The Best LNG Carrier for the Environment SAYAENDO UST: Capable of Gas-Only Combustion in All Operations

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In response to the recent trend towards progressively more stringent environmental regulations for exhaust emissions from vessels, liquefied natural gas (LNG)-fueled vessels have started to emerge. As LNG carrier vessels fitted with steam turbine propulsion plant produces a low level of nitrogen oxide (NOx), they can stay ahead of planned NOx and sulfur oxide (SOx) emission regulations by using the LNG cargo as the fuel source. However, such LNG carriers currently adopt the dual-fuel combustion method (gas and fuel oil) in order to achieve a stable load following while maneuvering operation, where significant load fluctuations occur. This article describes new gas-only combustion technology that enables safe maneuvering operation with superior economic efficiency.

1. Introduction

As shown in **Figure 1**, environmental regulations for exhaust emissions from vessels are becoming more stringent. Particularly strict restrictions have been adopted in the Emission Control Areas (ECA) designated by each country. These controls focus mainly on SOx and NOx. To adhere to SOx emission rules, use of low-sulfur fuels or installation of desulfurization equipment is being considered. With LNG carriers, however, SOx-related regulatory compliance is possible by using the LNG cargo as the fuel. NOx emission control strategies require installation of NOx removing equipment and use of exhaust recirculation systems for conventional vessels with diesel engine propulsion. Meanwhile, NOx emissions generated in the main boilers of LNG vessels with turbine propulsion plants are significantly low and thus have not been made subject to NOx regulations.

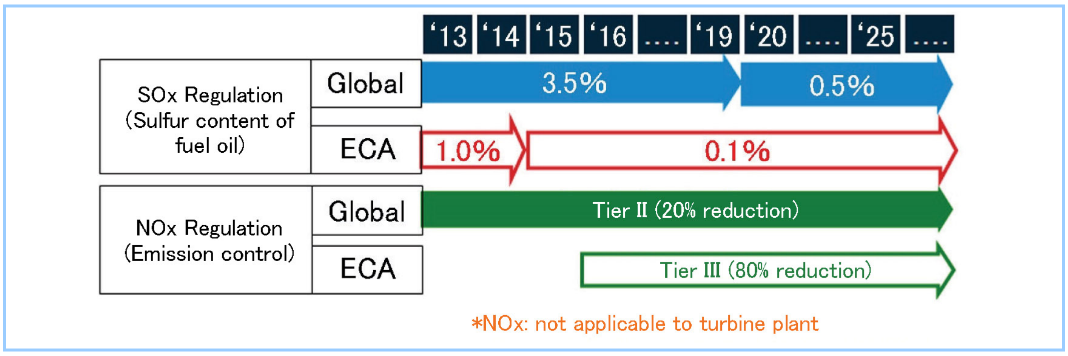

Figure 1 Trends in environmental regulations

Furthermore, LNG vessels fitted with turbine propulsion plants can also meet SOx-related regulations by using the LNG cargo as the gas-only fuel source, thus achieving overall gas emission compliance.

Conventional LNG vessels use boil-off gas (BOG) generated in cargo tanks as the main fuel source, which creates a slow response in fuel supply. In harbors, these vessels operate using the dual-fuel combustion method (gas and fuel oil) as operating on gas-only combustion causes the

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inner pressure to drop, thereby creating operational difficulty during significant load fluctuations. In order to meet more stringent exhaust gas requirements and to optimize the use of surplus BOG, the Low-Load Gas Mode (LLGM) has been developed to achieve gas-only combustion while maneuvering operation. The LLGM's gas-only capability ensures a smooth transition from gas-only to dual-fuel combustion mode in the event of any abnormalities as specified in the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code). The LLGM system manages such a swift transition by continuously maintaining a minimum pressure in the gas header. This capability, however, constantly uses more gas fuel than necessary to support the load required by the turbine plant. Mitsubishi Heavy Industries, Ltd. (MHI) has developed the system called New Low-Load Gas Mode (NLLGM) that, while achieving the same swift transition to dual-fuel combustion mode, does not use more BOG than necessary for combustion. To do so, the NLLGM is equipped with an Low duty gas compressor circulation system that utilizes cargo lines. The system instantly restores gas header pressure to a point above the minimum level in the event of an abnormality.

2. Gas-only combustion for conventional vessels

LNG vessels fitted with turbine propulsion plants can meet tighter SOx regulations by using the LNG cargo as the fuel gas. In maneuvering operation, however, conventional vessels use the dual-fuel combustion method (gas and fuel oil) due to the aforementioned issue regarding load following capability. Therefore, the current system is not capable of meeting stricter SOx restrictions by using the dual-fuel mode while operating in harbors, requiring instead use of low-sulfur fuel oil.

3. Recent developments in gas-only combustion during maneuvering operations

To maintain gas-only combustion during maneuvering operations, the system must have a backup capability for safe transition to dual-fuel (gas and fuel oil) combustion mode as specified in the IGC Code. Consequently, the LLGM designed specifically for gas mode has been developed (**Figure 2**). The LLGM allows continuous gas-only combustion by maintaining the minimum gas header pressure needed to properly ignite the fuel oil. This capability, however, uses more gas fuel than necessary to support the load required by the turbine plant. As such, the surplus steam is processed by steam dumping as shown in **Figure 3**.

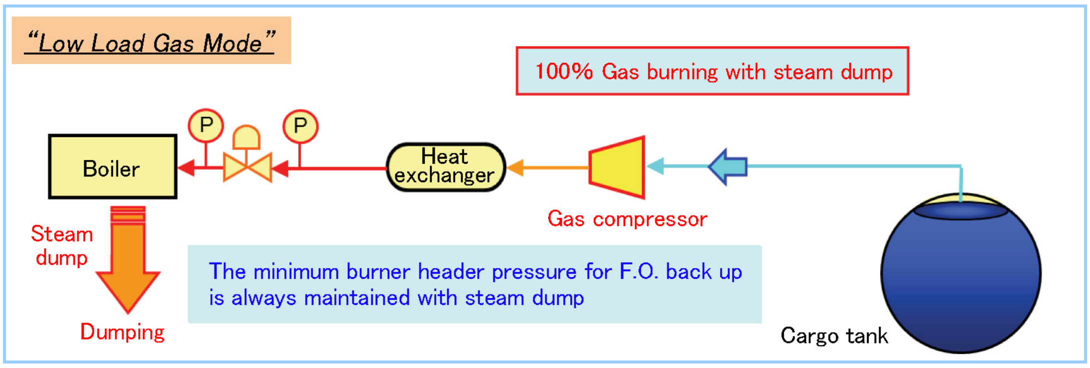

Figure 2 Overview of Low Load Gas Mode (LLGM)

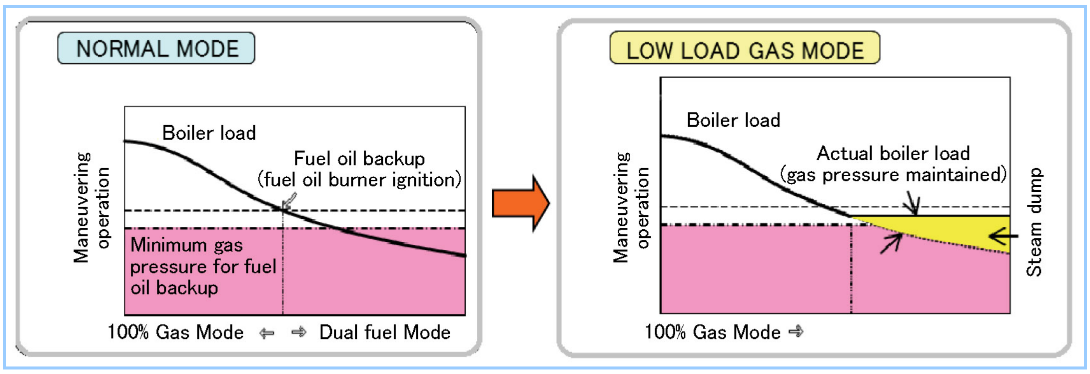

Figure 3 Comparisons: Boiler load and fuel mode

4. New cost-efficient gas-only combustion system

As described in Section 3, the LLGM uses more gas than the turbine plant demands during low-load operation mode such as while maneuvering operation. To facilitate use of gas that properly corresponds to the demand, we propose the NLLGM shown in **Figure 4**. In currently used systems, including the LLGM, a fuel gas compressor controls the flow rate in accordance with boiler load changes. In the NLLGM, the compressor controls the discharge pressure only up to the entrance to the gas flow control valve (FCV), and the FCV alone controls the flow rate to the boiler. The pressure at the entrance of the FCV, therefore, is the pressure that is required to recover appropriate header pressure for safe and instant injection of fuel oil via opening of the FCV. Thus, safe boiler combustion that consistently uses as much fuel gas as required by the plant is achieved without consuming excess fuel gas.

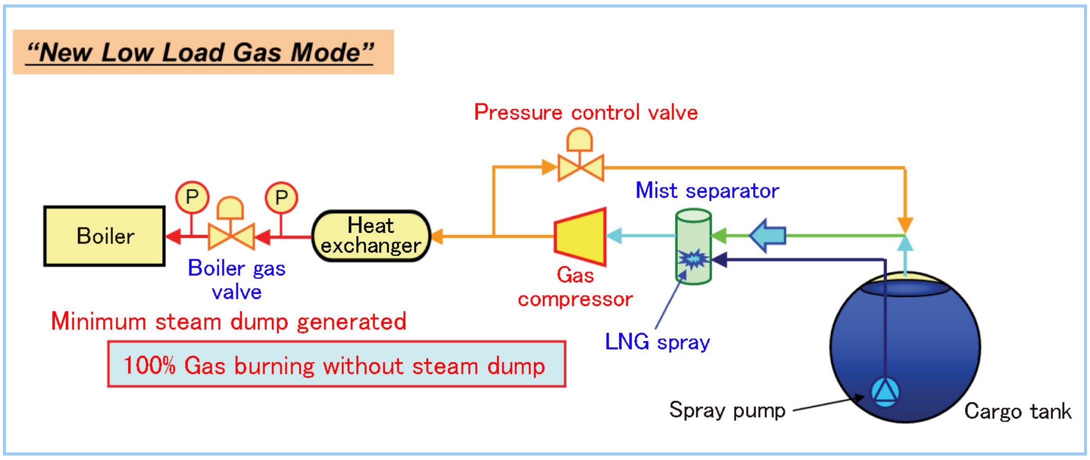

Figure 4 Overview of New Low Load Gas Mode (NLLGM)

5. Advantages of NLLGM

Comparisons for gas consumption were made between the LLGM and NLLGM operations. Using a 153,000m^3 SAYAENDO as a model vessel, the consumption during cargo discharge and loading in a harbor was calculated (**Figures 5** and **6**).

While with LLGM the gas header pressure must be continuously maintained at a level enabling a switch to fuel oil throughout the operation, the NLLGM is capable of various header pressures in accordance with load changes. This difference resulted in gas consumption with the NLLGM 31.3 tons lower at discharge and 24.4 tons lower at loading compared to the LLGM. Thus, a 153,000m^3-class LNG vessel with NLLGM can save a total of 55.7 tons in gas consumption per voyage over a vessel utilizing the LLGM system.

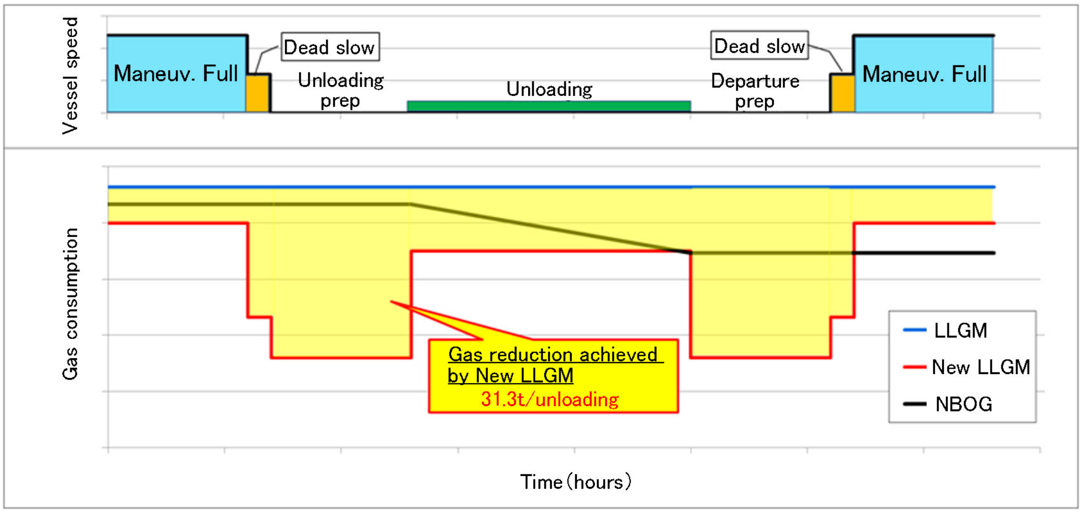

Figure 5 LLGM vs. NLLGM performance comparison: unloading

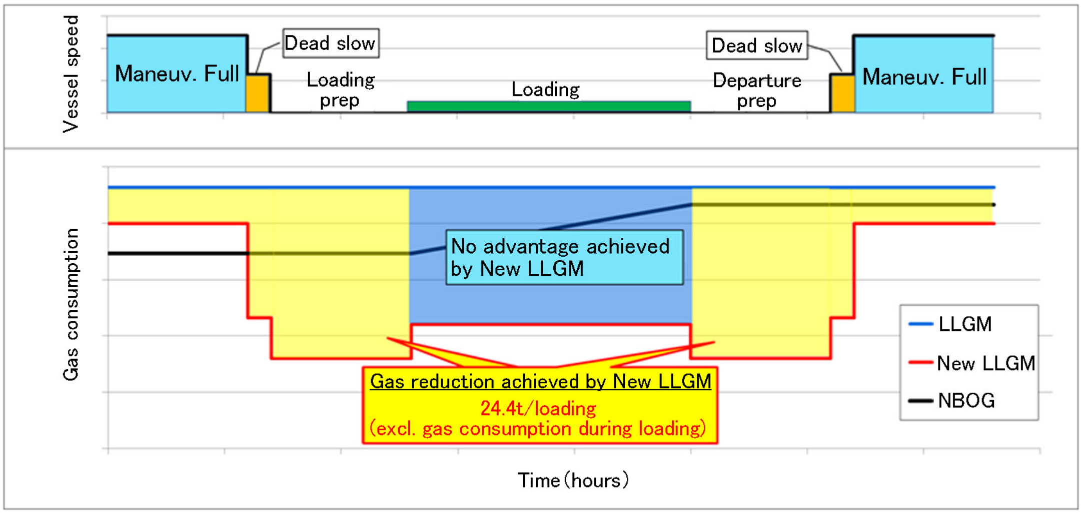

Figure 6　LLGM vs. NLLGM performance comparison: loading

6. Conclusion

With the recent trend towards more stringent environmental regulations governing exhaust emissions, marine vessel propulsion systems are at a major turning point. Although not subject to NOx regulations, conventional turbine plants need to address SOx regulations. As the SOx regulations are based on the sulfur content of fuel oils, regular diesel-powered vessels require post-processing systems such as an exhaust gas treatment device or use of fuel oils with low sulfur concentration. For LNG vessels with a turbine plant, the LLGM using natural gas, which is more cost effective than low-sulfur fuel oils, has been developed in order to adhere to the SOx regulations. In this article, a more advanced system, the NLLGM, which facilitates gas supply corresponding to turbine plant demand, has been proposed. The NLLGM enables compliance with more stringent exhaust gas regulations while achieving cost-efficient operation.