The general design of a LNG-terminal

Project MAGALOG (Marin Gas Logistics) is a contribution to addressing port emission problems in Europe, with a special focus on the Baltic Sea, through the establishment of an alternative fuel (LNG or Liquefied Natural Gas) supply chain. The project is part financed by the European Commission under the "Intelligent Energy Europe" programme.

As a part of the MAGALOG project five harbours in the Baltic Sea area will be studied to investigate the possibilities to establish LNG bunkering terminals in these harbours. This article gives an introduction to the technical design for a small scale LNG terminal designed to supply natural gas as a fuel to ships.

Background

The most common way to transport natural gas is by pipelines, and in most countries in Europe there is a well established gas grid. This grid is in turn supplied with transmission pipelines from the gas fields. LNG (Liquefied Natural Gas) has been developed as a supplement to the gas grids for storage and transportation purposes. When natural gas is cooled below -160°C, the methane becomes liquid and are compressed 600 times compared with gas form. Thus LNG is a space efficient way to store and transport natural gas when pipelines are not a feasible solution.

Norway is a country with deep fjords, high mountains and scattered population. This means that natural gas can not be distributed to the whole country by pipelines in a cost-effective way. As an answerer to this challenge there are developed a technology for small scale LNG distribution. This includes liquefaction plants for production of LNG, small scale LNG ships and road trucks for transportation, and dedicated end user LNG terminals for storage.

The LNG distribution system was developed with industrial customers in mind, but this technology has also made it possible to make use of natural gas as a ship fuel in the form of LNG. Today there are several ships operating with LNG as fuel, and there are constructed several LNG terminal with the purpose of supplying ships with this fuel.
Storage tanks

Fore the storage of LNG there are used cylindrical pressurised tanks. Because of LNG’s low temperature they are built as double shell vessels with highly effective powder-vacuum or multi-layer-vacuum insulation, which ensures long time storage with limited vaporization.

The tanks are produced in a variety of dimensions and capacities depending on the storage purpose. The storage in a bunkering terminal for ships will consist of tanks with a capacity of 500 to 700m$^3$ LNG. These tanks will have a length of about 35 meters and a diameter of about 5,5 meters. In a terminal the tanks are placed in series according to the storage capacity required. Terminals can also be design so that capacity can be increased over time by adding storage tanks.

Filling line

An insulated pipeline transports LNG between the storage tanks and the ship. The same pipeline is used for the supply of LNG from a LNG freighter to the terminal and the bunkering of a vessel from the terminal. Because the pipeline is transporting a cryogenic liquid the distance between the terminal and the quay should be as short as possible to minimize boil off. The range should preferably not exceed a maximum of about 250 meters.
The pipeline between the quay and the terminal can be placed in an underground culvert and thus allow other activity in the quay area when not bunkering are taking place.

Quay

The quay in use must meet the requirement from the ship supplying the terminal with LNG and preferably also the ships calling at the harbour that is potential users of LNG as fuel. Generally the quay should have a water depth of 10 meters.

One of the ships which will supply LNG to the terminals are the Coral Methane. It has the capacity to transport $7500m^3$ LNG.

The requirements of the ships that will be bunkering LNG must be considered in each case, especially the requirements of passenger ferries and freighters in fixed returning routes, but the quay should also be able to offer bunkering to normal freight vessels which calls to obtain bunkering service. However, if there are potential users that can not access the quay, dedicated intermediate storage solutions could also be considered.

The most feasible solution is to use existing quays so that investments in new quays can be avoided. The quay area can be used for other purposes when unloading or bunkering of LNG is not taking place. If an existing quay not can be used and new investments are necessary, a duc d'albe solution could be used instead of a full scale quay structure in order to reduce investments.

Gasification unit

When there are delivery of gas from the LNG-terminal into a gas grid or to a nearby gas customer, the LNG are heated and transformed from liquid to gas form. For the heating there are normally used air based evaporators. This is a stable an efficient way of heating the gas.
Alternative solutions are the use of excess heat from industry if that is available nearby. Automation systems and pressure regulators ensure proper gas pressure and temperature in the downstream pipelines.

The air based evaporators are operated in two alternating sets, with one set defrosting while the other is in operation. The size and number of evaporators depends on the output effect required from the terminal.

**Local transportation of LNG**

LNG can be transported from the terminal to ships elsewhere in the harbour, nearby industries or also other harbours in the region with LNG semi-trailers. The trailers have cryogenic tanks constructed after the same principles as the terminal storage tanks. Distribution of natural gas in the form of LNG on road trucks is well established in Norway, and is used to supply a range of industrial and other customers. The trucks in operation in Norway have a transport capacity of 50m³ LNG, but this can vary according to different national transport regulations.

Not all shipping routes can call at a bunkering facility for the bunkering. For instance Ropax vessels, such as passenger ferries with daily crossings, will depend upon the bunkering taking place at the ferry terminal. There are established procedures for bunkering of ships directly from semi-trailers that are in operation on passenger ferries in Norway today. Another solution can be that LNG is stored at a smaller buffer tank dedicated for the ship in question, and that this buffer tank is supplied with trailer from the main terminal.

**Terminal lay out**

A standard LNG-terminal for bunkering purposes will have a lay out with five 700m³ tanks in series. The gross storage capacity will be 3500m³ LNG which is equal to 2 millions Sm³ of natural gas or 20 GWh energy. The size of this installation will be about 50 by 50 meters. This standard lay-out will be adapted to local conditions such as capacity required, available
area and the form of delivery from the terminal. There is also possible to prepare the terminal for increased capacity by preparing for installation of additional storage tanks.

The terminal is built with all connections and valves in one side and, for safety purposes, there are built an accumulation pool in this end of the terminal. In the low probability of a leakage of LNG the liquid will be collected in this pool. There will be a safety zone of about 30 meters radius around accumulation pool. In this zone there will be restrictions on other activity that can involve ignition sources.

![Figure 1 Standard terminal lay-out with five 700m3 storage tanks.](image)

From the terminal there is a pipeline connection to the filling point at the quay and there is a new safety zone around the filling point. There is also an evacuation zone of 100 meters around the terminal. This area will be evacuated in the case of an incident at the terminal.
If there will be deliveries of gas into the local gas grid or to a local on shore consumption the terminal design will include evaporators for the heating of LNG and transforming to gas. Further, if there will be a regional distribution of LNG, the terminal will be equipped with a filling station for LNG road trucks. Figure 3 shows a lay out of a terminal with air based evaporators and a filling station for road trucks.

Figure 2 Terminal lay-out with pipeline and filling point at the quay.

Figure 3: Terminal with evaporators and truck filling.
The technology in this terminal design is used in over 30 terminals in operation in Norway today. Storage capacity, services offered and lay out are design options that vary and will be adjusted to local conditions in each new case, but the main principles are the same.

The picture shows an example of a standard terminal lay out in operation. This terminal is built in Mosjøen in Norway and the supply of LNG to the terminal is done by ship. The main purpose of this terminal is to supply natural gas to an aluminium plant located near by, but the terminal is also prepared for further regional distribution of LNG by road trucks.

**Safety**

LNG has been transported and used safely worldwide for roughly 40 years and the industry has an excellent safety record. In Norway there are today over 30 small scale LNG terminals in safe operation.

The physical and chemical property of LNG determines the level of reliability and the hazards that are taken into consideration. LNG is odourless, non-toxic, non-corrosive and less dense than water. LNG vapours (primarily methane) are harder to ignite than other types of flammable liquid fuels. Above approximately -110°C LNG vapour is lighter than air. If LNG spills on the ground or on water and the vapour does not encounter an ignition source, it will warm, rise and dissipate into the atmosphere. Because of these properties, the potential hazards associated with LNG include heat from ignited LNG vapours and direct exposure of skin or equipment to a cryogenic (cold) substance.

The handling of LNG is reliable and safe do to LNGs low temperature, high ignition temperature and narrow range of ignition concentration. Further the operations are conducted according high safety standards. The terminals are designed, built and operated according the standard CEN EN 1473 Installation and equipment for liquefied natural gas - Design of onshore installations, and the Council Directive 96/82/EC on the control of major-accident hazards involving dangerous substances.