and liquefaction technology, and is supplied by Tractebel Gas Engineering (TGE) in Germany for storage and filling of LNG. The raw material of the plant comes from the oil and gas fields of the nearby Tahuqiu oil production plant. The LNG produced is filled in a container tank and transported by road to each receiving station. The LNG is then vaporized and delivered to the industrial and civilian customers via a short pipeline. In this paper, the technical process of the factory is analyzed, with a view to the domestic liquefied natural gas plant design to provide some useful reference.

1. Factory design data

1.1. Factory production and storage requirements

The factory is the basic load type liquefied natural gas production factory, the continuous running time is 8000 h, the liquefaction capacity is 54t / h, the operation elasticity is 50% - 100%. LNG tank capacity of 30000 m^3 is to meet the 10-day production of storage. Every day LNG distribution and filling system is filling 100 container tanks in 14 h, of which 90% are for road transport.

1.2. Raw material gas conditions and product specifications

The raw material gas from the pipeline is from the nearby oil and gas fields. The raw material gas composition is shown in **Table 1**. The feed gas pressure range is 0.7 to 1.1 MPa and the design pressure is 0.7 MPa, the temperature range of -15 – 40 ℃, the design temperature is 28 ℃, the raw material gas content (dew point) normal -42 ℃, maximum -10 ℃. LNG product specifications in **Table 2**, the tank pressure 0.01 MPa, the temperature is -163 ℃, in the design of raw gas composition, LNG at 162.3 ℃ when the liquid density of about 486.3 kg / m^3.

1.3 On-site environmental conditions

The environmental conditions of the LNG plant are shown in **Table 3**.

2. Factory technical analysis

The basic load type Nissan 1.5 million m^3 LNG liquefied natural gas plants includes natural gas pretreatment and natural gas liquefaction, liquefied natural gas storage and liquefied natural gas distribution system.

From the oil field to the raw material gas pressure about 0.7 MPa, with the raw material gas compressor pressurized, the use of Monoethanolamine (MEA) to absorb carbon dioxide, molecular sieve adsorption of water, purified natural gas using mixed refrigerant circulating cooling (MRC) process liquefaction, which is my factory only chemical reaction. The rest are changes in the physical state, liquefied natural gas sent to the LNG storage.

Table 1. Ingredients gas composition.

Component	Mole Fraction (Design Composition)
N_2	3.81
CH_4	81.02
C_2H_6	9.99
C_3H_8	4.10
C_4H_{10}	0.93
C_5	0.05
C_6	< 0.0021
CO_2	0.10
H_2S	0.28-3.2 mg/m^3
Hg	Nil

Table 2. LNG product specifications

Component	Mole Fraction
N_2	0.8 (Highest 1.0)
CH_4	82.4
C_2H_6	11.1
C_3H_8	416
CO_2	$<50\times10^{-6}$
H_2O	$<1\times10^{6}$
Others	1.1

Table 3. LNG plant site environmental conditions

Atmospheric Pressure/ MPa	Annual Average	0.09972
	Maximum Value	0.10096
	Minimum Value	0.09418
Ambient Temperature/C	Average Maximum	37.1
	Average Minimum	-15.1
Design Temperature (Process)/C	30	
Maximum Snowfall Depth/mm	180	
Design Snow Load (KN/m^2)	250	
Site Elevation (Yellow Sea Process)/m	790	
Relative Temperature Average	Year Average	43%
	Year Maximum	61%
Maximum Wind Speed (m/s)	34	
Earthquake Intensity	Chinese Standard Seven	

The mixed refrigerant is mainly composed of nitrogen, methane, ethylene, propane and pentane, and the mixed refrigerant compressor is driven by a gas turbine, and the fuel of the gas turbine is mainly from the flash gas in the tank. Natural gas and cold exchange of cold box using Linde unique winding tube heat exchanger. The finished product is stored in a 30000 m^3 single-packed, normally-loaded double-walled metal tank designed by TGE. The LNG is lifted from the liquid pump in the tank to the loading arms for loading of the container cans.

3. Process system

3.1. Natural gas pretreatment

From the raw material composition of the factory can be seen, mercury, hydrogen sulfide and aromatics content has to meet the purification requirements. Therefore, the devices only consider off-carbon dioxide and water. According to the existing raw material gas conditions is from the natural gas to remove carbon dioxide using a chemical washing method. MEA washing process is a mature process, no patent license fee, cheap and reliable, the device uses 12% (mass concentration) MEA as a washing solvent. Dehydration using molecular sieve adsorption, because this method has a strong adsorption capacity, low water vapor pressure under the high adsorption characteristics, and can remove residual acid gas.

The low pressure natural gas (feed gas) from the boundary zone is first removed by the feed gas filter separator, solid particles, and then compressed by the feed gas compressor Class I, and then cooled down to about 40 ℃ by intercooler air coolers The intermittent gas-liquid separator separates the condensed water and enters the carbon dioxide scrubber by the compressor II stage, the inter-stage air cooler and the inter-stage separator, respectively, and the carbon dioxide is separated from the 0.1 mole fraction Reduced to 50 × 10 volume fraction, after the separator into the compressor III level compression, after cooling and separation of condensate, to dry the dehydration unit.

Since the feed gas pressure is too low, in order to effectively liquefy, it is necessary to increase the pressure of the natural gas to meet the operating pressure requirements of the carbon dioxide washing unit and the molecular sieve dewatering system at the same time. Where the plant is located in an arid area, in order to save water, almost all of the cooling is air cooled and no recirculating cooling water system is installed. In order to remove mercury from the feed gas, a mercury adsorbed unit was designed downstream of the feed gas compressor Class I, which included a mercury adsorbed and a downstream filter. The downstream filter is used to prevent dust from entering the feed gas line.

The feed gas enters from the bottom of the MEA scrubber and flows from the bottom up through the float valve tray in contact with the reverse flow of the amide solution. The poor amine solution absorbs the acid gas and the carbon dioxide reacts with the weak base in the solvent to form the weak bond Acid salt. At the top of the column, the purge gas is recovered by means of four additional trays, which are washed with water. The purified natural gas from the top of the tower contains 50 × 10 books of carbon dioxide and 40 ℃ of saturated water. The rich amine from the bottom of the scrubber is returned to the stripper and regenerated by heating the oil and the cooler. The carbon dioxide is Separation and purification of the poor amine solution back to the scrubber. To reduce the amount of acid A in the acid gas at the top of the stripping tower, the top of the column is provided with a water wash. The acid gas at the top of the column is cooled by the air cooler, and the gas and condensate tank separation, acid gas sent to the torch system emissions.

The operation of the MEA wash unit is very sensitive to contamination. Before the test, the system must be thoroughly rinsed with purified water, potassium salt solution and a certain percentage of MEA solution to remove oil or grease and avoid 'foaming' during operation. The circulation flow of the MEA must be adjusted according to the load variation of the plant to maintain a qualified carbon dioxide concentration. MEA concentration, water balance, heat balance, tower pressure drop and temperature are the main points of control.

Foam will reduce the contact between the gas phase and the liquid phase, thereby reducing the absorption efficiency, resulting in excessive carbon dioxide. The foam may be caused by solid particles and other impurities in the wash solution. Filtration of the solution by mechanical means greatly reduces the possibility of foaming. So that the flow of the adjustable flow side of the filter, and while defamer injection facilities. The condensate of the booster unit is sent to the washing unit to reduce the utility water. The online analyzer checks the carbon dioxide content and confirms the results of the on-line meter by laboratory analysis.

The dryer is a two-bed adsorption unit with a cycle time of 8 h. Natural gas flows down in an adsorbed, and the moisture is adsorbed by the adsorbent, down to the extent that the liquefaction unit does not freeze. During this period the other adsorbed is heated and cooled with a regenerated gas (compressed LNG tank flash vapor). The regenerated gas is heated by the heat transfer oil through the heat exchanger for cooling after the regeneration by the air cooler, and then the gas is separated by the regeneration gas separation tank, and the gas is the fuel of the gas turbine unit. The two absorbers are controlled by the program for periodic switching operations, and the operating pressure for adsorption and regeneration is different, so a slow boost or depressurization process is required. The estimated life expectancy of the adsorbent is about 3 years.

The water content was checked by an on-line analyzer and the results of the in-line water meter were confirmed by laboratory analysis. Before allowing the gas to enter the liquefaction unit, the water content should be less than 0.5×10 books. The amount of regeneration gas at the beginning of the heating and the end of the cooling will change, and the pressure control of the fuel gas to the gas turbine unit becomes important.

3.2. Natural gas liquefaction and mixed refrigerant system

Liquefaction of natural gas

Natural gas liquefaction using Linde's advanced mixed refrigerant cycle (MRc) technology, which is characterized by a mixed refrigerant instead of a variety of single refrigerant compression cycle, less compression equipment, only one compressor unit, and Condensation, separation and expansion of the series of process optimization.

Through the pretreatment system, the natural gas in the carbon dioxide and water content compliance, the natural gas into the cold zone, cold by the integration of a shell in the three spiral wound heat exchanger and several gas-liquid separator composition. The gas is first pre-cooled in the pre-cooler (the feed gas is only near the liquefaction conditions) and the heavy hydrocarbon components that may be present are removed in the feed gas heavy hydrocarbon separator: then the liquefier is then condensed and the sub cooler is cooled to a 155°C. The temperature of the sub cooler is controlled by adjusting the amount of flue gas consumed by the fuel gas required for operation of the gas turbine unit. The cooling capacity of the liquefaction is provided by the circulation of the multi-component mixed refrigerant consisting of nitrogen, methane, ethylene, propane and pentane.

The principle of natural gas flow regulation is to transport as much natural gas as possible to the liquefaction of the MRC. But in fact there is not so much raw material gas but according to the pressure of a compressor and the compressor load to adjust the intake of LNG. Before the natural gas enters the LNG storage tank through the throttle expansion valve, the natural gas flow rate is adjusted according to the temperature of the liquefied natural gas after the valve (as a measure of the correct liquefaction of the LNG), so that the expansion valve is delivered to the device in the natural flow of the indirect flow controller. By adjusting the valve, the amount of flash gas in the LNG tank can be changed. In this way, there is a balanced control between the input flow and the liquefaction of the natural gas.

Refrigerant circulation

The refrigerant is discharged from the lower side of the cold box side, and the temperature is slightly higher than the temperature in the saturated state. The refrigerant is first passed through the compressor I stage inlet separator and then cooled by the refrigerant circulating compressor class I, cooled by the air cooler and part of the gas is condensed. The gas and liquid are fed together into the compressor II stage separation tank for separation. The recycle gas is further compressed at the compressor II level: the separated liquid is pumped to the inlet of the recycle compressor II stage air cooler by the MRC, with the II grade outlet gas mixing. After cooling by the air cooler, the gas and condensate are separated in the recycle compressor III stage inlet separator. The separated gases are compressed by a Class III, cooled by a cooler, the heavy components are condensed, and the gas is separated in a circulating high-pressure separation tank.

This tank is also used as a buffer tank for recirculating refrigerant components. The liquid in the circulating high-pressure separation tank flows into the III stage inlet separator, and all the liquid hydrocarbons flow into the precooler and then pass through. After the throttle expansion and expansion, the cooling capacity is provided for the precooling of natural gas. The recycle gas from the circulating high pressure separation tank is also cooled to the same temperature in the pre-cooler, partially condensed into the MRC separator, the liquid coming out of the separator is cooled in the liquefier and then cooled by the J-T valve after expansion, and it is used to provide refrigeration for the liquefier. And the separated gas is condensed in the liquefier, supercoiled in the sub cooler, and the final cooling capacity for the sub cooling of the natural gas after the J-T valve. The expanded recirculation gas stream is reheated in the pre-cooler, liquefier and sub cooler shared shell side of the low-temperature spiral wound tube heat exchanger, and is returned to the recirculation stage of the recycle compressor by the I-stage inlet separator.

Refrigerant storage and replenishment

The refrigerant replenishment system is provided for the loss of circulating gas in the refrigerant system caused by the gas sealing system of the recycle compressor. The amount of each component of the refrigerant is adjusted according to the composition of the refrigerant on-line composition; the temperature of the cold zone is adjusted and added to the system by metering. When filling, it should avoid excessive filling of the refrigerant and exceed the design value. The actual filling amount should be recalculated according to the actual piping and the volume value of the equipment to correct the theoretical design. After each filling step is completed, the state of the gas must be confirmed.

3.3. Liquefied natural gas storage and filling system

The LNG enters the LNG cryogenic tank from the liquefaction unit and enters the tank from the top of the tank into the tank. The feed can be injected into the upper part of the tank or injected into the lower part of the tank, either in the upper and lower stages. The upper or lower feed is determined by the operator according to the liquid density and temperature conditions in the tank. To ensure that LNG and tank LNG can be fully mixed, to avoid the tank liquid phase to create a layer to prevent the 'roll' phenomenon occurs to ensure the stability of low temperature tank operation and safety.

The tank is equipped with liquid level, pressure and temperature measuring instruments. The protection system of the tank is connected with the DCS by the safety control system. When the tank is at high or high pressure, the feed valve of the tank is automatically closed. LNG tank at different levels of height, not only the layout of the thermometer, also equipped with a densitometer to monitor, to prevent the liquid in the tank may occur in the 'roll' phenomenon.

The LNG tank is equipped with two vertical centrifugal submersible pumps (one of which is supplied) and installed at the bottom of the tank through the drum. The LNG pump is in continuous operation and re-injects the LNG in the tank from the tank inlet line into the tank through the return line on the pump. It serves to circulate the LNG in the tank and reduce the LNG Phenomenon: At the same time to keep the tank inside and outside the pipeline is always in a cooling state, easy to operate the normal operation of the process.

LNG is transported by LNG pump in low temperature tank to LNG car, low temperature container tank; gas return line is connected with gas chamber space in tank to balance the pressure of car tanker and container tank when loading. Phase full rate. In the non-loading time, through the tank and loading facilities between the LNG recycling pipeline, to maintain the loading equipment and pipeline cooling, is conducive to loading facilities in the loading quickly when the start.

The evaporative gas produced by the exchange of heat from the outside, the heat transfer of the LNG in the tank, the LNG loading and the natural convection of the LNG in the tank, and the evaporation of the vapor due to the loading facility, Compressor handling, used as regenerative gas and gas turbine unit fuel gas.

At the same time in order to control the tank during operation due to operating accidents, changes in the external environment and changes in the vapor pressure in the tank and other reasons arising from the positive and negative pressure, the tank is equipped with a discharge control system to the torch control valve and emissions to the atmosphere Safety valve. In order to prevent the tank negative pressure, also set a vacuum valve.

In normal operation or emergency conditions, from the LNG storage tanks, natural gas purification, liquefaction devices and loading facilities to the venting gas, the tank into the flare combustion. At LNG plant production, LNG is continuously fed into the tank at a flow rate of 111 m^3/h. Two LNG submerged pumps are installed in the tank, each designed flow of 320 m^3/h, one for one, for pumping and filling. The liquid pump is placed on the tank inside the tank with a bottom valve. Each pump has a return line that returns to the tank and can be used to maintain the minimum flow rate of the pump when stopping filling. The filling lines to the tanker and the container tank filling station are always circulated by a small amount of LNG to maintain the cold state of the system.

The car cans are weighed by the weighbridge, and they are sent to the filling point after the measurement. The gas- liquid interface on the tanker is manually connected with the gas-liquid interface of the filling arm. At the beginning, the LNG enters the tanker with a higher temperature and vaporizes immediately, and the resulting gas is returned to the tank through the filling arm gas return pipe. After the cold tank, the filling flow can be increased to the maximum. When the accumulated flow reaches the set value, the control valve is cut off and the filling is stopped automatically. The tanker and the filling arm are manually unloaded and, after weighing, the tanker leaves the station area.

The filling procedure of the container tank is the same as that of the tanker. The difference is that the car tanker moves for itself, and the container tank uses a flatbed trailer as a moving tool in the filling area. After filling, the car tanker is shipped to the factory, the container tank is transported by the flat trailer to the railway line located in the factory, and the container is placed in the container on the wagon. 1 car tanker or container tank filling the whole process takes about 112h, filling station design capacity of 16h filled with volume 40 m^3 car tankers or container box 100. The filling station consists of six container tank filling arms, three car tank filling arms and a motorized tanker filling hose.

3.4. Fuel gas systems

The flash gas of the LNG storage tank is compressed by the flash vapor compressor, cooled by the air cooler, regenerated as a drying unit, and finally sent to the gas turbine unit as fuel gas. To ensure the fuel gas pressure, a gas is withdrawn from the feed gas compressor II as a supplement to the fuel gas.

3.5. Conductive oil system

The heat transfer oil system provides two temperature-level process heats to the device. The heat transfer oil maintains a steady flow in the system. Flows through two circulation systems are a medium temperature circulation system and a high temperature circulation system. The heat is provided by a hot oil heater (waste heat recovery system) installed in the gas turbine exhaust chimney. In order to ensure the normal start of the winter, the thermal oil system has electric heating facilities.

In order to make full use of the flash gas of the liquefied natural gas storage tank, the circulating refrigeration compressor is driven by the gas turbine unit by using the flash gas as the regeneration gas of the drying unit and the fuel of the gas turbine unit. The heat source of the drying unit and the heat source of the carbon dioxide unit are the exhaust heat of the exhaust gas discharged from the gas turbine unit, so there is no steam system. As a result of investment control and there are no energy recovery users, the existing gas turbine unit exhaust emissions without energy recovery device, but part of the use of waste heat, that is, part of the energy recovery.

3.6. Torch system

There are two torch systems, the thermal torch system handles the warm gas, and the cold torch system handles the cold fluid. The use of online automatic ignition system, when the torch has exhaust gas, the automatic light, the torch lit after a long light off. This control system with a flow computer automatically records the emissions of the torch, the amount of fuel for the long lamp, and the amount of gas used to seal the gas. It can provide specific and reliable data for the entire torch system. The location and height of the torch should take into account the effects of thermal radiation during combustion, allowing the value of the thermal radiation value and the permissible pressure force drop.

4. Major equipment

The main equipment of the factory is cold box, large low temperature tank, cryogenic pump, centrifugal compressor, reciprocating compressor and gas turbine unit. These equipment and LNG storage tanks are used in the introduction of low temperature materials. Most of the other equipment is materials based on domestic supply.

4.1. Liquefied natural gas storage tank

Considering the capacity of liquefied natural gas plants to deal with natural gas and the amount of liquefied products, the storage requirements and characteristics of the project and the geographical environment of the site are based on the mature LNG storage technology at home and abroad. The atmospheric pressure, low temperature, reduced investment. In addition to the application of the specification, in addition to the basic domestic fire protection regulations must be met, the United States NFPA259A liquefied natural gas (LNG) production, storage and shipping standards.

LNG storage tank with APl26202Q standard, storage capacity: 30000 m^3; Design pressure: 5 × 10^4/150 × 10^4 MPa (-5 / 150 mbar): Design temperature: -165 °C / 50 °C: Dimensions: 41000 mm × 24200 mm (Inner tank), 43500 mm × 27000 mm (outer tank): Material: ASTMA553I (inner tank), 16 MnDR (outer tank): Insulation material: Foam glass brick (bottom), perlite concrete (bearing ring), perlite and mineral wool (ceiling).

5. Conclusion

At present, the domestic LNG related technology has made great progress, but compared with foreign countries there is still a big gap, mainly on the liquefaction technology and large-scale low-temperature storage tanks and Xiang Qiang equipment master. Natural gas liquefaction technology itself is not complicated, the domestic simulation software can also be more accurate calculation, but the industrial scale, the whole process design is still a lot of difficulties, to strengthen the understanding of the whole process of process control and understanding of equipment performance. So that the process, equipment selection and process control technology is a good combination of the three, perhaps to improve the level of process design key.

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