



Guideline No. M-28 (202204)

M-28

REFORMER

Issued Date: April 14, 2022

© China Classification Society

Foreword

China Classification Society (hereinafter referred to as 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 service@ccs.org.cn.

Historical version and release date: Newly released

Main changes: None

CONTENTS

1 Application 4

2 Normative References..... 4

3 Terms and Definitions 5

4 Drawings and Documents 6

5 Technical Requirements 7

6 Materials and Components 8

7 Type Tests..... 8

8 Unit/batch inspection (Factory Survey)..... 17

REFORMER

1 Application

1.1 The provisions of the Guidelines apply to the approval and survey of reformers installed and used on ships and offshore installations. The reformer is a complete, self-contained or factory-assembled hydrogen production system with a capacity of less than 400 m³/h at 0 °C and 101325 Pa (hereinafter referred to as hydrogen generator). This hydrogen production system converts the input fuel into hydrogen-rich gas. The gas composition, pressure and temperature meet the use requirements of hydrogen-using installations (hydrogen-using installations include fuel cell power systems or hydrogen compression, storage and transportation systems). Its input fuel includes: Natural gas and other methane-rich gases from renewable (biomass) or fossil fuels, such as landfill gas, biogas, coal mine gas; Fuels from refining, such as diesel, gasoline, kerosene, liquefied petroleum gas (such as propane and butane); Alcohols, esters, ethers, aldehydes, ketones, Fischer-Tropsch liquids and other suitable hydrogen-rich organic compounds derived from renewable (biomass) or fossil fuel sources such as methanol, ethanol, dimethyl ether, biodiesel; Gas mixtures containing hydrogen, such as synthesis gas and city gas.

1.2 As the technology of hydrogen fuel cell reformers is still under continuous development, the Guidelines are only for reformers that use alcohol-based fuels. For other types of reformers that do not meet the requirements of this guideline, they shall be considered by CCS on a case-by-case basis.

2 Normative References

- 2.1 ISO 16110-1 Hydrogen generators using fuel processing technologies — Part 1: Safety
- 2.2 CCS Rules for Classification of Sea-Going Steel Ships and its Amendment
- 2.3 CCS Rules for Materials and Welding
- 2.4 CCS Guidelines for Ships Using Methanol/Ethanol Fuels
- 2.5 CCS Guidelines for Hydrogen Fuel Cell Product Survey
- 2.6 GB/T 34540 Specification of Hydrogen Production by Methanol Reforming and Pressure Swing Adsorption
- 2.7 GB/T 29412 Absorber of Pressure Swing Adsorption for Hydrogen Purification
- 2.8 GB/T 19773 Specification of Hydrogen Purification System on Pressure Swing Adsorption

2.9 GB/T29729 Essential Requirements for the Safety of Hydrogen Systems

2.10 HG/T5037-2016 Test Method for Activity of Methanol Catalyst for Hydrogen Production

3 Terms and Definitions

The terms and definitions as determined in the aforementioned survey references apply to the Guidelines. For the purpose of compilation and ease of use, the Guidelines directly cite or supplement the following definitions.

3.1 Burner System

Burner system refers to a system that monitors the operation of fuel burners, which consists of control devices and flame detectors and may include ignition sources and ignition devices.

3.2 Partial Catalytic Oxidation

A chemical reaction in which hydrocarbons and a small amount of air undergo partial catalytic oxidation on the catalyst surface, releasing heat and producing hydrogen.

3.3 Maximum Allowable Pressure

The maximum pressure designed for the hydrogen generator and its components.

3.4 Design Temperature

The temperature suitable for the design of hydrogen generators and their pressure-containing components.

3.5 Flame Detector

A flame measuring device providing the signal of the presence or absence of a flame.

Note: Flame detectors include flame sensors and may also include amplifiers and relays for signal transmission. The amplifiers and relays can be embedded in the detector housing or combined with a programming unit.

3.6 Fuel Processing System

A series of catalytic or chemical reactors that convert the input fuel into a hydrogen-rich gas stream with predetermined composition and conditions.

3.7 Intermittent Igniter

An igniter that automatically ignites when the device is required to operate. It keeps igniting continuously during each phase of the main burner's operation and extinguishes automatically at the end of each main burner operation cycle.

3.8 Water Treatment System

A system for treating and purifying recycled or added water used in hydrogen generators.

3.9 Reforming Reaction

The process in which fuel and desalted water react to generate hydrogen under certain temperature, pressure and catalyst action, generally including steam reforming, partial oxidation reforming and autothermal reforming.

3.10 Hydrogen Purification

The process of removing impurities from hydrogen-containing gas to increase the hydrogen concentration to a specified value.

3.11 Pressure Swing Adsorption

A gas separation method that separates gases by adsorbing gases under a certain pressure, and releasing the adsorbed gases after lowering partial pressure. This method is mainly based on the selective adsorption of different gases by solid adsorbents and the characteristic that the amount adsorbed varies with pressure.

3.12 Palladium Membrane Separation Method

A method of gas separation that takes advantage of the fact that different gases have different solubility and diffusion rates in palladium membranes.

4 Drawings and Documents

4.1 The following drawings and documentation shall be submitted to CCS for approval.

(1) General arrangement drawings (outline and installation drawings)

(2) Product technical conditions (including system flow chart)

(3) Electrical schematic diagram

4.2 The following drawings and documentation shall be submitted to CCS for information:

- (1) External wiring diagrams;
- (2) External piping connection diagrams;
- (3) List of specifications of main parts;
- (4) Nameplate drawing;
- (5) Risk assessment of reformer.

Note: The actual names of drawings/documents may differ from those listed above, but shall reflect their content requirements.

5 Technical Requirements

5.1 General Provisions

5.1.1 The equipment shall work normally under the working conditions specified in Section 2, Chapter 1, Part 4 of the CCS Rules for Classification of Sea-Going Steel Ships.

5.2 The commissioning, testing and maintenance of the reformer shall meet the requirements of safety, practicality and reliability.

5.3 The design, manufacturing, installation, operation, maintenance, and protection of hydrogen fuel cell power generation systems and their components shall ensure their safe and reliable operation.

5.4 The structure shall be designed to prevent the concentration and accumulation of explosive, flammable and toxic gas; non-flammable materials shall be used as much as possible inside the structure; the components of the system shall be properly protected from external damage.

5.5 The fuel pipelines shall have sufficient strength and be able to absorb the thermal expansion or contraction of the fuel caused by extreme temperatures.

5.6 The main hardware of the reformer includes: fuel processing system, hydrogen purification system and control system.

5.7 The tail hydrogen of the hydrogen purification system shall be recycled and used as heating fuel for the reformer.

5.8 Unreacted fuel and water shall be recycled and shall not be discharged directly to the environment. The unreacted water shall be treated before being recycled.

5.9 The catalytic oxidation reaction of fuel or hydrogen shall be used to provide heat for the reforming reaction. If open flame combustion is used for heating, the burner control system shall be equipped with a flame detector and an intermittent igniter.

5.10 The reformer shall be equipped with a purge gas connection port, and nitrogen shall be used as the purge gas.

5.11 Materials in contact with hydrogen are compatible with hydrogen and shall comply with the relevant provisions of GB/T29729 Essential Requirements for The Safety of Hydrogen Systems

5.12 The design, manufacture, survey and use of equipment belonging to pressure vessels shall comply with the relevant provisions of Chapter 6, Part 3 of the CCS Rules for Classification of Sea-Going Steel Ships.

5.13 The design, manufacture, survey and acceptance of equipment belonging to heat exchangers shall comply with the relevant provisions of Chapter 6, Part 3 of the CCS Rules for Classification of Sea-Going Steel Ships.

6 Materials and Components

6.1 The materials of methanol and ethanol fuel pipelines and other relevant components shall comply with the provisions of Section 3, Chapter 3 of CCS Guidelines for Ships Using Methanol/Ethanol Fuels.

6.2 Seamless steel pipes shall be used for hydrogen pipelines, and the chemical composition and mechanical properties of the materials shall meet the requirements of Chapter 4, Part 1 of CCS Rules for Materials and Welding.

6.3 The main equipment included in the fuel processing system is: burner (or catalytic oxidation reactor), reforming reactor, preheater, vaporizer, cooler and raw material pump.

7 Type Tests

The reformer shall be subject to type tests by CCS. The issuance, maintenance, modification,

renewal, and cancellation of the Type Approval Certificate shall follow the relevant requirements of Chapter 3, Part 1 of the CCS Rules for Classification of Sea-Going Steel Ships.

7.1 Selection of representative samples

7.1.1 The model and specifications of the test sample(s) shall be technically representative and shall cover the range of products for which type approval is sought.

7.1.2 For products with identical structure and working principles, the product with the maximum rated output power may be selected for type approval tests. For the selected product model, a quantity of one unit may be taken as the test sample. The test sample(s) shall be selected on-site at the product manufacturer's premises by a CCS surveyor.

7.2 Testing bodies

Type approval tests shall preferably be conducted by testing bodies approved by CCS or by authoritative and impartial testing bodies. For certain functional test items, if the manufacturer possesses adequate testing conditions, they may be conducted at the manufacturer's premises subject to the review, agreement, and on-site supervision of a CCS surveyor.

7.3 Type approval test requirements:

7.3.1 The reformer shall be tested in accordance with ISO 16110-1 Hydrogen Generators Using Fuel Processing Technologies — Part 1: Safety, and at least the following test items shall be carried out:

(1) Hydrostatic pressure test;

Hydrostatic pressure tests shall be performed on reformer components. When hydrostatic pressure tests are not feasible, gas pressure tests can be used to verify the dangers of compressed gases.

① Hydrostatic pressure test

The test medium shall be liquid fuel, coolant and other liquids. When testing the compressive strength of gas containers, the test medium shall be water.

(a) Metal test part

The metal test area shall be a certain section of the metal parts of the device, and the

pressure test at any point in the test area shall meet the following conditions:

Not less than 1.5 times the maximum allowable pressure;

When the design temperature is higher than the test temperature, the minimum test pressure shall be calculated as follows, but the S_T/S value shall not exceed 6.5:

$$P_T = 1.5 (PS_T)/S$$

Where,

P_T —minimum test gauge pressure

P —internal design pressure gauge pressure

S_T —stress values at test temperatures in Table A-1 of ANSI/ASME B31.3 required by ISO 15649;

S —stress value at design temperature, according to Table A-1 of ANSI/ASME B31.3, in accordance with ISO 15649

If the nominal pressure or longitudinal stress generated by the test pressure exceeds the yield strength at the test temperature, the test pressure may be reduced to a maximum pressure that does not exceed the yield strength at the test temperature.

If the test pressure of the pipe connected to the container is the same as or lower than the test pressure of the container, the pipe and the container can be tested at the test pressure of the pipe.

When the test pressure of the pipeline exceeds that of the container, and it is deemed unfeasible to isolate the pipeline from the container, the pipeline and container may be tested together at the container's test pressure, provided that the container's test pressure is not less than 77% of the pipeline's test pressure.

Before conducting the hydrostatic pressure test, a leak test can be carried out first. The pressure shall not be less than 170kPa (gauge pressure) to determine the main leakage points.

(b) Non-metallic test part

The hydrostatic test pressure at any point in the test area consisting of non-metallic components shall not be less than 1.5 times the maximum design pressure, but shall not exceed 1.5 times the maximum design pressure of the lowest design pressure component in the system.

Test procedure

The test section shall be filled with test fluid and connected to an appropriate hydraulic system, including a pressure measuring device capable of withstanding the required leak test pressure. Evacuate the gas in the test area and gradually increase the pressure until the test pressure reaches the set value, and keep the boost pressure difference constant at each step to balance the pipeline strain. The pressure shall be maintained for at least 10 minutes until there is no gas leakage at all connection points and connections, and the pressure has no change.

Acceptance criteria

Pressure-containing components shall be able to withstand the hydrostatic test pressure without cracking, breaking or other physical damage. During the test, there shall be no signs of leakage in the test section.

② Air pressure test

(a) Test gas

Non-flammable, non-toxic gases or vapors (such as clean dry air or inert gas).

(b) Test pressure

The test pressure for gas leak testing shall be 110% of the maximum design pressure.

When conducting pressure tests on pipelines affected by external pressure, the pressure inside the pipe shall be 1.5 times the pressure outside the pipe and not less than 105kPa.

(c) Test procedures

A pressure gauge with sufficient range shall be installed at the air inlet of the test device. Seal the test device and gradually increase the pressure until the set value is reached. During pressurization, the pressure difference of each stage of increasing

pressure shall be kept constant to balance the pressure strain in the pipelines of the test device. Maintain the test pressure for at least 10 minutes and monitor whether the pressure value of the pressure gauge changes to ensure that there is no leakage in the test device.

(d) Acceptance criteria

Pressure-containing components shall be able to withstand the pressure from the air pressure test without cracking, breaking or other physical damage.

(2) Hazardous gas leakage test;

① Test Gas

Non-flammable, non-toxic gases or vapors (such as clean dry air or inert gas).

② Test Pressure

The test pressure for gas leak testing shall be 110% of the maximum design pressure.

When conducting pressure tests on pipelines affected by external pressure, the pressure inside the pipe shall be 1.5 times the pressure outside the pipe and not less than 105kPa.

③ Test procedures

A pressure gauge with sufficient range shall be installed at the air inlet of the test device. Seal the test device and gradually increase the pressure until the set value is reached. During pressurization, the pressure difference of each stage of increasing pressure shall be kept constant to balance the pressure strain in the pipelines of the test device. Maintain the test pressure for at least 10 minutes and monitor whether the pressure value of the pressure gauge changes to ensure that there is no leakage in the test device.

④ Result expression

If helium is used as the test gas, the leakage rate shall be expressed as follows.

$$L_H = R \cdot L_{\text{Test}}$$

Where,

LH—Leakage rate of hazardous gas

L_{Test}—Leakage rate of test gas

$$R = \left(\frac{d_{\text{Test}}}{d_{\text{Fuel}}} \right)^{\frac{1}{2}}$$

Where,

d_{Test}—specific gravity of test gas

d_{Fuel}—specific gravity of fuel gas

$$R = \frac{\mu_{\text{Test}}}{\mu_{\text{Fuel}}}$$

Where,

μ_{Test}—absolute viscosity of test gas

μ_{Fuel}—absolute viscosity of fuel gas

After calculation by the above two equations, the higher value as the leakage rate R of hazardous gases.

⑤ Acceptance criteria:

For the total leakage rate of the hydrogen generator, with ventilation provided, the maximum concentration of any combustible gas in the hydrogen generator should be less than 25% of the lower explosive limit and less than 25% of the lower ignition limit.

Pressure-containing components shall be able to withstand the pressure from the air pressure test without cracking, breaking or other physical damage.

(3) Burner (if any) operating characteristics test;

① Adaptability

(a) Use the specified test.

(b) Perform the tests at the highest and lowest fuel supply pressures respectively.

- (c) The burner shall operate at 85% and 110% of the rated input voltage. When the hydrogen generator provides voltage change protection within this range, the system shall be tested under the extreme conditions specified by the protection device.

② Overall test

The automatic ignition system shall ignite immediately after the burner fuel reaches the ignition point.

During the test, it shall be verified that:

- (a) When the burner fuel is turned on: The burner fuel is effectively ignited without delayed ignition, flash fire, noise or equipment damage;
- (b) When the supply of burner fuel is cut off, the burner flame goes out without flash fire or noise;
- (c) The burner flame does not flash out of the combustion chamber;
- (d) No deposited carbon appears at the bottom of the burner;
- (e) No gas leakage or back pressure at the air inlet of the burner.

③ Extreme test

The test shall be carried out without adjusting the burner and axial burner. The inlet pressure shall be reduced to 70% of the normal pressure, and the burner operates safely with CO emissions below 300 $\mu\text{L/L}$. If normal ignition can be achieved under these conditions, the inlet pressure shall continue to be reduced and the test repeated.

- (4) Automatic control test of burner (if any) and catalytic oxidation reactor (if any);

① Hydrogen generator burner automatic ignition control test

(a) Effective ignition test

When the hydrogen generator is maintained at rated voltage, start the igniter and observe the ignition. When the fuel reaches the main burner port, the igniter shall immediately ignite the main burner fuel. There shall be no flame flickering outside the hydrogen generator.

And it shall be ensured that the fuel is ignited immediately after reaching the main burner port.

(b) Ignition voltage test

Undervoltage detection

The voltage of the hydrogen generator shall be adjusted to 85% of the rated plate voltage. In this case, the igniter shall ignite the main burner fuel during the build-up of the main burner. CO emissions shall be measured to verify that they are less than 300 $\mu\text{L/L}$. There shall be no flame flickering outside the hydrogen generator and no damage to the hydrogen generator.

The ignition test shall be carried out at least 5 times and the ignition shall occur during the build-up of the main flame

Overvoltage test

The voltage of the hydrogen generator shall be adjusted to 110% of the rated voltage. In this case, the igniter shall ignite the main burner fuel during the build-up of the main flame. CO emissions shall be measured during the test to verify that they are less than 300 $\mu\text{L/L}$. There shall be no flame flickering outside the hydrogen generator and no damage to the hydrogen generator.

The ignition test shall be carried out at least 5 times and the ignition shall occur during the build-up of the main flame.

(c) Main flame build-up test

When the hydrogen generator is running stably, the flame build-up time shall be checked. The time from the start of injection of the main fuel flow to the appearance of the ignition device or burner flame shall not exceed the rated main flame build-up time.

(d) Temperature Test of Ignition System Components

Thermocouples or equivalent temperature measuring devices shall be installed at applicable points on each ignition system component. The hydrogen generator shall be operated at the rated fuel consumption rate until balance is reached and the temperature of each component is measured.

② Automation control test of catalytic oxidation reactor

(a) Reaction start time test

The reaction start time of the generator shall be counted from the moment when fuel and air are turned on at the same time until the monitoring system of the generator issues a signal indicating successful startup.

The reaction time shall not exceed the maximum reaction start time provided by the manufacturer.

(b) Reaction stop time test

When the reactor is in stable working condition, the reaction stop time shall be counted from the start of shutting off the supply of fuel and air to the time when the generator monitoring system shows a signal that the reaction has stopped.

The reaction time shall not exceed the maximum reaction stop time provided by the manufacturer.

(5) Surface and component temperature test;

The heat generated by the hydrogen generator shall not cause the surrounding temperature to exceed the ambient temperature outside the generator by more than 50 °C.

(6) CO emission test;

Operation under balanced conditions;The hydrogen generator shall be tested at 25%, 50%, 75% and 100% variable output capacity respectively with CO emissions less than 300 μL/L when the generator reaches balanced operating conditions.

(7) Supply (such as fuel supply, power supply, water supply, cooling water, etc.) interruption test;

When the generator's fuel, power, water supply, cooling water, and ventilation systems are interrupted, the generator shall be safely shut down without producing any hazardous gases or deforming the generator structure.

7.3.2 For the test method and performance parameter detection of the pressure swing adsorption hydrogen purification system, refer to GB/T 19773 *Specification of Hydrogen Purification System on Pressure Swing Adsorption*.

7.4 Determination of volume fraction of hydrogen

The volume fraction of hydrogen shall be determined and calculated in accordance with HG/T5037-2016 Test Method for Activity of Methanol Catalyst for Hydrogen Production. Take the standard gas as the external standard sample and the reaction-generated gas as the measured sample, fill them into the gas chromatograph, measure the peak area of hydrogen, and calculate the volume fraction of hydrogen.

7.5 Determination of Hydrogen Purity

The purity of hydrogen shall be determined in accordance with GB/T 3634.1-2006 *Hydrogen - Part 1: Industrial Hydrogen* and GB/T 3634.2-2011 *Hydrogen - Part 2: Pure Hydrogen, High Pure Hydrogen and Ultra-pure Hydrogen*.

7.6 Catalyst Activity Determination

The volume fraction of hydrogen shall be determined and calculated in accordance with HG/T5037-2016 Test Method for Activity of Methanol Catalyst for Hydrogen Production. The catalyst activity shall be determined using the hydrogen space-time yield as the indicator, and the range of hydrogen space-time yield values calculated from three consecutive measurements shall not exceed $10 \text{ Nm}^3/(\text{m}^3 \text{ h})$.

8 Unit/batch inspection (Factory Survey)

8.1 After obtaining the CCS type approval certificate, the factory shall still conduct single piece/single batch survey on each reformer and submit a factory self-survey report. The CCS surveyor conducts a unit-by-unit survey.

8.2 Unit/batch survey items shall be carried out in accordance with ISO 16110-1 *Hydrogen Generators Using Fuel Processing Technologies — Part 1: Safety*, including at least the following items:

- (1) Pressure test;
- (2) Hazardous gas leakage test;
- (3) Burner (if any) operating characteristics test;
- (4) Insulation test;

(5) Withstand Voltage Test;

(6) Grounding protection test.