

GUIDE FOR

PROPULSION SYSTEMS FOR LNG CARRIERS SEPTEMBER 2005

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Foreword (1 February 2011)

Every LNG carrier, in service at the time of the issuance of this Guide, has been fitted with a steam turbine powered propulsion plant. However, recently, many owners and shipyards, looking to improve operational efficiency and reduce the size of the engine room to increase cargo carrying capacity have selected propulsion plants alternatives to steam turbine

There are various proposed machinery arrangements being considered by the industry which include:

- Direct drive slow speed diesel engine propulsion with a reliquefaction plant as the means to dispose of the boil-off gas.
- Direct drive slow speed dual fuel diesel engine(s) propulsion.
- Electric propulsion with medium speed dual fuel diesel engines
- Electric propulsion with dual fuel gas turbine(s) as the prime mover(s).

In some cases, with the combination of propulsion and power generation alternatives mentioned above, there may be a need to also install a gas combustion unit to dispose of excess boil-off gas.

It must be acknowledged that while the IMO IGC Code permits these various arrangements as acceptable means for pressure/temperature control in the cargo tanks, it does not comprehensively address propulsion systems other than steam turbine.

Accordingly, this Guide has been developed in order to provide guidance for the design and construction of aforementioned propulsion solutions with particular attention to the safe utilization of boil-off gas. The requirements in this Guide are consistent with the intent of the requirements of the IGC Code and have been developed by extensive use of the risk based rule-making methodology, i.e., risk identification by a group of specialists and stipulation as to the means of mitigation of the risks identified.

In all cases the requirements of this Guide is to supplement areas which are not addressed in the IGC Code and is not intended to conflict or replace any of the requirements in the IGC Code.

Where the requirements of this Guide are proposed to be used to comply with Chapter 16.6 of the IGC Code, such application is subject to approval by the flag Administration prior to issuance of Certificate of Fitness on behalf of the flag Administration by ABS.

This Guide has been developed for the propulsion system for LNG carriers. However, the Guide may be applied to other types of vessels that utilize methane as fuel.

This Guide supersedes the ABS *Guide for Design and Installation of Dual Fuel Engines*, January 2003.

The applicable edition of the *Rules for Building and Classing Steel Vessels* is to be used in association with the subject Guide.

This Guide becomes effective immediately upon publication.

We welcome your feedback. Comments or suggestions can be sent electronically to rdd@eagle.org.



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SECTION 1 General

This Guide has been developed to provide guidance for the design, construction and survey of systems and arrangements provided for the propulsion system and for the safe utilization of boil-off gas on LNG carriers.

1 Definitions

1.1 BOG Utilization System

A *BOG (boil-off gas) utilization system* is an arrangement of BOG consumers (e.g., dual fuel diesel engines, dual fuel gas turbine(s), re-liquefaction units or gas combustion unit(s)), including piping systems, electrical systems, control and safety systems, which are intended for controlling cargo tank pressure and maintaining it below the maximum allowable relief valve setting.

1.2 Dual Fuel Diesel Engine

Dual Fuel Diesel Engines are diesel engines using BOG as fuel and also having the capability of running on liquid fuel.

1.3 Re-Liquefaction Unit

A *Re-liquefaction Unit* is a system used for taking the boil-off gas from cargo tanks and condensing it in a refrigeration system. LNG is then returned to the cargo tanks. A typical re-liquefaction plant will comprise an electric motor-driven boil-off gas compressor, cryogenic heat exchangers, pre-coolers, separator, nitrogen storage tanks, an LNG transfer system, electric-driven refrigeration compressors/expanders with interstage coolers, a discharge cooler and associated control systems.

1.4 Gas Combustion Unit (or Thermal Oxidizer)

A *Gas Combustion Unit (or Thermal Oxidizer)* is a system used for controlling the pressure in the cargo tanks by burning the excess boil-off gas from the cargo tanks inside an enclosed combustion chamber under controlled and safe conditions.

1.5 Dual Fuel Propulsion or Auxiliary Gas Turbine

Dual Fuel Gas Turbine, Propulsion or Auxiliary is a gas turbine using boil-off gas as fuel and also having the capability of running on liquid fuel.

1.6 Normal Boil-off Gas Rate (NBOR)

For the purposes of this Guide, the *Normal Boil-off Rate* is the specified BOR in the shipbuilding contract, conforming to the design boil-off rate at the conditions as specified in the IGC code.

1.7 Rules

The applicable edition of the *ABS Rules for Building and Classing Steel Vessels (Steel Vessel Rules)*.

1.8 MARVS

Maximum allowable relief valve setting.

2 Operating and Maintenance Instruction Manuals

Detailed instruction manuals are to be provided onboard, covering the operations, safety and maintenance requirements and occupational health hazards relevant to the use of gas as a fuel.

The manuals are to include, but not be limited to, the test procedure for the gas detection system, safety shut-off system and the integrity of backup systems, with special attention given to the periodical maintenance procedures for the gas detection system.

The manuals are to be submitted for review solely to ensure the presence of all the information required by this Section.



SECTION 2 Notations

1 Re-Liquefaction Unit

Where a Re-Liquefaction Unit is designed, constructed and tested in accordance with Sections 3 and 4 of this Guide, the **RELIQ** notation will be assigned.

2 Gas Combustion Unit

Where a Gas Combustion Unit is designed, constructed and tested in accordance with Sections 3 and 5 of this Guide, the **GCU** notation will be assigned.

3 Dual Fuel Diesel Engine Power Plant

Where a dual fuel diesel engine power plant is designed, constructed and tested in accordance with Sections 3 and 6 of this Guide, the **DFD** notation will be assigned.

4 Dual Fuel Gas Turbine Power Plant

Where a dual fuel gas turbine power plant is designed, constructed and tested in accordance with Sections 3 and 7 of this Guide, the **DFGT** notation will be assigned.



SECTION 3 Boil-off Gas Utilization

1 Utilization or Disposal of Boil-off Gas

1.1 BOG Utilization Arrangement

Unless the entire cargo system is designed to withstand the full gauge vapor pressure of the cargo under conditions of the upper ambient design temperatures, as specified in 5C-8-7/1.2 of the *Steel Vessel Rules*, means are to be provided to maintain the cargo tank pressure below the MARVS by safely utilizing or disposing of the natural LNG boil-off at all times, including while in port, while maneuvering or standing by, as per Section 5C-8-7 of the *Steel Vessel Rules*. Systems and arrangements that may be provided for this purpose may include one or any combination of the following:

- i) A steam boiler with a common propulsion steam turbine and steam dump system
- ii) A dual fuel diesel engine plant for propulsion and power generation
- iii) A gas turbine plant for propulsion and power generation
- iv) A re-liquefaction system
- v) A gas combustion unit
- vi) Other approved BOG utilization units, such as an auxiliary steam boiler capable of burning boil-off vapors

The aggregate capacity of the means provided for BOG utilization/disposal is to be not less than the normal boil-off rate (NBOR).

2 Supply of BOG to Utilization Units (1 October 2017)

For Arrangement of Spaces Containing Gas Consumers and Gas Fuel Supply, reference is to be made to 5C-8-16/3 and 5C-8-16/4 of the *Steel Vessel Rules*.



SECTION 4 Re-liquefaction Unit

1 General

It is understood that the re-liquefaction unit is likely to be used under most modes of operation while the vessel is at sea or in port.

The re-liquefaction system typically comprises:

- i) Cargo vapor BOG/LNG (condensate) circuit, which is vapor from the cargo tanks and LNG return to the cargo tanks.
- ii) Refrigeration circuit for cooling down and re-liquefying the boil-off vapor.

1.1 Capacity

- i) The capacity of the re-liquefaction unit is to be based on the requirements of 3/1.1 of this Guide.
- ii) The re-liquefaction unit is to be capable of operating satisfactorily with a reduced rate of boil-off gas, as may be the case during the ballast voyage when there is a residual amount of LNG remaining in the cargo tanks.
- iii) Where the re-liquefaction plant is the only means of satisfying 5C-8-7/1.1 of the *Steel Vessel Rules*, a complete standby unit will be required. This standby unit is to consist of a compressor with its driving motor, control system and any necessary fittings to permit operation independent of the normal service units. A standby LNG/refrigerant heat exchanger will not be required. Other heat exchangers utilizing water cooling are required to have a stand-by unit unless the heat exchanger has an excess capacity of at least 25% of the largest required capacity.
- iv) Where a re-liquefaction unit is provided as the means of disposing of excess energy, as required by 5C-8-7/1.1.2 of the *Steel Vessel Rules*, no standby unit will be required.

1.2 LNG Return to Cargo Tanks

- i) The re-liquefaction system is to be arranged such that the LNG returned to cargo tanks can be distributed in such a way so as not to cause the liquid level in any cargo tank to exceed that permitted by 5C-8-15/1.1 of the *Steel Vessel Rules*.
- ii) Where it is proposed that LNG from the re-liquefaction system is returned without the use of a pump, by way of a gravity return or pressure return system, pressure drop calculations for the as-fitted system are to be submitted. The calculations are to consider ship motion and fluid motion inside the cargo tanks.

1.3 Plans and Data to be Submitted

Plans and specifications covering the entire installation with all of the accessories are to be submitted (see 4-1-1/5 of the *Steel Vessel Rules*) and are to include:

- General arrangement of re-liquefaction unit compartment, as applicable, including location of the gas detectors, electrical equipment and lighting
- Ventilation systems for re-liquefaction unit compartment
- Fixed gas detection and alarm systems, and associated shut off and shutdown systems
- Gas fuel piping systems including details of pipes and associated components, design pressures and temperatures

- Gas compressors
- Gas heaters
- Gas storage pressure vessels
- Descriptions and schematic diagrams for control and monitoring system including set points for abnormal conditions
- Details of all electrical equipment in the re-liquefaction unit compartment
- Electric bonding (earthing) arrangement
- Failure Modes and Effects Analysis (FMEA) to determine possible failures and their effects in the safe operation of the re-liquefaction unit [see 4/4.1ii) of this Guide]
- Emergency shutdown arrangements (see Section 4, Table 1 of this Guide)
- Forced boil-off gas supply system from the tanks to the consumers
- Testing procedures during sea/gas trials

2 Cargo Vapor (BOG)/LNG Circuit

2.1 BOG Compressors

- Compressors for pressurizing the boil-off gas in the re-liquefaction system are to be independent of all other gas duties associated with the cargo system.
- The compressors are to be designed in accordance with 5C-8-16/4.2 of the *Steel Vessel Rules*, except that the compressors are to be capable of being stopped locally and remotely from the cargo control room and from the bridge.
- For pressure and temperature measurement and control, see Section 4, Table 1 of this Guide.

2.2 LNG Pumps

- Where LNG pumps are used for the return of LNG to the cargo tanks, these pumps are to be entirely independent of all other cargo pumps.
- Material used in the design of the LNG pumps is to be in accordance with 5C-8-6/1.3 of the *Steel Vessel Rules*.

2.3 Separation of Impurities

Impurities in the boil-off gas, as well as nitrogen, may be separated prior to the return of LNG from the re-liquefaction plant to the cargo tanks. The separation of impurities may be through a separator or by other approved means. Details of the separation system are to be submitted.

3 Refrigeration System

3.1 General

Refrigeration systems are to be provided with environmentally acceptable refrigerants. The use of ozone depleting refrigerants and those refrigerants contributing to the global warming potential (ODP and GWP), as defined by the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer, is not acceptable.

3.2 Refrigerants

- Refrigerants other than those referred to 6-2-6/3.1.6 of the *Steel Vessel Rules*, may be used, provided they are considered to be adequate for use in shipboard applications in accordance with national or international standards, international treaties adopted by the government(s) and the Flag States or other similar legislation laid down by the Flag State. Details, such as the chemical properties, toxicity and flammability, together with the supporting data, are to be submitted for review.

- ii) The refrigerant capacities are to be as follows:
 - Where nitrogen is used as the refrigerant supplied by the vessel's nitrogen generation system, there is to be a minimum of two independent units fitted, so that with any one unit inoperative, 100% of the required capacity will be available.
 - Where a cascade system is fitted, there is to be a sufficient capacity of the refrigerant onboard to recharge the system once.
- iii) Where a cascade system is used requiring onboard storage of refrigerant, the refrigeration system is to be fitted with a receiver capable of holding the complete charge of the refrigerating units. Where each refrigeration unit is fitted with an individual receiver, the capacity is to be sufficient to hold the charge of that unit.
- iv) In the case of nitrogen, part of the charge may be discharged/vented to the atmosphere.

3.3 Compressors/Expanders

- i) Air-cooled compressors are to be designed for an air temperature of at least 45°C (113°F). Water-cooled compressors are to be designed for a water temperature of at least 32°C (90°F).
- ii) Compressor vibration resulting from gas pressure pulses and inertia forces is to be taken into account in the compressor design and mounting arrangement. Acceptable mounting arrangements include resilient rubber mounts or springs.
- iii) Material for housings, rotors and rotor casings is to be in accordance with the applicable requirements of 6-2-6/7 of the *Steel Vessel Rules*. The compressor casing design is to be suitable for the maximum design pressure of the high pressure side of the system.
- iv) For instrumentation, monitoring and control system for the compressors, see Section 4, Table 1 of this Guide.

3.4 Cryogenic Heat Exchangers and Cold Box

- i) The heat exchangers are to be designed, constructed and certified in accordance with Section 4-4-1 of the *Steel Vessel Rules*. If nitrogen refrigeration compressors are to be located in gas-safe spaces to mitigate the risks of boil-off gas returning to the refrigeration compressors through the refrigerant system, the pressure in the refrigerant circuit is to be maintained greater than the pressure in the boil-off gas circuit at all times.
- ii) Piping inside the cold box is to be of all-welded construction. Where flanged connections are essential, details indicating the necessity for this connection are to be submitted for approval on a case-by-case basis.
- iii) For pressure and temperature measurements and controls, see Section 4, Table 1 of this Guide.
- iv) Where the heat exchanger is enclosed in a cold box, the following requirements apply:
 - a. The cold box is to be designed to withstand nitrogen purge pressures likely to be encountered in service and is to be fitted with pressure and vacuum relief devices to prevent over- and under pressurization.
 - b. To prevent overpressuring of the cold box by leaking nitrogen or BOG/LNG, a safety relief valve is to be provided. The vent from the cold box safety relief valve is to be led to the weather.
 - c. Means of detecting boil-off gas leakage within the cold box is to be provided. The detection system is to give an audible and visual alarm at the cargo control station and the bridge upon detection of gas leakage.
 - d. Where the cold box is insulated, means are to be provided for continuous purging of the insulation spaces with nitrogen or other suitable inert gas.

4 Instrumentation and Safety Systems

4.1 General

- i) The control system for the re-liquefaction unit may be connected to an integrated control system or be a stand-alone system.
- ii) An analysis is to be carried out for the re-liquefaction unit identifying component criticality.
- iii) The overall system design is to be based on single-fault criteria. The system is to be designed such that a single fault of a component will not lead to catastrophic consequences.
- iv) Where the re-liquefaction system is the primary means of handling the boil-off gas, the re-liquefaction system is to remain operational unless there is an imminent need to shut down the vapor valves on cargo tanks, such as in the event of fire on deck or main power failure causing a blackout.

4.2 Control and Monitoring System

- i) Automatic control, alarm and safety functions are to be provided to ensure operations within preset parameters in both laden and ballast conditions.
- ii) The temperature and pressures in the re-liquefaction unit are to be controlled as follows:
 - a. A control and monitoring system is to be provided in the cargo control room. Additionally, a motor control panel is to be provided in the vicinity of the boil-off gas compressor and the refrigeration compressor motors.
 - b. The design of the control system is to be such as to ensure identification of faults in the equipment, as well as the process system. The control and monitoring systems are to comply with the requirements of 4-9-2/3.1, 4-9-2/7, and 4-9-2/9 of the *Steel Vessel Rules*, as applicable.
 - c. Indications of parameters necessary for the safe and effective operation of the process are to be provided, as per Section 4, Table 1 of this Guide.
 - d. All electrical control systems are to have two means of power supply and each is to be individually monitored for faults.
 - e. All computer-based control systems are to comply with the applicable requirements of Section 4-9-3 of the *Steel Vessel Rules*.
 - f. All electronic control equipment is to be performance tested in the presence of the Surveyor or by a recognized testing laboratory, in accordance with the criteria of 4-9-8/Tables 1 and 2 of the *Steel Vessel Rules*.
- iii) Gas compressor control and monitoring system is to include anti surge protection.

4.3 Safety Shutdown System

An independent shutdown system is to be provided. This safety shutdown system is to be based on the following principles:

- i) Means are to be provided to indicate the parameters causing shutdown.
- ii) Upon activation of the safety shutdown system, alarms are to be given at the normal control position and at the local control position.
- iii) In the event where shutdown by the safety shutdown system is activated or where the shutdown is initiated by the vessel's emergency shutdown system (ESD), the restart should not occur automatically, unless after the system is reset.
- iv) The safety shutdown system is to be supplied by two sources of power.
- v) Means are to be provided to evacuate LNG remaining in the system after a shutdown.

Safety shutdowns are to be in accordance with Section 4, Table 1 of this Guide.

5 Electrical System

The electrical systems intended for the re-liquefaction unit are to be designed, constructed, tested, certified and installed in accordance with the requirements of this Subsection and Part 4, Chapter 8 and Section 5C-8-10 of the *Steel Vessel Rules*, as applicable.

5.1 Motor Controllers

Means are to be provided to shutdown the compressor from outside space of the compressor room.

6 Location and Installation

- i) The boil-off gas compressors, cryogenic heat exchangers, separator (where installed) and LNG pumps are to be located in the cargo area.
- ii) The refrigeration compressors/expanders, driving motors, and interstage/after coolers are to be located in a gas-safe space within the deckhouse or in the main/ auxiliary machinery spaces.
- iii) Structural details of the deckhouse, as well as the under deck strengthening in way of the re-liquefaction units, are to be submitted, in accordance with Sections 3-2-7 and 3-2-11 of the *Steel Vessel Rules*. Doors and openings to the deckhouse are to be in accordance with 5C-8-3/2.4 of the *Steel Vessel Rules*.

7 Mechanical Ventilation

- i) Ventilation arrangements for the spaces in the deckhouse containing boil-off gas compressors, cryogenic heat exchangers and cold box, the separator where provided and LNG pumps are to be in accordance with 5C-8-12/1 of the *Steel Vessel Rules*.
- ii) Ventilation arrangements for the spaces in the deckhouse containing the electric motors are to have a minimum capacity of eight (8) air changes per hour and be of the positive pressure type.
- iii) Ventilation arrangements for spaces containing the refrigeration machinery are to be in accordance with 6-2-6/11 of the *Steel Vessel Rules*.

8 Gas Detection System

The gas detection system for the spaces in the deckhouse containing boil-off gas compressors, cryogenic heat exchangers and cold box, separator and LNG pumps and associated electric motors are to be in accordance with 5C-8-13/6 of the *Steel Vessel Rules*.

The spaces in the deckhouse containing the refrigeration equipment are to be fitted with a low oxygen level detection system (see also Section 4, Table 1 of this Guide).

Where the refrigerant being used is considered to be toxic, an alarm system is to be fitted to detect refrigerant concentration exceeding the time-weighted average to which personnel may be repeatedly exposed in the space.

9 Ancillary Systems

Where cooling water is required in refrigeration systems, the cooling water supply is to be as follows:

- i) A minimum of two pumps are to be provided, one of which is to be exclusively provided for this duty.
- ii) Where seawater is used, each pump is to have at least two sea suction lines, where practicable leading from sea chests, one port and one starboard.