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M-22

DUAL FUEL ENGINE

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Foreword:

CCS Product Inspection and Testing Guideline (hereinafter referred to as this Guideline) contains the technical requirements, inspection and testing criteria related to classification and statutory survey of marine products to be applied for CCS approval/inspection.

This Guideline frees the users to adopt other test methods and requirements which are equivalent to or are stricter than this Guideline.

This Guideline is published and updated by CCS, and is released at http://www.ccs.org.cn. Your comments or suggestions are welcomed and may be sent to our email addressed mp@ccs.org.cn.

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DUAL FUEL ENGINE

1 Application

1.1 This Guideline is applicable to the approval and product inspection of propulsion and drive engines used on ships and mobile units as well as other marine dual fuel engines related to classification.

1.2 Dual fuel engines used on small crafts less than 20m in length may also be surveyed and tested with reference to the requirements of the Guidelines in addition to compliance with the applicable domestic regulatory requirements.

1.3 Single gas fuel engines may be surveyed with reference to the Guidelines.

1.4 The gas used as fuel described in the Guidelines refers to natural gas only. Where other gas fuels are intended to be used, the risks thereof are to be taken into account.

2 Normative references

Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships (hereinafter referred to as the Rules)

Chapter 16 of CCS Rules for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk

CCS Rules for Natural Gas Fuelled Ships

CCS Guidelines for Design and Installation of Dual Fuel Engine System

3 Terms and definitions

3.1 For the purpose of this Guideline, the definitions in CCS Rules for Classification of Sea-going Steel Ships, Rules for Natural Gas Fuelled Ships and Guidelines for Design and Installation of Dual Fuel Engine System are applicable.

3.2 The definitions for the purpose of this Guideline are as follows:

(1) Gas engine: includes dual fuel engine and single gas fuel engine. The gas used as fuel described in this Guideline only refers to natural gas (methane). Flue gas may be injected in the following modes:

Flue gas being injected directly into gas cylinder;

Flue gas being injected into air inlet manifold or scavenging air box, or air intake by single cylinder;

Flue gas being premixed in front of the supercharger.

(2) Low pressure gas engine: generally means the engine to which the air is from a low pressure air supply, with flue gas being injected into the gas cylinder after premixed with air, and which usually works on the Otto cycle.

(3) High pressure gas engine: generally means the engine which usually works on the Diesel cycle, with the high pressure gas being injected directly into the gas cylinder.

(4) Methane number: is an index to indicate the antiknock quality of gas fuels. When the

antiknock quality of the gas fuel being measured is identical to that of the standard methane-hydrogen mixture fuel mixed by a certain ratio, the value of the volume percentage of the methane contained in such standard fuel is the methane value of the gas fuel.

4 Drawings and documentation to be submitted

4.1 In addition to those specified in 9.1.10, Chapter 9, PART THREE of CCS Rules for Sea-going Steel Ships, plans and technical documents containing the following information are to be submitted to CCS for approval (only when applicable).

(1)Schematic diagram of engine control system, which may include electronic injection control, pilot fuel oil or ignition control, combustion monitoring, operating condition monitoring, exhaust bypass control, alarm and safety protection arrangements, etc.;

(2)Explosion-proof safety valve arrangement plan (including the explosion-proof arrangement and calculations for crankcase, air inlet manifold and exhaust manifold);

(3)Crankcase ventilation, combustible gas detector and oil mist detector arrangement plan;

(4)Engine exhaust system arrangement plan;

(5)Diagram and arrangement plan of gas fuel system (including double containment piping and engine-mounted part);

(6)Parts diagram of high pressure flue gas piping system;

(7)Diagrams of flue gas inlet valve (low pressure), flue gas injection valve (high pressure), control valve block and its driving and sealing systems;

(8)Diagram and arrangement plan of pilot fuel oil system, high pressure piping and protection diagrams, high pressure parts diagram;

(9)Diagram of the mixer of premixed type engines (engines with flue gas being premixed with air in front of the supercharger);

(10)Other drawings and documentation should be submitted if deemed necessary by CCS.

4.2 The following plans and technical documents are to be submitted to CCS for review:

(1)Project guidelines or design specifications: including the general description of the engine, especially introduction of the working mode and principle of the control system.

(2)Safety concept description: a document that describes the safety of gas fuel engines, the risks associated with the use of gas fuel, failure mode and safety means, generally including but not limited to the program introduction, safety means, safety protection, list of alarm points, etc. of the following systems:

Pilot fuel oil system;

Exhaust system;

Crankcase ventilation system;

Air inlet system;

Cooling water system;

Lubricating system;

Engine control system;

Engine room air supply system, including valve sets (part associated with engine);

Measures to be taken in case of flue gas leak or fire in the engine room.

(3)Dual fuel engine risk analysis (e.g. FMEA) reports;

(4)Operation manual;

(5)Test report (if applicable) for completed engine and control system (including critical parts);

(6)Equivalent value of the engine's torsional vibration;

(7)Description of the engine's capacity of working under inclined state.

Note: the documents submitted to CCS for review may have different name but are to cover sufficient necessary information.

5 Failure mode and effect analysis

5.1 Scope of risk analysis

The risk analysis is to cover at least the following aspects:

Single failure of any system or part of the engine under flue gas mode;

One flue gas leakage from the engine;

The safety of the engine under emergency shutdown or power outage conditions when the engine is operating under flue gas mode;

The risk analysis is also to consider that the failure of the engine's external systems (e.g. fuel containment system or fuel supply system) may require the engine's control and monitoring system to perform its due function under alarm or failure condition.

5.2 Method of risk analysis

The risk analysis may be carried out by means of FMEA or any other equivalent risk analysis method.

FMEA is to be carried out by a formal structured method in accordance with accepted national or international standards such as IEC60812.

The analysis is to be based on the single failure concept, i.e. only one single failure mode needs to be considered at one time. Both detectable and undetectable failures are to be taken into account.

Cascade failure, i.e. the single failure of another component caused directly by the failure of one component, is also to be taken into account.

5.3 Risk analysis procedure

(1) The possible failure modes of the systems or equipment concerned, including those leading to functional failure or flue gas leakage, are to be identified;

(2) The effects of failure are to be evaluated;

(3) The means of failure detection is to be determined where necessary;

(4) Improvement measures are to be determined where necessary:

During the design phase, redundancy design is to be adopted or safety equipment, monitoring and alarm equipment are to be provided to allow the system to operate under restrictive conditions;

During operation, redundant or alternative operating mode (fuel oil mode) is to be capable of being started;

The results of risk analysis are to be documented and where necessary, verified through tests.

5.4 Systems and equipment to be analyzed

(1) Failure of flue gas related systems and components, especially the flue gas supply valves on flue gas piping, its enclosure (if applicable) and engine body;

(2) Failure of ignition system, including the pilot fuel oil and spark plug;

(3) Failure of air-fuel ratio control system, including the charge air bypass, flue gas pressure control valves, etc.;

(4) Where the supercharger front premixing technology is employed, failures of the parts that may give rise to fire sources (hot spots) must be analyzed;

(5) Combustion failures or abnormal combustion of gas (stalling or deflagration);

(6) Failure of engine monitoring, alarm and safety system;

Note: when this system is integrated with the electronic control system, it is to be ensured that failure of the electronic control system will not result in the loss of the most basic servo functions allowing for normal operation of the engine, and will not render the main engine inoperable or reduce the engine performance to an unacceptable level.(7)Risks of abnormal presence of flue gas in the air inlet manifold or exhaust manifold and/or external systems (e.g. exhaust pipe) of the engine;

(8)Risks arising during the switch of the operating modes of dual fuel engines.

5.5 Where the failure mode and effect analysis are intended to be used as the basis for exemption from compliance with the requirements of relevant rules, detailed analysis is to be carried out, the corresponding calculations or descriptions are to be provided where necessary and/or a failure simulation test is to be carried out.

6 Materials and components

6.1 The requirements for main parts specified in Guideline DIESEL ENGINES AND THEIR MAIN PARTS are applicable to the purpose of this Guideline.

6.2 Additional critical parts of dual fuel engines:

Including engine-mounted flue gas piping and accessories (inclusive of valves, hoses, bellows, joints, etc.), flue gas control valve set/block, flue gas injection valve (high pressure engine), flue gas inlet valve (low pressure engine), hydraulic oil and sealing oil high pressure piping, combustible gas detector, flame arrester, explosion-proof valve, electronic control system of engine and pilot fuel oil system. Among these parts, combustible gas detector, flame arrester, crankcase door explosion relief device and electronic control system of engine (including controller, data collection and monitoring unit, combustion pressure sensor, flue gas pressure sensor, critical sensors used in safety system) are to have the approval certificates and manufacturer’s quality certification. Other critical parts are to hold CCS product certificates or to be inspected and tested in the diesel engine manufacturer.

The electronic control systems (Electronic Control Units -ECU) used on the natural gas fuelled ships is also to hold CCS product certificates according to the requirements of relevant rules.

Note: For parts subject to abovementioned certification requirements, the requirements for their plan approval and inspection are not included in the Guidelines.

7 Manufacturing process control

7.1 The welding procedure for critical parts and engine-mounted flue gas piping is to be qualified prior to commencement of welding operation.

7.2 Double-wall pipe manufacturing process is to be qualified to ensure that the annular space between the inner and outer pipes has adequate flow area and allows for sufficient air changes.

8 Technical requirements

General requirements

8.1 Dual fuel engines used on natural gas fuelled ships are to be designed, manufactured, installed and tested in accordance with the applicable requirements of CCS Rules for Natural Gas Fuelled Ships and Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

8.2 Dual fuel engines used on gas carriers and mobile units are to be designed, manufactured, installed and tested in accordance with the applicable requirements of CCS Guidelines for Design and Installation of Dual Fuel Engine System and Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

8.3 High pressure dual fuel engines are also to be in compliance with the requirements of Annex 1, Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ship.

8.4 The electronic injection control system of the dual fuel engine is also to in compliance with the applicable requirements of Annex 2, Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ship.

8.5The control, monitoring, alarm and safety systems of dual fuel engines are also to be approved in accordance with the relevant requirements of Chapter 9, PART THREE and PART SEVEN of CCS Rules for Classification of Sea-going Steel Ship.

8.6 In recognition that the gas engine technology is under rapid development and improvement, the technical requirements presented in the Guidelines are supplements to CCS rules. Once such relevant requirements have been included into the rules, the rules are to prevail.

8.7 Marine environmental conditions

Engines, depending on their intended purposes, are to comply with the requirements of the rules for ships or units on which the engines are intended to be used. Unless otherwise specially stated, the requirements of the Rules for Classification of Sea-going Steel Ships on marine conditions are to be complied with.

8.8 As a fundamental principle, dual fuel engines are to have the same safety and reliability levels as similar conventional diesel engines.

8.9 Dual fuel engines are to be capable of using natural gas having methane number and low heat number within a certain range. The fluctuation range of methane value and low heat value of the natural gas to be used is to be specified by the engine manufacturers.

8.10 Parts which contain or may contain combustible gas are to be:

(1) Verified to be free from any explosion hazard; or

(2) Having adequate strength or fitted with safety relief valves so that the consequences of explosion can be controlled within acceptable levels. The substance released from safety valves is to be kept away from personnel, equipment or safe locations of the system, and it is to be ensured any explosion will not affect the normal operation of the engine (unless shutdown of the engine is

allowed as other safety means are available).

8.11 Flue gas piping systems or parts, when they are subjected to a flue gas leakage, are to be capable of maintaining sufficient propulsion and maneuverability and ensuring normal operation of critical safety systems.

8.12 Where the flue gas is likely to leak into other media (e.g. lubricating oil, cooling water) of the engine's auxiliary systems, appropriate means of gas exhaust are to be provided and must be installed immediately downstream to the outlet of the auxiliary systems to prevent gas dispersion. The released gas is to be discharged to a safe open location.

8.13 Alternative design

CCS may accept the design programs with equivalent safety level after adequate risk assessment. A failure simulation test is to be carried out where necessary to verify the results of risk analysis.

8.14 Nitrogen oxides emission from engines

(1) The nitrogen oxides emission from dual fuel engines is to be tested in accordance with CCS Guidelines for Testing and Inspection of Emission of Nitrogen Oxides from Marine Engines.

(2) Where the engines are intended to be operating normally under flue gas mode only, i.e. the flue gas is mainly used and only a small amount of pilot fuel oil is used, the engines only need to be tested under such mode and during the test, the engines are to be operating at the maximum operating fuel oil/flue gas ratio allowed by the instructions for use.

(3) Where the engines are also intended to be operating normally under fuel oil mode, testing of nitrogen oxide emission under such mode is to be carried out.

(4) For engines employing blended combustion technology (an appropriate amount of flue gas is blended for combustion while flue gas is being used, and the dedicated pilot fuel oil system is not provided), the emission testing is to be carried out under the operating mode of the most severe emission selected according to testing data.

System design requirements

8.15 Start and fuel changeover

(1) Dual fuel engines are to be capable of operating with both fuel oil and gas fuel plus a small amount of plot fuel oil. The engines are to be capable of swift changeover from flue gas operating mode to fuel oil operating mode. During fuel mode changeover, the engines are to be capable of outputting power continuously and uninterruptedly.

(2) The engine fuel mode changeover is to be achieved only within a certain power range and the reliability of such changeover is to be verified by test. The changeover process is to be achieved automatically and capable of being manually disrupted under any circumstances.

(3) The engines are to be capable of being automatically switched to fuel oil mode when their power is reduced to a level lower than the minimum power under flue gas mode.

(4) Only fuel oil is to be used for starts and normal shutdowns. The engines are to be capable of continuing the operation with fuel oil only when the gas fuel supply is cut off.

(5) The cutoff of gas fuel supply is to be no later than that of fuel oil supply during normal and emergency shutdowns. The cutoff of pilot fuel oil is not to be in advance of the shutoff of gas fuel supply.

8.16 Injection of pilot fuel oil

The amount of pilot fuel oil injected into each gas cylinder is to be sufficient to ensure forced ignition of the flue gas mixture in the cylinder. It is to be ensured that the flue gas will not be

injected into the gas cylinder before injection of pilot fuel oil is stopped. Pilot fuel oil injection is to be monitored by oil pressure and combustion parameters.

Safety means

8.17 The crankcase is to be protected in compliance with 4.4 and 4.5 of the Guidelines for Design and Installation of Dual Fuel Engine System.

8.18 The crankcase is to be ventilated in compliance with 4.6 of the Guidelines for Design and Installation of Dual Fuel Engine System.

8.19 The starting air and air inlet system is to be protected in compliance with 4.3 of the Guidelines for Design and Installation of Dual Fuel Engine System.

8.20 The exhaust system is to be in compliance with 4.7 of the Guidelines for Design and Installation of Dual Fuel Engine System.

8.21The control, monitoring and safety system is to be in compliance with 5.2 of the Guidelines for Design and Installation of Dual Fuel Engine System.

8.22 Gas fuel piping system

The gas fuel piping system mounted on diesel engines is to be of conventional “double-wall pipe” or “single-wall pipe” type, depending on the arrangement of the machinery spaces. The gas fuel piping system is to be designed, manufactured and surveyed in accordance with Chapter 3 and Chapter 4 of the Rules for Natural Gas Fuelled Ships or Chapter 2 and Chapter 3 of the Guidelines for Design and Installation of Dual Fuel Engine System. In addition, the gas fuel piping system is to comply with the following requirements:

(1) The raw materials and strength of gas fuel piping system and parts are to comply with the requirements of applicable international code and CCS rules.

(2) Valves, expansion joints, raw materials, etc. used in gas fuel piping system are also to comply with the relevant requirements of Chapter 16 of the Rules for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. Emergency shutoff valves are to be made of metal materials having a melting point not less than 925℃ and to be fire tested.

(3) The piping is to be connected by the means of welding as far as practicable and use of flanged connection is to be minimized. The type of pipe connections is to be in compliance with the requirements of 3.2.6 of the Rules for Natural Gas Fuelled Ships, and in addition, the requirements in Chapter 2, PART THREE of CCS Rules for Classification of Sea-going Steel Ships is to be considered for high pressure flue gas piping systems. The flanged connections of special types may also be accepted by CCS according to recognized standards. The gaskets for flange connections are to be effectively protected.

(4) The piping is to be manufactured and inspected in compliance with the requirements of applicable rules while considering the requirements of Chapter 9, PART THREE of CCS Rules for Materials and Welding.

(5) Flue gas piping systems are to be installed with sufficient flexibility to accommodate the oscillation or vibration of the engines and to prevent fatigue damage at the connections between the piping and the engine.

(6) Where the insulation is furnished between the pipe or pipe joint, hose joint and the hull structure, means of electrical earthing is to be provided.

(7) All flue gas piping systems are to be uniformly color coded.

8.23 Engines with flue gas premixed in front of the supercharger

(1) Single-wall pipe may be used for the piping under negative pressure in front of the supercharger, provided that such pipe is qualified through the risk assessment.

(2) Air inlet manifold, supercharger and air cooler are to be protected as the components of a flue gas supply system.

9 Type test

9.1 Selection of typical prototype

(1) The prototype for type test of low-speed engines is to be selected by the following principles:

① The selected engine type is to be representative;

② The prototype is to be manufactured according to the plans and technical documents approved by CCS;

③ The prototype has been tested and its reliable performance ascertained by the manufacturer.

(2) The prototype for type testof medium and high speed engines is to be selected by the following principles:

① The selected engine type is to be reflective of the manufacturer's production level;

② The prototype is to have higher enhanced indexes.

(3) The type of engines is to be defined in accordance with 9.10.4.3, Chapter 9, PART THREE of the Rules for Classification of Sea-going Steel Ships and taking into account the following characteristics:

① Flue gas supply pressure: high pressure, low pressure;

② Flue gas inlet mode: direct injection, inlet via inlet manifold, inlet via inlet branch, premixing in front of supercharger, etc.;

③ Flue gas inlet control method: cam shaft control, electronic control;

④ Ignition system: pilot fuel oil or spark ignition, electronic control or mechanical control;

⑤ Fuel type.

9.2 Type test items

The type test of engines used on natural gas fuelled ships is to be carried out in accordance with Annex 2 of the Rules for Natural Gas Fuelled Ships.

The type test of other engines is to be carried out in accordance with Chapter 9, PART THREE of the Rules for Classification of Sea-going Steel Ships and in compliance with the following additional requirements for dual fuel engines:

① The composition report of natural gas used by dual fuel engines is to be submitted to CCS for review and the natural gas used is to be in line with the methane number and low heat value range specified by the manufacturers.

② Test records are to include the relevant parameters of gas fuel.

③ Dual fuel engines are to be load point and function tested under all modes.

④ Flue gas mode versus fuel oil mode changeover of dual fuel engines are to be tested under

different loads.

⑤ The effectiveness of ventilation of double-wall flue gas piping is to be tested.

⑥ The ability of the engine of the driving power generator to withstand suddenly applied load and suddenly removed load is to be tested. For dual fuel engines, automatic changeover to fuel oil mode during the test is acceptable. The multi-stage loading capacity may be determined by the manufacturer and customer according to the demands of ships.

⑦ The integrated test is to include necessary test on the functions related to flue gas system and failure simulation test.

⑧ For engines of blended combustion type, the flue gas mode described in this section means the operating condition under which the proportion of flue gas in the fuel is at the highest level.

⑨ For medium and high speed engines manufactured in batches, 100h endurance test may be conducted based on the conditions of design and evaluation during the manufacturer's internal test.

9.3 Safety protection and test conditions

(1) Normal operation of all safety systems and equipment is to be ensured prior to the test. In particular, the reliable strength and tightness of flue gas supply system, normal operation of systems and reliability of safety systems are to be ensured.

(2) The test bench of the manufacturer, where it is used as the location of approval test, is to be competent to complete the test concerning the items specified in the test program. CCS will examine the testing capacity, method and personnel of the manufacturer to verify they meet the test requirements.

(3) Measuring instruments used for the test are to hold valid metrological verification certificate.

10 Unit/batch inspection

Unit/batch inspection after approval is to include manufacturer acceptance test specified by applicable CCS rules. For engines which have to be disassembled and then reinstalled on board, the request for inspection is to be addressed to CCS attending surveyor according to the technical requirements of the manufacturer so that relevant inspection may be carried out.

Dual fuel engines are to be subject to the following tests under both flue gas mode and fuel oil mode depending on their application conditions.

Flue gas mode versus fuel oil mode changeover test for dual fuel engines is to be carried out under different loads;

The same safety protection and test conditions as those for type approval test are to be achieved during the test.

10.1 Inspection of engines not produced in batches

(1) Inspection is to be carried out in accordance with the corresponding rules and approved inspection plan. The inspection unit of CCS may determine the inspection items as appropriate by the manufacturer's quality level.

(2) Purchased critical parts are to be certified in accordance with the requirements of CCS rules and guidelines.

(3) Inspections of the critical parts that are manufactured independently by the engine manufacturer, such as material inspection, weld inspection, NDT and manufacturing process

inspection, are to be attended by the surveyor.

(4) The surveyor will attend assembly inspection or review records according to the inspection plan.

(5) The bench test, disassembly and inspection of each engine are to be witnessed by the surveyor.

10.2 Inspection of engines produced in batches

(1) Engines manufactured in batches are to comply with the definitions of batch production in Chapter 9, PART THREE of CCS Rules for Classification of Sea-going Steel Ships. Unit/batch inspection by CCS may be requested only for the engines which have been qualified through inspection/test of the manufacturer and are ready for delivery.

(2) Inspections to be carried out in accordance with the corresponding rules and approved inspection plan. The sampling proportion is to be specified in the inspection plan but at least one engine is to be selected for test. The retest of engine bench test is to be attended by the surveyor on a random basis.

(3) Whenever a unit/batch inspection is being requested, the quality certificates and related inspection/test records of the raw materials used to manufacture the main parts of this batch are to be submitted along with the request for review by CCS surveyor.