# LNG Receiving Terminal Process System and Equipment

*LNG is usually transported from the output terminal of the production place to the receiving terminal of the destination by a special carrier, and then transported to the user after regasification. At present, a complete LNG production, transportation and sales industrial system has been formed, including LNG production, storage, transportation, acceptance, regasification, and cold energy utilization.*

## 1 LNG receiving terminal process system

### 1.1 Main physical properties of LNG

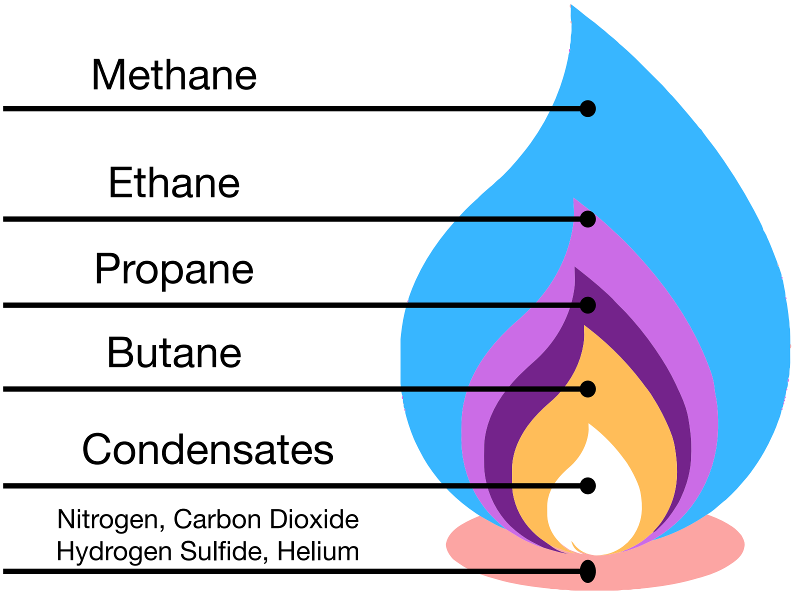
The typical LNG composition (%, mole) used in the design:

| | $CH_4$ | $C_2H_6$ | $C_3H_8$ | $C_4H_{10}$ | C+5 |
|---|---|---|---|---|---|
| LNG composition %/ mole | 85～90 | 3～8 | 1～3 | 1～2 | trace |

The latent heat of vaporization during LNG regasification (about -162 °C) is about 511 kJ/kg,

Main physical properties of LNG Relative density (gas) Liquid density, $kg/m^3$ High calorific value.

The H2S content in LNG is usually required to be no more than $4\times10^{-6}$ (body), the total sulfur content is required to be no more than $30mg/m^3$ (gas), and the N2 content is required to be no more than 1.0% (mol).



## 1.2 The process flow of the LNG receiving terminal

The LNG receiving terminal generally consists of 6 parts of the LNG unloading (bunkering), storage, regasification/export, BOG (BOG) treatment, anti-vacuum supply and flare/venting (some terminals also have cooling utilization system).

LNG ship unloading system consists of unloading arm, pipeline, BOG return arm, LNG sampler, BOG return pipeline and LNG circulation cold insulation pipeline. After the LNG carrier berths at the wharf, the ship's LNG output pipeline is connected to the shore unloading pipeline through the unloading arm on the wharf, and the LNG is transported to the terminal storage tank by the transfer pump (submersible pump) in the ship's storage tank. With the continuous output of LNG, the gas phase pressure in the onboard storage tank gradually decreases. In order to maintain a certain value, a part of the vaporized gas in the onshore storage tank is pressurized and sent to the shipboard storage tank through the return line and return arm.

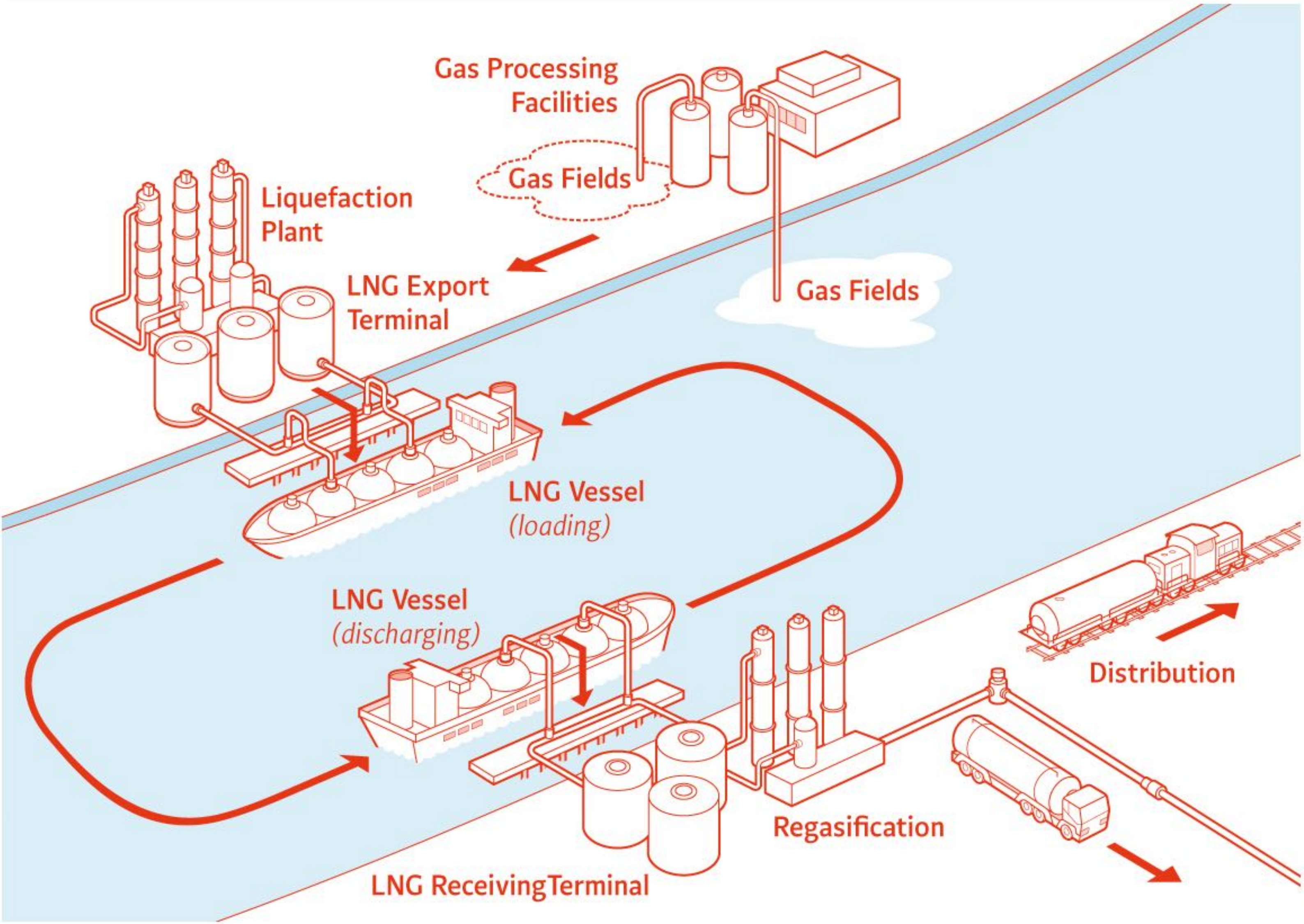
The LNG ship unloading pipeline generally adopts the double main pipe design. When unloading the ship, the two main pipes work at the same time, and each undertakes 50% of the conveying capacity. When one main pipe fails, the other main pipe can still work without interruption of unloading. During the non-unloading period, the double main pipe can make the unloading pipeline form a cycle, which is convenient for circulating and cooling the main pipe, keeping it low temperature, and reducing the increase of LNG evaporation due to pipeline heat leakage. Usually, a part of LNG is separated from the outlet of the onshore storage tank transfer pump to cool the pipeline that needs to be kept cold, and then returned to the tank through the circulating cold preservation pipeline.

Before each unloading, it is necessary to use on-board LNG to pre-cool the unloading arms, etc., and then gradually increase the unloading volume to the normal volume after the pre-cooling. The unloading pipeline is equipped with a sampler to sample and analyze the composition, density and calorific value of LNG before each unloading.

The LNG storage system consists of low temperature storage tanks, auxiliary pipelines and control instruments. The LNG cryogenic storage tank adopts adiabatic cooling design. Due to the introduction of external heat or other energy, such as heat leakage from the insulation layer of the storage tank, auxiliary pipe fittings, etc., pressure changes in the storage tank and heat dissipation of the transfer pump, it will cause a small amount of LNG in the storage tank to evaporate.

During normal operation, the daily evaporation rate of LNG in the tank is about 0.06%～0.08%. When unloading the ship, due to the heat dissipation of the transfer pump in the ship's storage tank, the pressure difference between the ship's storage tank and the terminal storage tank, the heat leakage of the unloading arm, and the replacement of LNG liquid and BOG, the volume of BOG can be increased several times. In order to minimize the amount of evaporative gas during unloading, the pressure in the storage tank should be as high as possible at this time.

Evaporation gas contains more volatile components, such as N2, CH4, etc. For example, when the N2 content in LNG is about 1% (mol), the N2 content in the BOG can reach 20%, so its calorific value is much lower than that of the terminal gas. Usually, propane can be added to the BOG or mixed with the external gas to meet the user's calorific value requirements for this fuel gas.



The storage capacity of the receiving terminal can be calculated according to the following formula:

$$Vs = Vt + nQ - tq$$

Vs= storage capacity, m³
Vt= LNG carrier capacity, m³
n= continuous non-operational days, d
Q= average daily delivery volume, m³/d
t= unloading time, h
q= delivery volume during unloading, m³/d.

Generally speaking, the receiving terminal should have at least 2 tanks of equal volume. For example, this scheme accepts that the scale of the first phase of the terminal is 2.0 Mt/d, and the LNG carrier used is 135,000 m³. If the number of consecutive non-operational days is 5d and the unloading time is 12h, the 135,000 m³ LNG carrier should be selected.

The LNG regasification/export system includes the transfer pump (submersible pump) in the LNG storage tank, the low/high pressure external transfer pump outside the storage tank, the open-frame water spray evaporator, the submerged combustion evaporator and the metering facilities, etc. . The LNG in the storage tank is pressurized by the transfer pump in the tank and then enters the recondenser to liquefy the BOG from the top of the storage tank. The LNG flowing out of the recondenser can be pressurized to different pressures according to different user requirements.

For example, part of the LNG in this scheme is pressurized to 4.0 MPa by the low-pressure external pump, and then enters the low-pressure water shower evaporator to evaporate. When the water spray evaporator is running under the basic load, the submerged combustion evaporator is used as a backup device, and it is operated during the maintenance of the water spray evaporator or in parallel when it is necessary to increase the gas volume peak adjustment; The other part of LNG is pressurized to 7.0 MPa by the high-pressure external pump, and then enters the high-pressure water spray evaporator to evaporate for remote users.

The high-pressure water shower evaporator is also equipped with a submerged combustion evaporator as a spare. After regasification, the high and low pressure natural gas (external transmission gas) is separately measured by the metering facility and then transported to the user. In order to ensure the normal operation of the transfer pump in the tank, the low-pressure and high-pressure external transfer pumps outside the tank, the pump outlet is equipped with a return line. When the LNG delivery volume changes, the return line can be used to adjust the flow. When the output is stopped, the return line can be used for circulation to ensure that the pump is in a low temperature state.

Evaporative gas treatment system Including evaporative gas cooler, liquid separation tank, compressor and recondenser, etc. This system should ensure that the LNG storage tank works normally within a certain pressure range. The pressure of the storage tank depends on the pressure of the gas phase (vapor) inside the tank. When the storage tanks are in different working states, for example, when the storage tanks have LNG exported, are receiving LNG, or neither export nor receive LNG, the amount of BOG is quite different. If it is not properly handled, the gas phase pressure cannot be controlled. Therefore, a pressure switch should be set in the storage tank, and several levels of overpressure and underpressure should be set respectively. When the pressure exceeds or falls below the set value of each level, the evaporated gas treatment system will act accordingly according to the pressure switch. to control the gas phase pressure in the storage tank.

Evaporative gas compressors operating at low temperatures usually have certain restrictions on the inlet temperature. The reciprocating compressor is generally required to be -80 ~ -160 °C, and the centrifugal compressor is -120 ~ -160 °C. In order to ensure that the inlet temperature does not exceed the upper limit (mainly to prevent exceeding the upper limit), it is required to install an evaporative gas cooler at the compressor inlet, and use the cooling capacity of LNG to ensure that the inlet temperature is lower than the upper limit.

Anti-vacuum supply system for storage tank In order to prevent the LNG storage tank from generating vacuum during operation, an anti-vacuum supply system is equipped in the process. The source of supplemental gas is usually natural gas drawn from the evaporator outlet manifold. Some storage tanks also adopt the practice of connecting the safety valve directly to the atmosphere. When the storage tank generates a vacuum, the atmosphere can directly enter the tank through the valve to make up the air.

Flare/venting system When the gas phase space in the LNG storage tank is overpressured, the vaporized gas compressor cannot be controlled and the pressure exceeds the set value of the relief valve, the excess vaporized gas in the tank will enter the flare through the relief valve and be burned. When an accident such as a tumbling phenomenon occurs, a large amount of gas cannot be burned in time, and venting measures must be taken to discharge it.

# 2 Main equipment of LNG receiving terminal

## 2.1 Unloading arm

Usually, several unloading arms and one BOG return arm are configured according to the size of the terminal. The size of the two can be the same or different, but the structure and performance are the same. Interchangeable if they are the same size. The selection of the unloading arm should consider the LNG unloading volume and the unloading time, and at the same time determine the pressure level, pipe diameter and quantity according to the length of the trestle, the distance of the pipeline, the elevation, and the lift of the transfer pump in the storage tank on the ship. The evaporative gas return arm should determine its pipe diameter according to the evaporative gas return flow. The rotary joint of the unloading arm can be translated and rotated in the working state, and it is also equipped with a safety cut-off device.

## 2.2 LNG storage tank

LNG storage tank is a large storage tank at atmospheric pressure and low temperature, which is divided into two types: above-ground type and underground type. The inner wall of the storage tank is in direct contact with LNG. Generally, alloy steel containing 9% nickel is used. It can also be all-aluminum, stainless steel film or prestressed concrete, and the outer wall is carbon steel or prestressed concrete. The suspended thermally insulated support platform at the top of the wall is made of aluminium and the roof of the tank is made of carbon steel or concrete. Insulation materials in the tank are mainly expanded perlite, elastic glass fiber mat and foam glass bricks. There are three types of LNG storage tanks: single-capacity (single closed) tank, double-capacity (double-enclosed) tank and full-capacity (fully closed) tank

The inner wall of the main container of a single-container tank is generally made of alloy steel containing 9% nickel, and the outer wall is carbon steel, while the auxiliary container is only a liquid collection tank surrounded by a lower protective embankment, which is used to prevent LNG from overflowing and spreading in the event of an accident in the main container.

Compared with the single-capacity tank, the auxiliary container of the double-capacity tank is a cylindrical concrete protective wall with a height similar to the tank wall and separated from the main container. The inner wall of the full-capacity tank is made of alloy steel containing 9% nickel, stainless steel film (full-capacity film tank) or prestressed concrete, and the outer wall is prestressed concrete. Therefore, the outer wall of the full-capacity tank can not only prevent the leakage of LNG in the tank, but also prevent bullet breakdown, heat radiation, etc., so it also plays the role of an auxiliary container. These three types of storage tanks have their own advantages and disadvantages.

When choosing a tank type, factors such as technology, economy, safety performance, floor space, site conditions, construction period and environment should be comprehensively considered. The design pressure of gas phase space is an important parameter for large storage tanks at atmospheric pressure and low temperature, especially for terminal storage tanks.

With the advancement of science and technology, the design pressure of the gas phase space of such storage tanks is increasing year by year. In particular, the film tank can adopt a higher design pressure due to its inherent structural characteristics. For example, the inner wall of an above-ground low-temperature full-capacity storage tank is made of stainless steel film, and the outer wall is made of prestressed concrete, the daily evaporation rate is 0.08%. All openings of the storage tank should be selected at the top of the tank to avoid LNG leakage from the interface. In addition, measures should be taken to prevent tumbling due to liquid stratification and heat leaking from the tank in some cases. For example, considering the density difference between the LNG to be unloaded by the transport ship and the LNG already in the terminal storage tank, the liquid inlet of the unloading pipeline can be led to the top and bottom of the tank respectively. If the density of the LNG to be unloaded is greater than that of the existing LNG in the storage tank, the liquid inlet at the top of the tank shall be used; otherwise, the liquid inlet at the bottom of the tank shall be used.

## 2.3 LNG transfer pump

The terminal storage tank is equipped with a submersible pump for transporting LNG. If natural gas is required to be piped under high pressure, an external pump should also be configured before the evaporator for pressurization. Before the pump is put into operation for the first time and after maintenance, and when the pump is in a standby state, it is necessary to pre-cool or keep cold. After the pump is out of service, if the cooling is not well maintained, with the increase of heat leakage, the LNG in the pump will gradually evaporate, and the concentration of $CO_2$ dissolved in the LNG will increase relatively. flow path, or even make the pump unable to operate normally.

## 2.4 LNG evaporators (gasifiers)

It can be divided into plate-fin type, shell-and-tube type, medium-flow type, open-frame type and submerged combustion type according to different structures or heat sources. LNG receiving terminals mostly use open-frame water spray evaporators and submerged combustion evaporators. The former uses seawater as the heating medium, which is bulky and needs to be equipped with a seawater system, so the investment is high, the floor space is large, but the operating cost is low, and it is safe and reliable. For basic load air supply requirements, multiple units can be used in parallel. The latter uses terminal BOG as fuel and adopts combustion heating, which has the advantages of low investment, fast start-up and rapid adjustment of LNG evaporation, but high operating costs and is usually only used for peak regulation.

In the open-frame water spray evaporator, LNG flows vertically from bottom to top in the tube bundle plate with fins, and seawater is sprayed from top to bottom outside the tube bundle plate. In order to avoid affecting the ecological balance of the surrounding sea area, the temperature difference between the inlet and outlet of seawater should not exceed 7°C, and it is usually controlled within 4-5°C in practice. The common material of the tube bundle plate is aluminum alloy, and the outer layer is coated with zinc. Submerged combustion evaporators include heat exchange tubes, water baths, submerged burners, combustion chambers and blowers, etc. The burner burns on the water surface of the water bath, and the hot flue gas is discharged into the water in the water bath by the sprayer through the lower exhaust pipe, which makes the water highly turbulent. The LNG in the heat exchange tube and the highly turbulent water outside the tube fully exchange heat, so that the LNG is heated and evaporated. The thermal efficiency of this evaporator can reach more than 95%, and it is safe and reliable.

## 2.5 Evaporated gas compressors

Since the LNG storage tanks have different amounts of evaporated gas under different working conditions, the evaporated gas compressors should be divided into two groups. One set is for non-ship unloading conditions and one set is for unloading conditions. Usually reciprocating or centrifugal. The former is suitable for small air volume and high compression ratio, while the latter is suitable for large air volume and medium and low compression ratio.

## 2.6 Recondenser

The recondenser has two functions: condensation and liquid separation. Under normal circumstances, the evaporated gas from the storage tank is liquefied; when the amount of evaporated gas increases, the uncondensed evaporated gas is separated into liquid and discharged to the torch; when the amount of evaporated gas is insufficient, a small amount of external gas can be introduced to the recondenser to make it Pressure remains normal.