Enabling the safe storage of gas onboard ships with the Wärtsilä LNGPac

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The use of liquefied natural gas (LNG) as a marine fuel has taken on added significance as a result of the IMO's stringent requirements concerning emissions from ships. The safe and convenient onboard storage of LNG is ensured by the Wärtsilä LNGPac system.

In October 2008, the IMO finalized its revision of the Marpol Annex VI – the Prevention of Air Pollution from Ships. The stringent requirements thus introduced concern mostly the sulphur oxide (SO_X) and nitrogen oxide (NO_X) emissions from the exhaust gases. However, the IMO is also working on other measures intended to reduce greenhouse gases from shipping.

Wärtsilä dual-fuel engines in gas mode produce roughly 80% less NO_X compared to IMO Tier I levels and practically zero SO_X and particulates, and are, therefore, compliant with the most stringent regulations. Moreover, when gas is used in a dual-fuel engine, CO_2 emissions are reduced by about 20% compared to liquid fuels.

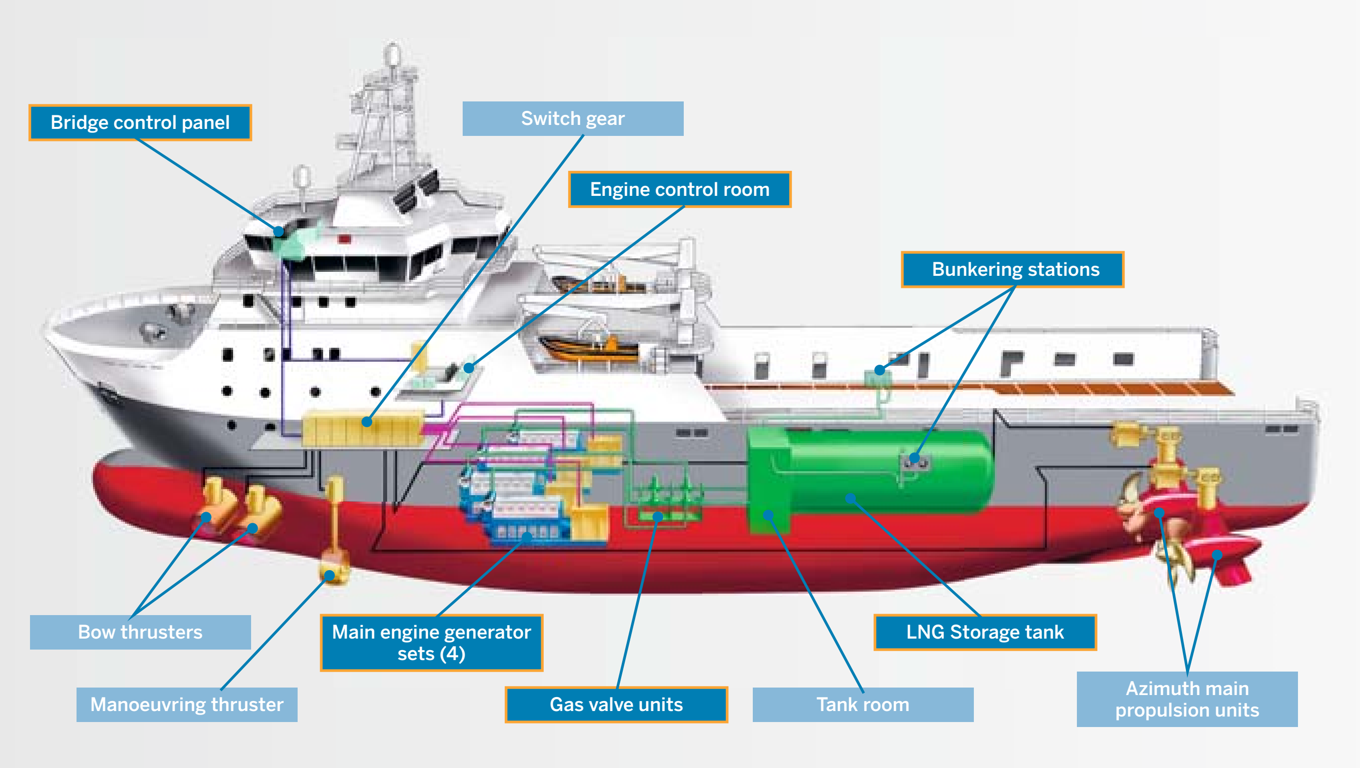
In addition to the environmental issues, the use of LNG as a marine fuel has positive effects on a ship's operating costs. Depending on the initial purchase price, the LNG used to power ship engines can be expected to have a similar, or slightly higher, price per energy content than heavy fuel oil.

The handling of gas in a safe way is, of course, of great importance. It requires the adequate integration of the entire chain, from the bunkering stations at shipside to the engine inlet, until the stored hydrocarbon energy is finally converted into power. Wärtsilä's LNGPac system ensures that the safety aspects onboard ship are handled by one single qualified supplier. The development of LNGPac is supported by Wärtsilä's Ship Power system integration capabilities.

Key features

The design philosophy of the LNGPac has been to focus on safety and simplicity.

Fig. 1 – The LNGPac system layout.



From the beginning, the emphasis has been on a complete system approach and on achieving a seamless interface with other Wärtsilä products and systems.

The LNGPac is designed according to the IMO's recently published "*Interim Guidelines on Safety for Natural Gas-Fuelled Engine Installations in Ships*" (Resolution MSC285-86).

The system includes the key components described below and shown in Figure 1.

Bunkering station(s)

This is the ship's connection with the LNG terminal on shore or with the LNG bunkering barge. Each station includes one bunkering line (LNG line), one return line, and one nitrogen purging line with respective control/thermal relief valves (pressure safety valves) and flanges. The return line is used in case the bunkering operation takes place with two hoses connected, and the evaporated gas is returned to the bunkering terminal or barge. During bunkering operations, LNG could evaporate due to heat leakages in the piping and/or due to the higher temperature in the storage tank onboard compared to the refilling tank.

LNG vacuum insulated pipes

From the bunkering station, LNG is led to the tank via insulated pipes. Vacuum insulation is selected for its excellent insulation properties, and to minimize LNG evaporation during bunkering.

LNG tank

The pressurized storage tank is cylindrically shaped with dished ends.
The tank is designed in accordance with the IMO IGC Code, the *"International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk"*, and EN 13458-2 *"Cryogenic vessels. Static vacuum insulated vessels"*.

LNGPac tanks are insulated with perlite/vacuum. The tank consists of a stainless steel inner vessel, which is designed for an internal pressure, and an outer vessel that acts as a secondary barrier. The outer vessel can be made of either stainless steel or carbon steel.

According to the current IMO Guidelines, the LNG fuel tanks have to be selected from among the "Independent Types A, B, or C". The LNGPac is designed according to Type C requirements.

A summary of the main characteristics of the independent tank types is shown in Table 1.

As summarized in Table 1, the pressure vessel (as selected for LNGPac) allows easy handling of the evaporated gas (boil-off), since the tank is designed to withstand a significant pressure increase and the pressure relief valves are set at 9 bar(g). In practice, vessels can operate for a long time in liquid fuel mode (HFO or MDO) before having to take care of the pressure increase in the tank. The handling of the boil-off is done very simply by a temporary switch over of the engines to gas mode, and the gas is taken from the vapor phase in the upper part of the tank. As an indication, a 200 m^3 pressurized type C tank, filled at 50% could hold LNG for about 25 days, even without any gas consumption from the tank.

A Wärtsilä dual-fuel engine requires approximately 4 – 5 bar(g) at the inlet of the gas valve unit. In case LNG is stored at atmospheric pressure (Type A and Type B tanks), the fuel system should include either compressors or cryogenic pumps to deliver the fuel at the correct pressure.

Process skid and tank room

The process skid includes all the connections and valves between the tank and the *Pressure Build-Up Unit* (PBU) and the *Product Evaporator*, together with the evaporators themselves.

The PBU consists of an insulated pipe, an evaporator, valves, a single wall pipe and sensors. The mission of the PBU is to build up the pressure in the tank after bunkering LNG and to maintain the required pressure in the tank (around 5 bar(g)), during normal operation. Maintaining the correct pressure in the tank ensures that the Wärtsilä dual-fuel engines are able to meet the maximum power (100% MCR) at any time. Since the LNGPac system doesn't have any cryogenic pump or compressor, the engine gas inlet pressure requirements are met by achieving the correct storage pressure inside the LNG tank. The circulation of LNG to the PBU evaporator is achieved by the hydrostatic pressure difference between the top and bottom of the tank, with LNG from the bottom of the tank being fed to the evaporator. The evaporated gas is then returned to the top of the tank. The natural circulation through the PBU continues until the required pressure in the tank is achieved. →

Table 1 - Comparison of IMO IGC[1] independent tanks.

Tank Type	Description	Pressure	Pros	Cons
A	Prismatic tank adjustable to hull shapes. Full secondary barrier	< 0.7 bar(g)	Space efficient	■ Boil-off gas handling ■ More complex fuel system (compressor required)
B	Prismatic tank adjustable to hull shapes. Partial secondary barrier	< 0.7 bar(g)	Space efficient	■ Boil-off gas handling ■ More complex fuel system (compressor required)
	Spherical (Moss type). Full secondary barrier	< 0.7 bar(g)	Reliable/proven system	■ Boil-off gas handling ■ More complex fuel system (compressor required)
C	Pressure vessel (cylindrical shape with dished ends)	> 2 bar	■ Allows pressure increase (easy boil-off gas handling) ■ Very simple fuel system ■ Little maintenance ■ Easy installation	■ Space demand on board the ship

[1]IMO IGC code = International code for the construction and equipment of ships carrying liquefied gases in bulk.

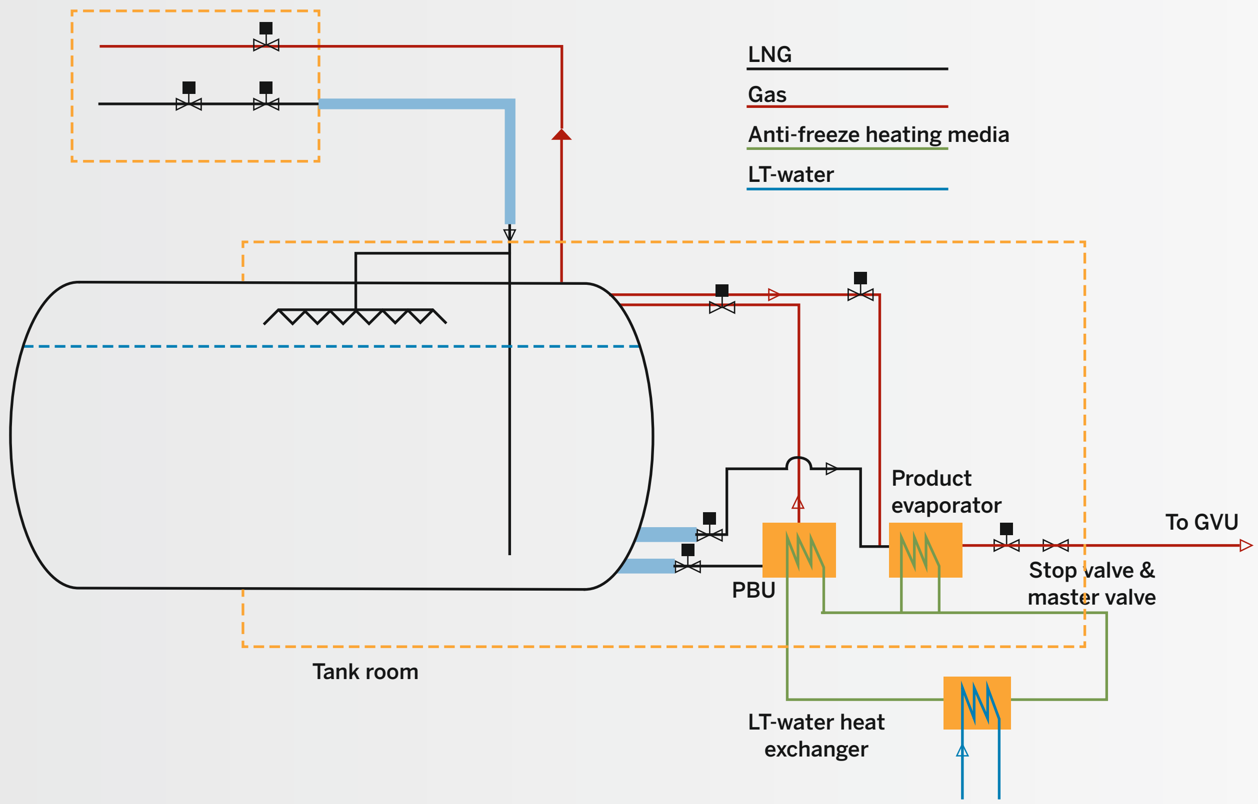


Fig. 2 – LNGPac simplified P&ID.

Table 2 – The LNGPac tank range.

Type		LNGPac 105	LNGPac 145	LNGPac 194	LNGPac 239	LNGPac 284
Geometric volume	[m3]	105	145	194	239	284
Net volume (90%)	[m3]	95	131	175	215	256
Diameter	[m]	3.5	4.0	4.3	4.3	4.3
Tank length	[m]	16.7	16.9	19.1	23.1	27.1
Tank room	[m]	2.5	2.5	2.7	2.7	3.0
Total length	[m]	19.2	19.4	21.8	25.8	30.1
LNGPac empty weight	[ton]	47	62	77	90	104
Tank full weight	[ton]	92	125	161	195	228
LNGPac max operating weight	[ton]	94	127	164	198	231
Theoretical Max. Autonomy	[MWh]	244	318	427	525	625

* Includes an estimate of the process skid weight.

The *Product Evaporator* circuit consists of an insulated pipe, an evaporator, valves, a single wall pipe, and sensors. The task of the product evaporator is to evaporate the LNG into gas and heat it to a minimum of 0°C as per engine specifications. The gas is then fed to the gas valve unit before the engines.

Both the PBU and *Product Evaporator* are heated by a water/glycol mixture, which is re-circulated to an external cooler. Here, the mixture is heated by the waste heat from the low temperature engine cooling water circuit.

The process skid has a modular design, making it easy to be selected and assembled for the entire LNGPac product range. The key parameters influencing the modularization of the process skid are the sizes and volume of the tank, and the engines (model and number) connected to the tank.

The tank room is a stainless steel barrier welded to the outer vessel of the tank. The structure contains the process skid and all the pipe penetrations to the tank. In the unlikely event of an LNG leakage, the tank room acts as a barrier that avoids damage to the external compartments, and facilitates the quick ventilation of the evaporated gas. The tank room and ventilation system are to be fire protected to A-60/A-0 insulation class, depending on the safety designation of the adjacent space.

Automation

The LNGPac control system is based on Wärtsilä's vessel automation system platform. When combined with the Wärtsilä Integrated Automation System (IAS), the same hardware and Human Machine Interface can be used throughout the vessel to operate the LNGPac, the dual-fuel (DF) engines, and the propulsion system. In addition, separately delivered features typical of DF-engine applications, have been incorporated into the Wärtsilä IAS. These include the Wärtsilä Operator's Interface System (WOIS), Condition Based Maintenance (CBM), and monitoring of IMO Tier III* compliance in Emission Control Areas.

The core of the control system is a PLC cabinet placed in a safe area near the tank room. All LNGPac transmitters and intrinsically safe sensors, as well as all interfaces to external systems such as fire & alarm, gas detection, etc., originate from the cabinet. The pneumatic valves are controlled by solenoids placed in a safe area adjacent to the tank room and bunkering station(s).

In the case of ships retrofitted with LNGPac, the control system is able to operate as a separate system with monitors on the bridge and ECR (Engine Control Room), or by being integrated into the existing system.

The LNGPac portfolio

LNGPac will be offered in various configurations that allow the installation of multiple tanks and gas valve units (GVUs), i.e. multiple engines. Table 2 below illustrates the most straightforward configuration (i.e. single tank installation).

Inherent redundancy of the dual-fuel technology

The superior redundancy and reliability of the dual-fuel technology has been taken into consideration by authorities when developing their rules for the use of gas as fuel on board ships. The possibility of switching over from gas to liquid fuel is considered as a valid methodology to achieve 100% redundancy in case of a leakage or a failure in the gas supply system.

The main redundancy requirements are summarized as being:

- For single fuel installations (gas only), the fuel storage should be divided between two or more tanks of approximately equal size. The tanks should be located in separate compartments (Resolution MSC 285-86, 2.6.2.3).
- In the case of leakage in a gas supply pipe making shutdown of the gas supply necessary, a secondary independent fuel supply should be available. Alternatively, in the case of multi-engine installations, independent and separate gas supply systems for each engine or group of engines may be accepted. (Resolution MSC 285-86, 2.6.2.2). →

* The Wärtsilä DF engine portfolio fulfils IMO Tier III in gas mode.

LNGPac 280	LNGPac 308	LNGPac 339	LNGPac 402	LNGPac 440	LNGPac 465	LNGPac 520	LNGPac 527
280	308	339	402	440	465	520	527
252	277	305	362	396	419	468	474
4.8	4.8	5.0	5.0	5.6	5.0	5.6	5.0
21.3	23.4	23.5	27.5	23.8	31.5	27.8	35.5
3.0	3.0	3.0	3.0	3.0	3.5	3.5	3.5
24.3	26.4	26.5	30.5	26.8	35.0	31.3	39.0
105	113	119	135	142	152	162	168
229	248	267	312	336	357	392	401
233	252	271	316	340	362	397	406
616	677	745	884	967	1022	1143	1159

Note: Data reported in the table are indications only and can be subject to change.

For an installation with engines able to run only on gas, the redundancy requirements can be met either by installing double LNG tanks and fuel systems, or by installing additional diesel generators. The generators must provide sufficient power during shut-down of the gas system.

If there is sufficient space onboard the vessel for one LNG tank, dividing the tank volume will result in increased, higher complexity, and reduced holding time due to increased heat leakage into the tank.

For installations without dual-fuel engines, the requirement of a secondary independent fuel supply system has been typically fulfilled by installing back-up generators running on liquid fuel (diesel or HFO). Depending on the vessel propulsion configuration, for instance diesel electric or mechanical propulsion, the classification rules of redundant propulsion or emergency propulsion can be applied in order to achieve the required redundancy level. As a consequence, the total installed power onboard a ship without dual-fuel engines might increase considerably, since separate gas burning engines and engines running on diesel fuel are installed simultaneously. The amount of auxiliary power may, therefore, increase considerably as compared to where the power requirements would be those of the hotel load only.

A reference group of installations where redundancy has been met by installing both engines capable of burning gas, and engines running on diesel is shown in Table 3. For this group of vessels, the ratio between installed diesel engines power and installed gas engines power varies from 10% up to 161%; the emergency generators have been excluded from the calculation. Despite the higher amount of installed power, the complete propulsion plant cannot be run at full load on both fuels.

Conversely, in LNG carriers and offshore supply vessels equipped with Wärtsilä dual-fuel engines, no prime movers other than the DF engines were installed. Thanks to the inherent fuel flexibility of the dual-fuel technology, the complete vessel power needs can be fulfilled by gas or liquid fuel (even liquid biofuel if requested).

Furthermore, there are a number of operational reasons that favour a high degree of fuel flexibility:

- During bunkering, local authorities may require that the vessel not be operated on gas.
- The availability of LNG during operation cannot be guaranteed.
- Inadequate LNG storage volume for transit from shipyard to end user (for example from China to Europe).
- Options of fuel choice to the operator or owner decision based on fuel prices.

As a conclusion, it is possible from both a technical and regulatory standpoint to build a vessel without diesel back-up generators and without redundant tanks/gas supply system. A safe and cost efficient approach is to select Wärtsilä dual-fuel engines and the LNGPac storage system.

Table 3 – Reference group of gas-fuelled ships with diesel generators installed for redundancy.

Vessel-type	Gas engines [kW]	Diesel engines [kW]	Propulsion power [kW]	Ratio diesel engine/gas engine installed power [%]
A	2 x 2600 2 x 3400	2 x 600	4 x 2750	10%
B	1 x 5250	2 x 720	5250	27%
C	2 x 900	1 x 1000	2 x 2000	56%
D	3 x 900 1 x 676	1 x 4000 1 x 400	6500	77%
E	2 x 2380	2 x 3840	2 x 5000	161%