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GUIDANCE ON LNG – BoG MONITORING

1 PURPOSE

This paper provides guidance to the verifier and the company for the on-onboard monitoring of boil off gas (BoG) and recording of data for the purpose of monitoring of fuel consumption required by Regulation (EU) 2015/757.

2 BACKGROUND

As required by the Regulation (EU) 2015/757, Annex-1 (Methods for monitoring CO_2 emissions), the company shall define in the monitoring plan which monitoring method is to be used to calculate fuel consumption for each ship under its responsibility and ensure that once the method has been chosen, it is consistently applied. However, the `Method A` states that `This method shall not be used when BDN are not available on board ships, especially when cargo is used as a fuel, for example, liquefied natural gas (LNG) boil-off [1].
Since BDN cannot be used for the BoG therefore, it is important for the verifier and the company to ensure that BoG measurement, calculation and documentation is in accordance with in fact use and is accurate, relevant and consistent.

LNG tankers are designed to carry natural gas in liquid form at a temperature of about - 163°C, close to the vaporization temperature. Despite that tank insulation is designed to limit the admission of external heat, even a small amount of it will cause slight evaporation of the cargo. This natural evaporation, known as “natural boil-off” (NBoG) is unavoidable[2] and has to be removed from the tanks in order to control / limit the cargo tank pressure. Typical values are about 0.15%/day and below, recent projected LNG carriers are offered with a NBoR close to or even beneath 0.1%[3].

Where insufficient NBOG volumes are available for propulsion, forced vaporization of LNG can be effected or otherwise liquid fuel (HFO /MDO/MGO) can supplement the additional energy demand. The force vaporized LNG is called Forced Boil Of Gas (FBOG). The NBOG and the FBOG will be collectively called BOG in this paper.

Boil-off gas (BoG) handling systems (known as Gas Management Systems) are typically used onboard LNG carriers as a means of pressure and temperature control. BoG is sent to the engine room via gas heaters by low capacity compressors and is burned by the main boilers or nowadays by dual fuel diesel engines as fuel.

On steam turbine powered vessels, the main boilers are capable of operating under different fuel combustion modes such as exclusively BoG mode (NBoG or NBoG + FBoG), combined BoG and fuel oil mode, and exclusively fuel oil mode. Although steam turbine systems have been the main form of propulsion used onboard LNG carriers and still comprise a large percentage of the operating LNG fleet, diesel engines capable of using BoG as fuel have become a preferred solution due to their higher operating efficiencies.

LNG carriers with diesel engines are required[4] to have a “Gas Combustion Unit” onboard. This GCU acts as a secondary means of controlling the tank pressure, in particular to cater for certain conditions like bad weather causing excessive NBoG generation, the temporary

[1] Use of cargo as fuel may apply to other low flash point hydrocarbons like Ethane, LPG, etc.
[2] with the exception of vessels with re-liquefaction capability
[3] it may be noted that first boil-off phases contain almost exclusively nitrogen which has no calorific value for combustion
[4] to fulfil the “historical 2 times 100% BoG capacity rule”

inability of the engines to burn gas or at engines' low load operation lower than what is required to consume the available NBOG for propulsion and other services or when the vessel is idle. The flow to the GCU is to be included in the amount "consumed". In general, GCU's are equipped with flowmeters. However, there might be other uses for the GCU which may cause conflicts, e.g. when preparing for dry-dock, contaminated BoG / inert gas mixture is disposed off in this unit.

On the Steam LNG Carriers if the required energy for propulsion and other services drops below the energy available by the BOG, the main boilers continue to consume the available BOG and the excess steam generated is dumped directly into the condenser.

The natural Boil-off rate (BoR) is the amount of liquid that is evaporating from a cargo and expressed in % of total liquid volume per unit time.

It shall be noted that the MRV regulation requires the reporting for LNG carries has to be done as follows:

- LNG cargo carried onboard to be reported in VOLUME units
- LNG consumed onboard as fuel to be reported in MASS units

It should be noted that a number of LNG carriers are equipped with re-liquefaction systems which depending on the capacity can partially or fully re-liquefy the NBOG and send it back to the cargo tanks.

3 RESPONSIBILITIES

Usually the Master has overall responsibility for the monitoring of ship's bunker consumption and BoG use / consumption. This will be described in detail in company´s management procedures.

4 A GENERIC BoG HANDLING SYSTEM ONBOARD LNG VESSELS

The following diagram shows a generic ships BoG fuel oil system.

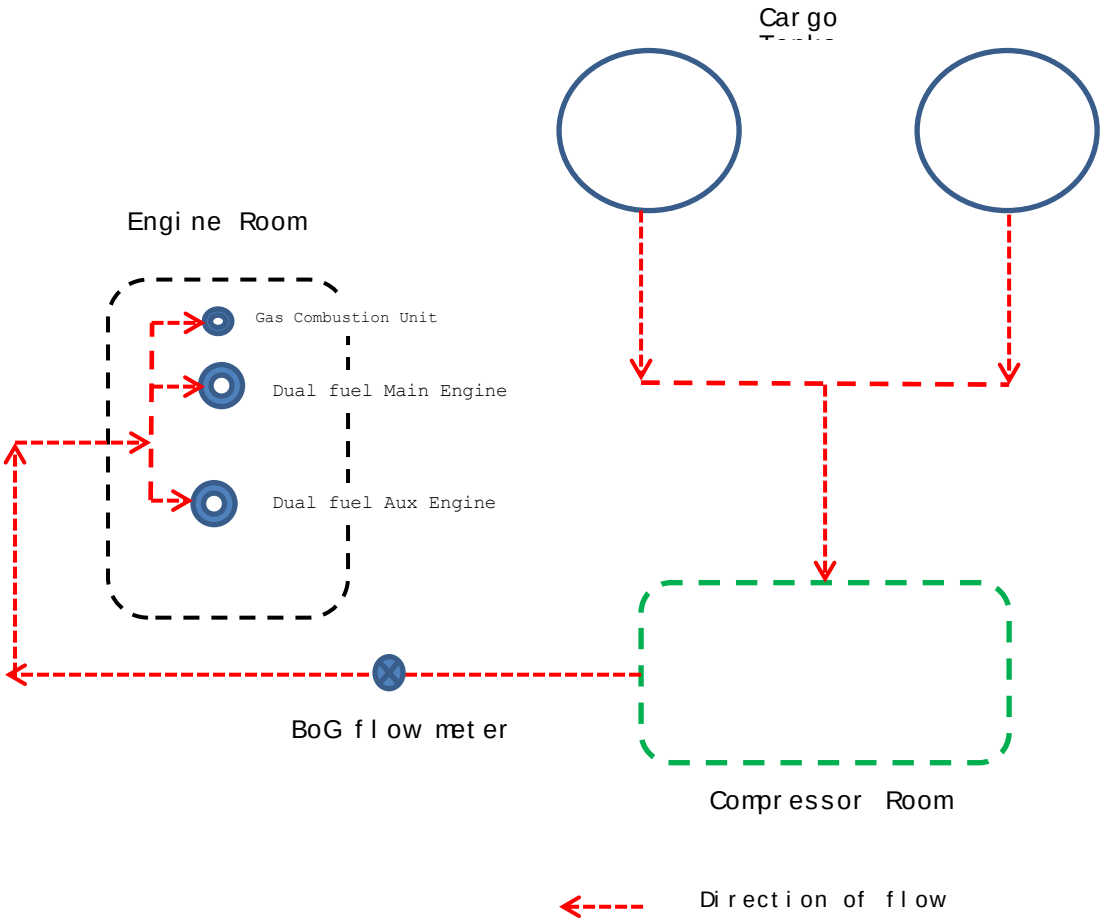

Figure 1: a generic ships BoG fuel oil system

5 BoG MEASUREMENT AND MONITORING

The BoG can be measured by calculating the total LNG consumed for a voyage by custody transfer measurement system (CTMS) or by flow meters (onboard).
CTMS systems are the predominant systems available for all LNG carriers. They are used for determining the amount of cargo loaded or discharged and they have universally accepted with commercial relevance and are typically third-party verified.

a) Calculating BoG quantity by CTMS

Cargo consumed on the passage is calculated by using the “CTMS closing” (final volume on board at the loading terminal upon completion of loading) and “CTMS opening” (total volume upon arrival at the discharge terminal just before commencement of discharging) figures.

CTMS measures the volume of cargo in the tanks and further calculations convert the volume to weight / mass at the reference temperature. Therefore, the BoG is calculated as the difference between “CTMS closing” figure at the loading port and the “CTMS opening” figure at the discharging port.

In case of cargo discharge at several locations in a port of call, the discharged volumes have to be aggregated. In case of further discharges in other ports of call (in other words: during the subsequent voyages), the volumes discharged in these ports have to be added to the discharged volume, until new cargo is loaded.

On the ballast passage LNG carriers may maintain a comparatively small amount of LNG called “the heel” which can be used as fuel and/or for maintaining the cargo tanks in cold state ready to be loaded at the next loading port, using the same methodology as for the laden passage consumption.

b) Calculating BoG quantity by flow meters

If it is chosen to measure the BoG with flow meters (pls. refer to Figure 1) instead of measuring through the CTMS, the BoG is measured either in volume and then converted to mass using appropriate density, pressure and temperature corrections or measured directly in mass (Coriolis type flow meters).
Flow meters are typically installed on the BoG supply lines to the main boilers, diesel engines and the GCU as the case may be. The sum of all such flow meters determines the total BoG consumed

In cases where the BoG is measured via onboard volume flow meters, the method to convert volume to weight (e.g. using the composition of the cargo at load port for deriving its density and converting volume to mass) will be decided by the Company and described in the company’s management procedures. Bases on this method, the BoG used to fuel the ship during the voyage will be determined.

Shipping companies may determine the LNG vapour density for onboard flow meters using standard temperature of 15°C and at vapour space conditions ρ_{vt} by the following calculation based upon ideal gas laws [5]:

$$\rho_{vt} = \frac{T_s}{T_v} \cdot \frac{T_v}{T_s} \cdot \frac{M_m}{I} \quad \left[\frac{kg}{m^3}\right]$$

Where:

T_s is the standard temperature of 288 K (15°C)
T_v is the average temperature of vapour in degrees in Kelvin
P_v is the is absolute pressure of vapour space in bar
P_s is the standard pressure of 1.013 bar
M_m is the molecular mass of vapour mixture in [kg/k mol] (provided from industry tables or from shore)
I is the ideal gaseous molar volume at standard temperature (288 K) and standard pressure (1.013 bar) = 23.645 [m^3/k mol]

Note: An accurate knowledge of the vapour composition in deriving M_m is not necessary and the deviation of saturated liquid gas vapours from the ideal gas laws is usually ignored

[5] the formula is derived from SIGTTO publication:
'Liquefied Gas Handling Principles on Ships and in Terminals' (LGHP4) 4th Edition, Section 8.5.2S

The amount of BoG consumed at berth may be derived by the flow meters installed on the piping supplying gas to the consumers (engines, boilers, etc.).

However, for the consumption in ports, the CTMS (opening and closing) might not in all cases reveal the full picture. Therefore, flow meters are the favourable alternative for port consumption. In particular, the shore meters of the Vapour Return line are useful to mention in this context as they are a commercial method which is applied, accurate and typically verified by a specialized 3rd party. Usually, the commercial calculation process does explicitly calculate the amount (the balance) consumed by the ship during the cargo operations.

6 ACCURACY AND CALIBRATION OF MEASURING EQUIPMENT

All measuring equipment used for the monitoring should be maintained in good order and calibrated or certified for "fitness of purpose" in accordance with the maker's guidance. Further information on maintenance procedures or in correlation with the PMS should be provided from the shipping company.
A copy of maintenance records and / or the calibration certificate should be kept on board.

7 Other relevant considerations

Existing EU legislation, namely the DIRECTIVE (EU) 2016/802 relating to a reduction in the sulphur content of certain liquid fuels and more specifically the Commission Decision 2010/769/EU allow LNG carriers to use a specified BoG mixture as an equivalent abatement method to the low sulphur content oil-based fuels i.e. for sulphur compliance reasons. For this purpose, it is required by *Article 4* of Commission Decision 2010/769/EU that these ships are equipped with continuous monitoring and metering of the boil-off gas and marine fuel (i.e. pilot fuel) consumption.

More recently, the European Commission and EU Member States (through the Committee on Safe Seas and the Prevention of Pollution from Ships (COSS)) agreed, under certain circumstances (ship-specific design, operational profile & predefined BoG mixtures) on an extension to this equivalence also for propulsion purposes while sailing in the SECA.

Thus, it should be assumed that all the LNG Carriers that would trade in the EU and planning to use BoG and marine fuel mixture as an abatement method, are already equipped with such continuous measuring/metering devices plus related recording logs.

Appendix

Abbreviations

BDN	Bunker Delivery Note
BoG	Boil off Gas which can be Natural NBoG or Forced FBoG
NBoG	Natural Boil off Gas
FBoG	Forced Boil off Gas
BoR	Boil-off rate
CTMS	Custody Transfer Measurement System
COSS	Committee on Safe Seas and the Prevention of Pollution from

	Ships
ESSF	European Sustainable Shipping Forum
GMS	Gas Management Systems
HFO	Heavy Fuel Oil
IMO	International Maritime Organisation
LFO	Light Fuel Oil
LNG	Liquefied Natural Gas
MARPOL	International Convention for the Prevention of Pollution from Ships
MDO	Marine Diesel Oil
MEPC	Maritime Environmental Protection Committee
MGO	Marine Gas Oil
NG	Natural Gas
PMS	Plant Management System Planned Maintenance System
RO	Recognised Organisation
ROB	Remaining fuel on Board (Liquid fuel or LNG)
SECA	Sulphur Emission Control Area
SEEMP	Ship Energy Efficiency Management Plan
SMS	Safety Management System