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天然气燃料动力船舶规范

RULES FOR NATURAL GAS FUELLED SHIPS

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CONTENTS

CHAPTER 1 GENERAL

Section 1 GENERAL PROVISIONS

1.1.1 Application

1.1.1.1 Rules for Natural Gas Fuelled Ships (hereinafter referred to as the Rules) apply to steel ships installed with gas fuel engine(s) and of not less than 20m in length, other than passenger ships and dangerous goods carriers.

1.1.1.2 In addition to the Rules, natural gas fuelled ships are to comply with the applicable requirements of CCS (hereinafter referred to as the Society) Rules for the Classification of Steel Sea-going Ships or Rules for the Construction of Domestic Sea-going Ships or Rules for the Construction of Steel Inland Waterway Ships (hereinafter referred to as CCS Relevant Rules) correspondingly. Requirements imposed by the flag condition Administration, if any, are to be applied.

1.1.1.3 Gas fuel engine(s) may be powered by single fuel (natural gas) or dual fuel (natural gas and fuel oil), the natural gas may be stored on board in gas form or liquid form.

1.1.1.4 Retrofit of current ships' diesel engine(s) to gas fuel engine(s) is to be considered as major conversion, relevant requirements imposed by the flag condition Administration on major conversion (if applicable) or the Rules and CCS Guidelines for the Implement of Ships' Major Conversion are to be met.

1.1.2 Goal and functional requirements

1.1.2.1 The goal of the Rules is to provide requirements for arrangement, construction and installation of gas-related machinery, equipment and system on board natural gas fuelled ships, in order to minimize the risk arising from natural gas that might affect the safety of the ship, personnel and environment.

1.1.2.2 To achieve this goal, the functional requirements described below are to be implemented during the design and construction of natural gas fuelled ships:

(1) The safety, reliability and dependability of the systems are to be equivalent to that achieved with new and comparable conventional oil-fuelled main and auxiliary machinery;

(2) The probability and consequences of gas fuel-related hazards are to be limited to a minimum through arrangement and system design, such as ventilation, detection and safety actions;

(3) Hazardous areas are to be restricted, as far as practicable, to minimize the potential risks that might affect the safety of the ship, persons on board, and equipment;

(4) Equipment installed in hazardous areas is to be minimized to that required for operational purposes and are to be suitably and appropriately certified by the Society;

(5) Unintended accumulation of explosive, flammable gas concentrations are to be prevented;

(6) Fuel gas system components are to be protected against external damages;

(7) Sources of ignition in hazardous areas are to be eliminated to reduce the probability of explosions;

(8) It is to be arranged for safe and suitable, storage and bunkering arrangements capable of receiving and containing the fuel in the required condition without leakage. The system is to be

designed to prevent venting under all normal operating conditions including idle periods;

(9) Piping systems, containment and over-pressure relief arrangements that are of suitable design, construction and installation for their intended application are to be provided;

(10) Machineries, systems and components are to be designed, constructed, installed, operated, maintained and protected to ensure safe and reliable operation;

(11) Fuel containment systems and machinery spaces containing source that might release gas into the space are to be arranged and located such that a fire or explosion in either will not render the essential machinery or equipment in other compartments inoperable;

(12) Suitable control, alarm, monitoring, shutdown and gas detection systems are to be provided to ensure safe and reliable operation of gas fuel systems;

(13) Fire detection, protection and extinction measures appropriate to the hazards concerned are to be provided;

(14) Commissioning, trials and maintenance of gas fuel systems and gas utilization machinery are to satisfy the goal in terms of safety, availability and reliability; and

(15) Warning sign and safeguards are to be provided at the area where cryogenic equipment or piping located, in order to avoid cryogenic injury to personnel due to unintended approach or touch.

1.1.3 **Definitions**

The following definitions apply in the Rules unless expressly provided otherwise:

1.1.3.1 Natural gas means the flammable gas produced from oil-gas or shale gas field and in gas form at normal temperature and pressures, where the predominant component is methane with small amounts of ethane, propane, butane. The natural gas composition can vary depending on the source of gas. Typical composition in volume (%):

- Methane (C_1) 94%
- Ethane (C_2)4.7%
- Propane (C_3) 0.8%
- Butane (C_4+) 0.2%
- Nitrogen 0.3%
- Density gas0.73kg/m^3（at normal atmosphere pressure and 20℃）
- Density liquid 450kg/m^3
- Calorific value (low) 49.5MJ/kg
- Methane number 83

1.1.3.2 Compressed natural gas（CNG）means the natural gas stored in gas tank by high-pressure compression.

1.1.3.3 Liquefied natural gas（LNG）means the gas stored in gas tank in liquid form by liquefaction or other processing techniques.

1.1.3.4 Hazard for the purpose of the Rules means the potential damage to ships or person arising from fire, explosion, low temperature and pressure.

1.1.3.5 ***Certified safe type*** means electrical equipment that is certified safe by the relevant authorities recognized by the Administration for operation in a flammable atmosphere based on a recognized standard.[1]

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[1] Refer to IEC 60079 series, Explosive atmospheres and IEC 60092-502:1999 Electrical Installations in Ships – Tankers – Special Features.

1.1.3.6 Failure mode and effect analysis（FMEA）a systematic technique for analyzing the potential failure modes and their causes and effects in product development and operation management. It involves reviewing and assessment on the potential risk and taking necessary measures to eliminate or mitigate the risk to an acceptable level based on current technologies.

1.1.3.7 *Fuel containment system* is the arrangement for the storage of fuel including tank connections. It includes where fitted, a primary and secondary barrier, associated insulation and any intervening spaces, and adjacent structure if necessary for the support of these elements. If the secondary barrier is part of the hull structure it may be a boundary of the fuel storage hold space. Related items are defined as follows:

(1) ***Storage tank*** for the purpose of the Rules means the tank which storing CNG or LNG. LNG storage tank can be divided into membrane type, semi-membrane type and independent type (further divided into type A independent tank, type B independent tank and type C independent tank).

(2) ***tank space*** is the space enclosed by the ship's structure in which a fuel containment system is situated.

(3) ***interbarrier Space*** is the space between a primary and a secondary barrier, whether or not completely or partially occupied by insulation or other material; and

(4) ***Tank connection space*** is a space surrounding all tank connections and tank valves that is required for tanks with such connections in enclosed spaces.

The above definitions can be referred to in fig.1.1.3.7.

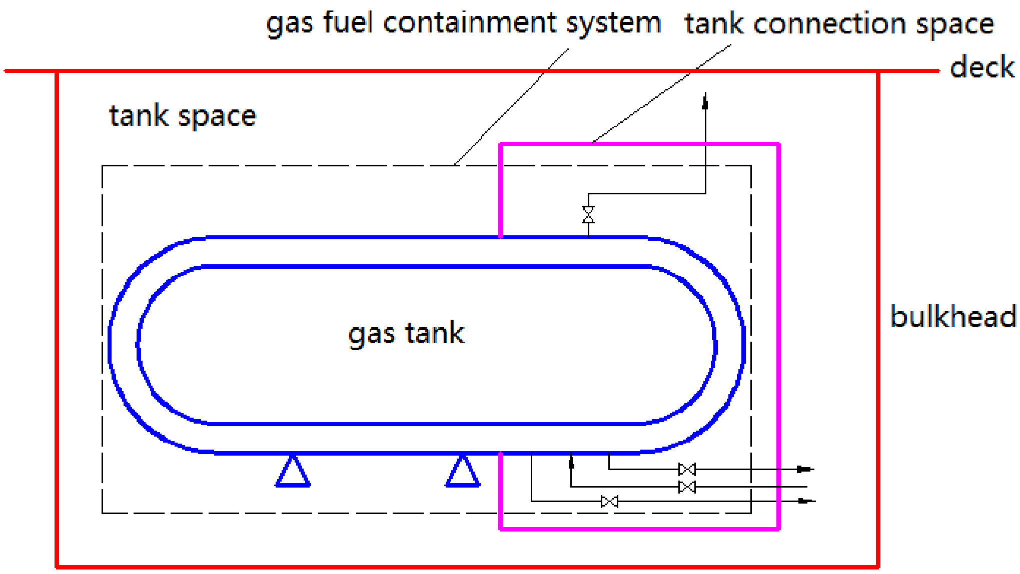


Figure 1.1.3.7 Gas fuel containment (with type C tank) in enclosed space

1.1.3.8 Portable tank for the purpose of the Rules means the tank which can be removed out board for bunkering by hoisting or RO/RO operation.

1.1.3.9 *Gas valve unit (GVU)spaces* are spaces or boxes containing valves for control and regulation of gas supply before the gas engine(s).

1.1.3.10 *Enclosed space* means any space within which, in the absence of artificial ventilation, the ventilation will be limited and any explosive atmosphere will not be dispersed naturally.

1.1.3.11 *Semi-enclosed space* means a space where the natural conditions of ventilation are notably different from those on open deck due to the presence of structure such as roofs, wind breakers and bulkheads and which are so arranged that dispersion of gas may not occur.

1.1.3.12 *Open deck* means a deck that at least is open on both ends/sides, or is open on one end and equipped with adequate natural ventilation that is effective over the entire length of the deck through permanent openings distributed in the side panels or in the deck above.

1.1.3.13 Accommodation spaces are those spaces used for public spaces, corridors, lavatories, cabins, offices, hospitals, cinemas, game and hobby rooms, barber shops, pantries containing no cooking appliances and similar spaces.

1.1.3.14 LEL means lower explosion level.

1.1.3.15 Hazardous area mean an area in which an explosive gas atmosphere or a flammable gas or vapour is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of electrical apparatus or any other equipment that may provide potential sources of ignition.

Hazardous areas are divided into zone 0, 1 and 2 as defined below:

(1) Zone 0 is an area in which an explosive gas atmosphere or a flammable gas or vapour is present continuously or is present for long periods.

(2) Zone 1 is an area in which an explosive gas atmosphere or a flammable gas or vapour is likely to occur in normal operation.

(3) Zone 2 is an area in which an explosive gas atmosphere or a flammable gas or vapour is not likely to occur in normal operation and, if it does occur, is likely to do so only infrequently and will exist for a short period only.

1.1.3.16 Gas safe space or area is those space or area outside the hazardous area.

1.1.3.17 High pressure piping means gas fuel piping with maximum working pressure greater than 10 bar.

1.1.3.18 Double block and bleed valve (DBB valves) is a set of three automatic valves located at the fuel supply to each of the gas engines. Two of these valves shall be in series in the gas fuel pipe to the gas engine. The third valve shall be in a pipe that vents to a safe location in the open air, that portion of the gas fuel piping that is between the two valves in series. Functionally, requirements specified in 4.2.1.3, chapter 4 of the Rules shall be met for DBB valves.

1.1.3.19 Gas only engine means a power generating engine capable of operating on gas-only, and not able to switch over to oil fuel operation.

1.1.3.20 Dual fuel engine means internal combustion engine that can burn gaseous and liquid fuel simultaneously and in a wide variety of proportions, or can operate successively on oil fuel and gas.

1.1.3.21 Gas fuel engine means gas only engine or dual fuel engine.

1.1.3.22 High pressure gas fuel engine means gas fuel engine with gas admission pressure not less than 1 MPa.

1.1.3.23 Low pressure gas fuel engine means gas fuel engine with gas admission pressure less than 1 MPa.

1.1.3.24 Main tank valve means a remote operated valve on the gas supply line from a gas tank, located as close to the tank outlet as possible. The main tank valve shall be of the fail-closed (closed on loss of power) type.

1.1.3.25 Master gas valve means an automatic valve in the gas supply line to each engine located outside the engine room and as close to the heater (if appropriate) as possible. The main tank valve shall be of the fail-closed (closed on loss of power) type. For the installation of multi gas fuel engines, the master gas valve may be located either on main gas supply pipe or on each branch gas supply pipe.

1.1.3.26 Source of release means any point or location in the fuel system from which a flammable fuel may be released into the atmosphere, such as valves, flange connections, pump seals, etc.

1.1.3.27 Double walled pipe means a pipe that is used for gas fuel supply to engines. It consists of the inner pipe and outer pipe. The space between the concentric pipes is pressurized with inert gas at a pressure greater than the gas fuel pressure or ventilated according to given requirements.

1.1.3.28 Bunkering station means the space or area where gas bunkering connection, vapor connection and relevant valves are located.

1.1.3.29 Dangerous goods carriers for the purpose of the Rules means oil tankers, chemical tankers, liquefied gas carriers and ships carrying dangerous goods in package form.

1.1.4 **Additional notations**

1.1.4.1 Ships applying for classification and satisfying the requirements in the Rules will be given the additional notation:

CNG FUELLED; or

LNG FUELLED

Dual FUEL SYSTEM

1.1.5 **Materials**

1.1.5.1 Materials used in gas tanks, gas piping, process pressure vessels and other components or hull in contact with gas with high pressure or may suffer unacceptable low temperature shall be in accordance with the Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, Ch.6.

1.1.5.2 The outer pipe in enclosed spaces with high pressure gas in the inner pipe is as least required to fulfill the material requirements for pipe materials with design temperature down to -55°C in the Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, Ch.6.

1.1.5.3 The outer pipe or duct around gas pipes with liquid gas shall be made of cold resistant steel unless it is efficiently protected from possible leakages from the inner pipe.

1.1.6 **Equivalents or alternatives**

1.1.6.1 Where the Rules require that a particular fitting, material, appliance, apparatus, item of equipment or type thereof should be fitted or carried in a ship, or that any particular provision should be made, or any procedure or arrangement should be complied with, the Society may allow any other fitting, material, appliance, apparatus, item of equipment or type thereof to be fitted or carried, or any other provision, procedure or arrangement to be made in that ship, if it is satisfied by trial thereof or otherwise that such fitting, material, appliance, apparatus, item of equipment or type thereof or that any particular provision, procedure or arrangement is at least as effective as that required by the Rules.

1.1.6.2 However the Society not allow operational methods or procedures to be made an alternative to particular fitting, material, appliance, apparatus, item of equipment, or type thereof which is prescribed by the Rules.

Section 2 PLANS AND DOCUMENTS

1.2.1 Plans and documents for approval

1.2.1.1 In addition to those specified in CCS rules and regulations, the following plans and documents are to be submitted to CCS in triple for approval:

(1) ship arrangement

① arrangement of machinery spaces and boiler rooms, accommodation spaces, service spaces and control stations;

② arrangement of fuel containment systems;

③ arrangement of pump and compressor rooms, if any;

④ arrangement of gas fuel bunkering systems, including the bunkering joints;

⑤ arrangement of accesses, vent pipes and other openings of tank spaces, tank connection spaces;

⑥ arrangement of ventilation pipes, doors and openings in pump and compressor rooms and other gas hazardous spaces;

⑦ arrangement of entrances and air inlets leading of accommodation spaces, service spaces and control stations;

⑧ location and structure of air locks, if any;

⑨ penetrations in bulkheads, if any;

⑩ direction of drip trays and other protective measures; and

□ gas hazardous areas.

(2) piping

① details or instruction of gas fuel piping, including pressure relief valves and vent pipes;

② technical documents for branches, return pipes, elbows, expansion joints, bellows and similar devices;

③ drawing and instruction of flanges, valves and other similar devices in gas fuel piping systems;

④ technical documents for the material, welding, post-weld heat treatment and non-destructive testing of gas pipes;

⑤ technical documents for pressure tests (strength and tightness tests) of gas pipes;

⑥ functional test guidelines for all piping, including valves, fittings and equipment relating to gas (liquid or vapour) operation;

⑦ technical documents for electrical ground system of pipes;

⑧ technical documents for the measures to remove the fuel from the fuel bunkering pipes before shutoff the bunkering joints;

⑨ cooling water systems or hot water systems relating to gas fuel systems, if any;

⑩ arrangement and instruction of gas freeing and inert gas systems;

□ arrangement of bilge and drainage systems for gas pump rooms, compressor rooms and gas tank connection spaces, if any; and

□ calculation for the discharge volume of pressure relief valves of pipes.

(3) ventilation systems

① arrangement and instruction of mechanical ventilation systems in hazardous areas, including the capacity and arrangement of fans and their motors, structures and material of the moving parts and covers of fans; and

② arrangement of double wall pipes (vent pipes).

(4) firefighting appliances and systems

① arrangement and instruction (capacity calculation, etc.) of water spray systems, including pipes, valves, nozzles and fittings;

② arrangement of fire detection systems;

③ structural fire protection arrangement of tank spaces, gas tank connection spaces and their vent pipes, bunkering stations (if applicable); and

④ arrangement of dry powder fire-extinguishing arrangements.

(5) electrical systems

① arrangement of all electrical equipment within the gas hazardous areas;

② single line diagram of intrinsically safe circuits; and

③ list of certified explosion-proof equipment.

(6) control and monitoring systems

① arrangement and instruction of gas detection and alarm systems, including probes, alarm arrangements and alarm set points;

② arrangement and instruction of gas tank monitoring and control systems, including sensors, alarm set points;

③ arrangement and instruction of compressor monitoring and control systems, if any; and

④ arrangement and instruction of gas fuel engine monitoring and control systems.

(7) test or procedure document

① dock and sea trials procedure relating to gas fuel, e.g. functional tests for all gas piping and their valves, fittings and relevant equipment.

Notes: The actual drawing names may be different from those mentioned above, but the drawings are to show the requirements above.

1.2.2 Plans and documents for information

1.2.2.1 The following plans and documents are to be submitted to CCS in triple for information:

(1) thermal stress analysis reports of pipes having a design temperature of less than minus 110℃;

(2) arrangement of low temperature piping isolation; and

(3) related risk analysis reports, if applicable.

1.2.3 Plans and documents kept on board

1.2.3.1 In addition to those specified in CCS rules and regulations, the following documents are to be kept on board:

(1) one gas fuel system operational booklet, which is to comply with the requirements specified in 12.4.1.2, CHAPTER 12 of this Rules; and

(2) one periodic test scheme for the instruments and equipment of gas control, monitoring and safety systems, which is to contain test intervals, requirements and direction and so on. For

the instruments and equipment used for emergency shutoff, which are mentioned in Table 10.4.1.1(1) and Table 10.4.1.1(2), CHAPTER 10 of the Rules, the test interval is not to exceed 6 months, and not to exceed 12 months for other instruments and equipment.

Section 3 INSPECTIONS OF PRODUCTS

1.3.1 General requirements

1.3.1.1 The products are to be inspected in accordance with the requirements of the relevant CCS rules and regulations, and the product on board is to hold a marine products certificate according to CCS Relevant Rules.

1.3.1.2 The important products relating to gas fuel systems, such as gas tanks, gas fuel engines, heat exchangers, electrical control systems, all valves, hoses and bellows of gas fuel pipes, pumps and compressors, are to hold a CCS marine products certificate and comply with the relevant requirements specified in 1.3.1.3 to 1.3.1.8 of this CHAPTER.

1.3.1.3 Gas tanks are to comply with the following:

(1) The following plans and documents are to be submitted to CCS in triple for approval:

① detailed drawings of gas tanks, including the internal structures, secondary barriers (if any), isolation, pipes, valves and joints;

② detailed drawings of gas tank supports;

③ material specification of gas tanks and connecting lines;

④ technical documents about the design loads and structure analysis of gas tanks, including pressurized component calculation;

⑤ complete stress analysis of type B or C independent tanks;

⑥ discharge volume calculation of pressure relief valves;

⑦ documents of non-destructive examination and strength of tank welds and tank tightness tests;

⑧ calculation or test documents of tank isolation performance;

⑨ tank welding procedure specification; and

⑩ drawings or documents of gas tank connection spaces, if any.

(2) In addition to those specified in CCS rules and regulations, pressure vessels containing liquid and/or gaseous gas fuel are to comply with the applicable requirements of CHAPTER 5 and Appendix 1 of the Rules.

1.3.1.4 Gas fuel engines are to comply with the following:

(1) The following plans and documents are to be submitted to CCS in triple for approval:

① plans and documents required to be submitted for diesel engines by CCS Relevant Rules;

② plans of gas injection valves and their driving and sealing systems. For intermixing gas fuel engines, the drawing and document of the mixer are to be submitted;

③ arrangement and detailed instruction of crankcase protection;

④ arrangement and calculation of explosion protection of inlet manifolds and outlet manifolds;

⑤ schematic diagrams of engine control systems relating to gas fuel combustion, including monitoring, alarm and safety equipment;

⑥ test procedures and reports of engines relating to gas fuel combustion;

⑦ arrangement of engine exhaust systems;

⑧ risk analysis reports of gas fuel engines, such as FMEA; and

⑨ other plans and documents considered necessary by CCS.

(2) In addition to those specified in CCS Relevant Rules, gas fuel endings are to comply with the applicable requirements of CHAPTER 11 and Appendix 2 of the Rules.

1.3.1.5 Electrical control systems are to comply with the following:

(1) In addition to those specified in CCS Relevant Rules, electrical control systems used for gas fuel engines or gas fuel supply are to comply with the applicable requirements of CHAPTER 10 and Appendix 3 of the Rules.

1.3.1.6 Heat exchangers are to comply with the following:

(1) In addition to those specified in CCS Relevant Rules, heat exchangers used for gas fuel heating or gasifying are to comply with the applicable requirements of Appendix 4 of the Rules.

1.3.1.7 Valves, hoses and bellows pipes are to comply with the following:

(1) The relevant requirements specified in CCS rules; and

(2) The valves in all sizes and types, which are intended to operate at the working temperature of minus -55℃, are to comply with the requirements of 3.3.1.7, CHAPTER 3 of the Rules.

1.3.1.8 Pumps and compressors are to comply with the following:

(1) Pumps and compressors, if any, are to comply with the relevant requirements of CCS rules or the standards accepted by CCS.

Section 4 SURVEYS OF SHIPS

1.4.1 General requirements

1.4.1.1 For sea-going ships, all the programmes, ways, types, intervals, conditions, and preparation of surveys, survey and test requirements and the preservation of the plans, documents, certificates, records and reports are to comply with the relevant requirements of CCS Rules for Classification of Sea-going Steel Ships or Regulations for Classification of Sea-going Ships Engaged on Domestic Voyage, and for inland waterways ships, they are to comply with the relevant requirements of CCS Regulations for Classification of Inland Waterways Ships.

1.4.2 Surveys during construction

1.4.2.1 In addition to the survey items in CCS Relevant Rules, the following items are to be carried out:

(1) installation and tests of gas fuel engines;

(2) installation and tests of fuel containment systems;

(3) installation and tests of fuel bunkering systems;

(4) installation and tests of gas supply systems, including heat exchangers. Radiographic or ultrasonic inspection is to be carried out for each butt welding joints on the gas supply pipes located within increased safety machinery spaces;

(5) installation and tests of the ventilation systems in gas fuel engine rooms, gas tank spaces and gas tank connection spaces (if any);

(6) installation and tests of the remote closing equipment of gas fuel engines;

(7) location and quantity of gas probes and tests of gas detection and alarm systems;

(8) confirmation and safety inspection of explosion-proof equipment or anti-igniting equipment. Where the safety of explosion-proof electrical equipment depends on the action of protection arrangement (e.g. overload protective relay) and/or alarm arrangement (e.g. no volt alarm of atmospheres-pressurized equipment), a function test is to be carried out for the protection arrangement and alarm arrangement to verify the accuracy of the action and alarm set values;

(9) confirmation of the positive pressure ventilation ability of the spaces protected by positive pressure. The clarification time at the lowest ventilation discharge is to be tested and recorded in the relevant document, and the responding valve to carry out safety measures (shutoff and/or alarm) at abnormal pressure is to be verified;

(10) function tests of ventilation equipment located in the space of which the danger class depends on mechanical ventilation; the ventilation is to be enough and the alarm for the fault of ventilation systems is to be correct;

(11) confirmation of the installation accuracy of the equipment and cables of intrinsically safe circuits;

(12) installation and tests of detection and fire-extinguishing arrangement;

(13) check of gas fuel system operational booklets.

1.4.3 Surveys after construction

1.4.3.1 Annual surveys: In addition to the survey items in CCS Relevant Rules (if applicable), the following items are to be carried out:

(1) fuel containment systems

① examination of clarity, security and integrity of the tank nameplates;

② examination of the operational condition of the liquid level indicators of gas tanks and the normal condition of high level alarm systems and high level automatic shutdown systems;

③ calibration of the maximum starting pressure setting of gas tank pressure relief valves;

④ examination of the normal conditions of means for indicating its pressure and temperature (if any) and its attached alarm equipment;

⑤ examination of the denudation, erosion or cut, depression, deformation, welding flaws, frosting, sweating, etc. of tank shells;

⑥ visual examination of the weld cracks in way of tank connecting parts; and

⑦ confirming that the tank operation procedure, including main valve safety control, liquid level and volume cross-references, emergency isolation of pressure relief valves and precooling for bunkering, etc.) is on board.

(2) examination of heat exchangers to verify that its operation condition, heating ability and so on is in compliance with the technical specification;

(3) examining that the sealing devices of gas tank connection spaces and gas valve unit spaces are in a normal condition;

(4) examination of the satisfactory condition of the doors, scuttles and windows of superstructures or deskhouses facing hazardous area;

(5) examining that the means of closure and other equipment (if any) in any special enclosed space, which is used for protecting the crew in the case of the leakage of gas fuel, are in a normal condition;

(6) examining that the portable ventilation equipment fitted in the spaces, where no man enter always, are in a normal condition;

(7) examining that the drip tray (if any) and the isolation between it and the deck are in a normal condition;

(8) examining that the ventilation system and air lock (if any) of working spaces and the ventilation closing equipment of accommodation spaces are in a normal condition;

(9) examining that the manual emergency closing system and compressor automatic closing equipment are in a normal condition;

(10) examination of gas fuel vent piping, including the vent tubular masts and protective screens. Special attention is to be paid to the expansion joints and cradles on the gas fuel pipes;

(11) examination of the satisfactory condition of the electrical equipment in gas hazardous areas and examination of the maintenance and repairing record;

(12) examining and testing the gas fuel detection system to confirm that it is in a normal working condition. If necessary, checking the sample gas;

(13) examining the detection and firefighting equipment and testing to start one main fire pump;

(14) examining that the water spray system is in a normal condition;

(15) examining that the dry powder fire-extinguishers are in a normal condition; and

(16) checking of the safe operational booklet of gas fuel engines.

1.4.3.2 Intermediate surveys: In addition to the survey items in CCS Relevant Rules (if applicable), the following items are to be carried out:

(1) confirmation of the electrical ground between the pipes and gas tanks and the hull;

(2) confirmation of the spares of mechanical fans used in hazardous spaces;

(3) visual examination of the means for indicating pressure, temperature and liquid level of gas fuel systems, and a comparative test is to be carried out by change the pressure, temperature and liquid level. A simulation test may be accepted for the sensors being inaccessible, including alarm and safety function tests;

(4) testing of the vacuum rate of vacuum insulated tanks in accordance with the relevant requirements in 4.1.4, Appendix 1 of the Rules; and

(5) electrical equipment: functional testing of ground protection (checking of earthing contact), integrity of flame-proof enclosure, damage of cable jackets, atmospheres-pressurized apparatuses and relevant alarm devices for the electrical equipment in hazardous areas as far as possible, testing of shutoff the power supply for non-certificated explosion-proof electrical equipment in the spaces protected by air locks, and measurement of insulation resistance.

1.4.3.3 Special surveys: In addition to the survey items in CCS Relevant Rules (if applicable) and in 1.4.3.2 of this CHAPTER, the following items are to be carried out:

(1) fuel containment systems

① The gas tanks with manholes are to be opened up to visually examine the following:

(a) connection of wash board (if any) to tank, cracks in way of connection welds, looseness of set bolts, cracks, split or dropping-off of wash board, etc.; and

(b) cracks, split or looseness in way of the connection of vapour pipes of gas tanks and fixed entry guides of lever indicators to tanks;

② A tightness test is to be carried out to gas tanks and their vapour and liquid pipes, and the test medium is to be dry and clean nitrogen or air. Before the test, air is not to be used as the test medium unless the gas composition in the tank is examined to be qualified;

③ A hydraulic test is to be carried out to gas tanks and their vapour and liquid pipes. Where the plate or tower structures, bearing, pipe connection attachments and sealing devices in way of the deck penetration are in a good condition, the running of gas leakage monitoring systems is satisfied, and the navigational record shows no any abnormal running, the hydraulic test may be required;

④ All valves and cocks connecting directly to gas tanks are to be opened up for examination, and internal inspection is to be carried out for the connective pipes, if practicable;

⑤ Pressure relief valves and vacuum relief valves are to be opened up for examination and if applicable, the set value of the relief valve is to be checked; and

⑥ Where the gas tank is covered with insulation material, the insulation material is to be removed sufficient enough to determine the situation of the tank.

(2) checking of the set value of pressure relief valves on gas and liquid fuel pipes;

(3) checking of the valves on gas fuel piping and in checking, the valve may be detached and adjusted by air or other applicable gas;

(4) overhauling and function testing of heat exchangers;

(5) examination of inert gas generators to confirm the generated inert gas for compliance with the technical specification and the normal running of the equipment

(6) general inspection of distribution valves and pipes of inert gas, external inspection of pressure vessels storing inert gas, and special inspection of securing equipment to confirm that the pressure relief valves are in a good working condition;

(7) removing the shaft seal on the gastight bulkhead and examining the sealing device;

(8) each compressor being opened up to examine the moving parts, fixed parts, valves, valve seat rings, gland covers, relief devices, filters and lubricating equipment, etc. where the Surveyor is satisfied to the alignment and abrasion, the lower bearing and crankcase seal glands may not be opened up for examination;

(9) examination of the pipes covered with insulation material by removing sufficient insulation material to be r determine the situation of the pipe. A special inspection is to be carried out to the sealing condition; and

(10) In addition to the special survey items for diesel engines specified in CCS Relevant Rules, the following items are to be carried out: general inspection of the ducts or cover enclosure of gas pipes, inspection of discharge or inerting equipment for pipes, and operating testing of gas fuel engines at work.

CHAPTER 2 SHIP ARRANGEMENT

Section 1 GENERAL PROVISIONS

2.1.1 General requirements

2.1.1.1 Natural gas fuelled ships are to be so arranged that an explosion or fire in any space containing gas sources is not to:

(1) cause damage to any space other than that in which the incident occurs;

(2) disrupt the proper functioning of equipment/systems located in other areas;

(3) damage the ship in such a way that flooding of water below the main deck or any progressive flooding occur;

(4) damage work areas or accommodation in such a way that persons who stay in such areas under normal operating conditions are injured;

(5) disrupt the proper functioning of control stations and switchboard rooms necessary for power distribution;

(6) damage life-saving equipment or associated launching arrangements;

(7) disrupt the proper functioning of fire-fighting equipment located outside the explosion-damaged space; or

(8) affect other areas of the vessel in such a way that chain reactions involving, inter alia, cargo, gas and bunker oil may arise.

2.1.1.2 Gas fuel systems (including bunkering, storing, supplying and utilizing) are to be such arranged as to minimize their potential hazardous areas as far as practicable.

2.1.1.3 A low temperature drip tray is to be fitted under the source of release where any piping or equipment contains low temperature liquid; for high-pressure compassed gas, low temperature steel shielding is to be considered to determine if the escape of cold jets impinging on surrounding hull structure is possible. The hull or deck structures surrounding the source of release are not to be exposed to unacceptable cooling, in case of leakage of liquid or compassed gas.

2.1.1.4 The bilge system (if any) for tank connection space, gas compressor room, gas pump room and similar spaces are to be independent of that for any other part.

Section 2 LOCATION AND SEPARATION OF SPACES

2.2.1 Tank spaces and tank connection spaces

2.2.1.1 A tank space is not to contain any machinery or equipment that may introduce the risk of fire.

2.2.1.2 Where the tank joints, flanks and valves and so on are not located on open deck, they are to be enclosed in tank connection space. This space is to be capable of safely containing any leakage which may occur at the tank joint, its boundary material is to have the same design temperature as to the tank, and it is to be designed to withstand the maximum pressure build up within it or be provided with a pressure relief device towards a secure location (e.g. vent mast). This space is to be thermally insulated so that the surrounding hull structures are not exposed to unacceptable cooling in case of leakage of gas fuel.

2.2.1.3 The equipments within a tank connection space are to be capable of withstanding the leakage of low temperature liquid and not render their failure to operate normally.

2.2.1.4 The boundaries of a tank connection space including its access doors, if any, are to be of gastight type.

2.2.1.5 The tank including its secondary barriers, if any, is to be separated from the machinery spaces or other rooms with high fire risks. If the separation is done by a cofferdam, the width of the cofferdam is to be at least 900 mm. For vacuum insulation type C tanks, the tank space may serve as a cofferdam when the tank shell is at least 900 mm far from the bulkhead, except that the tank is located above the machinery space or other hazardous areas with possible fire risks.

2.2.1.6 The door sill for the entrance (if any) of a tank connection space is not to be less than 300mm in height or not to be the same high as the liquid level after the LNG leakage. The tank connection space is, as far as practicable, to have an independent access direct from the open deck. Where a room is connected to the tank connection space by an access or hatch cover, the accesses of the room are to comply with the requirements of this regulation.

2.2.2 **Bunkering station**

2.2.2.1 The bunkering station is to be located on open deck. Closed or semi-enclosed bunkering stations is to be subject to special consideration to prevent any accumulation of flammable gas and approved by CCS.

2.2.2.2 Bunkering stations, accommodation spaces, cargo/operating decks and control stations are to be subdivided or structurally protected, and special consideration is to be taken to prevent any potential mechanical damage due to loading and unloading cargoes. Connections and piping are to be so positioned and arranged that any damage to the gas piping does not cause damage to the ship’s fuel containment system resulting in an uncontrolled gas discharge.

2.2.3 **Machinery spaces**

2.2.3.1 The machinery spaces provided with gas fuelled engines are to have as simple a geometrical shape as possible to avoid the formation of air-pockets.

2.2.3.2 When more than one machinery space (ESD-protected machinery space) is required and these spaces are separated by a single bulkhead, the bulkhead is to provide a degree of strength not less than that of watertight bulkhead.

2.2.4 **Pump and compressor rooms**

2.2.4.1 Compressor rooms, if arranged, are to be located on open deck, unless those rooms are arranged and positioned in accordance with the requirements of the Rules for tank connection spaces.

2.2.4.2 The prime mover driving a compressor is to be located in the adjacent gas-safety space, the bulkhead penetration for the driving shaft is to be gastight and the temperature is to be monitored.

2.2.5 **Other spaces provided with equipments related to bunkering gas**

2.2.5.1 In general, other spaces provided with equipments containing low temperature liquid, such as valves, evaporators and heaters, are to comply with the requirements for pump and compressor rooms.

Section 3 ACCESSES

2.3.1 General requirements

2.3.1.1 In general, a direct access is not to be permitted from a gas hazardous space. Where such an access is necessary for operational reasons, an air lock which complies with the requirements in Section 4 of this CHAPTER is to be provided.

2.3.1.2 The tank connection space is, as far as practicable, to have an independent access direct from the open deck. Where this is impracticable, an air lock, which complies with the requirements in Section 4 of this CHAPTER, is to be provided.

2.3.1.3 Where the access of a tank connection space is neither direct from the open deck or provided with an air lock, the space is to be:

(1) provided with independent ventilation for at least eight air changes per hour;

(2) considered gas safe under normal conditions, except for gas hazardous when its access to the tank connection space is required; in which in these circumstances the non-explosion protected equipments are to be kept to be power off, and other equipments required to be used are to be designed in accordance with the requirements for zone 2, except the cables passing through this space.

2.3.1.4 If the gas compressor room is located below open deck, the room is to have an independent access from the open deck, and the access is not to be common with other spaces. Where a separate access from deck is not practicable, an air lock, which complies with the requirements in Section 4 of this CHAPTER, is to be provided.

2.3.1.5 The machinery space containing gas-fuelled engines is to have at least two completely independent accesses, and one access may be permitted for those of the ships with a length of less than 30 m.

2.3.1.6 Where an ESD-protected machinery space is provided with an access from another enclosed space, the entrances is to be fitted with self-closing doors. An aural alarm is to be given if the door is open continuously for more than 1 min. As an alternative, an arrangement with two self-closing doors in series may be acceptable.

2.3.1.7 A machinery space is not to have an access from a gas hazardous space, except that an access to the gas valve unit space is permitted.

Section 4 AIR LOCKS

2.4.1 General requirements

2.4.1.1 An air lock is a space enclosed by gastight steel bulkheads with two substantially gastight doors spaced at least 1.5 m and nor more than 2.5 m. The doors are to be self-closing without any holding back arrangements.

2.4.1.2 Air locks are to be mechanically ventilated from a gas safe space at an overpressure relative to the adjacent hazardous area or space.

2.4.1.3 Air locks are to have a simple geometrical form. They are to provide free and easy passage, and have a deck area not less than 1.5 m^2. Air locks are to not be used for other purposes, for instance store rooms.

2.4.1.4 An audible and visual alarm system to give a warning on both sides of the air lock is to be provided to indicate if more than one door is moved from the closed position.

2.4.1.5 Where the positive pressure within the air lock goes away, the non-certified explosion proof electrical equipment, which is fitted in a space protected by air locks, is to be kept to be power off. The non-certified explosion proof electrical equipment for maneuvering, anchoring and mooring equipment as well as the emergency fire pumps are not to be located in spaces to be protected by air locks.

2.4.1.6 A combustible gas detector is to be provided for the air lock.

CHAPTER 3 SYSTEM AND PIPING DESIGN

Section 1 POWER SYSTEM ARARNGMENTS

3.1.1 General requirements

3.1.1.1 A risk assessment is to be conducted to the arrangement for any novel power system which is not specified in this CHAPTER. Any risk affecting the hull structural strength and integrity, which is caused by using gas-fuelled engines, is to be identified and consideration is to be given to the hazards associated with installation, operation and maintenance. The risks are to be analyzed using acceptable and recognized risk analysis techniques[2], and the assessment report is to be approved by CCS.

3.1.1.2 Machinery spaces containing gas-fuel power systems, including dual-fule power systems, are to be arranged as follows:

(1) Intrinsic safety machinery spaces: Its arrangements are such that the spaces are considered gas safe under all conditions, normal as well as abnormal conditions;

(2) ESD-protected machinery spaces: Arrangements in machinery spaces are such that the spaces are considered non-hazardous under normal conditions, but under certain abnormal conditions, such as the leakage of gas, may have the potential to become hazardous. In the event of abnormal conditions involving gas hazards, emergency shutdown (ESD) of non-certified explosion proof equipment (ignition sources) and machinery is to be automatically executed while equipment or machinery in use or active during these conditions are to be of a certified safe type;

(3) Increased safety machinery spaces: its level of safety are to be accomplished by some measures, such as increasing the ventilation or the area covered by combustible gas detectors and providing full penetration butt-welds to the gas supply pipes in the machinery space.

3.1.2 **Intrinsic safety machinery spaces**

3.1.2.1 Gas supply piping within machinery spaces is to be provided with a gastight enclosure, e.g. double wall pipes.

3.1.2.2 Where the gas supply necessitates being shutdown due to any leakage from gas supply piping, an auxiliary independent fuel supply system is to be available. Where multi-engine propulsion machineries are provided and the gas supply system of each engine is independent, auxiliary independent fuel supply systems may be dispensed with.

3.1.3 **ESD-protected machinery spaces**

3.1.3.1 Gas supply piping within machinery spaces may be accepted without a gastight external enclosure on the following conditions:

(1) Engines for generating propulsion power and electric power are to be located in two or more machinery spaces, and at least 40% propulsion power and normal electric power are still available after a shutdown to the fuel supply for any machinery space;

(2) The gas machinery space is to contain only a minimum of such necessary equipment, components and systems as are required to ensure that the gas machinery maintains its function, and the equipment, such as incinerators, inert gas generators and oil boilers, is not to be fitted in the gas machinery space ;

(3) The pressure at gas supply system within the gas machinery space is to be less than 1MPa;

(4) The design pressure at gas supply piping within the gas machinery space is to be not less than 1 MPa; and

(5) A gas detection system arranged to automatically shutdown the gas supply (and also oil

[2] Fox example, FSA and FMEA.

fuel supply if dual fuel is used) and disconnect all non-explosion protected equipment or installations are to be fitted.

3.1.4 Increased safety machinery spaces

3.1.4.1 For cargo ships navigating in inland waterways, where dual-fuel gas engines are used, gas supply piping within machinery spaces may be accepted without a gastight external enclosure or the machinery space may not be subdivided on the following conditions, and the safety levels of electrical installations within machinery spaces, except for induced draught fans, combustible gas detecting instruments, fire detectors, alarms and lighting apparatus, may be equival to those of electrical installations within machinery spaces for general cargo ships.

(1) The pressure at gas supply system within the gas machinery space is to be less than 1 MPa;

(2) The design pressure at gas supply piping within the gas machinery space is not to be less than 1 MPa;

(3) All valves and the components where any leakage may occur on the gas supply pipes leading to the engines within the machinery space are to be located in gas valve unit spaces. The connection of gas supply pipes is to be provided with full penetration butt-welded joints and 100% radiographic inspection. Where this is impracticable, a flanged joint may be accepted by CCS providing that this joint is to be located in a gas valve unit space where the ventilation and gas detecting is to comply with the relevant requirements specified in Section 4, CHAPTER 7 and Section 3, CHAPTER 10 of this Rules;

(4) The gas supply pipes and gas-fuelled power engines are to be within the coverage of two independent gas detectors, and the location of the gas detectors is to be in accordance with their performance requirements and ensure to detect quickly and efficiently the possible leakage;

(5) The gas detectors within the machinery spaces and gas valve unit spaces are to be confirmed to be in the proper working order prior to starting gas-fuelled engines;

(6) The gas detection is to be carried out in a continuous process, and an audible and visual alarm is to be located in the bridge or control room. Where flammable gas concentration above 20% LEL is detected in the machinery space and gas valve unit space, an audible and visual alarm is to be activated, the gas supply to the machinery space is to be disconnected and the dual fuel engine is to automatically transfer from gas to wholly oil burning;

(7) Dual fuel engines are to automatically transfer to the mode of oil burning due to self-closing of control valves and shutoff of gas supply. The gas fuel supply is not to be restarted and the engine is not to be transferred to the mode of gas burning before the cause for shutoff of gas supply has been determined and necessary measures have been adopted;

(8) The machinery space is to be mechanically ventilated by fans of the suction type, the number of air changes is to be of at least 30 per hour, and the number and power of the fans is to be such that the ventilation capacity is still to meet the requirements specified for machinery spaces, if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is out of action. The fans are to be of the non-sparking type;

(9) The mechanical ventilation is to interlock with dual fuel engines in the mode of gas fuel, that means the engine can be operated in the mode of gas fuel after the ventilator being on for at least 10 min, and the engine is to be capable of automatically transferring to the mode of oil

burning where the ventilator shuts down due to accidents;

(10) Devices quickly detecting the rupture of gas supply pipes are to be provided and in case of such a rupture being detected, the gas supply to the machinery space is to be automatically shut down, and the engine is to automatically transfer to the mode of oil burning; and

(11) The flammable gas detectors, fire detectors, alarms and lighting apparatus are to be of a certified safe type.

Section 2 PIPING DESIGN

3.2.1 General requirements

3.2.1.1 The piping is to be so arranged as to prevent from excessive stresses due to thermal movement and form movements of the tank and hull structures.

3.2.1.2 Expansion joints are to be protected against over extension and compression and adjoining pipes are to be suitably supported and anchored. Bellows expansion joints are to be protected against mechanical damage and flanged joints are to be provided with devices to prevent the nuts from loosening (e.g. anti-loosing washers).

3.2.1.3 Where gas tanks or piping are separated from the hull structure by thermal isolation, provision is to be made for electrically bonding to the hull structure for both the piping and the tanks. All gasketed pipe joints and hose connections are to be electrically bonded and provision is to be made for electrically bonding for all stuffed pipe joints and hose connections.

3.2.1.4 The number of hoses and flanges in gas supply pipes is to be kept to a minimum and a sliding expansion joints is not to be permitted.

3.2.1.5 The distance from gas piping to the shell is not to be less than 800 mm.

3.2.1.6 The gas piping is to be so installed that the pipes have sufficient flexibility.

3.2.1.7 The gas piping is to be color marked uniformly.

3.2.1.8 Where the gas fuel contains heavier components that may condense in the system, a separating tank or equivalent means for removing the liquid is to be provided.

3.2.1.9 Pressure relief valves are to be provided for all pipes, which may be separated and contain liquid gas fuel, and the outlets are to lead to open areas.

3.2.1.10 For inland waterways ships to lock, the liquid gas fuel occurring in the separated pipes is to be capable of being efficiently recycled.

3.2.1.11 Installations to purge the gas bunkering pipes and supply pipes with inert gas are to be provided.

3.2.2 Wall thickness of pipes

3.2.2.1 The wall thickness t of pipes is not to be less than that obtained from the following formula:

$$t = \frac{t_0 + b + c}{1 - \frac{a}{100}} \quad \text{mm}$$

Where, t_0 --theoretical thickness, in mm, $t_0 = \dfrac{P \cdot D}{2[\sigma] \cdot e + P}$;

Where, P---design pressure, in MPa, refer to 3.2.3 of this CHAPTER;

D---outside diameter of pipes, in mm;

$[\sigma]$ ---allowable stress, in N/mm^2, refer to 3.2.4 of this CHAPTER;

e---efficiency factor equal to 1.0 for seamless pipes and for longitudinally or spirally welded pipes, delivered by approved manufacturers of welded pipes, which are considered equivalent to seamless pipes when non-destructive testing on welds is carried out in accordance with a recognized standard. In other cases, an efficiency factor of less than 1.0, in accordance with recognized standards, may be required depending on the manufacturing process.

b---allowance for bending, in mm. The value of b is to be chosen so that the calculated stress in the bend, due to internal pressure only, does not exceed the allowable stress. Where such justification is not given, b is to be:

$$b = \frac{Dt_0}{2.5r};$$

where, r---mean radius of the bend, in mm.

c---corrosion allowance, in mm. If corrosion or erosion is expected, the wall thickness of the piping is to be increased over that required by other design requirements. This allowance is to be consistent with the expected life of the piping;

a---negative manufacturing tolerance for thickness (%).

3.2.2.2 Where necessary for mechanical strength to prevent damage, collapse, excessive sag or buckling of pipes due to superimposed loads caused by the supporting members, hull distortion or other reasons, the wall thickness is to be increased over that required by 3.2.2.1 of this CHAPTER.

3.2.2.3 The absolute minimum wall thickness is to be in accordance with the provisions specified in CCS Relevant Rules.

3.2.3 Design pressures

3.2.3.1 The design pressure P specified in 3.2.2 of this CHAPTER means the maximum gauge pressure that the system might sustain in operation.

3.2.3.2 The greater of the following design conditions is to be used for pipes, piping system and components as appropriate:

(1) For systems or components which may be separated from their relief valves and which contain some liquid, saturated vapour pressure at 45 °C. However, an upper or lower pressure may be used for the ships navigating in restricted areas or in limited period after approved by CCS, having regard to the navigation remaining within a definite circumstance temperature;

(2) For systems or components which may be separated from their relief valves and which contain only vapour at all times, superheated vapour pressure at 45°C. However, an upper or lower pressure may be used for the ships navigating in restricted areas or in limited period after

approved by CCS, having regard to the navigation remaining within a definite circumstance temperature, at which time assuming an initial condition of saturated vapour in the system at the system operating pressure and temperature;

(3) the MARVS of the fuel tanks and fuel processing system;

(4) the pressure setting of the associated pump or compressor discharge relief valve;

(5) the maximum total discharge or loading head of the fuel piping system;

(6) the pressure setting of the piping system discharge relief valve; or

(7) The design pressure is not to be less than 1 MPa (gauge pressure), but not be less than 0.5 MPa (gauge pressure) for open ended lines.

3.2.3.3 The design pressure for flanges, valves and other fittings is to be considered according to 3.2.3.2 of this CHAPTER, and in accordance with the standards approved by CCS. The flanges, if not meeting the requirements of the standards approved by CCS, is to be used after the approval of CCS.

3.2.3.4 Type testing for the valves and fitting in pipes is to refer to the relevant requirements specified in the Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

3.2.4 Allowable stress

3.2.4.1 The allowable stress of the pipes to be considered in the formula in 3.2.2 of this CHAPTER is to be the lower of the following values:

$$\frac{R_m}{2.7} \text{ or } \frac{R_e}{1.8}$$

Where, R_m---specified minimum tensile strength at room temperature, in N/mm^2;

R_e---specified minimum yield stress at room temperature, in N/mm^2. If the stress-strain curve does not show a defined yield stress, the 0.2% proof stress applies.

3.2.5 Stress analysis

3.2.5.1 Where the design temperature is minus 110 ℃ or colder, a complete stress analysis, taking into account all the stresses due to weight of pipes, including acceleration loads if significant, internal pressure, thermal contraction and loads induced by hog and sag of the ship are to be carried out for each branch of the piping system. Where the design temperature is above minus 110 ℃, the content of stress analysis may include the design or rigid of piping system and the choice of material, etc. In all cases the thermal stress is to be considered without having to submit the calculation.

3.2.6 Flange connections

3.2.6.1 Direct connections without flange pipes may adopt the following ways:

(1) Butt-welded joints with complete penetration at the root may be used in all application;

(2) Slip-on welded joints with sleeves and related welding are only to be used for open-ended lines with an external diameter of 50 mm or less and a design temperature not colder than minus 55 ℃; and

(3) Screwed couplings complying with recognized standards are only to be used for accessory lines and instrumentation lines with an external diameter of 25 mm or less.

3.2.6.2 Flanges in flange connections are to be of the welded neck, slip-on or socket welded type. For all piping except open ended, the following restriction apply:

(1) for design temperatures colder than minus 55 ℃, only welded neck flanges are to be used;

(2)for design temperatures colder than minus 10 ℃, slip-on flanges are not to be used nominal sizes above 100 mm and socket welded flanges are not to be used in nominal sizes above 50mm.

3.2.7 Post-weld heat treatment

3.2.7.1 Post-weld heat treatment is to be required for all butt welds of pipes made with carbon, carbon-manganese and low alloy steels and comply with the requirements of Rules for Materials and Welding by CCS. CCS may the requirements for thermal stress relieving of pipes with a wall thickness of less than 10mm in relation to the design temperature and pressure of the piping system concerned.

Section 3 PIPING TESTS

3.3.1 General requirements

3.3.1.1 Welding procedure tests are to be carried out for gas pipes and comply with the following:

(1) Tensile tests: Generally, tensile strength is not to be less than the specified minimum tensile strength for the appropriate parent materials. CCS may also require that the transverse weld tensile strength is not to be less than the specified tensile strength for the weld metal, where the weld metal has a lower tensile strength than that of the parent metal. In every case, the position of fracture is to be reported for information.

(2) Bend tests: No fracture is to be acceptable after a 180° bend over a former of a diameter 4 times the thickness of the test piece, unless otherwise specially required or agreed by CCS.

(3) Charpy V-notch impact tests: Charpy tests are to be conducted at the temperature prescribed for the base material being joined. The results of the weld impact tests, minimum average energy (E), are to be no less than 27 J. The weld metal requirements for sub-size specimens and single energy values are to be in accordance with the relevant requirements specified in CHAPTER 6 of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. The results of fusion line and heat affected zone impact tests are to show a minimum average energy (E) in accordance with the transverse or longitudinal requirements of the base material, whichever applicable, and for sub-size specimens, the minimum average energy (E) is to be in accordance the relevant requirements specified in CHAPTER 6 of CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. If the material thickness does not permit machining either full-sized or standard sub-size specimens, the testing procedure and acceptance standards are to be in accordance with recognized standards. Impact testing is not required for piping with thickness less than 6 mm.

3.3.1.2 In addition to normal controls before and during the welding, and to the visual inspection of the finished welds, the following tests are to be required:

(1) 100% radiographic or ultrasonic inspection of butt-welded joints for piping systems with; design temperatures colder than –10 °C, or with inside diameters of more than 75 mm, or wall

thicknesses greater than 10 mm. 100% radiographic or ultrasonic inspection of butt-welded joints for gas fuel piping within increased safety machinery spaces;

(2) When such butt welded joints of piping sections are made by automatic welding procedures approved by CCS, then a progressive reduction in the extent of radiographic or ultrasonic inspection can be agreed, but in no case to less than 10% of each joint. If defects are revealed, the extent of examination is to be increased to 100% and to include inspection of previously accepted welds. This approval can be g only ranted if well-documented quality assurance procedures and records are available to assess the ability of the manufacturer to produce satisfactory welds consistently;

(3) For other butt-welded joints of pipes not covered by (1) and (2) above, spot radiographic or ultrasonic inspection or other non-destructive tests are to be carried out depending upon service, position and materials. In general, at least 10% of butt-welded joints of pipes are to be subjected to radiographic or ultrasonic inspection.

3.3.1.3 After assembly, all fuel piping are to be subjected to a hydrostatic test to at least 1.5 times the design pressure. Where piping systems or parts of systems are completely manufactured and equipped with all fittings, the test may be conducted prior to installation on board the ship. Joints welded on board are to be subjected to a hydrostatic test to at least 1.5 times the design pressure. Where no water is permitted within the pipes and these pipes cannot be dried before they are put in service, the recommendation on using other test liquids or test methods is to be submitted to approve. Where an air pressure test is carried out, the test pressure is to be at least 1.25 times the design pressure.

3.3.1.4 After assembly on board, the fuel piping system is to be subjected to a leak test using air, halides or other suitable medium to a pressure depending on the leak detection method applied. The test pressure is not to be less than the maximum system working pressure.

3.3.1.5 All piping systems, including valves, fittings and associated equipment for handling fuel or vapours, are to be subjected to a function test under normal operating conditions not later than the first bunkering operation.

3.3.1.6 Where high pressure pipes are situated within a ventilation duct, the duct is to be tested to at least 1MPa.

3.3.1.7 The valves in each size and each type which are intended for operating at a working temperature of less than minus -55 ℃are to be tested for tightness at the lowest design temperature or lower and the design pressure of not less than that of the valves. The valves are to be confirmed to have good ability to work during the test.

3.3.1.8 The following prototype tests are to be performed on each type of bellows expansion joints intended for use on gas piping:

(1) Elements of the bellows, not pre-compressed, are to be pressure tested at not less than 5 times the design pressure without bursting. The duration of the test is not to be less than 5 minutes;

(2) A pressure test is to be performed on a type expansion joint, complete with all the accessories such as flanges, stays and articulations, at twice the design pressure and in the extreme displacement conditions recommended by the manufacturer without permanent deformation. The minimum design temperature may be considered having regard to the material.

(3) A cyclic test (thermal movements) is to be performed on a complete expansion joint, which is to withstand at least as many cycles under the conditions of pressure, temperature, axial

movement, rotational movement and transverse movement as it will encounter in actual service. Testing at ambient temperature is permitted when this testing is at least as severe as testing at the service temperature.

(4) A cyclic fatigue test (ship deformation) is to be performed on a complete expansion joint, without internal pressure, by simulating the bellows movement corresponding to a compensated pipe length, for at least 2,000,000 cycles at a frequency not higher than 5 Hz. This test is only required when, due to the piping arrangement, ship deformation loads are actually experienced.

3.3.1.9 CCS may waive performance of the tests specified in 3.3.1.8 of this CHAPTER provided that complete documentation is supplied to establish the suitability of the expansion joints to withstand the expected working conditions. When the maximum internal pressure exceeds 1 bar, this documentation is to include sufficient tests data to justify the design method used, with particular reference to correlation between calculation and test results.

3.3.1.10 Hoses used in gas fuel systems are to be tested in accordance with the relevant requirements specified in CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

CHAPTER 4 GAS FUEL SUPPLY

Section 1 GENERAL PROVISIONS

4.1.1 General requirements

4.1.1.1 For single gas fuel systems, the fuel supply system from the gas tank to the consumer is to be arranged to comply with the following requirements so that a leakage in the fuel supply system does not lead to loss of propulsion, power generation or other main functions:

(1) The fuel storage is to be divided between two or more gas tanks with similar size, and these tanks are to be arranged in different spaces; or

(2) In the case type C gas tanks are used, one tank may be accepted if two completely separate tank connection spaces are installed for the one tank.

4.1.1.2 Each outlet of the gas tank is to be provided with a main tank valve and a manual stop valve located as close to the tank as possible.

4.1.1.3 Warning Notices

(1) If the gas supply is shut off due to activation of an automatic stop valve, the gas supply is not to be opened until the reason for the disconnection is ascertained and the necessary precautions taken. A readily visible notice giving instruction to this effect is to be placed at the operating station for the shut-off valves in the gas supply pipes.

(2) If the gas supply is shut off due to a gas leak, the gas supply is not to be opened until the leak has been found and dealt with. A readily visible notice giving instruction to this effect is to be placed in the machinery space containing gas engines.

(3) Any operation implying danger of damage to the gas pipes is not to be undertaken when the gas engines are running. A readily visible notice giving instruction to this effect is to be placed in the machinery space containing gas engines.

Section 2 GAS VALVES

4.2.1 General requirements

4.2.1.1 The main gas supply line to each gas engine or set of gas engines is to be equipped with a manual stop valve and a master gas valve coupled in series or a combined manually and automatically operated valve. The master gas valve is to be situated outside the machinery space, and placed as near as possible to the heat exchanger, if any.

4.2.1.2 The master gas valve is to automatically cut off the gas supply as given in CHAPTER 10 Table 10.4.1.1(2) of this Rule, and operable from a suitable position in the engine room, bridge house and control station.

4.2.1.3 The gas supply line to each gas engine is to be provided with a set of double block and bleed valves. These valves are to be arranged to comply with the following requirements:

(1) Two of these three valves are to be in series in the gas pipe to the gas engine, the third valve is to be in a pipe that vents to a safe location in the open air that portions of the gas pipe between the two valves in series;

(2) The two valves in series are to be automatically closed and the ventilation valve be automatically opened in case of the faults conditiond in CHAPTER 10 Table 10.4.1.1(2) of this Rules occur;

(3) The function of one of the two valves in series and the ventilation valve can be incorporated into one valve body, so arranged that the gas supply will be automatically blocked and the ventilation be automatically opened when the faults conditiond in CHAPTER 10 Table 10.4.1.1 of this Rules occur;

(4) These three valves are to be reset manually;

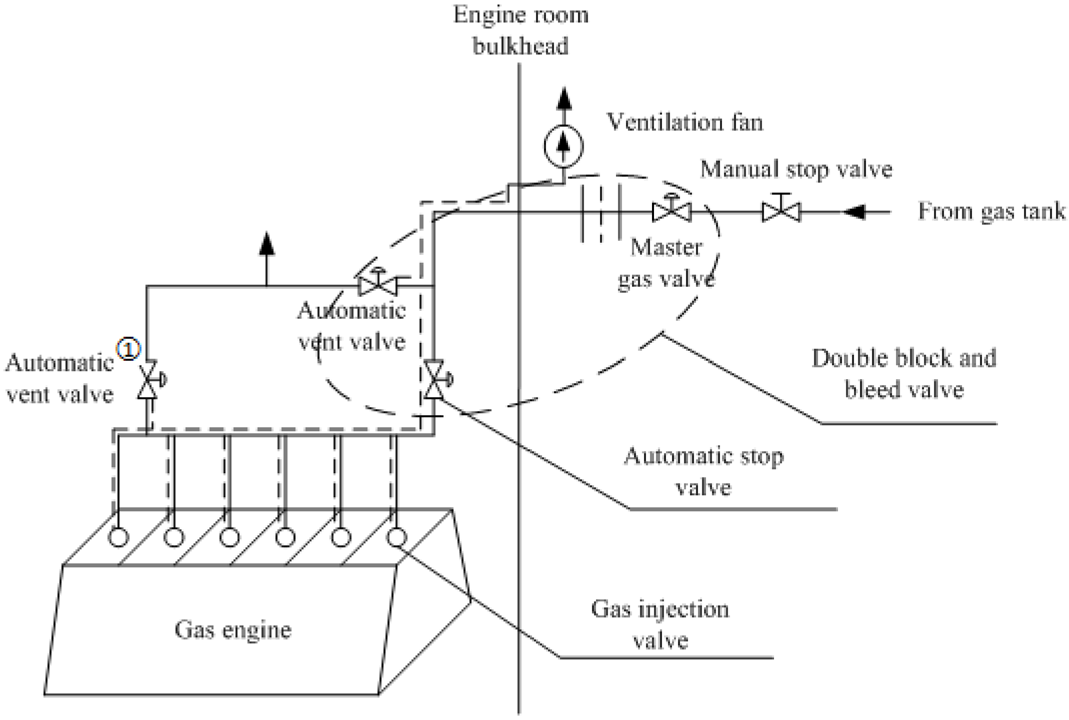
(5) The two valves in series are to be of the fail-to-close type, while the ventilation valves are to be of fail-to-open type;

(6) The double block and bleed valves are to be also used for normal stop of the gas engines.

4.2.1.4 For high pressure gas engines, the gas pipe between the master gas valve and the double block and bleed valve and the gas pipe between the double block and bleed valve and the gas engines are to be automatically vented when the master gas valve is automatically closed. The gas pipe between the double block and the gas engines is to be also vented automatically at normal stop of engine.

4.2.1.5 There is to be a manual stop valve in the gas supply line to each gas engine upstream of the double block and bleed valves to assure safe isolation during maintenance on the engines.

4.2.1.6 Where a separate master gas valve is provided for each gas engine, the master gas valve and the double block and bleed valve functions can be combined, that is, the master gas valve can be used as one stop valve of the double block and bleed valve to cut off the gas supply. Examples of gas valve arrangements for single engine system and for multi-engine system are respectively shown in Figure 4.2.1.6(1) and Figure 4.2.1.6(2).



Alternative ①

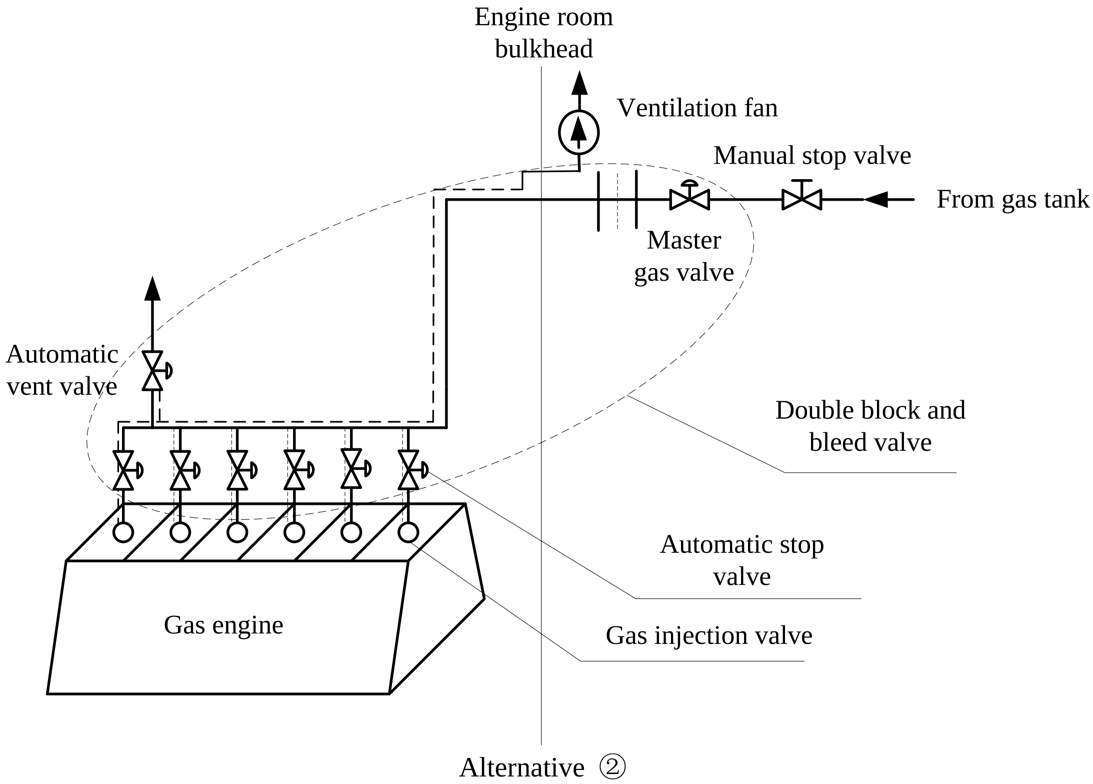
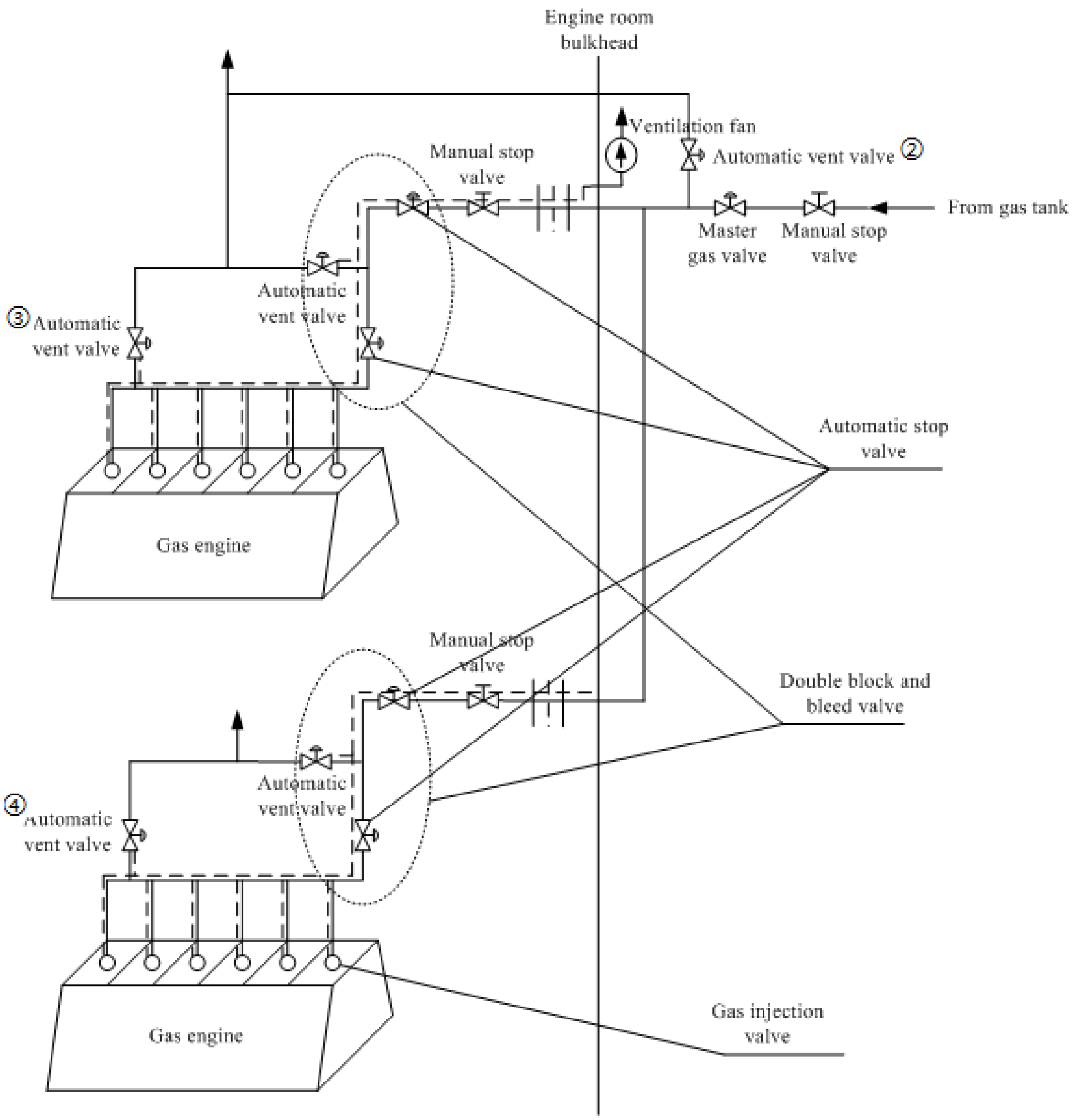


Figure 4.2.1.6(1) Gas valve arrangements for single engine system



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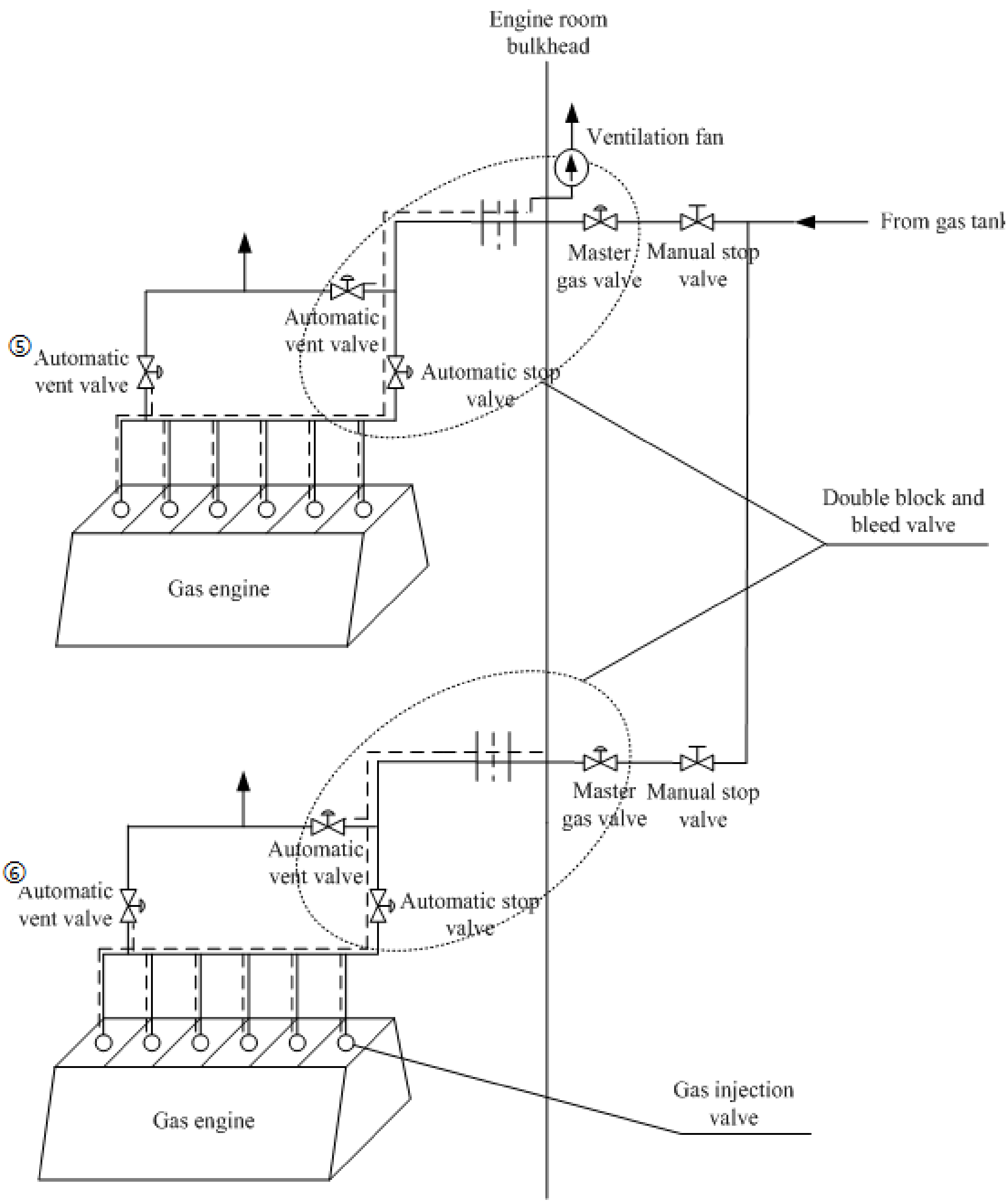

Alternative ②

Figure 4.2.1.6(2) Gas valve arrangements for multi-engine system

Notes: The valve ① may be dispensed for low-pressure gas fuel engines;

The valves ②, ③ and ④ may be dispensed for low-pressure gas fuel engines;

The valves ⑤ and ⑥ may be dispensed for low-pressure gas fuel engines.

Section 3 GAS SUPPLY SYSTEM IN MACHINERY SPACES

4.3.1 Gas supply system for intrinsic safety machinery spaces

4.3.1.1 Gas supply lines in intrinsic safety machinery spaces are to be double-wall pipes, which could be designed to be one of the following two forms:

(1) Concentric pipes made up by inner pipe and outer pipe. The gas fuel is contained in the inner pipe. The space between the inner pipe and the outer pipe is to be pressurized with inert gas at a pressure greater than the gas pressure in the inner pipe. Suitable alarms are to be provided to indicate a loss of inert gas pressure between the concentric pipes. When the inner pipe contains high pressure gas, the system is to be so arranged that the pipe between the master gas valve and the gas engine is automatically purged with inert gas when the master gas valve is closed.

(2) The gas pipe is to be installed within a ventilated pipe or duct. The air space between the gas pipe and the wall of the ventilation pipe or duct is to be equipped with independent mechanical exhaust fans in accordance with the requirements in CHAPTER 7 Section 6 of this Rule.

4.3.1.2 The connecting of gas pipe to the gas injection valve is to be of double wall. The arrangement is to facilitate replacement and/or overhaul of gas injection valves and cylinder covers. The double wall is to be required also for gas pipes on the engine itself, and all the way until gas is injected into the cylinders. If gas is supplied into the engine air inlet manifold/branch with a low pressure, double wall may be omitted on the air inlet manifold/branch on the condition that at least one gas detector is fitted above the gas engine.

4.3.1.3 The design pressure of the outer pipe of the concentric pipe is to be not less than the maximum working pressure of the inner pipe.

4.3.1.4 For high pressure gas pipe, the design pressure of the ventilation pipe or duct is to be taken as the higher of the following:

(1) The maximum built-up pressure: static pressure in way of the rupture resulting from the gas flowing in the annular space;

(2) Local instantaneous peak pressure in way of the rupture (p^*), given by the following expression:

$$p^* = p_0\left(\frac{2}{k+1}\right)^{\frac{k}{k-1}}$$

where: p_0——maximum working pressure of the gas pipe;

k——constant pressure specific heat divided by the constant volume specific heat, $k = C_p/C_v$, k = 1.31 for CH_4.

The tangential membrane stress of a straight pipe is not to exceed the tensile strength divided by 1.5 (R_m /1.5) when subjected to the above pressure. The pressure ratings of all other piping components are to reflect the same level of strength as straight pipes. As an alternative to using the peak pressure from the above formula, the peak pressure found from representative tests can be used. Test reports are then to be submitted.

For low-pressure gas pipes, the design pressure of the ventilation pipe or duct is not to be less than the maximum working pressure of the gas pipe. As an alternative, the ventilation pipe or duct can be pressure tested to show that it can withstand the expected maximum built-up pressure at gas pipe rupture.

4.3.1.5 High-pressure gas pipes are to be provided with means for rapid detection of a rupture in the gas line in the engine room. The master gas valve in the gas supply line, or a stop valve outside the engine room dedicated used for pipe rupture, is to be automatically closed.

Acceptable means of detection by CCS including but not limited to:

(1) a combined excess flow detector with automatic stop valve located close to the point of entry to the engine room; or

(2) a low pressure detector located at the engine inlet.

4.3.2 Gas supply systems for ESD-protected machinery spaces

4.3.2.1 Each gas supply line entering an ESD-protected machinery space is to be provided with means for rapid detection of a rupture in the gas line (refer to 4.3.1.5).

4.3.3 Gas supply systems for increased safety machinery spaces

4.3.3.1 Each gas supply line entering an increased safety machinery space is to be provided with means for rapid detection of a rupture in the gas line (refer to 4.3.1.5).

Section 4 GAS SUPPLY SYSTEM OUTSIDE MACHINERY SPACES

4.4.1 General requirements

4.4.1.1 The gas supply line is not to be lead through accommodation spaces, service spaces or control stations.

4.4.1.2 Where gas pipes must pass through enclosed spaces other than those mentioned in 4.4.1.1, they are to be double-wall pipes complying with requirements of 4.3.1.1, 4.3.1.3, and 4.3.1.4.

4.4.1.3 Unexpected danger of mechanical damage is to be avoided for the gas pipes situated in the open air.

4.4.1.4 The gas pipes outside the engine room are to be protected so as to minimize the risk of personal injury resulting from pipe rupture.

4.4.2 Gas heating

4.4.2.1 Temperature of gas outlet of the heat exchanger is to be monitored. In the case the gas outlet temperature is too low, an audible and visual alarm is to be provided at the bridge house or manned locations in the engine room, and the LNG delivery pump, if any, is to be automatically shut down and the main tank valve be closed.

4.4.2.2 The heating circuit expansion tank is to be vented to open air.

CHAPTER 5 FUEL CONTAINMENT SYSTEMS

Section 1 GENERAL PROVISIONS

5.1.1 **General requirements**

5.1.1.1 The storage tank used for liquefied gas is to be a membrane tank or an independent tank. Tanks used for compressed gas are to be a tank meeting pressure vessel criteria.

5.1.1.2 Unless otherwise specified in this CHAPTEr, membrane tanks, type A independent tanks, type B independent tanks are to comply respectively with CCS Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. Type C independent tanks are to be designed, manufactured and tested as specified in Appendix 1.

5.1.1.3 The design life of fixed liquefied gas fuel containment system is not to be less than 20 years.

5.1.1.4 The design life of portable tanks is not to be less than 20 years.

5.1.1.5 The fuel containment system is to be so designed that a leak from the tank or its connections does not cause the following dangers:

(1) exposure of ship materials to temperatures below acceptable limits;

(2) flammable fuels spreading to locations with ignition sources;

(3) toxicity potential and risk of oxygen deficiency due to fuels and inert gases;

(4) restriction of access to muster stations, escape routes and LSA;

(5) reduction in availability of LSA.

5.1.1.6 The fuel containment arrangement is to be so designed that the remaining power for propulsion and power generation after any gas leakage are to be sufficient for maintaining maneuverability and for providing power for essential services.

5.1.1.7 If portable tanks are used for fuel storage, the design of the fuel containment system is to be equivalent to permanent installed tanks as described in this chapter.

5.1.1.8 The gas fuel tankis to be fitted with a plate marking the type, design temperature, design pressure, test pressure, thermal insulation type (where applicable) and effective capacity.

5.1.1.9 Tank seating is to be located above the deck transverses or deck girders. Both ends of the web of seating are to be sloped.

5.1.1.10 The faceplate of tank seating is to have a width and length no less than that of the faceplate of tank saddle respectively. The thickness of the faceplate of tank seating is not to be less than that of the face plate of tank saddle and the deck where the tank is located. The web depth of the tank seating is neither to be less than 0.5 times the thickness of the face plate nor to be less than 150mm. the web thickness of the tank seating is to be no less than 0.85 times the thickness of the face plate.

5.1.1.11 The tank seating is to be stiffened by brackets symmetrical and normal to the web. The brackets are to be spaced not more than one frame space with the thickness no less than 0.85 times the thickness of the web. The brackets are to be welded to the deck, the face plate and web of the tank seating.

5.1.1.12 The deck of the tank seating area is to be strengthened by doubling plates with width no less than two frame spaces, length no less than 1.5 times than that of the saddle, thickness no less than that of the web of saddle.

Section 2 LIQUEFIED GAS FUEL CONTAINMENT SYSTEMS

5.2.1 Tanks

5.2.1.1 Natural gas in a liquid condition may be stored with a maximum allowable relief valve setting (MARVS) of up to: 1.0MPa for sea-going ships; 1.2 MPa for inland waterways ships.

5.2.1.2 The Maximum Allowable Working Pressure (MAWP) of the gas tank isl not to exceed 90 per cent of the Maximum Allowable relief Valve Setting (MARVS).

5.2.1.3 The pressure and temperature in the fuel tank is to be kept within the design limits of the containment system and possible carriage requirements of the fuel.

5.2.1.4 LNG tanks are to be fitted with multi-hole pipe and nozzles for pre cooing.

5.2.1.5 Piping between the tank and the first valve which release liquid in case of pipe failure is to have equivalent safety as the type C tank.

5.2.1.6 It is to be possible to empty, purge gas and vent fuel storage tanks and its connections.

5.2.1.7 Fuel tank's pressure and temperature is to be maintained by means acceptable to CCS. The method chosen is to be capable of maintaining tank pressure below the set pressure of the tank for a period of 15 days assuming full tank at normal service pressure and the ship in idle condition. The methods acceptable to CCS is to include the following:

(1) thermal insulation;

(2) reliquefaction of vapours;

(3) storage of BOG;

(4) liquefied gas fuel cooling; or

(5) consumption of vapours.

The above means may be used alone or combination thereof.

5.2.2 Supports

5.2.2.1 The liquefied gas fuel tanks are to be supported by the hull in a manner that prevents bodily movement of the tank under the static and dynamic loads defined in Section 2 of Appendix 1, where applicable, while allowing contraction and expansion of the tank under temperature variations and hull deflections without undue stressing of the tank and the hull.

5.2.2.2 Anti-flotation arrangements are to be provided for independent tanks and capable of withstanding the loads defined in 2.13 of Appendix 1 without plastic deformation likely to endanger the hull structure.

5.2.2.3 Supports and supporting arrangements are to withstand the loads defined in 2.4, 2.10, 2.11, 2.12, 2.13 of Appendix 1, but these loads need not be combined with each other or with wave-induced loads.

5.2.2.4 Where the outer shell of the fuel tank is made of low temperature-proof material, the supports are also to be made of low temperature-proof material. Interfaces between the supports and hull are to be thermal insulated by effective means.

5.2.3 Thermal insulation

5.2.3.1 Thermal insulation is to be provided as required to protect the hull from temperatures below those allowable.

5.2.4 Pressure relief systems

5.2.4.1 All fuel storage tanks are to be provided with a pressure relief system. Sizing of pressure relieving system is to comply with the requirements of 3.10 of appendix 1.

5.2.4.2 Fuel storage tanks, which may be subject to external pressures above their design pressure, are to be fitted with vacuum protection systems.

5.2.4.3 For vacuum insulated tanks, the outer shell is to be fitted with explosion proof equipment. The explosion proof equipment is to be provided in the tank connection space (if available).

5.2.4.4 LNG tanks are to be fitted at least two completely independent pressure relief valves.

5.2.4.5 The maximum allowable relief valve setting (MARVS) of the PRVs (pressure relief valves) is not to be higher than the vapour pressure that has been used in the design of the tank. Each valve is to be tested to ensure that it opens at the prescribed pressure setting with an allowance not exceeding ±10% for 0 to 0.15 MPa, ±6% for 0.15 to 0.3 MPa, ±3% for 0.3 MPa and above.

5.2.4.6 The following requirements apply to PRVs fitted to pressure relief systems:

(1) PRVs with a design temperature below 0℃ is to be designed and arranged to prevent their becoming inoperative due to ice formation.

(2) PRVs is to be constructed of materials with a melting point above 925°C. Lower melting point materials for internal parts and seals may be accepted provided that fail-safe operation of the PRV is not compromised.

5.2.4.7 In the event of a failure of a fuel tank PRV, a safe means of emergency isolation is to be available. The procedure is to allow only one of the installed PRVs for the liquefied gas fuel tanks to be isolated, physical interlocks are to be included to this effect.

5.2.4.8 Each pressure relief valve installed on a liquefied gas fuel tank is to be connected to a venting system, which is to be:

(1) so constructed that the discharge will be unimpeded and normally be directed vertically upwards at the exit;

(2) arranged to minimize the possibility of water or snow entering the vent system;

(3) arranged such that the height of vent exits is normally not to be less than B/3 (B being breadth of the ship, in m)or 6 m, whichever is the greater, above the weather deck and 6 m above working areas and walkways for sea-going ships. For inland waterways ships, vent mast height could be limited to 3m; and

(4) For sea-going ships, the outlet from the pressure relief valves is normally to be located at least 10 m from the nearest:

① air intake, air outlet or opening to accommodation, service and control spaces, or other gas safe spaces;

② exhaust outlet from machinery installations.

For inland waterways ships, above distance could be limited to 5m.

5.2.4.9 The PRVs and piping are to be arranged so that liquid can, under no circumstances, accumulate in or near the PRVs.

5.2.4.10 Suitable protection screens of not more than 13 mm square mesh are to be fitted on vent outlets.

5.2.4.11 All vent piping are to l be designed and arranged not to be damaged by the temperature variations to which it may be exposed, forces due to flow or the ship's motions.

5.2.4.12 PRVs is to be positioned on the liquid fuel tank so that they will remain in the vapour phase at the filling limit (FL) as defined in chapter 6 section 4, under conditions of 15° heel and 5° trim.

Section 3 COMPRESSED GAS CONTAINMENT SYSTEMS

5.3.1 General requirements

5.3.1.1 Supports of CNG fuel tanks are to comply with the requiements of 5.2.2.1 and 5.2.2.3.

5.3.1.2 The MARVS is to not be higher than the design pressure that has been used in the design of the tank. The outlet from the pressure relief valves is to comply with the requirements of 5.2.4.8.

5.3.1.3 Adequate means is to be provided to depressurize the tank in case of a fire which can affect the tank.

Section 4 PORTABLE TANKS

5.4.1 General requirements

5.4.1.1 Portable gas fuel tanks are to be secured to the deck while connected to the ship systems.

5.4.1.2 The portable LNG tank area is to be fitted with necessary spill protection, the portable CNG tank area is to be provided with suitable thermal protection.

5.4.1.3 Portable tanks are to be protected against mechanical damage.

5.4.1.4 Portable tanks are to be fitted with water spray systems for cooling if located on open deck; if located in an enclosed space, the space is to be considered as a tank connection space.

5.4.1.5 Connections between portable tanks and ship systems are to be specially considered, including shut down systems for tank valves and a fixed safety relief valve outlet.

5.4.1.6 With the exception of the pressure relief system, each portable tank is to be capable of being isolated at any time. Isolation of one tank is notto impair the availability of the remaining portable tanks.

5.4.1.7 The filling limit of portable tanks is to comply with the requirements of chapter 6 section 4.

5.4.1.8 Control and monitoring systems for portable gas fuel tanks are to be integrated in the ship's gas control and monitoring system.

Section 5 STORAGE ON O PEN DECK

5.5.1 General requirements

5.5.1.1 Both gases of the compressed and liquefied type will be accepted stored on open deck remote from the cargo area.

5.5.1.2 The arrangement of gas fuel tank and its attachments is to comply with the following requirements:

(1) For sea-going ships, the tank and its attachments are to be located at least B/5 (B being breadth of the ship, in m) from the ship's side. For ships other than multihull, a tank location closer than B/5 may be accepted. The inboard distance is to be in no case less than 0.8m.

(2) For inland waterways ships, the tank and its attachments are to be located at least $B/10$ (B being breadth of the ship, in m) from the ship's side. For ships other than multihulls, a tank location closer than $B/10$ may be accepted. The inboard distance is to be in no case less than 0.8m.

5.5.1.3 The tank and its attachments are to be located to assure sufficient natural ventilation, so as to prevent accumulation of escaped gas.

5.5.1.4 Tanks are to be protected against mechanical damage.

5.5.1.5 For vacuum insulated tanks, the outer shell is to be constructed of suitable materials with a design temperature at least equivalent to that of the inner shell.

5.5.1.6 For vacuum insulated tanks with all openings of the inner shell mounted above the highest liquid level in tank, the outer shell need not to comply with the requirement of 5.5.1.5.

5.5.1.7 Gas fuel tanks are to be fitted with drip trays under potential leakage points. The material of the drip tray is to be suitable for low temperatures, and there is to be efficient separation or insulation so that the hull or deck structures are not exposed to unacceptable cooling, in case of leakage of liquid gas.

5.5.1.8 Drip trays may be replaced with a tank connection space.

5.5.1.9 Tanks located at the rear deck are to be suitably protected against mechanical damage.

Section 6 STORAGE IN ENCLOSED SPACES

5.6.1 General requirements

5.6.1.1 A fuel containment system located in enclosed spaces is to be gas tight towards adjacent spaces, unless the possibility of a leakage from the fuel containment system can be excluded.

5.6.1.2 The materials of the bulkheads of the space are to have the same design temperature as the tank, and the space is to be designed to withstand the maximum pressure build-up. Alternatively, pressure relief venting to a safe location (mast) can be provided. The space is to be capable of containing leakage, and is to be isolated thermally so that the surrounding hull is not exposed to unacceptable cooling, in case of the leakage of the tank.

5.6.1.3 For vacuum insulated tanks with a outer shell constructed with material suitable for low temperature, the space need not to comply with the requirement of 5.5.1.5 provided that the tank connection space comply with the requirement of 2.2.1.2 is provided.

5.6.1.4 Storage of compressed gas in enclosed spaces is normally not acceptable, but may be permitted provided the following is fulfilled in addition to 2.2.1.2:

(1) adequate means are provided to depressurize the tank in case of a fire which can affect the tank;and

(2) all surfaces within such enclosed spaces containing the compressed gas storage are provided with suitable thermal protection against any lost high-pressure gas and resulting condensation unless the bulkheads are designed for the lowest temperature that can arise from gas expansion leakage; and

(3) a fixed fire-extinguishing system is installed in the enclosed spaces containing the compressed gas storage.

5.6.1.5 The gas storage tank is to be located as close as possible to the centerline and:

(1) for sea-going ships:

① Minimum, the lesser of *B*/5 (*B* being breadth of the ship, in m) and 11.5m from the ship side (the distance is to be measured inboard from the moulded line of outer shell at right angles to the centerline at the level of the summer water line). For ships other than multihulls, a tank location closer than *B*/5 from the ship side may be accepted.

② minimum, the lesser of *B*/15 (*B* being breadth of the ship, in m) and 2 m from the moulded line of the bottom shell plating at centreline; and

③ not less than 0.8m from the shell plating.

(2) for inland waterways ships:

① Minimum, the lesser of *B*/10 (*B* being breadth of the ship, in m) and 1.0m from the ship side (the distance is to be measured inboard from the moulded line of outer shell at right angles to the centerline at the level of the loaded water line).

② minimum, the lesser of *B*/15 (*B* being breadth of the ship, in m) and 0.8 m from the moulded line of the bottom shell plating at centreline; and

③ not less than 0.8m from the shell plating.

Section 7 SEMI-ENCLOSED SPACES

5.7.1 General requirements

5.7.1.1 The arrangement of gas fuel tank and its attachments is to comply with the following requirements:

(1) For sea-going ships, the tank and its attachments are to be located at least B/5 (B being breadth of the ship, in m) from the ship's side. For ships other than multihull, a tank location closer than B/5 may be accepted. The inboard distance is in no case to be less than 0.8m.

(2) For inland waterways ships, the tank and its attachments are to be located at least B/10 (B being breadth of the ship, in m) from the ship's side. For ships other than multihull, a tank location closer than B/10 may be accepted. The inboard distance is in no case to be less than 0.8m.

5.7.1.2 Tanks are to be protected against mechanical damage.

5.7.1.3 For vacuum insulated tanks, the outer shell is to be constructed of suitable materials with a design temperature at least equivalent to that of the inner shell.

5.7.1.4 For vacuum insulated tanks with all openings of the inner shell mounted above the highest liquid level in tank, the outer shell need not to comply with the requirement of 5.7.1.3.

5.7.1.5 Gas fuel tanks are generally to be fitted with tank connection space, which comply with the relevant requirements.

5.7.1.6 For tanks without a tank connection space where the potential leakage equipments (e.g. connections and valves) are fitted, surrounding structures of the semi-enclosed space are to be constructed with materials suitable for low temperature, at least 2 sets of gas detectors complying with the requirement of chapter 10 are to be fitted. Drip trays are to be fitted under potential leakage points.

CHAPTER 6 GAS FUEL BUNKERING

Section 1 GENERAL PROVISIONS

6.1.1 **General Requirements**

6.1.1.1 Vessel is to be equipped with at least two portable VHF wireless telephone for gas fuel filling operation. The explosive-proof grade of VHF wireless is to be suitable for the environment.

Section 2 FUEL BUNKERING STATIONS

6.2.1 General Requirements

6.2.1.1 Drip trays are to be fitted below liquid gas bunkering connections and where leakage may occur. The drip trays are to be made of stainless steel, and are to be drained over the ship's side by a pipe that preferably leads down near the sea. This pipe could be temporarily fitted for bunkering operations.

6.2.1.2 The surrounding hull or deck structures are not to be exposed to unacceptable cooling, in case of leakage of liquid gas, for example water curtain, protective cover etc; For compressed gas bunkering stations, low temperature steel shielding is to be provided to prevent the possible escape of cold jets impinging on surrounding hull structure.

6.2.1.3 Control of the bunkering is to be possible from a safe location in regard to bunkering operations. At this location tank pressure, tank temperature and tank level is to be monitored. Overfill alarm and automatic shutdown are also to be indicated at this location, as well as monitoring of ventilation and gas detection for the duct containing bunkering pipes.

Section 3 BUNKERING SYSTEMS

6.3.1 General Requirements

6.3.1.1 The bunkering system is to be so arranged that no gas is discharged to air during filling of the storage tanks.

6.3.1.2 The filling duct is to be provided with a filtering device and LNG vapor return pipeline. Filters are to be fitted to prevent the transfer of foreign objects. Connections for LNG vapor return lines are to be provided. The return line is typically used to return evaporated gas to the bunker supplier and may, subject to transfer arrangements, be used to balance delivering and receiving tank pressures.

6.3.1.3 The filling duct connected with the bunker supplier is to meet the requirements of 3.2.1.3 of chapter third of this regulation.

6.3.1.4 A manually operated stop valve and a remote operated shutdown valve in series, or a combined manually operated and remote valve are to be fitted in every bunkering line close to the shore connecting point. It is to be possible to release the remote-operated valve in the control location for bunkering control location.

6.3.1.5 If the bunkering lines through the enclosed spaces, it is to be ring fenced in the ventilation duct, the ventilation duct setting is to meet the requirement of the rule for the gas supply pipe ventilation duct. During bunkering operation of the vessel, Continuous ventilation and gas detection are to be kept , if ventilation in the ducting around the gas bunkering lines stops, or gas is detected in the ducting around the gas bunkering lines, an audible and visual alarm is to be provided at bunkering control location.

6.3.1.6 Means are to be provided for draining the liquid from the bunkering lines at bunkering completion.

6.3.1.7 Bunkering lines are to be arranged for inerting and gas freeing.

6.3.1.8 The entrance, air inlet and other openings of accommodation spaces, service spaces, the machinery spaces and control stations are not to face the bunkering connections position.

6.3.1.9 During bunkering operation of the vessel, the door, windows and other openings and air inlet on both sides of the superstructure and deckhouse are to be kept closed.

Section 4 FILLING LIMIT

6.4.1 General Requirements

6.4.1.1 For type C independent tanks, rated full rate of LNG tank is to be less than 90%. For other types of tank, the filling limit is to meet the relevant requirement of Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk of CCS.

6.4.1.2 The filling pressure of CNG tank is to meet the requirements of the tank factory.

Section 5 LNG STANDARD FILLING JOINTS

6.5.1 General Requirements

6.5.1.1 Natural gas fuelled ships are to be equipped with the LNG standard filling joint in order to connect up the filling flange of the bunker supplier.

6.5.1.2 Without bunkering operation, LNG standard filling joints are to be blind faulted by blind flange, the flanges are to have the same design pressure with the pipe.

6.5.2 Types and sizes

6.5.2.1 The flange sealing surface of the LNG standard filling joint is to be a raised face, the connection dimensions of flanges are shown in Figure 6.5.2.1 (1), the sizes of sealing surfaces are shown in Figure 6.5.2.1 (2), and the dimensions of LNG standard filling joints are to meet the requirements of Table 6.5.2.1.

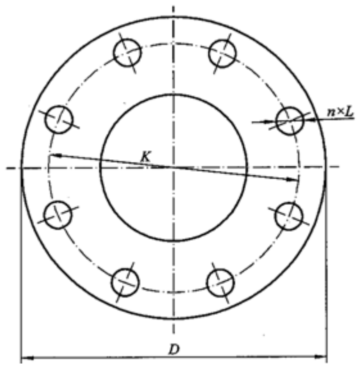

Figure 6.5.2.1(1) connection dimensions flanges

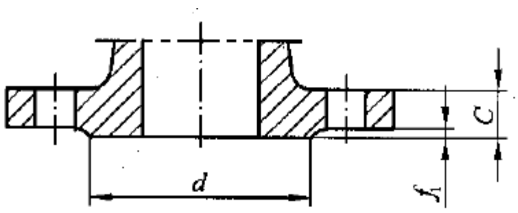

Figure 6.5.2.1(2) sizes of sealing surfaces

The dimensions of LNG standard filling joints Table 6.5.1.3

item	Outer diameter D	Inside diameter	Raised face diameter *d*	Bolt circle diameter *K*	Raised face thickness f_1	Flange thickness *C*	Bolts and nuts: the number *n* and the diameter *L*

尺寸（mm）	210	100	148	170	2	20	8 个，φ18mm
Note: the flange, bolts and nuts and the fastening are to be designed as made of low temperature resistant materials, are to be able to withstand the design temperature and pressure. The material of sealing ring is to be able to withstand the design temperature and pressure, and be insulated.							

Section 6 INERT GAS PIPING

6.6.1 General Requirements

6.6.1.1 An interlock valve is to be provided for inert gas supply piping, in order to prevent the flammable gas from backflowing to any gas safe area/space through an inert gas pipe and in addition, one closable non-return valve is to be provided between the interlock valve and the gas fuel system. Where an inert gas pipe is not permanently connected to a gas fuel pipe, two non-return valves may permitted to replace the interlock valve and closable non-return valve.

6.6.1.2 Inert gas piping can be only penetrate a well ventilated space, and the inert gas piping located in an enclosed space are to:

(1) full-penetration welded;

(2) provided with the flange joints which are to be only necessary to fit the valves and fitting and kept to a minimum; and

(3) short as far as possible.

CHAPTER 7 VENTILATION

Section 1 GENERAL PROVISIONS

7.1.1 General requirements

7.1.1.1 Any ducting used for the ventilation of hazardous spaces is to be separate from that used for the ventilation of non-hazardous spaces. The ventilation is to function at all temperatures and environmental conditions the ship will be operating in. Electric motors for ventilation fans are not to be located in ventilation ducts for hazardous spaces unless the motor is certified for the same hazard zone as the space served.

7.1.1.2 The required capacity of the ventilation plant is normally based on the total volume of the room. An increase in required ventilation capacity may be necessary for rooms having a complicated form.

7.1.1.3 The ventilation system is to ensure a good air circulation in all spaces, and in particular ensure that any formation of gas pockets in the room are detected.

7.1.1.4 Any ducting used for the ventilation of hazardous spaces is not to be through accommodation space、service space or other similar space.

7.1.1.5 Mobile ventilation plants are to be provided in hazardous spaces without regular access by people, such as empty place or similar place. Ventilation is to be provided before entrance into such places with the notice board of ventilation. The rate of explosion protection provided by mobile ventilation plant with marine product certificates is to match the level of gas hazardous area.

7.1.1.6 Ventilation fans and fan ducts associated with the hazardous space, in way of fans only, are to be of non sparking construction defined as:

(1) impellers or housings of non-metallic material, due regard being paid to the elimination of static electricity;

(2) impellers and housings of non-ferrous metals;

(3) impellers of aluminum alloys or magnesium alloys and a ferrous (including austenitic stainless steel) housing on which a ring of suitable thickness of non ferrous materials is fitted in way of the impeller, due regard being paid to static electricity and corrosion between ring and housing;

(4) any combination of ferrous (including austenitic stainless steel) impellers and housings with not less than 13 mm tip design clearance.

7.1.1.7 In no case is the radial air gap between the impeller and the casing to be less than 0.1 of the diameter of the impeller shaft in way of the bearing but not less than 2 mm. The gap need not be more than 13 mm.

7.1.1.8 Any combination of an aluminum or magnesium alloy fixed or rotating component and a ferrous fixed or rotating component, regardless of tip clearance, is to be considered a sparking hazard and is not to be used in these spaces.

7.1.1.9 Ventilation fans associated with the hazardous space are to be fitted with substitutes.

7.1.1.10 The hull of the fan is to be connected to ground.

7.1.1.11 Air outlets from hazardous spaces are to give single square mesh with side length less than 13mm as fence.

7.1.1.12 Any loss of the required ventilating capacity is to give an audible and visual alarm at a permanently manned location.

7.1.1.13 Ventilation systems required to avoid any gas accumulation are to consist of independent fans, each of sufficient capacity, unless otherwise specified.

7.1.1.14 Inlets of each air duct where exhausted fan located for hazardous area are to be carried out according to the area where combustible gas may be accumulated and are to be generally be arranged on the top of the spaces.

7.1.1.15 Air inlets for hazardous enclosed spaces are to be taken from areas that, in the absence of the considered inlet, would be non-hazardous.

7.1.1.16 Air outlets from hazardous enclosed spaces are to be located in an open area that, in the absence of the considered outlet, would be of the same or lesser hazard than the ventilated space.

7.1.1.17 Air inlets for non-hazardous enclosed spaces are to be taken from non-hazardous areas at least 1.5 m away from the boundaries of any hazardous area. Where the inlet duct passes through a more hazardous space, the duct is to be gas-tight and have over-pressure relative to this space.

7.1.1.18 Air outlets from non-hazardous spaces are to be located outside hazardous areas.

Section 2 TANK CONNECTION SPACES

7.2.1 General requirements

7.2.1.1 The tank connection space is to be provided with an effective mechanical forced ventilation system of extraction type. A ventilation capacity of at least 30 air changes per hour is to be provided. When the engine is in gas mode, the ventilation system is to be in operation.

7.2.1.2 The number and power of the ventilation fans are to be such that the capacity is not reduced by more than 50% of the total ventilation capacity if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable.

7.2.1.3 Approved automatic fail-safe fire dampers are to be fitted in the ventilation trunk for tank connection space.

Section 3 MACHINERY SPACES

7.3.1 Intrinsic safety machinery spaces

7.3.1.1 Ventilation in ducts containing gas piping in machinery spaces is to fulfill the requirements of in Section 6.

7.3.1.2 Ventilation in ducts containing gas piping in machinery spaces and ventilation in gas valve unit spaces is to be independent of other ventilation system.

7.3.2 ESD-protected machinery spaces

7.3.2.1 ventilation systems are to be dependent of other ventilation systems

7.3.2.2 Ventilation in ESD-protected safe machinery spaces is to be independent of other ventilation system.

7.3.2.3 Machinery spaces are to be fitted with an effective mechanical ventilation system of the extraction type, providing a ventilation capacity of at least 30 air changes per hour. As an alternative, arrangements whereby under normal operation the machinery spaces are ventilated with at least 15 air changes an hour is acceptable provided that, if gas is detected in the machinery space, the number of air changes will automatically be increased to 30 an hour. When the engine is in gas mode, the ventilation system is to be in operation.

7.3.2.4 The number and power of the ventilation fans are to be such that the capacity is not reduced by more than 50% of the total ventilation capacity if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable.

7.3.3 Increased safety machinery spaces

7.3.3.1 ventilation systems are to be dependent of other ventilation systems

7.3.3.2 Machinery spaces are to be fitted with an effective mechanical ventilation system of the extraction type, providing a ventilation capacity of at least 30 air changes per hour.

7.3.3.3 The number and power of the ventilation fans are to be such that the capacity can meet the requirement in machinery space if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable.

7.3.3.4 Gas modes of engine are to be in operation providing ventilation system, which means after at least 10mins of the start of ventilation, engines are to be in operation with gas mode. Engine modes are to be switched to oil mode automatically in the event of ventilation failure.

Section 4 GAS VALVE UNIT SPACES

7.4.1 General requirements

7.4.1.1 Ventilation systems in gas valve unit spaces are to meet the requirements in sec6.

Section 5 PUMP AND COMPRESSOR ROOMS

7.5.1 General requirements

7.5.1.1 Pumps and compressor rooms are to be provided with effective mechanical system of extraction type, with a ventilation capacity of at least 30 air changes per hour.

7.5.1.2 The number and power of the ventilation fans is to be such that the capacity is not reduced by more than 50% of the total ventilation capacity if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable.

7.5.1.3 Pump and compressor are to be activated after at least 10mins of the operation of ventilation system; Ventilation systems for pump and compressor rooms are to be in operation when pumps or compressors are working.

7.5.1.4 When the space is dependent on ventilation for its area classification, the following is to apply:

(1) During initial start-up and after the loss of ventilation, the space is to be purged (at least 5 air changes), before connecting electrical installations which are not certified for the area classification in the absence of ventilation.

(2) Operation of the ventilation is to be monitored.

(3) In the event of failure of ventilation, the following is to apply:

① an audible and visual alarm is to be given at a manned location;

② immediate action is to be taken to restore ventilation; and

③electrical installations are to be disconnected (except the intrinsically safe equipment applied in 0 area) if ventilation cannot be restored for an extended period. The disconnection is to be made outside the hazardous areas, and be protected against unauthorized reconnection, e.g. by lockable switches.

Section 6 DOUBLE WALL PIPES

7.6.1 **General requirements**

7.6.1.1 Ventilation systems of double wall pipes are to be mechanical ventilation system of extraction type with a ventilation capacity of at least 30 air changes per hour，where gas is detected, automatic nitrogen filling between inside and outside pipe is to be provided and he ventilation capacity can be reduced to 10 air changes per hour. When the engine is in gas mode, ventilation system is to be in operation.

7.6.1.2 The number and power of the ventilation fans are to be such that the capacity is not reduced by more than 50% of the total ventilation capacity if a fan with a separate circuit from the main switchboard or emergency switchboard or a group of fans with common circuit from the main switchboard or emergency switchboard, is inoperable.

Section 7 INERT GAS SPACES

7.7.1 **General requirements**

7.7.1.1 Where a inert generator or inert storage facilities are installed in a separate compartment, outside of the engine room, the separate compartment is to be fitted with an independent mechanical extraction ventilation system, providing 6 air changes per hour.

CHAPTER 8 FIRE SAFETY

Section 1 GENERAL PROVISIONS

8.1.1 **General requirements**

8.1.1.1 For inland waterways ships, a machinery space of category A mentioned in this CHAPTER refers to the machinery space containing main engines, auxiliary engines, boilers, fuel devices and so on.

8.1.1.2 A compressor room or gas pump room, if fitted, is to be regarded as a machinery space of category A for fire protection purposes.

8.1.1.3 The fire extinction required for gas pump and compressor rooms, if fitted, is to be the same as those for cargo pump and compressor rooms specified in the Rules for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

Section 2 FIRE PROTECTION

8.2.1 **Gas tanks**

8.2.1.1 Any boundary of accommodation, service spaces, cargo spaces, machinery spaces and control station facing gas fuel tanks on open deck is to have A-60 fire integrity. Such heat insulation is to be up to bridge deck or the actual bulkhead height.

8.2.1.2 Gas tanks in enclosed/semi-enclosed spaces

(1) If a tank space/tank connection space is separated from a machinery space of category A or other high fire risk spaces by means of a protective cofferdam, the insulation to class A-60 is to be fitted on the side of the machinery space of category A and high fire risk space.

For vacuum insulated type C, when the tank space can act as the protective cofferdam, the tank connection spaces and their ventilation trunks and tank spaces are to be separated by class A-60 divisions towards machinery spaces of category A and other high fire risk spaces.

(2) Tank connection spaces and their ventilation trunks and tank spaces are to be separated by class A-60 divisions towards other adjacent spaces except for those spaces described in 8.2.1.2（1） this CHAPTER. However, where the room is adjacent to voids, sanitary and similar spaces, and the insulation standard may be reduced to class A-0.

8.2.2 Bunkering stations

8.2.2.1 The bunkering station in enclosed/semi-enclosed space is to be separated by class A-60 divisions towards other adjacent spaces, except for spaces such as voids, sanitary and similar spaces where the insulation standard may be reduced to class A-0.

8.2.2.2 Bunkering connectors on open deck are to comply with the following:

(1) Boundaries of accommodation, service spaces, cargo spaces, machinery spaces and control station facing bunkering connectors are to have A-60 fire integrity. Such heat insulation of bulkheads is to have the width of at least 10m along the bunkering connectors left and right, and be up to bridge deck in height or the actual bulkhead height;

(2) If the actual bulkhead length along the bunkering connector left or right is less than 10m, such A-60 fire integrity may be up to the actual bulkhead length;

(3) If the bunkering connector is arranged more than 10 m away from the spaces mentioned in 8.1.3.2(1), the insulation standard of bulkheads may be reduced to class A-0;

(4) If bulkheads face the bunkering connector from different orientation, the above requirements are to be complied with; and

(5) While a bunkering connector is locating in a hollow part of the superstructure or deckhouse, the bunkering connector is to be regarded as being on open deck provided that the hollow depth is not exceeding 1m.

8.2.3 Engine machinery spaces

8.2.3.1 Where more than one engine room is required and these rooms are separated by a single bulkhead, the bulkhead is to be fire insulated to class A-60 standard.

Section 3 FIRE EXTINCTION

8.3.1 Fire main

8.3.1.1 At least two power pumps are to be provided, and each pump capacity and pressure is to be sufficient to ensure the simultaneous use of two water jets with a throw of 12 m at least.

8.3.1.2 The water spray system required in 8.3.2 of this CHAPTER may be part of the fire main system provided that the required fire pump capacity and pressure is sufficient for operation of both the required numbers of hydrants and the water spray system simultaneously.

8.3.1.3 Where the storage tank is located on open deck, isolating valves are to be fitted in the fire main in order to isolate damaged sections of the main. Isolation of a section of fire main is not to deprive the fire line ahead of the isolated section.

8.3.1.4 All fire hose nozzles are to be dual-purpose (water/water spray type) with switches.

8.3.2 **Water spray systems**

8.3.2.1 A water spray system for cooling, fire prevention and crew protection is to be fitted to cover exposed parts of storage tank located on open deck, as well as boundaries of the superstructures and any other deckhouses that face the storage tank except for these boundaries is more than 5m away from the tank.

8.3.2.2 The system is to be designed to cover all areas as specified above with an application rate of 10 $L/\ m^2$ per minute for horizontal projected surfaces and 4 $L/\ m^2$ per minute for vertical surfaces.

8.3.2.3 Stop valves are to be fitted at intervals in the spray main for the purpose of isolating damaged sections. Alternatively, the system may be divided into two or more sections with control valves located in a safe and readily accessible position not likely to be cut-off in case of fire.

8.3.2.4 The capacity of the water spray pump is to be sufficient to deliver the required amount of water to the hydraulically most demanding protected area as specified above.

8.3.2.5 A connection to the ship fire main through a stop valve is to be provided.

8.3.2.6 Start of pumps supplying the water spray system and operation of important control valves to the system is to be located in a readily accessible position which is not likely to be cut off in case of fire in the areas protected.

8.3.2.7 The nozzles are to be of an approved type and arranged to ensure an effective and even distribution of water towards the protected areas.

8.3.3 **Dry chemical powder fire extinguishing systems and extinguishers**

8.3.3.1 At least two portable powder fire extinguishers with a capacity of not less than 5 kg s are to be located near the tank on open deck.

8.3.3.2 At least one portable powder fire extinguishers with a capacity of not less than 5 kg is to be located at the entrance to the tank space containing LNG gas tank.

8.3.3.3 In the bunkering station area, a permanently installed dry chemical powder extinguishing system or a large transportable dry powder extinguisher is to cover all possible leak points. The capacity is to be at least 3.5 kg/s for a minimum of 45 s discharge. The system is to be arranged for easy manual release from a safe location outside the protected area.

For ships with two bunkering stations at both sides, the fix dry chemical powder extinguishing systems or the large transportable dry powder extinguishers are to cover both sides of bunkering stations.

8.3.3.4 At least one portable powder fire extinguisher with a capacity of not less than 5 kg is to be located near the bunkering station.

8.3.3.5 At least one portable powder fire extinguisher with a capacity of not less than 5 kg is to be located near the gaseous propellant engine, as well as the entrance to the machinery space containing the engine.

Section 4 FIRE DETECTION AND FIRE ALARM SYSTEMS

8.4.1 **Fire detection**

8.4.1.1 An approved fixed addressable fire detection system is to be provided for the tank space, the machinery space containing gaseous propellant engine, and the compress room and gas pump room.

8.4.1.2 Smoke detectors alone are not to be considered sufficient for rapid fire detection.

8.4.1.3 Where the fire detection system does not include means of remotely identifying each detector individually, the detectors are to be arranged on separate loops.

8.4.2 **Alarms and safety actions**

8.4.2.1 Required safety actions at fire detection in the above spaces are given in Table 10.4.1.1 (2) of CHAPTER 10. In addition, the ventilation is to stop automatically and fire dampers are to be closed.

CHAPTER 9 ELECTRICAL SYSTEM

Section 1 AREA CLASSIFICATION AND ELECTRICAL EUIPMENT

9.1.1 **Area classification**

9.1.1.1 In order to facilitate the selection of appropriate electrical apparatus and the design of suitable electrical installations, hazardous areas are divided into zones 0, 1 and 2. Areas and spaces other than those classified in this Section are to be classified according to the principles accepted by CCS[3].

9.1.1.2 Hazardous areas zone 0: the interiors of gas tanks, any pipework for pressure-relief or other venting systems for gas tanks, pipes and equipment containing gas.

9.1.1.3 Hazardous area zone1:

(1) Tank connection spaces;

(2) Gas compressor or pump room;

(3) Area on open deck, or semi-enclosed spaces on deck, within 3 m of any gas tank outlet,

[3] International Electrotechnical Commission: IEC60092-502。

gas or vapour outlet, bunker manifold valve, other gas valve, gas pipe flange, ventilation outlets from zone 1 hazardous spaces and gas tank openings for pressure release provided to permit the flow of small volumes of gas or vapour mixtures caused by thermal variation;

(4) areas on open deck or semi-enclosed spaces on deck, within 1.5 m of gas compressor and pump room entrances, gas pump and compressor room ventilation inlets and other openings into zone 1 spaces;

(5) areas on the open deck within spillage coamings surrounding gas bunker manifold valves and 3 m beyond these, up to a height of 2.4 m above the deck;

(6) enclosed or semi-enclosed spaces in which pipes containing gas are located, e.g., ducts around gas pipes, semi-enclosed bunkering stations;

(7) the ESD-protected machinery space is considered as non-hazardous area during normal operation, but will require equipment required to operate following detection of gas leakage to be certified as suitable for zone 1.

9.1.1.4 Harazdous area zone 2: areas within 1.5 m surrounding open or semi-enclosed spaces of zone 1, interal area of air-lock, an area within 2.4 m of the outer surface of tank which has single shell.

9.1.1.5 Where a space on open deck has an opening to a hazardous area, it may be made into a less hazardous space or non-hazardous space by over-pressure.

9.1.1.6 Ventilation pipe are to be designated as the same hazardous as the area be ventilated.

9.1.2 Electrical equipment and cables

9.1.2.1 Electrical equipment or cables is not normally to be installed in hazardous areas. Where essential for operational purposes, the types of equipment and cables may be considered according to the principles accepted by CCS[4]. The groups and temperature classes of electrical apparatus are not below IIAT2, The following equipment mey be considered for different hazardous zongs:

(1) The following equipment may be considered for zone 0:

a) Certified intrinsically-safe apparatus of category “ia”;

b) Simple electrical apparatus and components (for example thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically-safe circuits of category “ia”, not capable of storing or generating electrical power or energy in excess of the limits given in IEC 60079-14;

Note: Consideration may need to be given to matters such as the integrity of the insulation from earth of the circuit, the suitability of any plastics or light metals incorporated in the construction of the apparatus or component, and (except in the cases of switches, plugs and sockets, and terminals) the maximum surface temperature of any part of the apparatus. Apparatus reliant upon voltage or current limiting or suppression devices for remaining within the limits set by IEC 60079-14, is excluded from the category of “simple apparatus”.

c) Other electrical apparatus specifically designed and certified by the appropriate authority for use in zone 0;

d) Submersible electrically-driven pumps, having at least two independent methods of shutting down automatically in the event of low liquid level. The construction and installation of the pump and associated cabling, and the means by which it is prevented from being energized

[4] International Electrotechnical Commission: IEC60079 or China national standard: GB3836.

when not submerged or in an atmosphere incapable of supporting combustion.

(2) The following equipment may be considered for zone 1:

a) Equipment may be considered for zone 0;

b) Certified intrinsically-safe apparatus of category “ib”;

c) Simple electrical apparatus and components (for example thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically-safe circuits of category “ib”, not capable of storing or generating electrical power or energy in excess of the limit given in IEC 60079-14;

d) Certified flameproof (type “d”);

e) Certified pressurized (type “p”);

Note: Automatic shutdown may be required in complance with IEC 60079-2, when values of over-pressure and/ or protective gas flow fall below minimum prescribed values.

f) Certified increased safety (type “e”);

Note: Additional protection (for example air-purging prlor to starting) may be required to counter therisk of air-gap sparking in induction motors of 3 kV and above.

g) Certified encapsulated (type “m”);

h) Certified sand filled (type “q”);

i) Certified oil immersed (type “o”), only be used when certified by the appropriate authority separately;

j) Certified specially (type “s”);

k) Hull fittings containing the terminals or shell-plating penetrations for anodes or electrodes of an impressed current catholic protection system, or transducers such as those for depth sounding or log systems, provided that such fittings are of gastight construction, air tightness is to be certified by CCS;

l) Through runs of cable.

(3) The following equipment may be considered for zone 2:

a) Equipment may be considered for zone 1;

b) Tested specially for zone 2 (for example type “n” protection);

c) Tested specially for zone 2 (for example type “n” protection);

9.1.2.2 Electrical equipment fitted in an ESD protected machinery space are to fulfill the following:

(1) In addition to fire and hydrocarbon detectors and fire and gas alarms, lighting and ventilation fans are to be certified safe for hazardous area zone 1.

(2) All electrical equipment (including gas engine) in the engine room not certified for zone 1 are to be automatically disconnected if gas concentration above 40% LEL is detected on detectors in the engine room.

9.1.2.3 Where cables pass through gastight bulkheads or decks separating hazardous zones or spaces, arrangements are to be such that the gastight integrity of the bulkhead or deck is not impaired.

Section 2 POWER SUPPLY FOR ELECTRONIC CONTROL SYSTEMS

9.2.1 **General requirements**

9.2.1.1 The power for the electronic control system of gas engines and gas fuel supply system is to be supplied by two independent feeders from two power sources, one is to be the mian source of electrical power, and the other one is to be batteries. Automatically supplied by the batteries in the event of failure of the main source of electrical power. Period of supply of the betteries is not less than the period of supply of the emergency source required by CCS Relevant Rules. When the main source of electrical power is consist of only batteries, the power for the electronic control system of gas engines and gas fuel supply system are to be supplied by two independent feeders from the mail source of electrical power.

CHAPTER 10 CONTROL, MONITORING AND SAFETY SYSTEMS

Section 1 GENERAL PROVISIONS

10.1.1 **General requirements**

10.1.1.1 Local-reading pressure indicators are to be provided to indicate the pressure between ship manifold’s stop valves and hose connections to the shore. Those also are to be provided between fuel pump or gas compressor’s discharge line and fuel line.

10.1.1.2 A bilge well in each tank connection space (if applicable) is to be provided with both a level indicator and a temperature sensor. An alarm is to be given at high level in bilge well. Low temperature indication is to activate the safety system to close the main tank valve automatically.

Section 2 MONITORING

10.2.1 **Gas tanks**

10.2.1.1 Gas tanks are to be monitored and protected against overfilling as required in 《Rules for the construction and equipment of ships carrying liquefied gases in bulk》 of CCS.

10.2.1.2 Each tank is to be monitored with at least one local indicating instrument for pressure and level, meantime remote indication at the control position or bridge or manned locations in the engine room is to be provided. The pressure indicators are to be clearly marked with the highest and lowest pressure permitted in the tank. In addition, high-pressure alarm, and if vacuum protection is required, a low pressure alarm(if applicable), high level alarm and low level alarm are to be provided on the bridge or manned locations in the engine room. The alarms are to be activated before the set pressures of the safety valves are reached.

10.2.1.3 A temperature sensor of each LNG fuel tank is to be provided at the bunking control station.

10.2.2 Gas compressors

10.2.2.1 Gas compressors are to be fitted with audible and visual alarms both on the bridge and in the engine-room. As a minimum the alarms are to be in relation to low gas input pressure, low gas output pressure, high gas output pressure and compressor operation.

10.2.3 Heat exchangers

10.2.3.1 An audible and visible alarm is to be activated on the bridge and manned locations in the engine room in the event of the failure as described in 4.4.2.

10.2.4 Gas engines

10.2.4.1 Additional to the instrumentation provided in accordance with connecting rules of CCS, indicators are to be fitted on the bridge, the engine control room and the maneuvering platform for:

(1) operation of the engine in case of gas-only engines; or

(2) operation and mode of operation of the engine in the case of dual fuel engines.

Section 3 GAS DETECTION

10.3.1 General requirements

10.3.1.1 Requirements as described in Sec3.1.4 are to be provided for increased safety machinery spaces , while the following requirements are to be provided for other machinery spaces：

(1) Permanently installed gas detectors are to be located according to gas fuel system’s spaces described in 10.3.1.1.The number of detectors in each space ,which can be reduced to one in condition of the self-check function, is to be considered taking into account the size、layout and ventilation of the space in accordance with the minimum requirements set in 10.3.1.1.

The Minimum Number of Permanently installed gas detectors Table 10.3.1.1

spaces	The Minimum Number of Permanently installed gas detectors (set)

Semi-enclolsed/enclosed bunkering station	2
Tank connection space	2
The air space between the gas pipe and the wall of the ventilation pipe	2
Each of ESD protected machinery space	2
Gas compressor room	2
Gas valve unit space[1)]	2
Other enclosed spaces with gas equipment	2

[1)] If gas valve unit space is connected with ventilation pipe and the inner volume of gas valve unit space is no more than $2m^3$, gas valve unit space can be seen as a part of ventilation pipe.

(2) Unless a clear regulation is made, an audible and visible alarm is to be activated before the gas concentration reaches 20% of the lower explosion limit (LEL).For ventilated ducts around gas pipes in the machinery spaces containing gas-fuelled engines, the alarm limit can be set to 30% of LEL. The protective system is to be activated at a LEL of 40%.

10.3.1.2 Gas detection equipment are to be installed where gas may accumulate or in the ventilation outlets.

10.3.1.3 Audible and visible alarms from the gas detection equipment are to be located on the bridge and manned locations in the engine room.

10.3.1.4 Gas detection is to be continuous.

10.3.1.5 A set of portable gas detector is to be fitted for the cabin check.

10.3.1.6 Gas detectors are also to be installed in space where gas may leak or accumulate.

Section 4 SAFETY FUNCTIONS OF GAS SYSTEMS

10.4.1 **General requirements**

10.4.1.1 In the event of failure as described in table 10.4.1.1(1) and 10.4.1.1(2), connecting actions are to be taken in accordance with a recognized standard. The alarm as described in table10.4.1.1(1) is to be located at the bridge and bunking control station, while the alarm in table 10.4.1.1(2) is to be located at the bridge and manned locations in the engine room.

10.4.1.2 The total loss of ventilation in a machinery space for a single fuelled gas system is to, additionally to what is given in table10.4.1.1(2), lead to one of the following actions:

(1) For a gas electric propulsion system with more than one machinery space: Another engine is to start. When the second engine is connected to bus-bar, the first engine is to be shutdown automatically.

(2) For a direct propulsion system with more than one machinery space: The engine in the room with defect ventilation is to be manually shutdown, if at least 40% propulsion power is still available after such a shutdown.

(3) If only one machinery space for gas-fuelled engines is fitted and ventilation in one of the enclosed ducts around the gas pipes is lost or inert gas overpressure is lost, the master gas fuel and double block and bleed valves in the supply line are to close automatically provided the other gas

supply unit is ready to deliver.

Monitoring of gas bunkering systems Table 10.4.1.1（1）

Parameter	Alarm	Automatic shutdown of the manifold emergency shutdown valve	Comment
Gas detection in Semi-enclolsed/enclosed Bunkering Station exceed 20% LEL	×		
Gas detection in Semi-enclolsed/enclosed Bunkering Station exceed 40% LEL	×	×	
Loss of ventilation in ducting around gas bunkering lines	×		See 6.3.1.5
Gas detection in ducting around gas bunkering lines exceed 20% LEL	×		See 6.3.1.5
Gas detection in ducting around gas bunkering lines exceed 20% LEL	×	×	See 6.3.1.5
High level in tank	×	×	
High pressure in tank	×	×	
Manual valve shutdown		×	
Loss of emergency shutdown valve motive power	×		

Monitoring of gas supply system to engines Table 10.4.1.1（2）

Parameter	Alarm	Automatic shutdown of main tank valves	Automatic shutdown of master gas valve and DBB valves,Automatic open of vent valves open	Comment
Gas tanks				
High pressure in tank	×			
Low pressure in tank	×			If applicable
Low level in tank	×			
Fuel storage hold spaces and tank connection spaces				
Gas detection on one detector in	×			

tank connection space exceed 20% LEL				
Gas detection on two detectors[7)] in tank connection space exceed 40% LEL	×	×		
Fire detection in fuel storage hold space	×	×		
Bilge well high level in tank connection space	×			
Bilge well low temperature in tank connection space	×	×		
Heat exchangers				
Gas low temperature at heat exchanger outlet	×	×		See 4.4.2.1,Automatic stop of liquefied gas feed pump(if fitted)
Compressor rooms				
Gas detection on one detector in compressor room exceed 20% LEL	×			
Gas detection on two detectors[7)] in compressor room exceed 40% LEL	×	×[1)]		
Gas supply systems between tank connection space and engine room				
Gas detection on one detector in ventilation duct at 20%LEL	×			
Gas detection on two detectors[7)] in ventilation duct at 40%LEL	×	×[1)]		
Loss of ventilation in duct[5)]	×		×[1) 3)]	
Gas valve unit spaces				
Gas detection on one detector in gas valve unit space exceed 20% LEL	×			
Gas detection on two detectors7) in gas valve unit space exceed 40% LEL	×		×[2)]	
Loss of ventilation in gas valve unit space	×		×[2) 3)]	
Machinery spaces containing gas-fuelled engines				
Fire detection in machinery space containing gas-fuelled engines	×		×[8)]	

Rupture detection of gas line in the machinery space containing gas-fuelled engines	×		×6)	See 4.3.1.5、4.3.2.1、4.3.3.1
Intrinsic safety machinery spaces				
Gas detection on one detector in ventilation duct inside machinery space containing gas-fuelled engines exceed 30% LEL	×			
Gas detection on two detectors7) in ventilation duct inside machinery space containing gas-fuelled engines exceed 40% LEL	×		×2)	
Loss of ventilation in duct5) inside machinery space containing gas-fuelled engines	×		×2) 3)	
Gas detection one detector in machinery space containing gas-fuelled engines exceed 20% LEL	×			Applies only to some described in 4.3.1.2
Gas detection on two detectors7) in machinery space containing gas-fuelled engines exceed 40% LEL	×		×8)	Applies only to some described in 4.3.1.2
ESD-Protected engine spaces				
Gas detection on one detector in machinery space containing gas-fuelled engines exceed 20% LEL	×			
Gas detection on two detectors7) in machinery space containing gas-fuelled engines exceed 40% LEL	×		×	It is also disconnect non certified safe electrical equipment in machinery space containing gas-fuelled engines and disconnect oil-fuel supply if using double fuels.
Loss of ventilation in machinery space	×		×	
increased safety machinery spaces				
Gas detection on one detector in machinery space containing	×		×	Fuel supply is to be automatically converted

gas-fuelled engines exceed 20% LEL				into oil at the same time of cutting off the gas supply
Loss of ventilation in machinery space	×		×	Fuel supply is to be automatically converted into oil at the same time of cutting off the gas supply
other requirements				
Abnormal gas pressure in gas supply pipe	×		×3）	
Failure of valve control actuating medium	×		×4）	Time delayed as found necessary
Automatic shutdown of engine (engine failure)	×		×4）	
Manually activated emergency shutdown of engine	×		×	

1） If the tank is supplying gas to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to close.

2） If the gas is supplied to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct and outside of the machinery space containing gas-fuelled engines, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to close.

3） Only apply to dual fuel engines.

4） Only double block and bleed valves to close.

5） If the duct is protected by inert gas then loss of inert gas overpressure is to lead to the same actions as given in this tables.

6） May utilize a dedicated valve in case of pipe rupture. See 4.3.1.5

7） For detectors with self-check function, gas was detected by one detector, which is to be seen as detection of two detectors .

8） Only apply to ESD-Protected engine spaces or dual fuel engines

CHAPTER 11 GAS FUEL ENGINES

Section 1 GENERAL PROVISIONS

11.1.1 General requirements

11.1.1.1 This CHAPTER is to apply to gas fuel engines for propulsion and for driving generators or other important auxiliary equipments.

11.1.1.2 Design, manufacture, installation and test of gas fuel engines are to comply with not only the requirements for diesel engines of CCS Rule, but also the provisions of this CHAPTER, CHAPTER 10 and Appendix 2 of the Rules. Gas fuel engines are to be of marine product certificate.

11.1.1.3 Electronic control systems of electronic-controlled gas fuel engines are to comply with the provisions of Appendix 3 of the Rules.

11.1.1.4 Natural gas can be introduced into gas fuel engines as follows:

(1) mixed with air before the turbocharger and flowing into cylinder through air inlet manifold;

(2) mixed with air after the turbocharger and flowing into cylinder through air inlet manifold;

(3) mixed with air in air inlet branch or cylinder air inlet channel port and flowing into cylinder; or

(4) directly into the cylinder.

11.1.1.5 Gas fuel engines are to be capable of operating with possible variations of the methane number and lower heat value of natural gas. The extent of permitted variations of methane number and lower heat value are to be declared by the manufacturer.

11.1.1.6 Risk analysis is to be conducted on all possible faults affecting operation safety of gas fuel engine. Required engine monitoring items are to be determined based on the risk analysis results. Risk analysis is to comply with the requirements of Section 3 of this CHAPTER and the report is to be submitted to CCS.

11.1.2 **Safety protection**

11.1.2.1 All gas fuel engine components, systems and subsystems containing or likely to contain gas mixture are to be designed to:

(1) exclude any explosion at all possible situations； or

(2) allow explosions without detrimental effect and to discharge to a safe location far away from personnel, equipments and systems. The explosion event is not to interrupt the safe operation of the engine unless other safety measures allow the shutdown of the affected engine.

11.1.2.2 The design and arrangement of gas piping on gas fuel engines are to comply with the requirements of CHAPTER 3 and CHAPTER 4 of the Rules.

11.1.2.3 Where compressed air is introduced directly into the cylinders for starting purposes, the starting air pipes are to be provided with flame arresters, which are to be fitted at starting air branch pipe to each cylinder for direct reversing engines, and at starting air manifold for non-reversing engines.

11.1.2.4 Where gas fuel is mixed with air before the turbo-charger, the engine air intake is to be located outside the engine room provided that the engine is arranged in intrinsic safety machinery space. The engine air intake located inside the engine room may be accepted where the engine is arranged in ESD protected machinery space or increased safety machinery space.

11.1.2.5 Where air intakes are located inside the engine room, they are to be situated as far apart as practicable from the gas fuel supply pipe such that the risk of the leakage gas entering the intake is minimized. Air intakes located outside the engine room are to be lead from a non-hazardous area at least 1.5m from the boundaries of any hazardous area.

11.1.2.6 Where gas fuel is supplied mixed with air through the air inlet manifold, explosion relief valves or other explosion prevention measures are to be provided for the air inlet manifold. Alternatively, documentation may be submitted showing that the system has sufficient strength to withstand a worst-case explosion. When gas fuel is mixed with air before the turbo-charger, explosion relief valves are to be installed additionally on the turbo-charger or intercooler. Alternatively, documentation may be submitted showing that the turbo-charger or intercooler has sufficient strength to withstand a worst-case explosion.

11.1.2.7 The crankcase of gas fuel engines is to be provided with crankcase explosion relief valves with sufficient relief area. Alternatively, documentation may be submitted showing that the crankcase has sufficient strength to withstand a worst-case explosion. The combined free area of the crankcase relief valves fitted on a gas fuel engine is not to be less than $115cm^2$ per $1m^3$ of the volume of the crankcase, and the free area of each crankcase relief valve is not to be less than $45cm^2$. Crankcase explosion relief valves are to be installed according to the following requirements:

(1) For low pressure gas fuel engines, where the cylinder bore is 200mm or above, at least one relief valve is to be fitted at each end of the crankcase, and another relief valve is to be fitted near the middle of the crankcase provided that the number of the cranks is over eight. Where the

cylinder bore is more than 250mm, at least one relief valve is to be fitted on each crank. For the compartments of the crankcase with a gross volume of more than 0.6m^3, such as gear housing, chain cases or other similar devices for driving the camshaft, an explosion relief valve is to be provided.

(2) For high pressure gas fuel engines, at least one relief valve is to be fitted on each crank, and the compartments of the crankcase, such as gear housing, chain cases or other similar devices for driving the camshaft, are to be provided with explosion relief valves.

11.1.2.8 The crankcase of gas fuel engines is to be protected by the following measures:

(1) For trunk piston type engines, the crankcase is to be provided with independent vent system, and the outlet of the vent line is to be led to a non-hazardous area in the open air through a flame arrester; for the purpose of maintenance a connection (or other means) is to be provided for crankcase inerting; the crankcase is to be fitted with a gas detector, which could be arranged in the crankcase vent line such that contamination of the detector by oil mist is avoided. For cross-head type engines, a gas detector is to be provided in the space underside the piston.

(2) For low pressure gas fuel engines, the crankcase is to be protected by oil mist detectors (or bearing temperature detectors) where the cylinder bore is of 200mm and above. For high-pressure gas fuel engines, the crankcase is to be protected by oil mist detectors (or bearing temperature detectors).

Electrical installation and instruments fitted inside the crankcase are to be of the certified safe type.

11.1.2.9 The exhaust manifold of a gas fuel engine is to be equipped with an explosion relief valve (or other explosion prevention devices) sufficiently dimensioned to prevent serious damage in the event of explosion arose from the unburnt gas mixture accumulated in the exhaust manifold, except documentation demonstrating that the system has sufficient strength to contain the worst-case explosion.

11.1.2.10 The exhaust system is to be purged to discharge the combustible gas that may be present in the event a gas fuel engine stops during the gas fuel mode.

11.1.2.11 The exhaust pipes of gas fuel engines are not to be connected to the exhaust pipes of other engines or systems.

11.1.2.12 The installation and arrangement of the explosion relief valves is to minimize the dangers of discharged gas from valves to personnel.

11.1.2.13 Explosion relief valves that require dismantling or replacement after activated, which affects continuous engine operation, are not to be installed on single engine main propulsion installations, unless auxiliary propulsion system is provided.

11.1.2.14 Where gas can enter directly into the auxiliary system medium (lubricating oil, cooling water), an independent vent pipe is to be installed on these systems such that the gas leakage is to be led to a safe location outside the engine room through a flame arrester.

11.1.2.15 The combustion of the in-cylinder flammable gas mixture is to be monitored by the use of exhaust gas or combustion chamber temperature monitoring. The combustion of engines having a cylinder bore exceeding 200mm is to be monitored on an individual basis in order to avoid detonation or misfire. In the event that detonation or misfire is detected, the gas supply of the engine is to be shut down according to the specified safety control strategies, or only the gas supply to the concerned cylinders is shut down provided that the operation of the engine with one cylinder cut-off is acceptable with respects to torsion vibrations.

Section 2 FUNCTIONAL REQUIREMENTS

11.2.1 Dual fuel engines

11.2.1.1 Start, normal stop, idle operation, low power operation, high power operation and overload operation are to be on oil fuel only. Alternatively, documentation may be submitted showing that the engine can be safely started, normal stopped, low power operated, high power operated and overload operated under gas fuel mode.

11.2.1.2 Changeover of engine fuel modes (from oil fuel mode to gas fuel mode and from gas fuel mode to oil fuel mode) is only to be possible at a power level where it can be done with acceptable reliability as demonstrated through testing. On completion of preparations for changeover to gas fuel mode including checks of all essential conditions for changeover, the changeover process itself is to be automatic. On power reduction, the changeover to oil fuel mode is to be automatic. Manual interruption is to be possible in all cases.

11.2.1.3 On normal stop as well as emergency shutdown, gas fuel supply is to be shut off not later than simultaneously with the oil fuel. Shut-off of the gas fuel is not to be dependent on the shut off of the oil fuel.

11.2.1.4 Firing of the gas-air mixture in the cylinders is to be initiated by injection of pilot fuel. The amount of pilot fuel fed to each cylinder is to be sufficient to ensure a positive ignition of the gas mixture. It is not to be possible to shut off the supply pilot fuel without first or simultaneous closing the gas supply to each cylinder or to the complete engine. It is to ensure that gas fuel is not to be injected into cylinders while the oil fuel supply is shut off.

11.2.2 Gas-only engines

11.2.2.1 The starting sequence is to be that the ignition system is not activated until the engine has reached a minimum rotational speed, and gas fuel supply system is not to open until ignition is activated.

11.2.2.2 If ignition has not been detected by the engine monitoring system within an engine specified time after opening of gas supply system, the gas supply is to be automatically shut off and the starting sequence terminated.

11.2.2.3 Unburnt combustible mixture in the exhaust gas pipe is to be purged after a failed start. Restarting after a failed start is not to be possible before the exhaust gas pipe has been completely purged.

11.2.2.4 On normal stop as well as emergency shutdown, gas fuel supply is to be shut off not later than simultaneously with the ignition. It is not to be possible to shut off the ignition without first or simultaneously closing the gas supply to each cylinder or to the complete engine.

11.2.2.5 For constant speed engines, the shut down sequence is to be such that the engine gas supply system closes at idle speed and that the ignition system is kept active until the engine is down to standstill.

Section 3 RISK ANAYSIS

11.3.1 Scope of risk analysis

11.3.1.1 The risk analysis is at least to address:

(1) a failure or malfunction of any system or component involved in the gas operation of the engine;

(2) a gas leakage originating from the engine; or

(3) the safety of the engine in case of emergency shutdown or blackout when running on gas.

11.3.1.2 Failures in systems external to the engine (such as fuel storage or fuel gas supply systems) may require action from the engine control and monitoring system in the event of an alarm or fault condition.

11.3.2 Form of risk analysis

11.3.2.1 The required analysis may be a FMEA analysis or another type of analysis providing equivalent information. The FMEA is to be performed in accordance with an acceptable and relevant national or international standard (e.g. IEC 60812) by CCS.

11.3.2.2 The required analysis is to be based on the single failure concept, which means that only one failure needs to be considered at the same time. Both detectable and non-detectable failures are to be considered. Consequences failures, i.e. failures of any component directly caused by a single failure of another component, are also to be considered.

11.3.3 Procedure of risk analysis

11.3.3.1 The risk analysis is to：

(1) identify all the possible failures in the concerned equipment and systems which could lead:

① to the presence of gas in components or locations not designed for such purpose; and/or

② loss of the assigned functions.

(2) evaluate the consequences

(3) identify the failure detection method (if necessary)

(4) identify the corrective measures (if necessary) :

① in the system design, such as:

(a) redundancies;

(b)safety devices, monitoring or alarm provisions which permit restricted operation of the system.

② in the system operation, such as:

(a) initiation of the redundancy;

(b) activation of an alternative mode of operation.

11.3.3.2 The results of the risk analysis are to be documented and confirmed by a practical test.

11.3.4 Analysis of equipment and systems

11.3.4.1 The risk analysis required for engines is to cover at least the following aspects：

(1) failure of the gas-related systems or components, in particular:

① gas piping and its enclosure（where provided）;

② cylinder gas supply valves[5].

(2) failure of the ignition system (oil fuel pilot injection or sparking plugs)；

(3) failure of the air to fuel ratio control system (charge air by-pass, gas pressure control valve, etc.）;

(4) for engines where gas is injected before the turbo-charger, failure of a component likely to result in a source of ignition (hot spots)；

(5) failure of the gas combustion or abnormal combustion (misfiring, knocking)；

(6) failure of the engine monitoring, control and safety systems[6]；

(7) abnormal presence of gas in engines components (e.g. air inlet manifold and exhaust manifold) and in the external systems connected to the engines (e.g. exhaust duct)；

(8) changeover of fuel modes for dual fuel engines.

CHAPTER 12 OPERATIONAL AND TRAINING REQUIREMENTS

Section 1 GENERAL PROVISIONS

12.1.1 General requirements

12.1.1.1 The whole operational crew of a natural gas-fuelled ship is to have necessary training in gas-related safety, operation and maintenance prior to the commencement of work on board.

12.1.1.2 Crew members with a direct responsibility for the operation of gas-related equipment on board are to receive special training. The company is to document that the personnel have acquired the necessary knowledge and that this knowledge is maintained at all times.

12.1.1.3 Training is to be regularly reviewed by the company and onboard senior management team as part of the SMS system of ship-owning companies. Risk analysis is to be emphasized, and any risk analysis documents is to be available to course participants during training.

12.1.1.4 Gas-related emergency exercises is to be conducted at regular intervals. Safety and response systems for the handling of defined hazards and accidents are to be reviewed and tested.

12.1.1.5 A training manual is to be developed and a training programme and exercises are to be specially designed for each individual vessel and its gas installations.

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[5] Failures of the gas supply components not located directly on the engine (such as block-and-bleed valves and other components of the GVU) are not to be considered in the analysis.

[6] Where engines incorporate electronic control systems, the risk analysis is to demonstrate that failure of an electronic control system will not result in the loss of essential services for the operation of the engine and that operation of the engine will not be lost or degraded beyond an acceptable performance criterion of the engine.

Section 2 TRAINING

12.2.1 Basic training

12.2.1.1 The goal of basic training is to provide the basic safety crew with a basic understanding of the gas in question as a fuel, the technical properties of liquid and compressed gas, explosion limits, ignition sources, risk reducing and consequence reducing measures, and the rules and procedures that must be followed during normal operation and in emergency situations.

12.2.1.2 Basic training is to consist of both theoretical and practical exercises that involve gas and the relevant systems, as well as personal protection while handling liquid and compressed gas. Practical extinguishing of gas fires is to form part of the training.

12.2.2 Operational training

12.2.2.1 Deck and engineer officers are to have gas training beyond the general basic training.

12.2.2.2 Besides the courses of basic training, all gas-related systems on board, the ship's maintenance manual, gas supply manual and manual for electrical equipment in explosion hazardous spaces and zones are to be used as the content of the training.

Section 3 MAINTENANCE

12.3.1 General requirements

12.3.1.1 A special maintenance manual is to be prepared for the gas supply system on board.

12.3.1.2 The manual is to include maintenance procedures for all technical gas-related installations, and is to comply with the recommendations of the suppliers of the equipment. The intervals for, and the extent of, the replacement/approval of gas valves are to be established. The qualification of maintenance personnel is to be specified in the maintenance procedure.

12.3.1.3 A special maintenance manual is to be prepared for electrical equipment that is installed in explosion hazardous spaces and areas. The inspection and maintenance of electrical installations in explosion hazardous spaces is to be performed in accordance with a recognized standard[7].

12.3.1.4 Any personnel that is to carry out inspections and maintenance of electrical installations in explosion hazardous spaces is to be qualified.

Section 4 OPERATIONAL MANUAL OF GAS SUPPLY SYSTEM

[7] Refer to IEC 60079-17:2007 Explosive atmospheres . Part 17: Electrical installations inspection and maintenance.

12.4.1 **General requirements**

12.4.1.1 An operational manual of gas supply system, which is treated as the safety operation guide under normal and foreseeable emergence conditions, is to be always available onboard for the crew.

12.4.1.2 An operational manual of gas supply system is at least to cover the aspects as follows：

(1) safety inspection before sailing;

(2) engine start procedure;

(3) announcements during voyages and after engine stop;

(4) gas fuel bunkering procedure;

(5) maintenance and repair;

(6) operational procedure under emergence conditions;

(7) purging and inerting procedure.

Appendix 1 LNG TANKS

Section 1 GENERAL PROVISIONS

1.1 General requirements

1.1.1 This Appendix applies to the design of type C independent LNG tanks.

1.1.2 The requirements for pipes and valves in this Appendix apply to the connections and valves attached to the tanks.

1.1.3 Tanks are to comply with the provisions of a recognized pressure vessel code[8] in addition with the requirements of this Appendix.

Section 2 DESIGN LOADS

2.1 Loads to be considered

2.1.1 Tanks, together with their supporting structure and other fixtures, are to be designed taking into account relevant combinations of the loads described below:

（1）the weight of tank, liquefied gas fuel, thermal insulation, and other attachments.

（2）internal pressure

（3）external pressure

[8] E.g. GB 150, JB 4732, ASME <Boiler and Pressure Vessel Code>, EN 13530 etc.

(4) dynamic loads due to the motions of the ship
(5) thermal loads
(6) vibration
(7) interaction loads
(8) loads associated with construction and installation
(9) test loads
(10) static heel loads
(11) sloshing
(12) wave impacts and green sea effect for tanks installed on open deck
(13) wind impact

2.2 Internal pressure P_i

2.2.1 The internal pressure is to be resulted from the design vapour pressure P_0 and the pressure caused by the acceleration due to the motions of the ship.

2.2.2 The design vapour pressure P_0 is not to be less than:

$$P_0 = 0.2 + AC(\rho_r)^{1.5} \qquad \text{MPa}$$

Where, $A = 0.00185(\sigma_m / \Delta\sigma_A)^2$

Where, σ_m ——design primary membrane stress, in N/mm^2;

$\Delta\sigma_A$ ——allowable dynamic membrane stress (double amplitude at probability level Q=10^{-8}), in N/mm^2;

$\Delta\sigma_A$ =55 N/mm^2, for ferritic-perlitic, martensitic and austenitic steel

$\Delta\sigma_A$ =25 N/mm^2, for aluminium alloy(5083-0)

C —— a characteristic tank dimension to be taken as the greatest of the following: h; 0.75b; or 0.45l

where: h—— height of tank (dimension in ship's vertical direction), in m;
b—— width of tank (dimension in ship's transverse direction), in m;
l—— length of tank (dimension in ship's longitudinal direction), in m;

ρ_r —— the relative density of the cargo (ρ_r =1 for fresh water) at the design temperature.

When a specified design life of the tank is longer than 10^8 wave encounters, $\Delta\sigma_A$ is to be modified to give equivalent crack propagation corresponding to the design life.

2.2.3 In all cases, P_0 is not to be less than MARVS.

2.3 External pressure

2.3.1 External design pressure loads shall be based on the difference between the minimum internal pressure and the maximum external pressure to which any portion of the tank may be simultaneously subjected.

2.4 Loads due to ship motion

2.4.1 Following inertia forces may be used to determine the loads due to the motion of the ship (R——maximum gross mass; g is to be taken as 9.81 m/s^2):

(1) In the direction of travel: twice the total mass multiplied by the acceleration due to gravity（$2Rg$）;

(2) Horizontally at right-angle to the direction of travel: the total mass multiplied by the acceleration due to gravity（Rg）for inland waterways ships; 1.5 times the total mass multiplied by the acceleration due to gravity（1.5Rg） for see-going ships;

(3) Vertically upwards: the total mass multiplied by the acceleration due to gravity（Rg）;

(4) Vertically downwards: twice the total mass multiplied by the acceleration due to gravity（2Rg）.

2.4.2 The inertia forces conditiond in 2.4.1 of this Appendix (inertial forces corresponding with the weight of cargo) is to be uniformly distributed on the shell’s contact face perpendicular to the relevant direction of movement.

2.5 Thermal loads

2.5.1 Thermal loads are to be considered during the design of LNG tank and low temperature piping.

2.6 Vibration

2.6.1 The potentially damaging effects of vibration on the liquefied gas fuel containment system are to be considered.

2.7 Interaction loads

2.7.1 The static component of loads resulting from interaction between liquefied gas fuel containment system and the hull structure, as well as loads from associated structure and equipment are to be considered.

2.8 Loads or conditions associated with construction and installation

2.8.1 Loads or conditions associated with construction and installation are to be considered, e.g. lifting.

2.9 Test loads

2.9.1 Account is to be taken of the loads corresponding to the testing of the liquefied gas fuel containment system referred to in 4.1.1 of this Appendix.

2.10 Static heel loads

2.10.1 Loads corresponding to the most unfavourable static heel angle within the range 0° to 30°are to be considered.

2.11 Sloshing loads

2.11.1 The sloshing loads on a liquefied gas fuel containment system and internal components are to be evaluated by means of special tests and calculations covering the full range of intended filling levels.

2.12 Collision

2.12.1 Tanks and its supports are to be designed to withstand a collision force in the forward direction and aft direction without deformation likely to endanger the structure.

2.12.2 The collision load is to be determined based on the fuel containment system under fully loaded condition. The collision force is to be calculated according to:

(1) design acceleration: 0.5g, for $L > 100$ m;

(2) design acceleration $\left[2 - \frac{3}{80}(L-60)\right]g$:, for $60 < L \le 100$ m;

(3) design acceleration: 2g, for $L < 60$ m.

2.13 Loads due to flooding on ship

2.13.1 Loads caused by the buoyancy of a fully submerged empty tank or flooded compartment up to main deck, whichever is the worst, are to be considered in the design of the fuel containment system, anti-flotation chocks and the supporting hull structure.

Section 3 DESIGN AND MANUFACTURE

3.1 General requirements

3.1.1 Applicable loads to which the tank may be simultaneously subjected are to be considered during the design phase.

3.1.2 The most unfavourable scenarios for all relevant phases during construction, handling, testing and in service and conditions are to be considered.

3.1.3 Tanks are to comply with the provisions of a recognized pressure vessel code (see 1.1.3 of this Appendix). The affection of the dynamic loads on the integral structure, locally strengthening structure, connection parts between the inner and outer shell as well as the tank attachments are to be considered during the design phase.

3.1.4 The inertia forces conditiond in 2.4.1 of this Appendix are to be considered during the design phase.

3.1.5 LNG tanks are to be assessed integrally taking into account the weight, design internal and external pressure and the inertia forces conditiond in 2.4.1. The results of the analysis are to comply with the following requirements:

(1) Shells are to be assessed in accordance with the recognized pressure vessel code (assessment is to be carried out in accordance with JB4732, ASME <Boiler and Pressure Vessel Code> and EN13530 for shells designed according to GB150, ASME <Boiler and Pressure Vessel Code> and EN13530 respectively. For metals exhibiting with unclear yield point and austenitic steels, 0.2% proof strength is to be regarded as the yield limit).

(2) The resultant Von Mises stress of the supports is to satisfy the following requirements:

$$\sigma \le 0.9R_e$$

Where, R_e is the yield strength. For metals exhibiting with unclear yield point and austenitic steels, 0.2% proof strength is to be regarded as the yield limit.

3.1.6 The hull structures connecting to the tank are to comply with the requirements of relevant CCS Rules.

3.2 Structural construction

3.2.1 Horizontal LNG tanks are to be supported by two saddle supports.

3.2.2 For LNG tank with an effective volume no more than $25m^3$, the volume between surge plates is not to exceed $7.5m^3$; For tank with an effective volume exceeding $25m^3$, the interval between surge plates is not to exceed 4m.

3.2.3 Negative tolerance of thickness is to be considered for stainless steel. Corrosion allowance may be ignored for stainless steel.

3.2.4 For pressure vessels, the minimum thickness of shell and heads including corrosion allowance, after forming, is not to be less than 5 mm for carbon manganese steels and nickel steels, 3 mm for austenitic steels or 7 mm for aluminum alloys.

3.2.5 For pressure vessels, the thickness calculated according to 3.1.3 and 3.8 is to be considered as a minimum thickness after forming, without any negative tolerance.

3.3 Piping and valves

3.3.1 Emergency shutdown valves, stop valves are to be furnished with the CCS products certificates. Performance tests are to be carried out after installation. Requirements of the action are to be contained in theOperational instructions of the product.

3.3.2 Attachments of LNG tanks is to comply with the following requirements:

(1) All liquid and vapour connections, except safety relief valves and liquid level gauging devices, are to l be equipped with a manually operated stop valve and an emergency shutdown valve. These valves are to be located as close as to the tank as practicable.

(2) A single valve may be substituted for the two separate valves provided that the valve is capable of local manual operation and automatically shut down.

(3) Stop valves are to be fitted between tanks and pressure relief valves. The stop valves are to be sealed in open position during the normal operating conditions.

(4) Vapour connections are to be fitted with a manually operated pressure relief valve.

3.4 Instrumentation

3.4.1 Instrumentation of the tank is to comply with the requirements of filling and monitoring in CHAPTER 6 and CHAPTER 10 respectively.

3.4.2 For vacuum insulated tanks, the space between inner and outer shell is to be fitted with instrument or detection opening for the pressure monitoring.

3.5 Thermal insulation

3.5.1 Materials used in the LNG fuel containment system are to be suitable for the design loads and their intended use.

3.5.2 The above properties, where applicable, are to be tested for the range between the expected maximum temperature in service and 5°C below the minimum design temperature, but not lower than minus 196°C.

3.5.3 Due to location or environmental conditions, thermal insulation materials are to have suitable properties of resistance to fire and flame spread and be adequately protected against penetration of water vapour and mechanical damage. Where the thermal insulation is located on or above the exposed deck, it is to have suitable fire resistance properties in accordance with a recognized standard or be covered with a material having low flame spread characteristics and forming an efficient approved vapour seal.

3.5.4 Thermal insulation that does not meet recognized standards for fire resistance may be used in hold spaces that are not kept permanently inerted, provided its surfaces are covered with material with low flame spread characteristics and that forms an efficient approved vapour seal.

3.5.5 Where powder or granulated thermal insulation is used, measures are to be taken to reduce compaction in service and to maintain the required thermal conductivity and also prevent any undue increase of pressure on the liquefied gas fuel containment system.

3.6 Weld joints

3.6.1 Welding joint details for tanks are to be as follows:

(1) All longitudinal and circumferential joints are to be of butt welded, full penetration, double vee or single vee type. Full penetration butt welds are to be obtained by double welding or by the use of backing rings. If used, backing rings are to be removed except from very small process pressure vessels. Other edge preparations may be permitted, depending on the results of the tests carried out at the approval of the welding procedure.

(2) For vacuum insulated tanks without manholes, all longitudinal and circumferential joints of the inner shell are to be of butt welded, full penetration, double vee, except for the last circumferential joints used to nonnect the shell and head, which may be of butt welded by the use of backing rings. All longitudinal and circumferential joints of the outer shell are to be of butt welded, full penetration, double vee, except for the last circumferential joints used to nonnect the shell and head, which may be of butt welded by the use of backing rings.

3.6.2 Welding coefficient used to confirm the thickness of the pressure tanks is to comply with the provisions of pressure vessel codes mentioned in 3.1.3 of this Appendix.

3.7 Manufacture and non-destructive testing

3.7.1 The tolerances relating to manufacture and workmanship such as out-of-roundness, local deviations from the true form, welded joints alignment and tapering of plates having different thicknesses, is to comply with standards acceptable to CCS.

3.7.2 The method and extent of non-destructive testing are to comply with the provisions of the recognized standards.

3.8 Buckling analyses

3.8.1 The thickness and form of pressure vessels subject to external pressure and other loads causing compressive stresses are to be based on calculations using accepted pressure vessel buckling theory and are to adequately account for the difference in theoretical and actual buckling stress as a result of plate edge misalignment, ovality and deviation from true circular form over a specified arc or chord length.

3.8.2 The design external pressure P_e, used for verifying the buckling of the pressure vessels, is not to be less than that given by:

$$P_e = P_1 + P_2 + P_3 + P_4 \qquad \text{MPa}$$

Where: P_1—— setting value of vacuum relief valves. For vessels not fitted with vacuum relief valves P_1 is to be specially considered, but is not in general to be taken as less than 0.025 MPa;

P_2—— the set pressure of the pressure relief valves (PRVs) for completely closed spaces containing pressure vessels or parts of pressure vessels; elsewhere P_2 = 0;

P_3—— compressive actions in or on the shell due to the weight and contraction of thermal insulation, weight of shell including corrosion allowance and other miscellaneous external pressure loads to which the pressure vessel may be subjected. These include, but are not limited to, weight of domes, weight of towers and piping, effect of product in the partially filled condition, accelerations and hull deflection. In addition, the local effect of external or internal pressures or both are to be taken into account;

P_4—— external pressure due to head of water for pressure vessels or part of pressure vessels on exposed decks; elsewhere P_4 = 0.

3.9 Fatigue analyses

3.9.1 The liquefied gas fuel containment system is to be subjected to fatigue analysis, considering all fatigue loads and their appropriate combinations for the expected life of the liquefied gas fuel containment system. Consideration is to be given to various filling condition.

3.9.2 Where a fatigue analysis is required, the cumulative effect of the fatigue load is to comply with:

$$\sum \frac{n_i}{N_i} + \frac{n_{loading}}{N_{loading}} \le C_w$$

Where, n_i —— Number of stress cycles at each stress level furing the life of the ship;

N_i —— Number of cycles to fracture for the respective stress level according to the Wöhler(S-N) curve;

$n_{loading}$ ——Number of loading and unloading cycles during the life of the tank, normally taken as 1000. Loading and unloading cycles include a complete pressure and thermal cycle;

$N_{loading}$ ——Number of cycles to fracture for the fatigue loads due to loading and unloading;

C_w ——Maximum allowable cumulative fatigue damage ratio, is to be less than or equal to 0.5; is to be less than or equal to 0.1 for locations where effective defect or crack development detection cannot be assured.

3.9.3 The fatigue damage is to be based on the design life of the tank but not less than 10^8 wave encounters. The load spectrum shown in Fig. 3.9.3 may be used. This load spectrum consist of 8 fatigue loads, each of which is represented by a certain number of cycles, n_i, and an alternating load $\pm P_i$ .Corresponding values of P_i and n_i are given by:

$$P_i = \frac{17-2i}{16} P_0$$

$$n_i = 0.9 \times 10^i$$

Where: i —— $i = 1, 2, 3, 4, 5, 6, 7, 8$。

P_0 —— load on probability level 10^{-8}

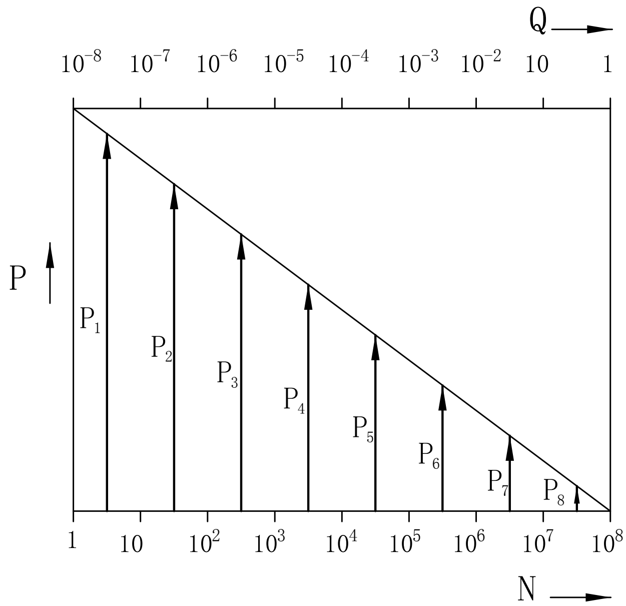

Figure 3.9.3 long term load spectrum

3.9.4 Design S-N curves used in the analysis are to be applicable to the materials and weldments, construction details, fabrication procedures and applicable condition of the stress envisioned. S-N curves in 2.2, CHAPTER 2 of CCS Guidelines for Assessment of Fatigue Strength of Hull Structure may be used.

3.9.5 The S-N curves are to be based on a 97.6% probability of survival corresponding to the mean-minus- two-standard-deviation curves of relevant experimental data up to final failure. Use of S-N curves derived in a different is to be subject to approval by CCS.

3.10 Sizing of pressure relieving system

3.10.1 For vacuum insulated cylindrical tanks with standard heads, the calculation of the size of pressure relieving system is to comply with the rules of GB/T 18442.

3.10.2 The pressure losses are to not exceed the values permitted by the manufacturer. If no data from the manufacturer is available, following values are to be used:

(1) spring loaded safety valves without balanced bellows: 3% of MARVS upstream, 10% of MARVS downstream;

(2) spring loaded safety valves with balanced bellows: 3% of MARVS upstream, 30% of MARVS downstream;

(3) pilot operated safety valves: 3% upstream if the sensing line is not located at the top of the tank; 50% downstream.

3.10.3 Upstream pressure losses

(1) The pressure drop in the vent line from the tank to the PRV inlet is not to exceed 3% of the valve set pressure at the calculated flow rate;

(2) Pilot-operated PRVs is to be unaffected by inlet pipe pressure losses when the pilot senses directly from the tank dome;

(3) Pressure losses in remotely sensed pilot lines are to be considered for flowing type pilots.

3.10.4 Downstream pressure losses

(1) Where common vent headers and vent masts are fitted, calculations are to include flow from all attached PRVs;

(2) The built-up back pressure in the vent piping from the PRV outlet to the location of discharge to the atmosphere, and including any vent pipe inter-connections that join other tanks, are not to exceed the following values:

① 10% MARVS； for unbalanced PRVs

② 30%MARVS； for balanced PRVs

③ 50% MARVS；for pilot operated PRVs

④ Alternative values provided by the PRV manufacturer may be accepted.

(3) To ensure stable PRV operation, the blow-down is not to be less than the sum of the inlet pressure loss and 0.02 × MARVS at the rated capacity.

Section 4 TESTING

4.1 General requirements

4.1.1 Tanks are to be subjected to a hydrostatic test at a pressure measured at the top of the tanks of not less than 1.5 Po (not less than 1.3 Po for vacuum insulated tanks).

4.1.2 After completion and assembly, each pressure vessel and its related fittings s are to be subjected to an adequate tightness test.

4.1.3 The temperature of the liquid used for the test is to be at least 30°C above the nil-ductility transition temperature of the material, as fabricated.

4.1.4 Vacuum insulated tanks are to be tested to confirm the cryogenic property (sealing-off vacuum, interspaced vacuum, leakage, leak and outgassing rate, etc.), which may be performed in accordance with GB/T 18443 Testing method of performance for vacuum insulation cryogenic equipment.

Appendix 2　TECHNICAL REQUIREMENTS OF TESTING FOR GAS FUEL ENGINES

Section 1　GENERAL PROVISIONS

1.1 General requirements

1.1.1 This Appendix is applicable to main propulsion gas fuel engine, gas fuel engine for driving generators and important auxiliary equipments.

1.1.2 Type testing, works trials, shipboard trials of gas fuel engine are comply with the requirements of this Appendix.

1.1.3 Every new engine type of non-mass produced or mass produced intended for the installation on board, one engine is to be presented for type testing as requires in section 2 of this Appendix. Omission or simplification of the type test may be considered for mass produced gas fuel engine after this kind type test have been finished, but is to be agreed by the Surveyor.

Section 2　TYPE TESTING

2.1 General requirements

2.1.1 All of the following items are to be completely same for the same type of gas fuel engine:

(1) the working cycle (four-stroke, two-stroke);

(2) the bore and stroke;

(3) gas admission method (directly into the cylinder, into the air inlet manifold through mixed with air before or after the turbo-charger, into the cylinder air inlet channel port or scavenge space);

(4) main and pilot fuel oil (if applicable) injection operation for dual-fuel engines (direct or indirect injection);

(5) gas admission valve operation for directly into cylinder or channel port (mechanical or electronically controlled);

(6) gas inlet valve operation for into the air inlet manifold, and gas valve operation from air inlet manifold to cylinder (mechanical or electronically controlled);

(7) the kind of fuel (liquid, dual-fuel, gaseous);

(8) the method of pressure charging (pulsating system, constant pressure system);

(9) the charging air cooling system (with or without intercooler);

(10) cylinder arrangement (in-line, vee);

(11) the rated power per cylinder at rated speed and/or mean effective pressure;

(12) propulsion or auxiliary duty including production of electricity for electric propulsion.

2.1.2 The type test is subdivided into three stages, namely:

(1) Stage A—Internal tests

This includes some of the testing made during the engine development, function testing, and collection of measured parameters and records of testing hours. The results of testing required by the Society or stipulated by the designer are to be presented to the Societies before starting stage B.

(2) Stage B—Type approval tests

This is the testing made in the presence of Classification Societies.

(3) Stage C—Component inspection

This is the inspection of engine parts to the extent as required by the Societies.

2.1.3 The complete type testing program is subject to approval by the Society. The extent of presence by a Surveyor is to be agreed in each case, but at least during stage B and C. Testing prior to the official type testing (stage B and C), is also considered as a part of the total type testing.

2.1.4 The components report of methane for gas fuel engine is to be submitted to the Society for reference. The engine is to be capable of operating with possible variations of the Methane Number and Lower Heating Value and the extent of those permitted variations are to be declared by the manufacturer.

2.15 During all testing, the ambient conditions (air temperature, air pressure and humidity) are to be recorded.

2.1.6 As a minimum, the following engine data are to be measured and recorded:

(1) engine r.p.m.

(2) engine power or torque;

(3) fuel index, both gas and diesel as applicable (or equivalent reading);

(4) maximum combustion pressure for each cylinder;

(5) gas feed pressure;

(6) charge air temperature;

(7) charge air pressure;

(8) exhaust gas temperature;

(9) turbocharger speed;

(10) all engine parameters that are required for control and monitoring for the intended use (propulsion, auxiliary, emergency).

2.1.7 Calibration records for the instrumentation used to collect data as listed above are to be presented to - and reviewed by the attending Surveyor.

2.1.8 The data are to be measured and recorded after gas fuel engine have achieved at steady condition condition, however sufficient time at the various load points is to be allowed for visual inspection by the Surveyors.

2.1.9 The effective readings for maximum continuous power at corresponding rpm (100% MCR) are to be taken twice at an internal of normally 30minutes.

2.1.10 Upon completion of total type testing (stage A through C), the engine manufacturer is to compile all measurements and operation values for the engine tested during the type test in a type test report which is to be handed over to the Surveyor. The type test report is to contain:

(1) overall description of tests performed during stage A. Records are to be kept by the builders QA management for presentation to the Classification Society;

(2) detailed description of the load and functional tests conducted during stage B;

(3) check data of stage C;

(4) result of measurements of surface temperatures;

(5) the data of crankshaft deflections.

2.2 **Stage A—Internal tests**

2.2.1 During the internal tests, the engine is to be operated at the load points important for the engine designer and the pertaining operating values are to be recorded. The load conditions to be tested are also to include the testing specified in the approved type approval programme.

2.2.2 Normal cases

(1) Start-up and shut-down tests, are to be comply with the requirements of CHAPTER 11 in this Rules;

(2) The load points 25%, 50%, 75%, 100% and 110% of the rated power in the case of the following engine application:

① along the nominal (theoretical) propeller curve and at constant speed for propulsion engines;

② at constant speed for gas fuel engines intended for generating sets including no load and full load;

(3) Dual-fuel engines are to run the above load points in both gas and oil mode as found applicable for the engine type;

(4) The limit points of the permissible operating range, these limit points are to be defined by the engine manufacture;

(5) The 100 hr full load endurance test apply as required in connection with the design assessment for mass produced gas fuel engines;

(6) For dual-fuel engines, switch over between gas and oil fuel modes are to be tested within certain power level[9];

(7) Specific test of parts of the engine required by the Society or stipulated by the designer;

(8) Inspection for advance angle of ignition (if applicable);

(9) Inspection for air-fuel ratio (if applicable);

(10) Inspection for gas-oil mixing ratio (if applicable).

2.3 Stage B—official tests

2.3.1 The official tests are to be carried out in the presence of the Surveyor and the results achieved are to be recorded and signed by the attending representatives. Deviations from this program, is any, are to be agreed between the engine manufacturer and the Surveyor.

2.3.2 Load tests and function tests are to be carried out in both oil and gas modes for dual-fuel engines as applicable by manufacturers, switchover between oil and gas mode during the tests is acceptable and is to be accompanied with an alarm indicating.

[9] Duel-fuel engines are able to rapidly changeover from gas mode to oil mode at all situations and power levels, and changeover from oil mode to gas mode within certain power level under reliability and safety condition, keeping that the speed and output power are stability in the whole process.

2.3.3 Load points

(1) Gas fuel engines are to be operated at load points as shown in Figure 2.3.3 of this Appendix.

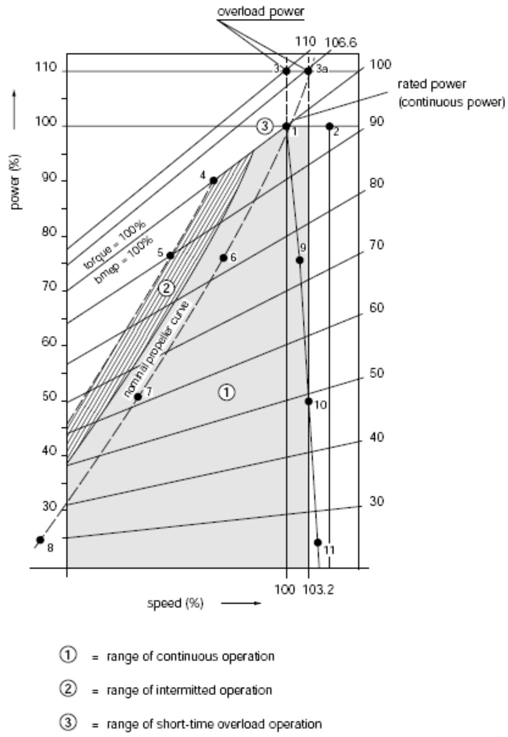

Figure 2.3.3 Power /Speed Diagram

(2) The data to be measured and recorded when testing the engine at various load points are to include all necessary parameters listed in 2.1.6 of this Appendix for the engine operation. The operating time per load points depends on the engine size (achievement of steady-condition condition) and on the time for collection of the operating values. Normally, an operating time of 0.5h may be assumed per load points, however sufficient time is to be allowed for visual inspection by the Surveyor.

① Rated power (MCR), i.e.100% output at 100% torque and 100% speed corresponding to load point 1, for 2 hours with data collection with an interval of 1 hour.

② 100% power at maximum permissible speed corresponding to load point 2.

③ Maximum permissible torque (normally 110%) at 100% speed corresponding to load at point 3, or maximum permissible power (normally 110%) and speed according to nominal propeller curve corresponding to load point 3a. Load point 3a applies to engines only driving fixed pitch propellers or water jets. Load point 3 applies to all other purposes.

④ Load point 3 (or 3a as applicable) is to be replaced with a load that corresponds to the specified overload and duration approved for intermittent use. This applies where such overload rating exceeds 110% of MCR. Where the approved intermittent overload rating is less than 110% of MCR, subject overload rating has to replace the load point at 100% of MCR. In such case the load point at 110% of MCR remains.

⑤ Minimum permissible speed at 100% torque corresponding to load point 4.

⑥ Minimum permissible speed at 90% torque corresponding to load point5.

⑦ Partial loads, e.g.75%, 50%, 25% of rated power and speed according to nominal propeller curve corresponding to points 6, 7, and 8, and at rated speed and constant governor setting corresponding to points 9, 10 and 11.

(3) Emergency operation

Gas fuel engines with turbochargers are to be able to run continuously at a certain output power when one turbocharger is out of operation. (The test can be performed by either fixing the turbocharger rotor shaft or removing the rotor.)

(4) Functional tests

① Verification of the lowest specified propulsion engine speed and the idling speed for auxiliary engines. During this operation, no alarm is to occur.

② Start-up tests, for non-reversible engines and/or starting and reversing tests, for reversible engines, for the purpose of determining the minimum air pressure and the consumption for a start. Start-up and shut-down tests are to be comply with the requirements of CHAPTER 11 in this Rule.

③ For dual-fuel engines, switch over between gas and oil fuel modes are to be tested within certain power level.

④ Governor is to comply with the relevant requirements in CHAPTER 9 Part 3of Rules for Classification of Sea-going Steel Ships or CHAPTER 6 Article 2 Part 2 of Rules for the Construction of Inland Waterway Steel Ships.

⑤ Function test of the ventilation arrangement of the double walled gas piping system.

⑥ Testing the safety protecting device, particularly for overspeed and low lubricating oil pressure.

(5) Engines intend to produce electrical power are to be also comply with the requirements as follows:

① The capability to take sudden add and loss of load to be tested, the maximum load steps are to be declared and demonstrated. For dual fuel engines automatic switchover to oil fuel during the test is acceptable.

② Sudden loss of load from full load of the rated power of the generator to zero load. The overspeed device is not to trip the engine and in any case a speed variation of more than 10% of the rated speed is not to occur.

(6) For electronically controlled gas fuel engines and dual fuel engines integration tests have to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intend operational modes. The scope of these tests is to subject to agreement of CCS based on the risk analysis. The following incidents as below for reference:

① Failure of ignition (spark ignition or pilot injection systems), both for one cylinder unit and common system failure.

② Failure of a cylinder gas supply valve.

③ Failure of the combustion (misfiring, exhaust temperature deviation high etc.).

④ Abnormal gas pressure.

⑤ Abnormal gas temperature.

2.4 Stage C—Component inspection

2.4.1 The crankshaft deflections are to be measured and comply with relevant requirements by manufacturer in the specified condition.

2.4.2 After the running test the components of one cylinder for in-line engines and two cylinders for V-engines are to be presented for inspection as follows:

(1) Piston removed and dismantled.

(2) Connecting rod bearings (big and small end) dismantled.

(3) Main bearing dismantled.

(4) Cylinder liner in the installed condition.

(5) Cylinder head, valves disassembled.

(6) Gas supply valve including pre-chamber (if applicable).

(7) Cam drive gear or chain, camshaft and crankcase with opened covers.

2.4.3 If deemed necessary by the surveyor, further dismantling of the engine may be required. Engines with long service experience from non-marine fields may have a reduced extent of opening based on proven history and submission of documentary evidence of successful service experience and subject to agreement with the Society.

Section 3 WORKS TRIALS

3.1 General requirements

3.1.1 Before any official testing the engines have to be run-in as prescribed by the engine manufacturer. Test bed facilities and testing conditions are to comply with relevant provisions.

3.1.2 The scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons. Exceptions to the scope require the agreement of the Society. E.g. if the machinery installation is arranged to burn gaseous fuel in combination with residuals or other special fuels, the suitability of the engine to burn such fuels is to be demonstrated.

3.1.3 Dual-fuel engines to be tested in both oil and gas modes as found applicable.

3.2 Scope of trials

3.2.1 Propulsion engines driving propeller or impeller only

(1) 100% power (rated power) at engine speed n_0 : at least 60min- after having reached steady conditions;

(2) 110% power at engine speed $n=1.032n_0$: at least 30min-after having reached steady conditions[10];

(3) approved intermittent overload: testing for duration as approved;

(4) 90% (or normal continuous cruise power), 75%, 50% , 25% power and minimum steady speed in accordance with the nominal propeller curve, the sequence to be selected by engine manufacturer.

(5) starting and reversing maneuvers (if applicable), start-up and shut-down is to comply with the relevant requirements in CHAPTER 11 of this Rule.

(6) for dual-fuel engines, switch over between gas and oil fuel modes are to be tested within certain power level.

(7) function test of the ventilation arrangement of the double walled gas piping system.

(8) testing of governor and overspeed protective devices.

3.2.2 Engines driving generators for propulsion

(1) 100% power (rated power) at rated engine speed n0: at least 60min-after having reached

[10] After running on the test bed, the fuel delivery system of engines is normally to be so adjusted that overload power cannot be given in service.

steady conditions;

(2) 110% power: at least 30min-after having reached steady conditions[11];

(3) 75%, 50%, and 25% power and idle run;

(4) same as 3.2.1(5)-(8) of this Appendix.

3.2.3 Engines driving generators for auxiliary purpose

Test to be performs as in 3.2.2 of this Appendix.

3.2.4 Propulsion engines also driving power take off (PTO) generator

(1) 100% power (rated power) at rated engine speed n0: at least 60min-after having reached steady conditions;

(2) 110% power at engine speed n0: at least 30min-after having reached steady conditions[12];

(3) 90% (or normal continuous cruse power), 75%, 50% and 25% power in accordance with the normal propeller curve or at constant speed n0, the sequence to be selected by engine manufacturer.

(4) Same as 3.2.1(5)-(8) of this Appendix.

3.2.5 Engines driving auxiliaries

(1) 100% power (rated power) at rated engine speed n0: at least 30min-after having reached steady conditions;

(2) Approved intermittent overload: testing for duration as approved;

(3) Same as 3.2.2(2)-(4) of this Appendix.

3.3 Integration tests

3.3.1 For electronically controlled gas fuel engines, integration tests are to be made to verify that the response of the complete mechanical, hydraulic and electronic system is as predicted for all intended operational modes. The scope of these tests is to be agreed with the Society for selected cases based on the risk analysis.

3.4 Inspection of components

3.4.1 After the running test the components of one cylinder for in-line engines and two cylinders for V-engines are to be presented for inspection. If deemed necessary by the surveyor, further dismantling of the engine may be required.

Section 4 SHIPBOARD TRIALS

4.1 General requirements

4.1.1 Dual-fuel engines to be tested in both oil and gas modes as found applicable.

4.1.2 The running test time at rated speed and normal continuous cruise speed can be shortened for dual-fuel engines driving main propulsion, the running test time at rated power and normal continuous cruise power can be shortened for dual-fuel engines driving generator, but is to

[11] After running on the test bed, the duel delivery system of engines dirving generators must be adjusted such that overload (110%) power can be given in service after installation on board, so that the governing characteristics including the activation of generator protective devices can be fulfilled at all times.

[12] After running on the test bed, the fuel delivery system shall be adjusted so that full power plus a margin for transient regulation can be given in service after installation onboard. The transient overload capability is required so that the required transient governing characteristics are achieved at any loading of engine. This margin may be 10% of the engine power but at least 10% of the PTO power.

be agreed with site surveyor.

4.2 Scope of trials

4.2.1 Main propulsion engines driving fixed pitch propeller or impeller

(1) At rated engine speed n0: at least 4h -after having reached steady conditions; at engine speed corresponding to normal continuous power: at least 2h -after having reached steady conditions;

(2) At engine speed n=1.032n0: at least 30min-after having reached steady conditions[13];

(3) At approved intermittent overload: testing for duration as approved;

(4) At minimum on-load speed;

(5) During mooring test or sea trials, in reverse direction of propeller rotation at a minimum engine speed of n=0.7n0: 10min;

(6) Starting and reversing manoeuvres (if applicable), start-up and shut-down is to be to comply with the relevant requirements in CHAPTER 11 of this Rule;

(7) For dual-fuel engines, switch over between gas and oil fuel modes are to be tested within certain power level;

(8) Function test of the ventilation arrangement of the double walled gas piping system;

(9) Monitoring, alarm and safety systems.

4.2.2 For main propulsion engines driving controllable pitch propellers or reversing gears

Controllable pitch propellers are to be tested with various propeller pitches according above 4.2.1 of this Appendix.

4.2.3 Engines driving generators for propulsion. The test to be performed at rated speed with a constant governor setting under condition of:

(1) 100% power (rated propulsion power): at least 4h-after having reached steady conditions; at normal continuous propulsion power: at least 2h-after having reached steady conditions;

(2) 110% power (rated propulsion power): at least 30min-after having reached steady conditions;

(3) At minimum no-load test;

(4) Same as 4.2.1(5)-(9) of this Appendix.

4.2.4 Propulsion engines also driving power take off (PTO) generator

(1) 100% power (rated power) at rated engine speed n0: at least 4 h-after having reached steady conditions;

(2) 100% propeller branch power at engine speed n0 (unless already covered in (1) above): at least 2h-after having reached steady conditions;

(3) 100% PTO branch power at engine speed n0: at least 1h-after having reached steady conditions;

(4) Same as 4.2.1(6)-(9) of this Appendix.

4.2.5 Engines driving auxiliary generator and auxiliaries

(1) 100% power (rated power) at rated engine speed n0: at least 4-after having reached steady conditions. During the test, the set concerned is required to operate at its rated power for an extended period;

(2) Approved intermittent overload: testing for duration as approved;

(3) At minimum no-load test;

[13] After running on the test bed, the fuel delivery system of engines is normally to be so adjusted that overload power cannot be given in service.

(4) Same as 4.2.1(6)-(9) of this Appendix.

It is to be demonstrated that the engine is capable of supplying 100% of its rated power, and in the case of shipboard generating sets account is to be taken of the times needed to actuate the generator's overload protection system.

4.2.6 The suitability of engine to burn residual or other special fuels is to be demonstratrated (if applicable).

4.2.7 In addition, the scope of the trals may be expanded in consideration of the special operating conditions, such as towing, trawing, etc.

4.3 Inspection of components

4.3.1 After the trial, at least one cylinder of the engine is to be opened up and examined.

Appendix 3 TECHNICAL REQUIREMENTS FOR ELECTRONIC CONTROL SYSTEMS

Section 1 GENERAL PROVISIONS

1.1 General requirements

1.1.1 Electronic control system of this appendix specifically refers to electronic control system of gas engines and gas fuel supply system.

1.1.2 The design and manufacturing of Electronic control system of this appendix, are to be surveyed by CCS.

1.1.3 Power supply for electronic control system of this appendix is to be comply with the relevant requirements in CHAPTER 9 SECTION 3 of the Rules.

Section 2 TECHNICAL REQUIREMENTS OF ELECTRONIC CONTROL SYSTEM OF GAS ENGINE

2.1 General requirements

2.1.1 The design, manufacture and inspection of the electronic equipment used for electronic control systems of gas engine, including software design, are to comply with the relevant requirements in PART SEVEN of CCS Rules for Classification Sea-going Steel Ships, PART FOUR of CCS Rules for the Construction of Inland Waterways Steel Ships and CCS Guidelines for Type Approval Test Approval Test of Electric and Electronic Products.

2.2 Functional requirements

2.2.1 Electronic control system of gas engine means a system where a electronic control is applied to systems of gas fuel injection, fuel oil injection (if any), etc. It control s paramenters such as amount of gas fuel, proportion with air, time of ignition, amont of oil fuel (if any), optimization the operation fo the engine, data exchange to other system, etc. the electronic system is composed of sensors, electronic control units (ECU), actuators, panel for local control and interfaces for remote control.

2.2.2 Moniting and control function of electronic system of gas engine are also to comply with the relevant requirements in CHAPTER 10 and CHAPTER 11 of the Rules.

2.2.3 Visual and audible alarms are to be given at local and remote control place in the event of failure of the main source of electrical power.

2.2.4 Electronic control systems are to have the functions of failure self-diagnosis and fail-safe protection. In case of failure, the system is to immediately perform a self-diagnose and initiate appropriate fail-safe protection to maintain operation of the gas engine.

2.2.5 Local controls and data communication interfaces for remote control system in central control room or bridge control system are to be provided.

2.2.6 The monitoring performed by the electronic control system is to be able to initiate alarms when main functions of sensors, ECUs and actuators fail, and visual and audible alarms are to be given at local and remote control place.

2.2.7 The electronic control system is to be able to monitor the working condition of gas engines, automatically adjust individual system parameters, and automatically detect and given alarms for failures of systems and components.

2.2.8 Electronic control systems are to be provided with test ports to facilitate test and maintenance.

2.2.9 The electronic control system is to be able to record data, which contains a certain number of latest operating data, alarm histories, failures of the engine. The record of alarm, failure and abnormal state only is to be eliminated manually.

2.2.10 The electronic control system is to be able to transfer signals such as states and alarms of the engine to other monitoring system, which including, but not limited to the clauses in Table 2.2.10.

Data for exchange **Table 2.2.10**

Category	Item	Remark
states	running	
	stop	
	Using only diesel oil	
	Using only gas fuel	
	Using both gas fuel and diesel oil	If applicable.
	Running normally	
	Local controlling	
	Remote controlling	
alarms	Electronic system alarm/failure	Detailed failure information is needed.
	Engine system alarm/failure	Detailed failure information is needed.
suutdown indicates	Normal shutdown	
	Emergency shutdown	
	Failure shutdown	

2.3 Design requirements

2.3.1 Those devices in the electronic control system which will affect normal operation of the main propulsion engine in case of functional failure, such as ECUs and crankshaft rotation angle indicators, ar to be provided as dual system. The type and function of such dual systems are to be fully identical. When one system fails, the other will automatically take over so as to maintain normal operation of the engine and an alarm will be given at the same time.

2.3.2 Components and parts of the electronic control system are to be changeable considering functional characteristics and structural dimensions, and capable of being disassembled, replaced and installed quickly.

2.3.3 For corrosive materials, anticorrosive coating is to be provided. Where parts made of different metals contact directly each other, means are generally to be provided to prevent electrolytic corrosion.

2.3.4 The installation of components of an electronic control system is to comply with the requirements for installation positions on the gas engine, interface dimension, joints, screening, heat and shock resistance. The components are to be capable of being easily installed and fixed on the gas engine. The wiring of all electronic circuits is to be secure and reliable to prevent looseing during operation.

2.3.5 When installing components with vibration dampers, sufficient spacing is to be left around to avoid collision with adjacent components or structures.

2.4 Test requirements

2.4.1 Type tests

(1) Electronic control system are to be subjected to type tests in accordance with the relevant requirements of CCS Guidelines for Type Approval Test Approval Test of Electric and Electronic Products and the requirements of this Section.

(2) Normal function of electronic control system, such as control and moniting function, is to be confirmed in type test. These functional tests are to be carried out with the gas engine, including all type tests required in appendix 2.

(3) The effective functions and failure processing of an electronic control system are to be verified during type tests, including, but not limited to the following items:

① Confirmation of software version;

② The effective function of back-up sensors in the event of one crankshaft rotation angle indicator failing[14];

③ The effective function of back-up module in the event of one control module failing;[①]

④ The effective function of local control in the event of remote control failing;

⑤ The effective function of remote control in the event of local control failing;

⑥ The effective function of record of data and failure history;

⑦ Automatically supplied by the batteries without any impact of function in the event of failure of the main source of electrical power;

⑧ The effective function of test ports.

2.4.2 Trails be carried out with the gas engine at the manufacturer's works

(1) Trails be carried out with the gas engine at the manufacturer's works are to comply with the applicable control and monitoring requirements of the Rules. These trails are to be done with gas engine together to finish the trails for gas engines that need to be carried out at the manufacturer's works required by appendix 2.

(2) The effective functions of an electronic control system are to be verified during tests, generally including the following items (if applicable):

① Confirmation of software version;

② Function of gas fuel injection control valve;

③ Function of ignition module;

④ The effective function of back-up module in the event of one control module failing[15];

⑤ The effective function of back-up sensors in the event of one crankshaft rotation angle indicator failing;[16]

⑥ The effective function of data communication interfaces;

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[14] If gas engine could change to use pure diesel oil automatically to maintain the operation in case of failure of electronic control system, verifing the effective function of this automatic mode change process instead of the back-up unit in the event of one unit failing.

[15] See 14 above.

[16] See 14 above.

⑦ Other applicable failure and function tests.

2.4.3 Shipboard trials

(1) Shipboard trails are to be done with gas engine together to finish the trails for gas engines that need to be carried out at shipboard required by appendix 2. Then verify the following items (if applicable):

① The effective function of data exchanges to other system, such as remote control system, safety/alarm system, and electronic control system of gas fuel supply system;

② Automatically supplied by the batteries without any impact of function in the event of failure of the main source of electrical power;

③ Test alarm/safety function of electronic control system by fault simulating as much as possible.

Section 3 TECHNICAL REQUIREMENTS OF ELECTRONIC CONTROL SYSTEM OF GAS FUEL SUPPLY SYSTEM

3.1 General requirements

3.1.1 The design, manufacture and inspection of the electronic equipment used for electronic control systems of gas fuel supply system, including software design, are to comply with the relevant requirements in PART SEVEN of CCS Rules for Classification Sea-going Steel Ships, PART FOUR of CCS Rules for the Construction of Inland Waterways Steel Ships and CCS Guidelines for Type Approval Test Approval Test of Electric and Electronic Products.

3.2 Function requirements

3.2.1 Electronic control system is to be continuous, effective and reliable operation when it’s functioning normally.

3.2.2 All automatic and remotely operated main tank values, master gas fuel valves, double block and bleed valves, ventilation valves are to be controlled by electronic control system.

3.2.3 The abnormal states need to be monitored is including but not limit the followings, and safety process need to be carried out according to CHAPTER 10 table 10.4.1.1(2) of the Rules:

(1) The effective function of ventilation or protection of inert gas in duct around gas pipes between tank connect space and machinery space;

(2) The effective function of ventilation or protection of inert gas in duct around gas pipes in gas safe machinery space;

(3) The effective function of ventilation in machinery space (if any);

(4) The effective function of ventilation in gas valve unit;

(5) Fire detection in tank spaces;

(6) Fire detection in machinery space;

(7) Gas detection in tank connect space;

(8) Gas detection in duct around gas pipes between tank connect spaces and machinery spaces;

(9) Gas detection in duct around gas pipes in gas safe machinery space;

(10) Gas detection in machinery spaces;

(11) Gas detection in gas valve units;

(12) Gas detection in compressor rooms;

(13) Temperature of outlet of heat exchanger;

(14) Gas pressure in gas supply pipe;

(15) The effective function of valve control actuation medium;

(16) Automatic shutdown of engine (engine failure);

(17) Emergency shutdown of engine;

(18) Level of bilge well in tank room;

(19) Temperature of bilge well in tank room;

(20) Pressure of tank;

(21) Level of tank;

(22) Rapid detection of rupture of gas supply pipe in machinery space.

3.2.4 Alarms are to be given at bridge control station and centralized control station (or attended space).

3.2.5 Visual and audible alarms are to be given at local and remote control place in the event of failure of the main source of electrical power.

3.2.6 Electronic control systems are to have the functions of failure self-diagnosis, which including main function’s failure of sensors, controllers, etc.

3.3 Design requirements

3.3.1 The sensors are to give stable and normal operational performance over a long period of time. The measuring range and frequency characteristic (if applicable) of sensors are to be consistent with the expected maximum variation range and variation of velocity of the parameters being detected. The sensors are to possess suitable accuracy and sensitivity.

3.3.2 The sensors are to have good compatibility with the environmental conditions at their positions. The sensors are to be mechanically robust and durable, having good mechanical protection, reliable electrical connections and good insulated property.

3.3.3 The sensors are to be so sited that they can properly reflect the monitored parameters and are readily accessible for testing and renewal. In order that maintenance and renewal can be carried out easily, a protective cover is to be fitted for sensors. Where the sensors are sited in positions inaccessible for renewal, a standby sensor is to be fitted.

3.4 Type tests

3.4.1 Electronic control systems are to be subjected to type tests in accordance with the relevant requirements of CCS Guidelines for Type Approval Test Approval Test of Electric and Electronic Products.

3.4.2 The effective function of electronic control system is to be verified in type test, simulative fault sginal could be used to test the correction of safety processes instead of actual ones in case of actual signals are not easy to acquire.

3.5 Shipboard trials

3.5.1 Test program is to be submitted to CCS for approval.

3.5.2 Verifying electronic control system is fitted correctly and performance stably.

3.5.3 An electronic control system are to be verified following items (if applicable):

(1) Automatically supplied by the batteries without any impact of function in the event of failure of the main source of electrical power;

(2) The effective function of failure self-diagnosis for all sensors;

(3) The effective function of safety process for all abnormal state.